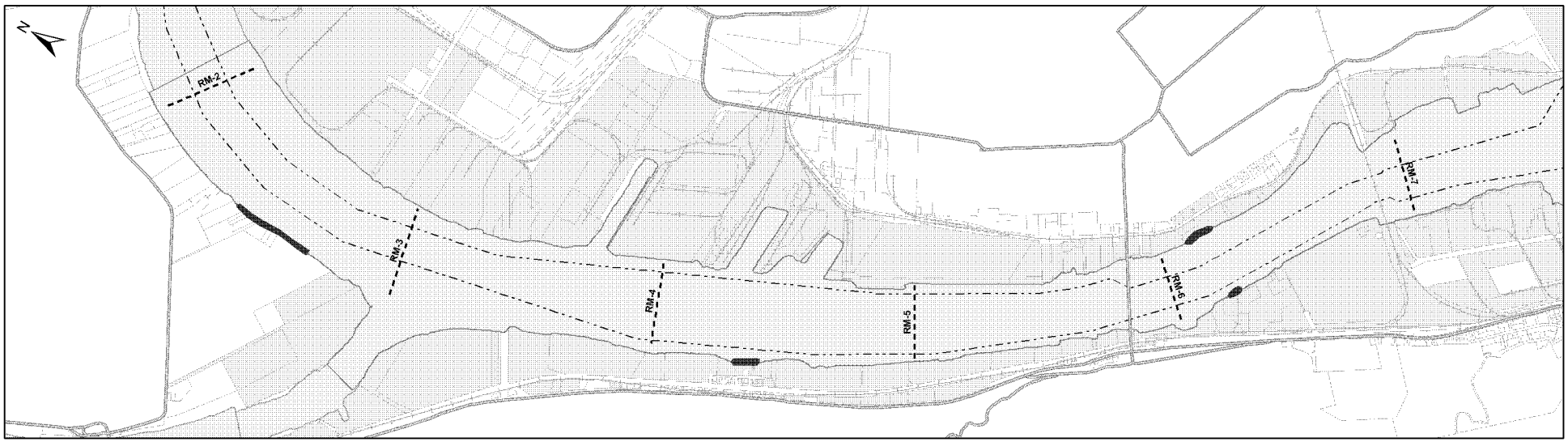
LWG
LOWER WILLAMETTE GROUP

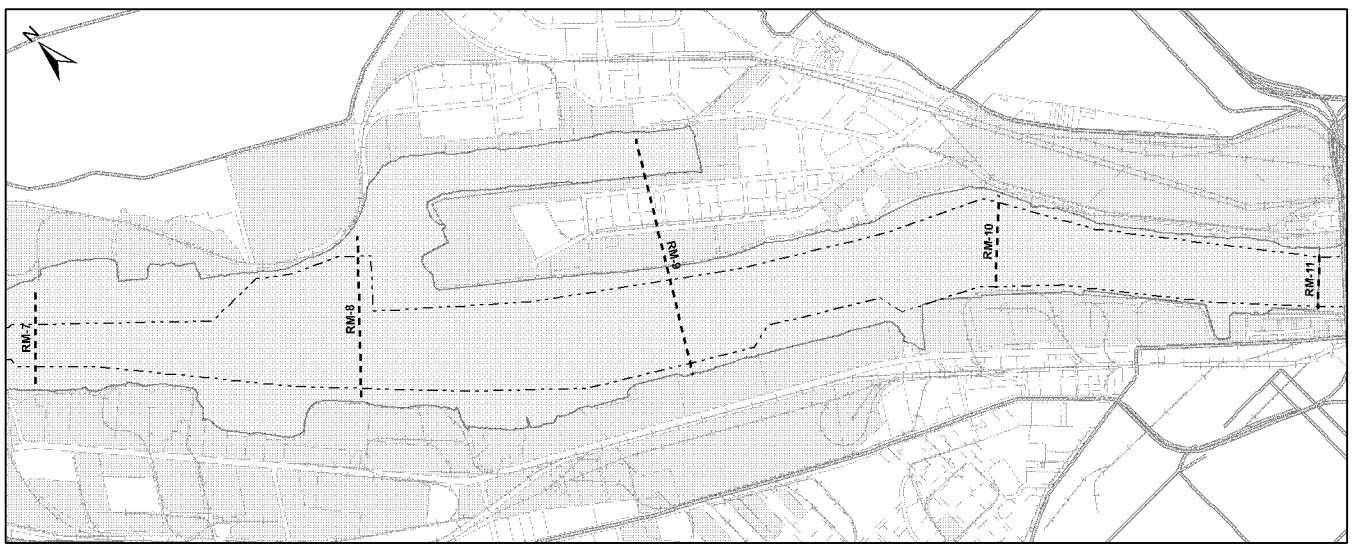
PORTLAND HARBOR RI/FS

COMPREHENSIVE ROUND 2 SITE CHARACTERIZATION SUMMARY AND DATA GAPS ANALYSIS REPORT

APPENDIX H
DERIVATION OF INITIAL AREAS OF POTENTIAL CONCERN

February 21, 2007

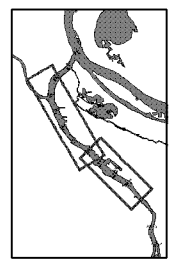




Beach Exposure
River miles
Railroads
Navigation Channel
Waterfront Taxlots

0 500 1,000 2,000
Scale in Feet

0 200 400 800
Meters



ANCHOR ENVIRONMENTAL, L.L.C.

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Figure H-1
Portland Harbor RI/FS
Comprehensive Round 2 Report
Initial Areas of Potential Concern
Human Health Exposure Scenarios - Beach
River Mile 02 to 11

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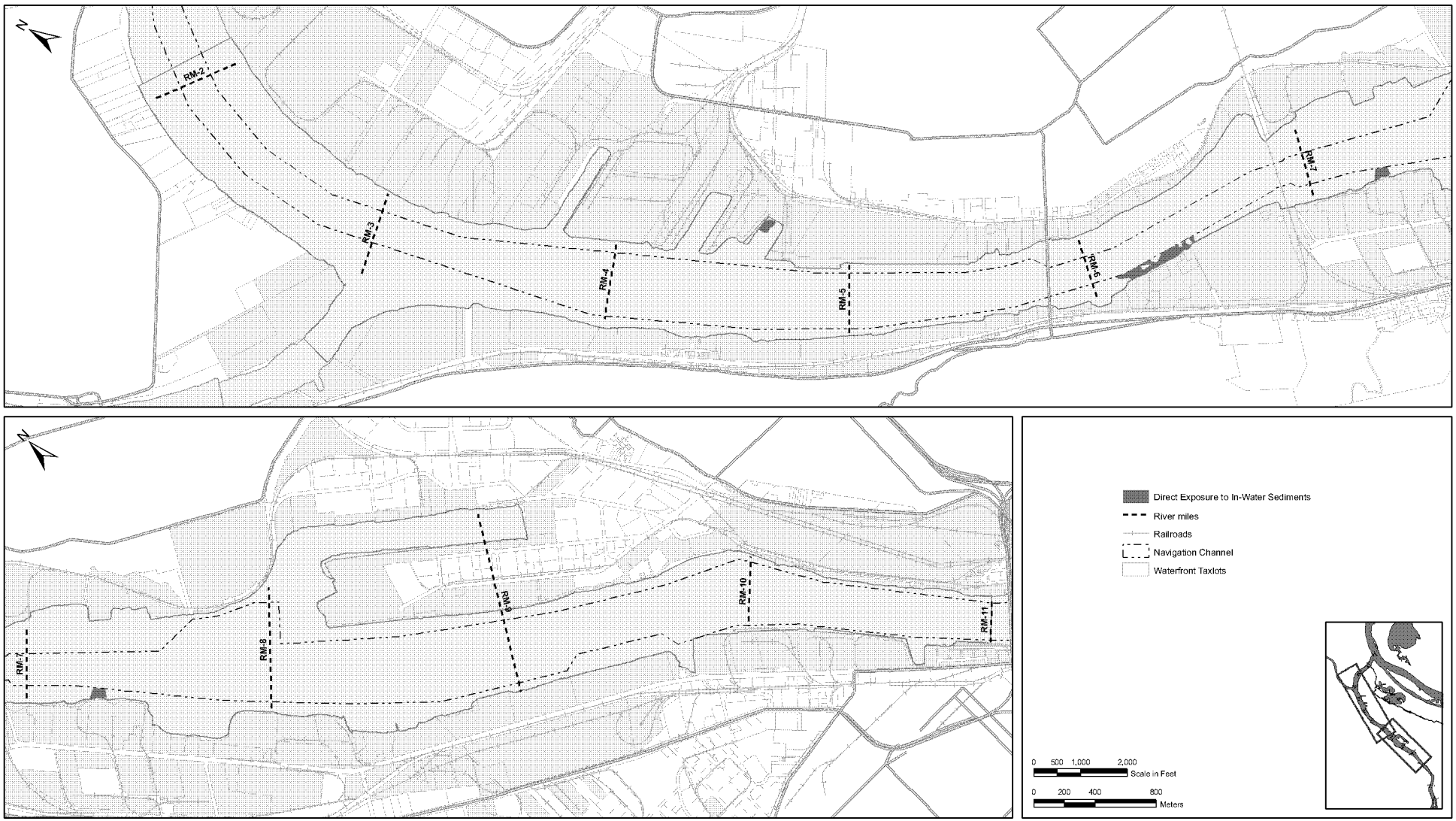

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Figure H-2
Portland Harbor RI/FS
Comprehensive Round 2 Report
Initial Areas of Potential Concern
Human Health Exposure Scenarios - In-Water Sediments
River Mile 02 to 11

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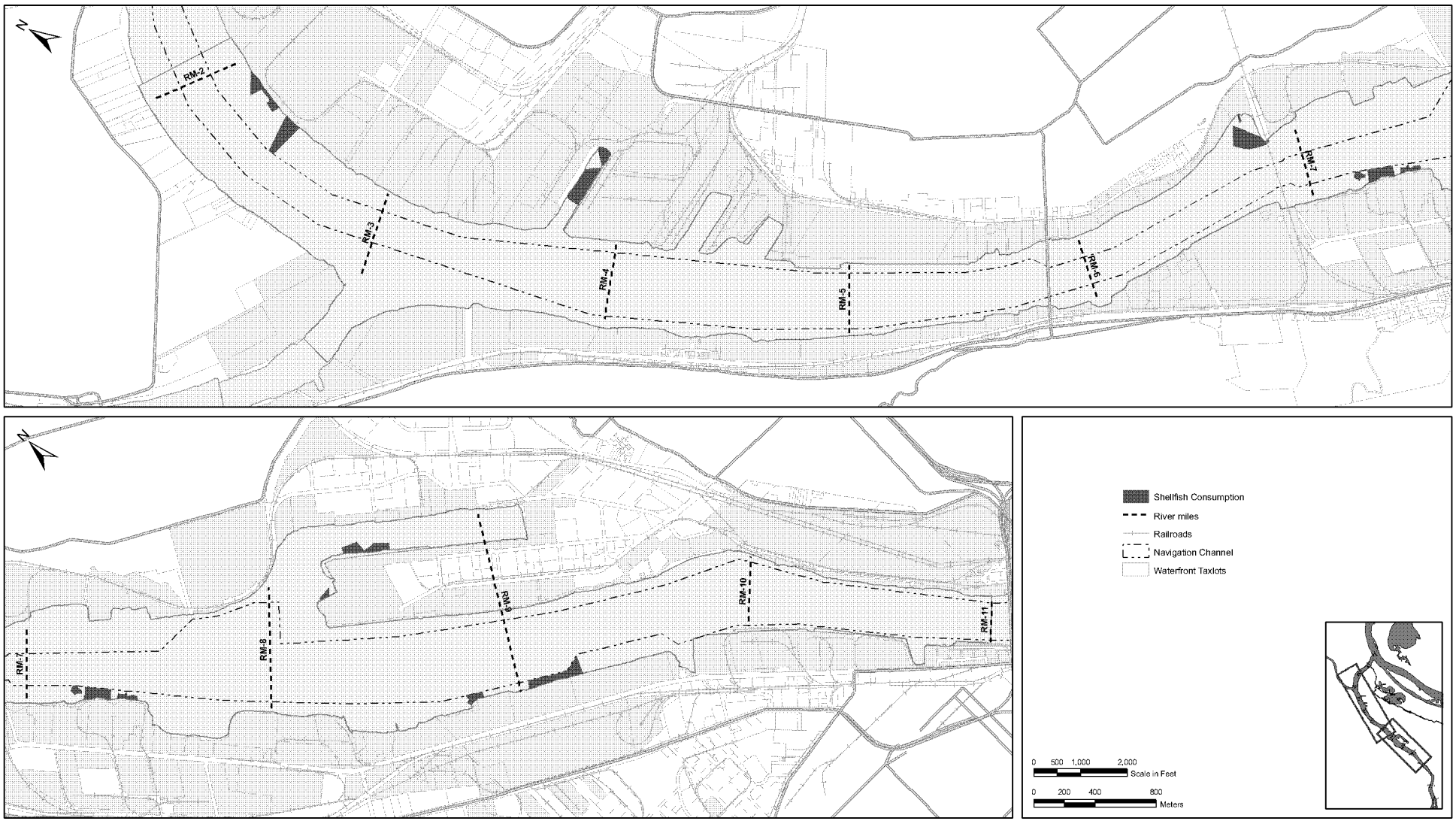

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Figure H-3
Portland Harbor RI/FS
Comprehensive Round 2 Report
Initial Areas of Potential Concern
Human Health Exposure Scenarios - Shellfish Consumption
River Mile 02 to 11

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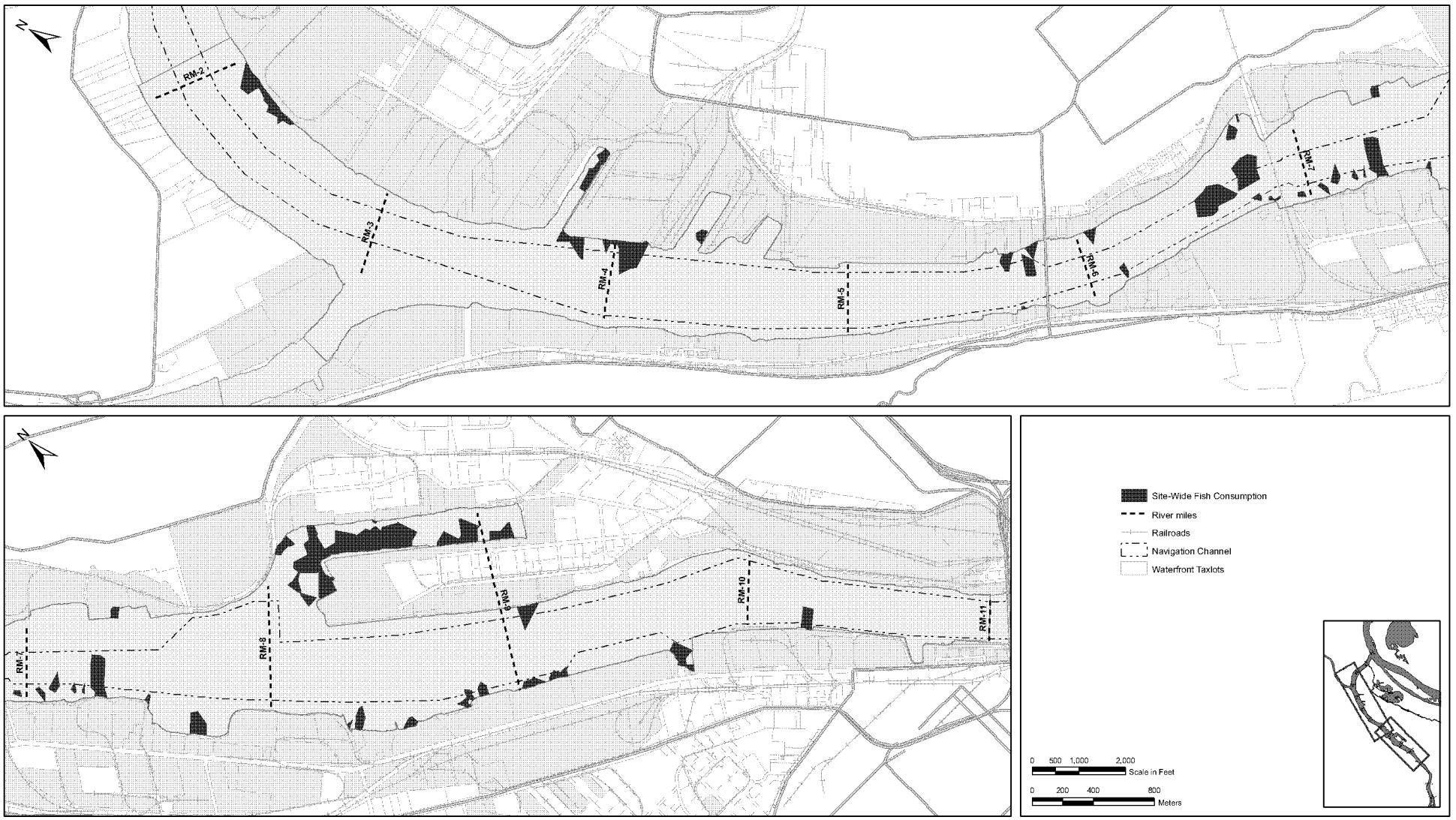
BZTO104(e)031355



ANCHOR ENVIRONMENTAL, L.L.C.

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Figure H-4
Portland Harbor RI/FS
Comprehensive Round 2 Report
Initial Areas of Potential Concern
Human Health Exposure Scenarios - Site-Wide Fish Consumption
River Mile 02 to 11

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Figure H-5
Portland Harbor RI/FS
Comprehensive Round 2 Report
Initial Areas of Potential Concern
Human Health Exposure Scenarios - Area-Specific Fish Consumption
River Mile 02 to 11

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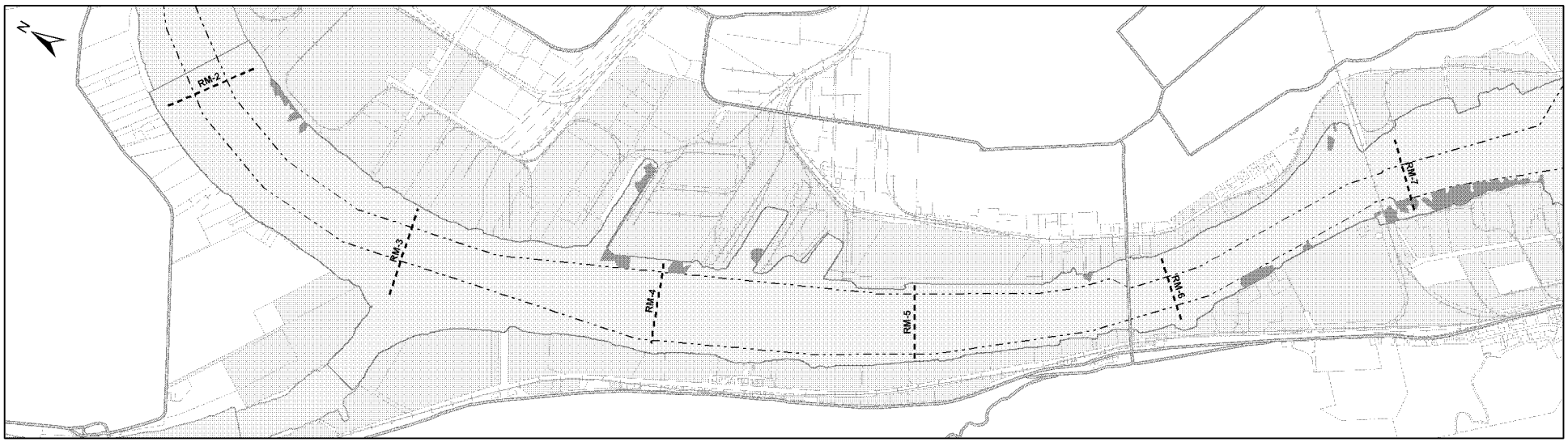
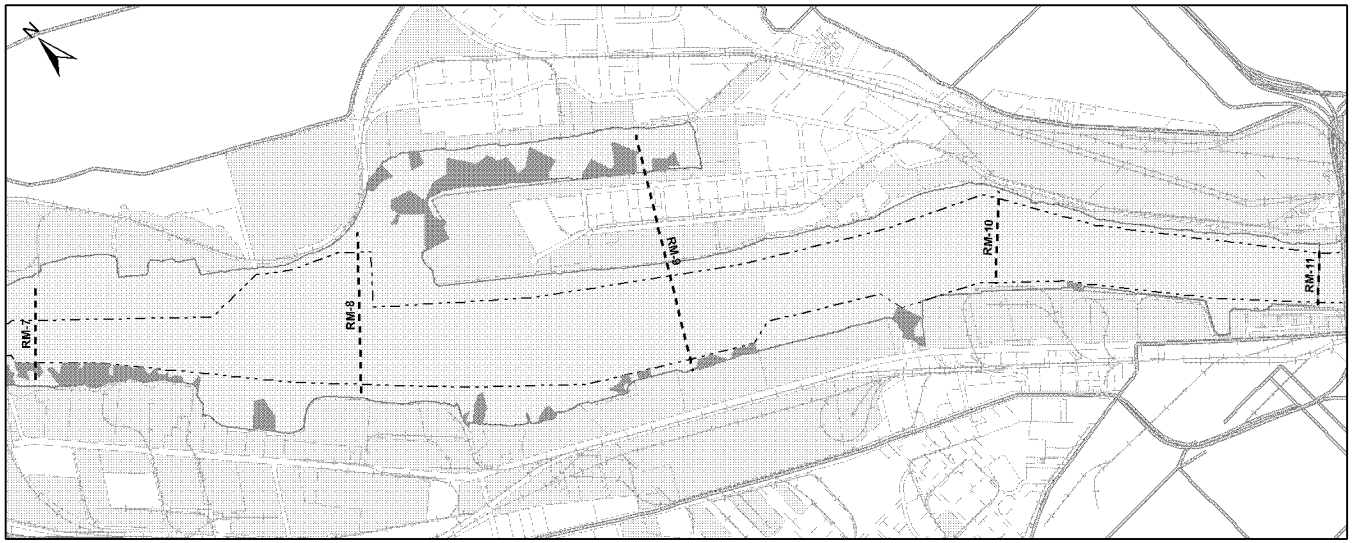
BZTO104(e)031357

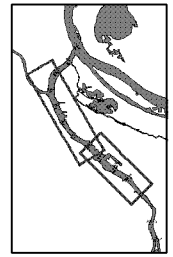




Ecology - Risk to Bass
River miles
Railroads
Navigation Channel
Waterfront Taxlots

0 500 1,000 2,000 Scale in Feet

0 200 400 800 Meters



ANCHOR ENVIRONMENTAL, L.L.C.

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Figure H-6
Portland Harbor RI/FS
Comprehensive Round 2 Report
Initial Areas of Potential Concern
Ecological Receptors - Bass
River Mile 02 to 11

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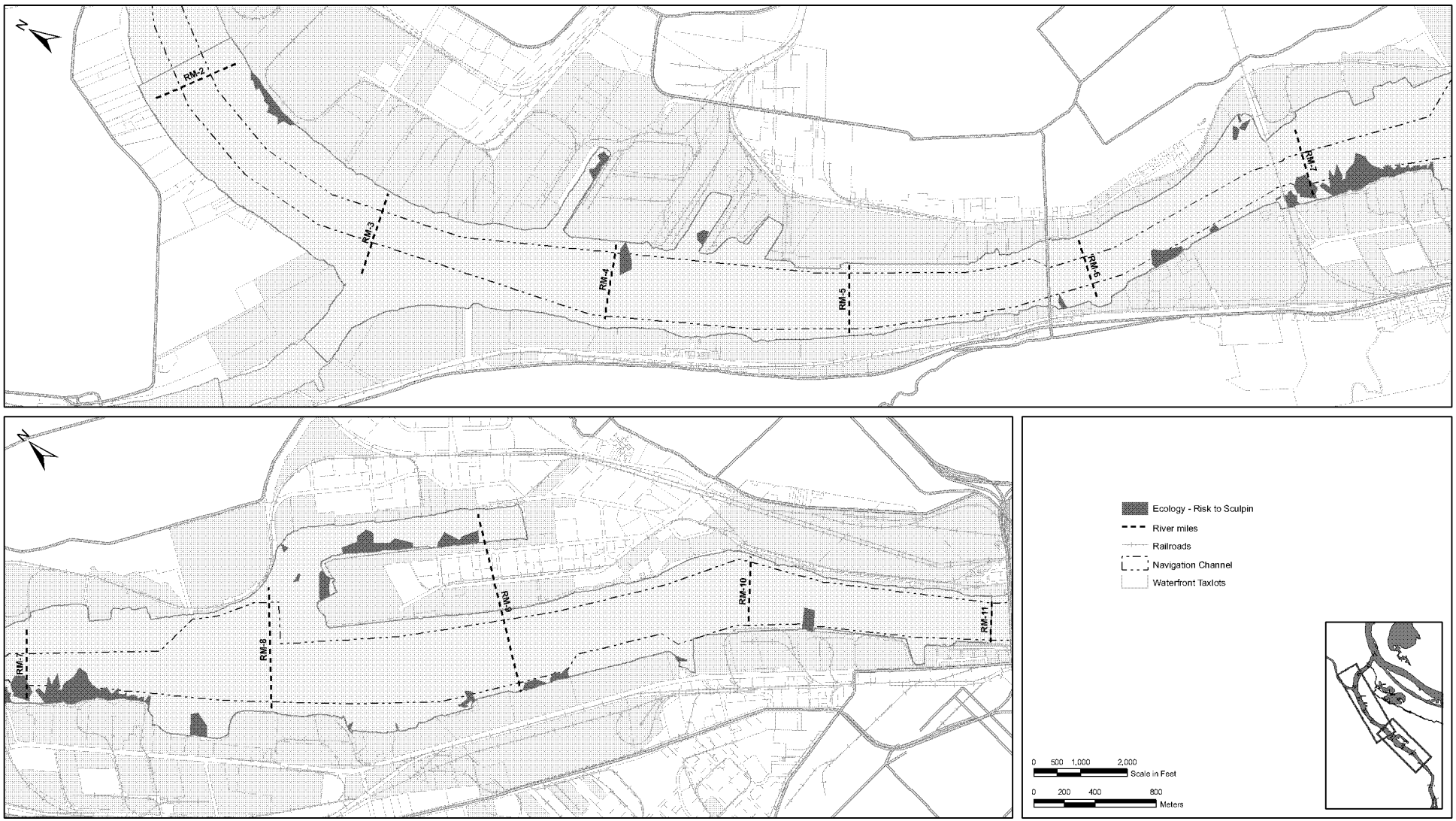

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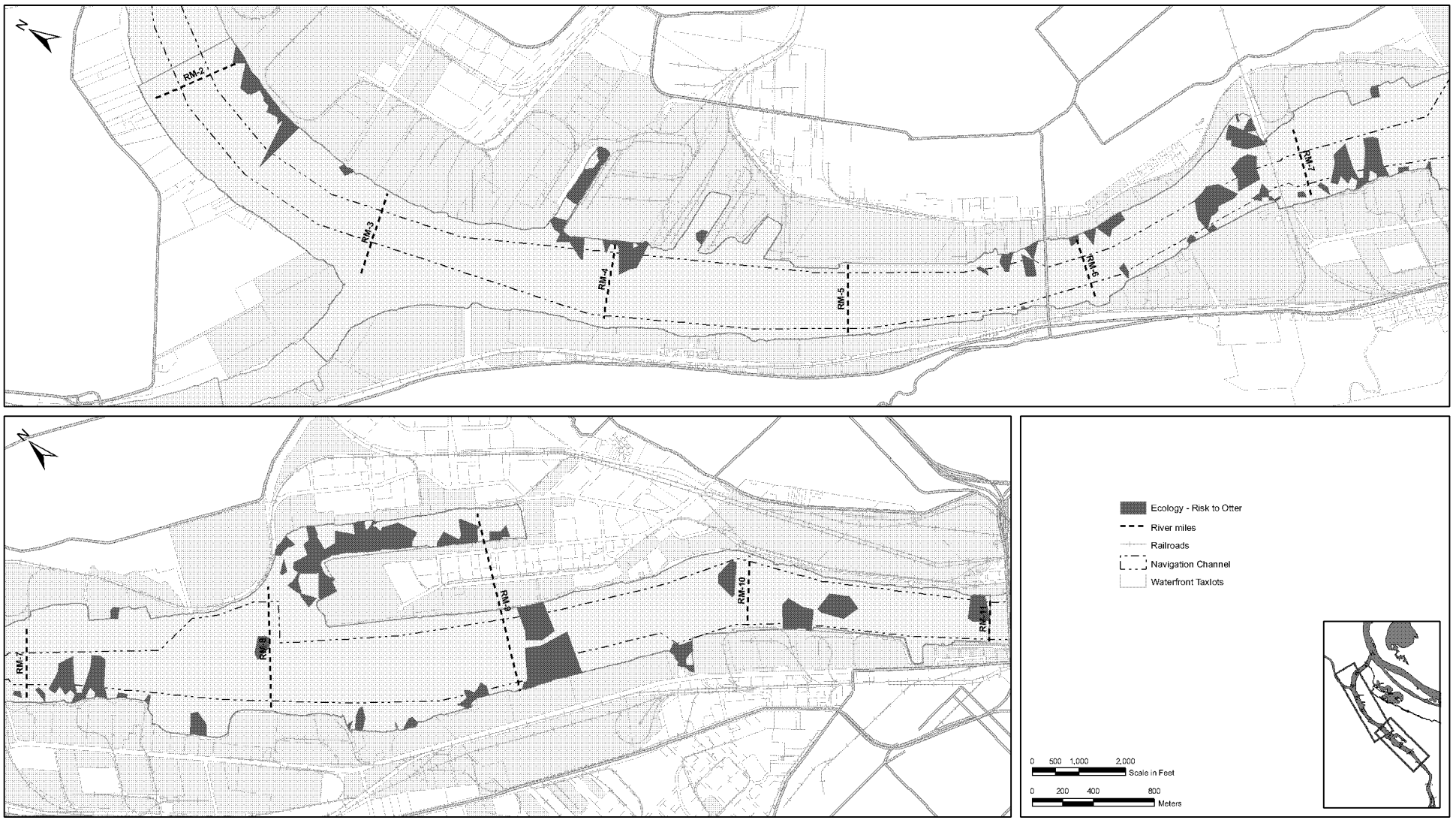
Figure H-7
Portland Harbor RI/FS
Comprehensive Round 2 Report
Initial Areas of Potential Concern
Ecological Receptors - Sculpin
River Mile 02 to 11

BZTO104(e)031359



ANCHOR ENVIRONMENTAL, L.L.C.

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Figure H-8
Portland Harbor RI/FS
Comprehensive Round 2 Report
Initial Areas of Potential Concern
Ecological Receptors - Otter
River Mile 02 to 11

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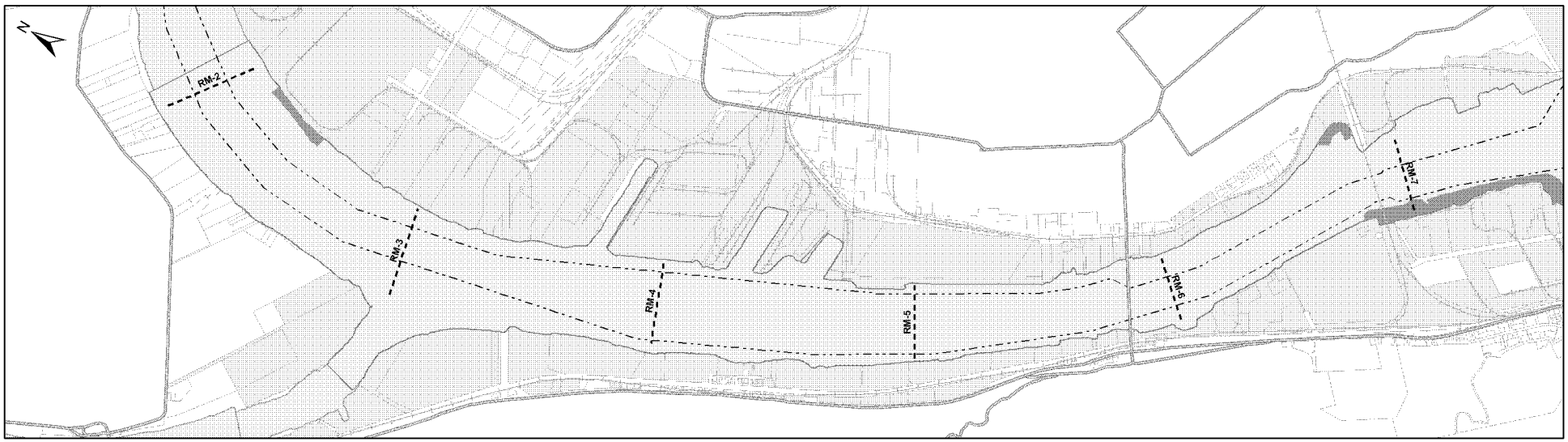
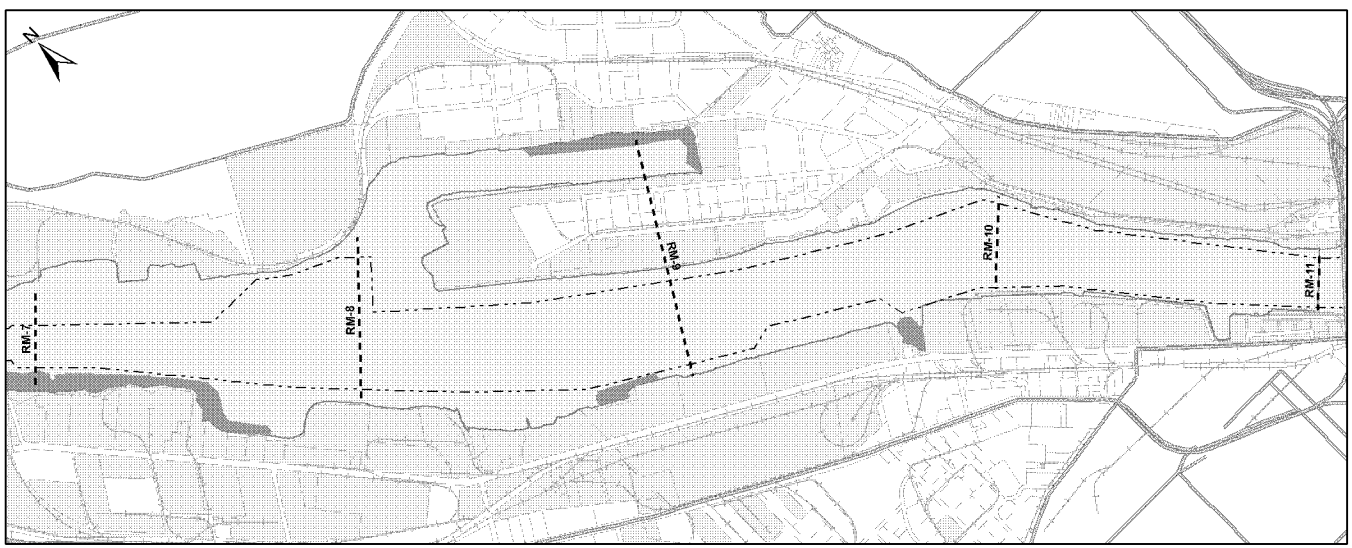
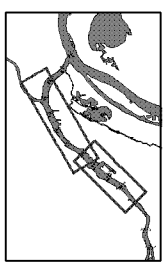




Ecology - Risk to Shorebirds
River miles
Railroads
Navigation Channel
Waterfront Taxlots

0 500 1,000 2,000
Scale in Feet

0 200 400 800
Meters



ANCHOR ENVIRONMENTAL, L.L.C.

LWG LOWER WILLAMETTE GROUP

Figure H-9
Portland Harbor RI/FS
Comprehensive Round 2 Report
Initial Areas of Potential Concern
Ecological Receptors - Shorebirds
River Mile 02 to 11

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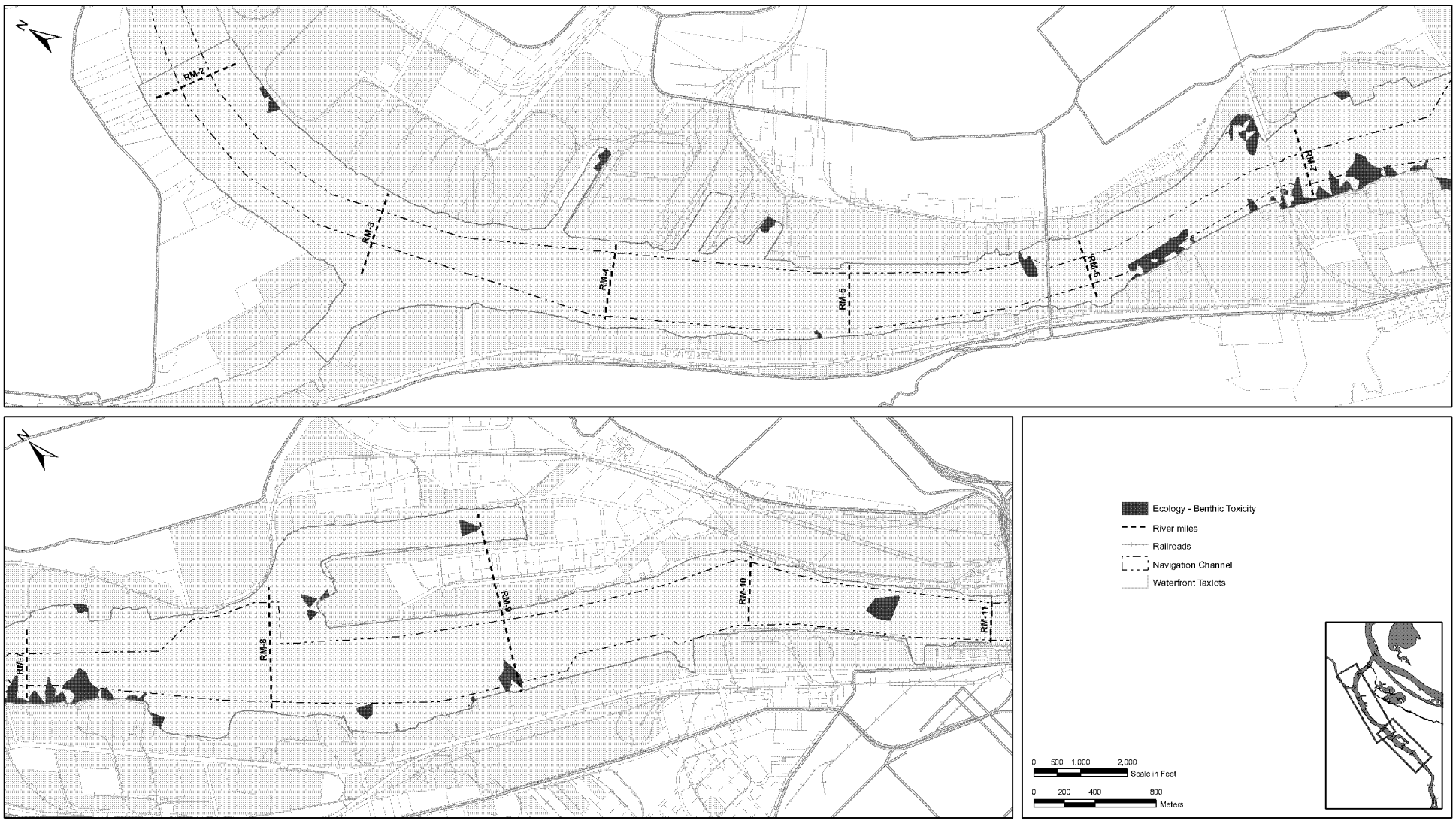

ANCHOR ENVIRONMENTAL, L.L.C.

LWG LOWER WILLAMETTE GROUP

Figure H-10
Portland Harbor RI/FS
Comprehensive Round 2 Report
Initial Areas of Potential Concern
Ecological Receptors - Benthic Toxicity
River Mile 02 to 11

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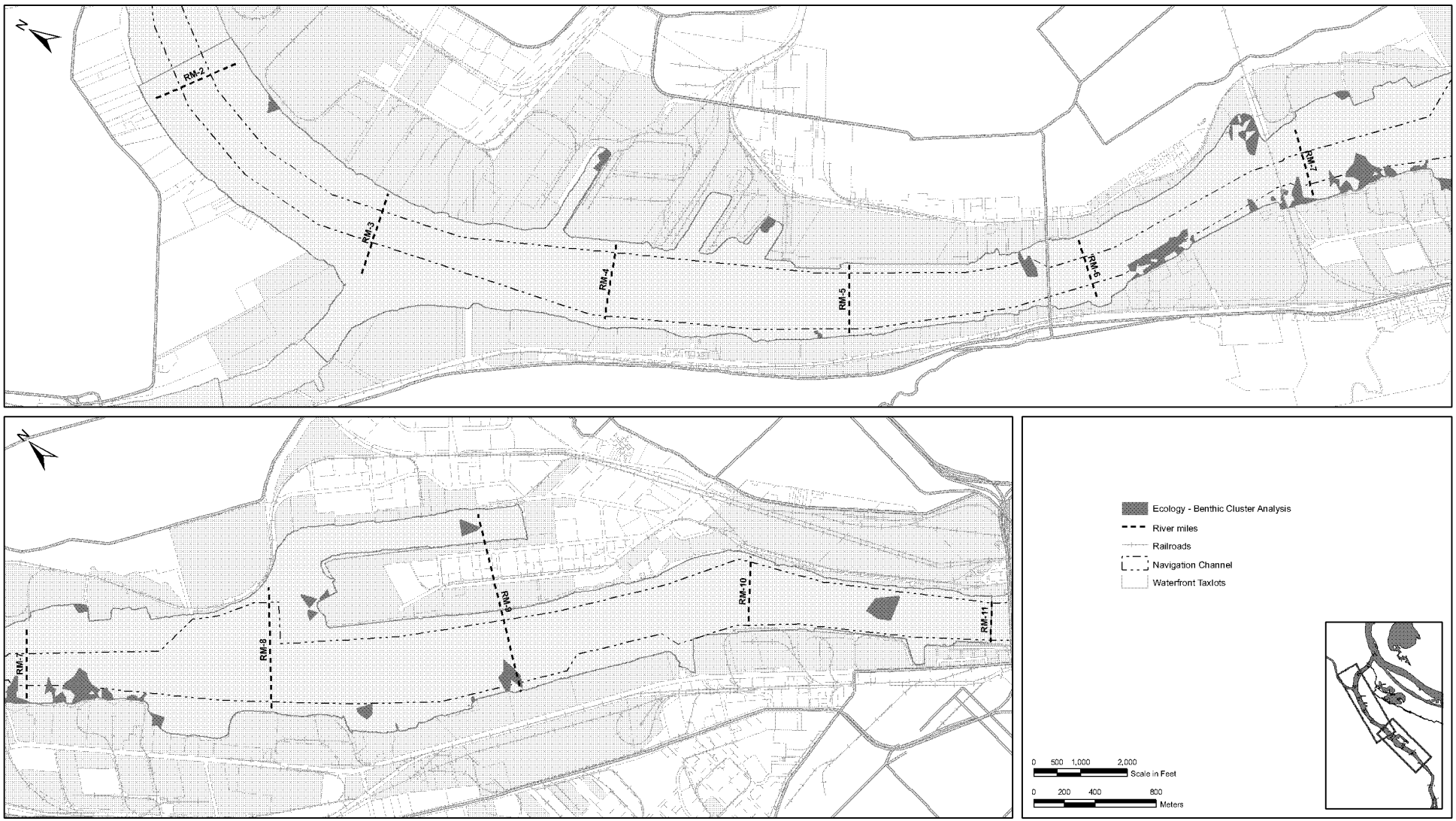

ANCHOR ENVIRONMENTAL, L.L.C.

LWG LOWER WILLAMETTE GROUP

Figure H-11
Portland Harbor RI/FS
Comprehensive Round 2 Report
Initial Areas of Potential Concern
Ecological Receptors - Benthic Cluster Analysis of iAOPC Development
River Mile 02 to 11

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BZTO104(e)031363

LWG
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PORTLAND HARBOR RI/FS

COMPREHENSIVE ROUND 2 SITE CHARACTERIZATION SUMMARY AND DATA GAPS ANALYSIS REPORT

APPENDIX I
iAOPC CSM DATA TABLES

February 21, 2007

Table I-1a. iAOPC 1 Sediment Samples Data.

Location	Sample	Upper cm	Lower cm	Dibutyl phthalate µg/kg	Dioxin-like PCB congener TCDD toxicity equivalent pg/g	Total PCB Aroclors µg/kg	Total PCB Congeners µg/kg	Zinc mg/kg
LW2-B002	LW2-B002	0	15	3.5 J	4.56 T	140 T	9.46 T	68.2
LW2-B004	LW2-B004	0	15	14	40.2 T	1400 T	106 T	247
LW2-C009	LW2-C009-B	30	153	3.1 U		724 T		120
LW2-C009	LW2-C009-C	153	273	4 U		29 JT		104
LW2-C011	LW2-C011-B1	30	127	7.1 JT		939 JT		148 T
LW2-C011	LW2-C011-C1	127	212	9 UT		97.6 JT		113 T
LW2-C011	LW2-C011-D1	212	341	37 UT		232 JT		106 T
LW2-C011	LW2-C011-F1	467	505	3.9 U		1.7 UT		
LW2-C011-2	LW2-C011-B2	30	91	6.7 U		1280 JT		147
LW2-C011-2	LW2-C011-C2	91	137	7.4 U		7900 JT		167
LW2-C011-2	LW2-C011-D2	137	199	8.7 U		125 JT		110
LW2-C011-2	LW2-C011-E2	199	256	19 U		577 JT		99
LW2-C011-2	LW2-C011-G2	381	499	3.9 U				
LW2-C015	LW2-C015-B	30	107	45 U		3130 JT		209
LW2-C015	LW2-C015-C	107	210	36 U		16 JT		95.4
LW2-C015	LW2-C015-D	210	270	42 U		63.2 JT		143
LW2-C015	LW2-C015-E	270	343	7 U		1.8 JT		70.2
LW2-C019	LW2-C019-B1	30	86	3.2 U		4080 JT		218
LW2-C019	LW2-C019-C1	86	175	18 U		96.2 JT		479
LW2-C019	LW2-C019-D1	175	264	3.7 U		470 JT		
LW2-C019-2	LW2-C019-B2	30	153		18.3 T		1100	
LW2-C019-2	LW2-C019-E2	363	485	3.8 U		1.6 UT		67
LW2-C020	LW2-C020-B	30	102	9.3 U		820 JT		264 T
LW2-C020	LW2-C020-C	102	179	6.7 U		2750 JT		185
LW2-C020	LW2-C020-D	179	232			1340 T		212
LW2-C025	LW2-C025-B1	30	78	3.6 U		2.43 UJT		69.8
LW2-C025	LW2-C025-C1	78	198	4.1 U		7170 JT		67.6
LW2-C025	LW2-C025-D1	198	305			1.7 UT		
LW2-C025-2	LW2-C025-B2	30	152		2.39 T		162	
LW2-C025-2	LW2-C025-D2	288	344	11		2.42 UT		86.8
LW2-C025-2	LW2-C025-E2	344	454			1.7 UT		
LW2-C027	LW2-C027-B	30	150	3.8 U		102 JT		84.7
LW2-C027	LW2-C027-C	150	249	3.8 U		27.8 JT		65.4
LW2-C027	LW2-C027-D	249	368			1.7 UT		
LW2-G007	LW2-G007-1	0	27	5.6 UT	5.85 JT	271 JT	222	190 T
LW2-G007-2	LW2-G007-2	0	27	8.2 J		382 JT		175
LW2-G009	LW2-G009	0	24	3.9 U	59 T	1760 T	2020	339
LW2-G010	LW2-G010	0	27	12 U		168 JT		153
LW2-G011	LW2-G011	0	25	4.9 J		1660 JT		365

BZTO104(e)031365

Table I-1a. iAOPC 1 Sediment Samples Data.

Location	Sample	Upper cm	Lower cm	Dibutyl phthalate µg/kg	Dioxin-like PCB congener TCDD toxicity equivalent pg/g	Total PCB Aroclors µg/kg	Total PCB Congeners µg/kg	Zinc mg/kg
LW2-G013	LW2-G013	0	29.5	8.7 J		98 JT		136
LW2-G015	LW2-G015	0	29	4.9 U		1750 T		260
LW2-G017	LW2-G017	0	29	12 U		750 T		301
LW2-G019	LW2-G019	0	20	41	22 JT	1530 T	849	703
LW2-G020	LW2-G020	0	29	5.9 U		440 T		235
LW2-G024	LW2-G024	0	29	12 U		89 T		139
LW2-G025	LW2-G025	0	19	12 U	149 JT	432 T	9780	287
LW2-G026	LW2-G026	0	28	6.6 J		58 T		135
LW2-G027	LW2-G027	0	26	3.9 U		111 T		84.5
LW2-G028	LW2-G028	0	29	5.3 U	4.85 T	87 T	201	114
LW2-GBT002	LW2-GBT002	0	10	180 J	28.7 T	1130 T	848	511
LWG0102R001SDS015C00	LWG0102R001SDS015C00	0	15	29 U	13.5 JT	1090 T	544 JT	194
LWG0102R015SDS015C00	LWG0102R015SDS015C00	0	15	58 U		1180 T		813
WLCOSJ00RB01	WLCOSJ00RB01SD0001	0	10	20 U		140 T		68.9
WLCOSJ00RB02	WLCOSJ00RB02SD0002	0	10	19 U		180 T		74.4
WLCOSJ00RB03	WLCOSJ00RB03SD0003	0	10	20 U		810 T		116
WLCOSJ00RB04	WLCOSJ00RB04SD0004	0	10	19 U		1770 T		698
WLCOSJ00RB04	WLCOSJ00RB04SD0014	0	30	19 U		9300 T		479
WLCOSJ00RB05	WLCOSJ00RB05SD0005	0	10	18 U		2790 T		345
WLCOSJ00RB06	WLCOSJ00RB06SD0006	0	10	20 U		1160 T		212
WLCOSJ00RB06	WLCOSJ00RB06SD0007	0	10	19 U		1020 T		338
WLCOSJ00RB07	WLCOSJ00RB07SD0008	0	10	20 U		200 UT		43.1
WLCOSJ00RB08	WLCOSJ00RB08SD0009	0	10	20 U		190 T		823
WLCOSJ00RB09	WLCOSJ00RB09SD0010	0	10	19 U		550 T		209
WLCOSJ00RB10	WLCOSJ00RB10SD0011	0	10	20 U		290 T		341
WLCOSJ00RB12	WLCOSJ00RB12SD0013	0	10	20 U		200 UT		66.7
WLCOSJ00RB13	WLCOSJ00RB13SD0015	0	30	19 U		1240 T		326
WLCOSJ00RB13	WLCOSJ00RB13SD0016	30	60	19 U		1620 T		234

BZTO104(e)031366

Table I-1b. iAOPC 1 Surface Water Samples Data.

Location	Sample	Dibutyl phthalate µg/l	Total PCB Aroclors µg/l	Zinc mg/l
LW2-W001	LW2-W001	0.084 U	0.0025 UJT	0.00165 T
LW2-W001	LW2-W2001	0.15 U	0.0025 UT	0.0014 T
LW2-W001	LW2-W3001	0.13 U	0.0063 JT	0.00347 JT

BZTO104(e)031367

Table I-1c. iAOPC 1 Tissue Samples Data.

Location	Sample	Species	Tissue	Dibutyl phthalate µg/kg-Wet	Dioxin-like PCB congener pg/g-Wet	Total PCB Aroclors µg/kg-Wet	Total PCB Congeners µg/kg-Wet	Zinc mg/kg-Wet
LW2-BTFC001	LW2-BTFC001	clam	body without shell	16 U	2.89 T	118 JT	157	33.2
LW2-BTFC002	LW2-BTFC002	clam	body without shell	16 U	5.52 T	240 JT	327	40.3
LW2-GBT002	LW2-BTLC002	lab clam	body without shell	210 U	1.07 T	53.5 JT	73.4	14.8
LW2-GBT002	LW2-BTLW002	Lumbriculus variegatus	whole body	16 U	48.8 JT	2120 JT	2970	30.6
LW2-MIT001	LW2-MIT001	multiplate invertebrates	whole body		0.796 JT	37.4 JT	46.5	12.6 J
LWG0102R001CR00	LWG0102R001TSCRWBC00	crayfish	whole body	330 U	4.55 T	21 JT	60.7 JT	16.6 J
LWG0102R001SP00	LWG0102R001TSSPWBC00	sculpin	whole body	310 U	43.7 T	2330 JT	1930 JT	14.1
LWG0102R015CR00	LWG0102R015TSCRWBC00	crayfish	whole body	330 U		28 JT		15.9 J
LWG0102R015SP00	LWG0102R015TSSPWBC00	sculpin	whole body	330 U		3360 T		16.3

BZTO104(e)031368

Table I-2. iAOPC 2 Sediment Samples Data.

Location	Sample	Upper cm	Lower cm	Dioxin-like PCB congener pg/g	Total PCB Aroclors µg/kg	Total PCB Congeners µg/kg
LW2-C038	LW2-C038-B	30	154		49.4 JT	
LW2-C038	LW2-C038-C	154	252		2.32 UT	
LW2-C038	LW2-C038-D	252	310		2.74 UT	
LW2-G038	LW2-G038	0	26	1.29 T	163 T	62

BZTO104(e)031369

Table I-3a. iAOPC 3 Sediment Samples Data.

Location	Sample	Upper cm	Lower cm	Dioxin-like PCB congener TCDD µg/kg	Diesel Range Hydrocarbons mg/kg	Dioxin-like PCB congener TCDD pg/g	Endrin ketone µg/kg	Residual Range Hydrocarbons mg/kg	Total PCB Aroclors µg/kg	Total PCB Congeners µg/kg	Zinc mg/kg
LW2-C078	LW2-C078-A	0	30		8 J			34 J			
LW2-C078	LW2-C078-B	30	152	4.2 U	4.9 U		0.08 U	14 J	1.6 UT		66.2 T
LW2-C078	LW2-C078-C	152	279	6.4 U	4.9 U		0.08 U	12 J	1.6 UT		63.8
LW2-C079	LW2-C079-A	0	30		16 J			76 J			
LW2-C079	LW2-C079-B	30	156	6 U	5.3 U		0.086 U	32 J	2.2 JT		85.1
LW2-C079	LW2-C079-C	156	274	5.4 U	4.9 U		0.081 U	15 J	1.6 UT		63
LW2-C080	LW2-C080-A	0	30		54 J			170 J			
LW2-C080	LW2-C080-B	30	87	3.3 U	81 J		0.44 U	270 J	42 JT		155
LW2-C080	LW2-C080-C	87	189	33 U	18.5 JT		0.071 U	41 JT	3.1 UT		69.4
LW2-C083	LW2-C083-A	0	30		49 J			190 J			
LW2-C083	LW2-C083-B	30	129	12 U	130 J		0.26 U	410 J	205 JT		141
LW2-C083	LW2-C083-C	129	188	9.5 U	150 J		0.22 U	350 J	234 JT		105
LW2-C084	LW2-C084-A	0	30		120 J		0.43 U	550 J			
LW2-C084	LW2-C084-B	30	65	17 U	210 J		0.099 U	820 J	290 T		161
LW2-C084	LW2-C084-C	65	169	7.7 U	37 J		0.21 U	110 J	36 JT		74.3
LW2-C084	LW2-C084-D	169	283	4.4 U	5 U		0.082 U	19 J	1.6 UT		66.3
LW2-C086	LW2-C086-B	30	130	28 J	150 J		0.0405 UJ	530 J	202 T		141 T
LW2-C086	LW2-C086-C	130	250	3.2 U	12 UT		0.0266 UJ	7.3 UT	2.11 UT		44.8
LW2-C087	LW2-C087-A	0	30		80 J		1.8 NJ	380 J			
LW2-C087	LW2-C087-B	30	110	8.4 U	230 J		0.094 U	800 J	284 JT		158
LW2-C087	LW2-C087-C	110	218	4.3 U	15.5 JT		0.33 U	56 JT	15 JT		58.4
LW2-C089	LW2-C089-A	0	30		1300 J			3600 J			
LW2-C089	LW2-C089-B	30	98	36 U	1400 JT		1.5 NJ	2400 JT	3200 T		132
LW2-C089	LW2-C089-C	98	196	7.8 U	59 J		0.071 UJ	110 J	46 T		51.4
LW2-C089	LW2-C089-D	196	312	5.7 U	7.1 J		0.083 UJ	42 U	1.7 UT		67.9
LW2-C090	LW2-C090-A	0	30		120 J			540 J			
LW2-C090	LW2-C090-B	30	112	32 U	130 J		3.2 U	510 J	430 T		197
LW2-C090	LW2-C090-C	112	236	3.6 U	4.2 U		0.2 U	4.9 U	4.7 JT		51.7
LW2-C091	LW2-C091-A	0	30		150 J			740 J			
LW2-C091	LW2-C091-B	30	143	24 U	300 J		0.19 U	1000 J	320 JT		163 T
LW2-C091	LW2-C091-C	143	211	23 U	440 J		0.2 U	1300 J	480 JT		175
LW2-C091	LW2-C091-D	211	306	4.9 U	4.5 UT		0.074 U	6.1 JT	1.5 UT		53.6
LW2-C092	LW2-C092-A	0	30		1200 J			6700 J			
LW2-C092	LW2-C092-B	30	152	100 U	3500 J		19 UJ	11000 J	26000 T		672
LW2-C092	LW2-C092-C	152	212	84 U	3200 J		16 J	6900 J	15000 T		450
LW2-C092	LW2-C092-D	212	276	76 U	800 J		0.45 UJ	1500 J	160 T		150
LW2-C092	LW2-C092-E	276	426	3.9 U	7.8 J		0.083 UJ	55 U	1.7 UT		66.4
LW2-C093	LW2-C093-A	0	30	110	1300 J	155 T	8.54 NJ	3600 J	2230 JT	4340	410
LW2-C093	LW2-C093-B	30	134	30 U	2300 JT	11.4 T	0.538 U	5500 JT	2820 T	730	510
LW2-C093	LW2-C093-C	134	256	3.6 U			0.0315 U		2.48 UT		62.9 T
LW2-C094	LW2-C094-A	0	30		340 J		12 NJ	1500 J			
LW2-C094	LW2-C094-B	30	72	57 U	700 J		1.1 U	2200 J	1990 T		347
LW2-C094	LW2-C094-C	72	198	5.1 U	5.2 U		0.086 U	34 J	3.4 JT		65.3
LW2-G078	LW2-G078	0	22	3.6 U			0.099 NJ		18 T		66
LW2-G079	LW2-G079	0	24	3.5 U			0.0324 U		2.5 UT		62
LW2-G080	LW2-G080	0	24	4.6 J			0.0294 U		57 T		143

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Table I-3a. iAOPC 3 Sediment Samples Data.

Location	Sample	Upper cm	Lower cm	Dioxin-like PCB congener TCDD µg/kg	Diesel Range Hydrocarbons mg/kg	Dioxin-like PCB congener TCDD pg/g	Endrin ketone µg/kg	Residual Range Hydrocarbons mg/kg	Total PCB Aroclors µg/kg	Total PCB Congeners µg/kg	Zinc mg/kg
LW2-G083	LW2-G083	0	24	13 J			0.317 NJ		69 T		114
LW2-G084	LW2-G084	0	29	27					214 JT		125
LW2-G085	LW2-G085	0	27	67 J			3.36 NJ		1700 T		472 T
LW2-G086	LW2-G086	0	28	9.5 U	100 J	9.8 JT	0.26 NJ	410 J	203 JT	307	140
LW2-G087	LW2-G087	0	28	9.1 J					353 JT		126
LW2-G089	LW2-G089	0	26	7.3 U			0.37 NJ		247 T		144
LW2-G090	LW2-G090	0	29.5	450		7.73 JT	0.0433 U		750 JT	617	185
LW2-G091	LW2-G091	0	28	11 U			0.463 NJ		210 JT		187
LW2-G092	LW2-G092	0	27	69 J		161 JT	2.64 NJ		1500 T	3490	717
LW2-G093	LW2-G093	0	25	1800		72.7 T	7.26 NJ		3370 T	2160	296
LW2-G094	LW2-G094	0	24	250 J			2.51 NJ		1450 T		630
LWG0103R005SDS015C00	LWG0103R005SDS015C00	0	15	120 U		58.7 JT	15 U		1500 T	3340 JT	370
WLCITC03SS05	WLCITC03SS050012	0	365.76	3.5 U					94		51.1
WLCITC03SS05	WLCITC03SS051416C	426.72	487.68	3.4 U					2.4 U		33
WLCITC03SS06	WLCITC03SS060007	0	213.36	7.8 J					300		91.5
WLCITC03SS06	WLCITC03SS060810C	243.84	304.8	3.3 U					2.3 U		33.8
WLCITH98SD11	WLCITH98SD11SD11	0	15	10 U			2 U				62
WLCITH98SD12	WLCITH98SD12SD12	0	15	10 U			2 U				101

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Table I-3b. iAOPC 3 Tissue Samples Data.

Location	Sample	Species	Tissue	Dibutyl phthalate µg/kg-Wet	Dioxin-like PCB congener pg/g-Wet	Endrin ketone µg/kg-Wet	Total PCB Aroclors µg/kg-Wet	Total PCB Congeners µg/kg-Wet	Zinc mg/kg-Wet
LWG0103R005CR00	LWG0103R005TSCRWBC00	crayfish	whole body	330 U	4.42 T	1 U	280 T	207 JT	14.8 J
LWG0103R005SP00	LWG0103R005TSSPWBC00	sculpin	whole body	300 U	13.8 T	1 UJ	360 T	758 JT	15.9

BZTO104(e)031372

Table I-4a. iAOPC 4 Sediment Samples Data.

Location	Sample	Upper cm	Lower cm	Dioxin-like PCB congener TCDD toxicity equivalent pg/g	Total PCB Aroclors µg/kg	Total PCB Congeners µg/kg
LW2-C082	LW2-C082-B1	30	137		67 JT	
LW2-C082	LW2-C082-C1	137	210		1.5 UT	
LW2-C082	LW2-C082-D1	210	295		1.3 UT	
LW2-C082-2	LW2-C082-B2	30	137		48.6 JT	
LW2-C082-2	LW2-C082-C2	137	210		7.8 JT	
LW2-C082-2	LW2-C082-D2	210	295		1.4 UT	
LW2-C096	LW2-C096-B	30	153		630 JT	
LW2-C096	LW2-C096-C	153	274		1.5 UT	
LW2-C099	LW2-C099-B	30	152		330 T	
LW2-C099	LW2-C099-C	152	305		130 T	
LW2-C103	LW2-C103-B	30	153		126 JT	
LW2-C103	LW2-C103-D	274	363		33 JT	
LW2-C103	LW2-C103-E	363	462		13 T	
LW2-G082	LW2-G082	0	27		150 JT	
LW2-G096	LW2-G096	0	25	7.75 JT	302 T	258
LW2-G099	LW2-G099	0	29		294 JT	
LW2-G103	LW2-G103	0	27	2 JT	104 JT	66.1
WLCITC03SS02	WLCITC03SS020013	0	396.24		190 J	
WLCITC03SS02	WLCITC03SS021517C	457.2	518.16		2.3 U	
WLCITC03SS03R	WLCITC03SS03R0204C	60.96	121.92		2.4 U	

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Table I-4b. iAOPC 4 Tissue Samples Data.

Location	Sample	Species	Tissue	Dioxin-like PCB congener TCDD pg/g-Wet	Total PCB Aroclors µg/kg-Wet	Total PCB Congeners µg/kg-Wet
LW2-BTFC005	LW2-BTFC005	clam	body without shell	4.2 T	234 JT	306

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Table I-5a. iAOPC 5 Sediment Samples Data.

Location	Sample	Upper cm	Lower cm	Dioxin-like PCB congener TCDD pg/g	Total PCB Aroclors µg/kg	Total PCB Congeners µg/kg
LW2-C109	LW2-C109-A	0	30		65 JT	
LW2-C109	LW2-C109-B	30	152		223 JT	
LW2-C109	LW2-C109-C	152	274		185 JT	
LW2-C109	LW2-C109-E	373	432		1.5 UT	
LW2-C111	LW2-C111-B	30	153		290 JT	
LW2-C111	LW2-C111-C	153	250		183 JT	
LW2-C111	LW2-C111-F	426	488		16.1 JT	
LW2-C111-2	LW2-C111-A2	0	30		296 JT	
LW2-C111-2	LW2-C111-B2	30	140	6.38 T	407 T	338 T
LW2-C111-2	LW2-C111-C2	140	256		183 T	
LW2-C111-2	LW2-C111-E2	369	420		220 T	
LW2-C112	LW2-C112-B	30	152		220 JT	
LW2-C112	LW2-C112-C	152	274		266 JT	
LW2-C112	LW2-C112-D	274	425		166 JT	
LW2-G106	LW2-G106	0	29		236 JT	
LW2-G108	LW2-G108	0	29		17.9 T	
LW2-G109	LW2-G109	0	28	3.42 JT	207 JT	219
LW2-G111	LW2-G111	0	24		1530 T	
LW2-G112	LW2-G112	0	29	4.37 JT	308 T	274
LW2-G519	LW2-G519-1	0	29	1.13 JT	69 T	55.3
LW2-G519-2	LW2-G519-2	0	29		62 T	
LWG0103R004SDS015C10	LWG0103R004SDS015C11	0	15	5.66 T	346 T	699 JT
LWG0103R004SDS015C20	LWG0103R004SDS015C20	0	15		259 T	
LWG0103R004SDS015C30	LWG0103R004SDS015C30	0	15		122 T	
WLCITC03SS01	WLCITC03SS010007	0	213.36		114	
WLCITC03SS01	WLCITC03SS010710C	213.36	304.8		2.3 U	
WLCT4C04UP01	WLCT4C04UP01UP0101	0	30.48		51 J	
WLCT4C04VC01	WLCT4C04VC01VC0101	0	30.48		250	
WLCT4C04VC01	WLCT4C04VC01VC0113	30.48	91.44		151	
WLCT4C04VC01	WLCT4C04VC01VC0135	91.44	152.4		11 U	

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Table I-5b. iAOPC 5 Tissue Samples Data.

Location	Sample	Species	Tissue	Dioxin-like PCB congener TCDD toxicity equivalent pg/g-Wet	Total PCB Aroclors µg/kg-Wet	Total PCB Congeners µg/kg-Wet
LWG0103R004CR00	LWG0103R004TSCRWBC00	crayfish	whole body	1.66 T	7 UT	31.5 JT
LWG0103R004SP10	LWG0103R004TSSPWBC10	sculpin	whole body	15.4 T	324 T	818 JT
LWG0103R004SP20	LWG0103R004TSSPWBC20	sculpin	whole body		305 T	
LWG01FZ0306Zone	LWG01FZ0306TSBBFLC10	brown bullhead	fillet without skin		53 T	
LWG01FZ0306Zone	LWG01FZ0306TSBBFLC20	brown bullhead	fillet without skin		37 T	
LWG01FZ0306Zone	LWG01FZ0306TSBBFLC30	brown bullhead	fillet without skin		56 T	
LWG01FZ0306Zone	LWG01FZ0306TSBBWBC10	brown bullhead	whole body	2.21 T	67 T	83.3 JT
LWG01FZ0306Zone	LWG01FZ0306TSBBWBC20	brown bullhead	whole body	4.37 T	90 T	177 JT
LWG01FZ0306Zone	LWG01FZ0306TSBBWBC30	brown bullhead	whole body	8.31 T	125 T	236 JT
LWG01FZ0306Zone	LWG01FZ0306TSBCFLC10	black crappie	fillet		22.2 T	
LWG01FZ0306Zone	LWG01FZ0306TSBCFLC20	black crappie	fillet		22.6 T	
LWG01FZ0306Zone	LWG01FZ0306TSBCWBC10	black crappie	whole body	2.93 T	85 T	103 JT
LWG01FZ0306Zone	LWG01FZ0306TSBCWBC20	black crappie	whole body	2.54 T	90 T	106 JT
LWG01FZ0306Zone	LWG01FZ0306TSCPFLC10	carp	fillet		670 T	
LWG01FZ0306Zone	LWG01FZ0306TSCPFLC20	carp	fillet		350 T	
LWG01FZ0306Zone	LWG01FZ0306TSCPFLC30	carp	fillet		1060 T	
LWG01FZ0306Zone	LWG01FZ0306TSCPWBC10	carp	whole body	8.43 T	300 T	451 JT
LWG01FZ0306Zone	LWG01FZ0306TSCPWBC20	carp	whole body	38.8 T	6500 JT	8150 JT
LWG01FZ0306Zone	LWG01FZ0306TSCPWBC30	carp	whole body	5.39 T	230 T	343 JT

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Table I-6. iAOPC 6 Sediment Samples Data.

Location	Sample	Upper cm	Lower cm	Dioxin-like PCB congener TCDD toxicity equivalent mg/kg	Mercury mg/kg	Silver mg/kg
LW2-C157	LW2-C157-B	30	152	800 J	0.152	0.276
LW2-C157	LW2-C157-C	152	250	470 J	0.194	0.357
LW2-G153	LW2-G153	0	28		0.74	0.174 J
LW2-G157	LW2-G157	0	25	400 J	0.022	0.09

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Table I-7a. iAOPC 7 Sediment Samples Data.

Location	Sample	Upper cm	Lower cm	Diesel Range Hydrocarbons mg/kg	Dioxin-like PCB congener TCDD toxicity equivalent pg/g	Silver mg/kg	Total PCB Aroclors µg/kg	Total PCB Congeners µg/kg
LW2-C192	LW2-C192-B	30	132	330 J		0.349	146 T	
LW2-C192	LW2-C192-C	132	249	1200 J		0.416	213 JT	
LW2-C192	LW2-C192-D	249	282	160 J		0.067	2.4 UT	
LW2-C197	LW2-C197-B	30	136	530 J		0.318	178 JT	
LW2-C197	LW2-C197-C	136	203	1600 J		0.533	240 JT	
LW2-C197	LW2-C197-D	203	259	13 UT		0.021	2.18 UT	
LW2-C199	LW2-C199-B	30	172	430 J		0.207	194 JT	
LW2-C199	LW2-C199-C	172	301	28 J		0.054	2.72 UT	
LW2-C202	LW2-C202-B	30	152	1900 J		0.596	406 JT	
LW2-C202	LW2-C202-C	152	188	3200 J		0.979	369 JT	
LW2-C202	LW2-C202-D	188	304	37 J		0.037 J	1.5 UT	
LW2-C203	LW2-C203-B	30	92	490 J		0.43	227 JT	
LW2-C203	LW2-C203-C	92	214	3400 J	86.7 T	0.378	1110 JT	2830
LW2-C203	LW2-C203-E	246	310	205 JT		0.09	36.4 JT	
LW2-C206	LW2-C206-B	30	137	1700 J		0.552	668 JT	
LW2-C206	LW2-C206-C	137	269	11 U		0.022 J	2.18 UT	
LW2-C207	LW2-C207-B	30	159	3500 J	5.56 T	0.626 T	642 JT	486
LW2-C207	LW2-C207-C	159	255	830 J		0.148	2.64 UT	
LW2-C207	LW2-C207-D	255	331	990 J		0.251	2.9 UT	
LW2-C207-2	LW2-C207-B2	30	143	2900 JT		0.573 T	232 JT	
LW2-C207-2	LW2-C207-C2	143	281	665 JT		0.174 T	2.73 UT	
LW2-C215	LW2-C215-B	30	119.5	13 UT		0.0305 T	1.4 UT	
LW2-C215	LW2-C215-C	119.5	241.5	12 U		0.028	1.4 UT	
LW2-G192	LW2-G192	0	25	91 J		0.193	52.1 JT	
LW2-G193	LW2-G193	0	26			0.117	23 JT	
LW2-G197	LW2-G197-1	0	25	150 JT		0.191	51.6 JT	
LW2-G197-2	LW2-G197-2	0	25	110 J	1.65 JT	0.162	60.2 JT	52.8
LW2-G198	LW2-G198	0	29	200 J	5.67 JT	0.729	112 T	180 JT
LW2-G199	LW2-G199	0	27	160 J		0.195	93.4 T	
LW2-G202	LW2-G202	0	26	110 J		0.238	63.6 JT	
LW2-G203	LW2-G203-1	0	27	210 JT		0.277 JT	66 JT	
LW2-G203-2	LW2-G203-2	0	27	230 J		0.376 J	57.5 JT	
LW2-G204	LW2-G204	0	25	200 J		0.099	57.4 JT	
LW2-G206	LW2-G206	0	26	230 J		0.248	120 JT	
LW2-G207	LW2-G207	0	21	300 J		0.269	205 JT	
LW2-G209	LW2-G209	0	14	83 J		0.12	196 T	
LW2-G214	LW2-G214-1	0	29			0.271 J	39 T	
LW2-G215	LW2-G215	0	25	360 J		0.304 JT	48 JT	
LW2-G218	LW2-G218	0	21		8.25 T	0.154 J	270 JT	250
LW2-GBT013	LW2-GBT013	0	10	50 J	2.1 T	0.36 JT	29 T	67.7

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Table I-7a. iAOPC 7 Sediment Samples Data.

Location	Sample	Upper cm	Lower cm	Diesel Range Hydrocarbons mg/kg	Dioxin-like PCB congener TCDD toxicity equivalent pg/g	Silver mg/kg	Total PCB Aroclors µg/kg	Total PCB Congeners µg/kg
LWG0105R003SDS015C00	LWG0105R003SDS015C00	0	15			0.05	250 T	
WLCDRD05PG023	WLCDRD05PG02323	0	20	290 J		0.231 J	180 T	
WLCDRD05PG027	WLCDRD05PG02727	0	20	76 J		3.71 J	250 T	
WLCDRD05PG027	WLCDRD05PG137137Dup	0	20	61 J		5.65 J	210 T	
WLCMCB02SED01	WLCMCB02SED01SED01	0	15			0.564		
WLCMCB02SED02	WLCMCB02SED02SED02	0	15			1.16		
WLCMCB02SED03	WLCMCB02SED03SED03	0	15			1 U		
WLCOFJ025201	WLCOFJ02520152010	0	10	47.3		3.2 B		49.5 T
WLCOFJ025202	WLCOFJ02520252020	0	15	41		0.394 B		11.4 JT
WLCOFJ025203	WLCOFJ02520352030	0	15	19.9		0.307 B		3.24 JT
WLCOFJ0252A01	WLCOFJ0252A0152A010	0	5	25.3		0.167		8.3 JT
WLCOFJ0252A02	WLCOFJ0252A0252A020	0	8	82.7		3.93		14.3 JT
WLCOFJ0252A03	WLCOFJ0252A0352A030	0	7	73.8		0.408		14.2 JT
WLCOFJ0252A04	WLCOFJ0252A0452A040	0	15	75.7		0.476		12.3 JT
WLCOFJ0252A05	WLCOFJ0252A0552A050	0	13	185		0.226		15.6 JT
WR-WSI98SD053	WR-WSI98SD0530	0	10			0.8		
WR-WSI98SD053	WR-WSI98SD0530000A	0	90			1.2		
WR-WSI98SD056	WR-WSI98SD0560	0	10			0.6		

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Table I-7b. iAOPC 7 Surface Water Samples Data.

Location	Sampling Method	Sample	Silver (dissolved) mg/l	Silver mg/l	Total PCB Aroclors µg/l
LW2-W010	bottle	LW2-W010	0.000009 U	0.000009 U	0.00267 UT
LW2-W010	bottle	LW2-W2010	0.000009 U	0.000009 U	0.0025 UT
LW2-W010	bottle	LW2-W3010	0.000005 UJ	0.000005 UJ	0.0025 UT

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Table I-7c. iAOPC 7 Tissue Samples Data.

Location	Sample	Species	Tissue	Dioxin-like PCB congener TCDD toxicity equivalent pg/g-Wet	Silver mg/kg-Wet	Total PCB Aroclors µg/kg-Wet	Total PCB Congeners µg/kg-Wet
LW2-BTFC013	LW2-BTFC013	clam	body without shell	2.04 T	0.0623 T	109 JT	153
LW2-GBT013	LW2-BTLC013	lab clam	body without shell	0.653 T	0.0129	21.5 JT	27.1
LW2-GBT013	LW2-BTLW013	Lumbriculus variegatus	whole body	4.36 JT	0.0068	187 JT	282
LWG0105R003CR00	LWG0105R003TSCRWBC00	crayfish	whole body		0.0238 J	27 T	

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Table I-7d. iAOPC 7 Porewater Samples Data.

Location	Sample	upper cm	lower cm	Silver mg/l
WR-WSI98SD053	WR-WSI98SD0530PW	0	10	0.0002 U
WR-WSI98SD056	WR-WSI98SD0560PW	0	10	0.0002 U

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Table I-8a. iAOPC 8 Sediment Samples Data.

Location	Sample	Upper cm	Lower cm	Dioxin-like PCB congener TCDD toxicity equivalent pg/g	Total PCB Aroclors µg/kg	Total PCB Congeners µg/kg
LW2-G230	LW2-G230	0	26	1.37 JT	220 T	31.7
WR-WSI98SD055C	WR-WSI98SD055C0000A	0	90		350 UT	

BZTO104(e)031383

Table I-8b. iAOPC 8 Tissue Samples Data.

Location	Sample	Species	Tissue	Total PCB Aroclors µg/kg-Wet
LWG0105R020SP00	LWG0105R020TSSPWBC00	sculpin	whole body	132 JT

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Table I-9. iAOPC 9 Sediment Samples Data.

Location	Sample	Upper cm	Lower cm	Dioxin-like PCB congener TCDD toxicity equivalent pg/g	Total of 2,4' and 4,4'-DDT µg/kg	Total PCB Aroclors µg/kg	Total PCB Congeners µg/kg
LW2-G241	LW2-G241	0	24	0.436 JT	13 JT	98 T	12.6
LW2-G242	LW2-G242	0	27		276 JT	3.5 UJT	
WLCMFH00SD05	WLCMFH00SD05SD05D	30	54			76 T	
WLCMFH00SD05	WLCMFH00SD05SD05S	0	20			19 T	

BZTO104(e)031385

Table I-10. iAOPC 10 Sediment Samples Data.

Location	Sample	Upper cm	Lower cm	Dioxin-like PCB congener TCDD toxicity equivalent mg/kg	Dioxin-like PCB congener TCDD toxicity equivalent pg/g	Total PCB Aroclors µg/kg	Total PCB Congeners µg/kg
LW2-C232	LW2-C232-B	30	159	1.49		2.21 UT	
LW2-C232	LW2-C232-C	159	221	1.69		2.5 UT	
LW2-C244	LW2-C244-B	30	133	5.58		133 JT	
LW2-C244	LW2-C244-C	133	270	5.1		219 JT	
LW2-C247	LW2-C247-B	30	63	9.18 J		2.6 UT	
LW2-C247	LW2-C247-C	63	181	7.62 JT		2.48 UT	
LW2-C247	LW2-C247-D	181	319	6.43 J		2.62 UT	
LW2-G232	LW2-G232	0	27	3.77		46.3 JT	
LW2-G236	LW2-G236	0	26	4.14		160 JT	
LW2-G238	LW2-G238	0	29	10.2		146 JT	
LW2-G239	LW2-G239	0	27	2.96		220 T	
LW2-G244	LW2-G244	0	29	3.91 J		182 JT	
LW2-G247	LW2-G247	0	29	3.86 J	4.17 T	157 T	111
LWG0106B030SDS015C00	LWG0106B030SDS015C00	0	15	9.9		16 T	
WLCOFJ025001	WLCOFJ02500150010	0	10	22			9.16 JT
WLCOFJ025002	WLCOFJ02500250020	0	14	16.9			10.9 JT
WLCOFJ025003	WLCOFJ02500350030	0	13	21.5			5.4 JT
WLCOFJ025004	WLCOFJ02500450040	0	10	15.1			6.26 JT
WLCOFJ025005	WLCOFJ02500550050	0	10	13.3			2.35 JT
WLCOFJ025006	WLCOFJ02500650060	0	15	14.6			29.3 T
WR-WSI98SD060	WR-WSI98SD0600	0	10	5			

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Table I-11a. iAOPC 11 Sediment Samples Summary Statistics.

Location	Sample	Upper cm	Lower cm	Ammonia mg/kg	Benzo(a)anthracene µg/kg	Benzo(a)pyrene µg/kg	Benzo(b)fluoranthene µg/kg	beta-Hexachlorocyclohexane µg/kg	delta-Hexachlorocyclohexane µg/kg	Dibenzo(a,h)anthracene µg/kg	Diesel Range Hydrocarbons mg/kg
GS-04-A-PG	LWG2-PG-GS4A	0	26	3.4 J	52000	85000	48000			6100	10000 J
GS-04-A-PG-2	LWG2-PG-GS4A-2	0	26	86.7	120000	160000	110000			15000	10000 J
GS-07-B-PG	LWG2-PG-GS7B	0	24	57	28000	43000	25000			3000	1700 J
GS-07-D-PG	LWG2-PG-GS7D	0	30	164	8600	14000	8400			1100	1050 JT
LW2-B016	LW2-B016	0	15		6200	10000	10000	0.0305 U	0.0644 UJ	980	
LW2-C263	LW2-C263-B	30	152		10000	10000	10000	51.8 NJ	1.16 UJ	1800	1700 J
LW2-C263	LW2-C263-C	152	277								
LW2-C263	LW2-C263-D	277	376		26000	30000	17000	7.87 NJ	1.06 UJ	2400	3300 J
LW2-C264	LW2-C264-B	30	156		95000	110000	72000	0.233 U	0.492 U	13000	4800 J
LW2-C264	LW2-C264-C	156	220		41000	54000	46000	5.57 J	0.435 U	6100	1300 J
LW2-C264	LW2-C264-D	220	290		38	76	44	0.17 U	0.078 U	6.1	
LW2-C269	LW2-C269-A	0	30								
LW2-C269	LW2-C269-B	30	151		3200	4800	4000	0.259 U	0.548 UJ	560	860 J
LW2-C269	LW2-C269-C	151	272		3900	4300	3800	0.241 U	0.51 UJ	390	1500 J
LW2-C269	LW2-C269-D	272	395					2.6 U	5.1 U		
LW2-C269	LW2-C269-F	509	541		10000	16000	14000	3.53 NJ	0.448 UJ	1200	1700 J
LW2-C270	LW2-C270-B	30	87		32000	41000	27000	13.9 NJ	2.65 UJ	4100	3000 J
LW2-C270	LW2-C270-C	87	182		13000	18000	13000	9.95 NJ	2.42 UJ	1600	2000 J
LW2-C270	LW2-C270-D	182	272		350	580	340	0.2 U	0.59	47	
LW2-C273	LW2-C273-B	30	153		95000	140000	130000	13.1 NJ	1.12 U	8700	4400 J
LW2-C273	LW2-C273-C	153	274		31000	49000	42000	0.442 U	0.934 U	3000	4900 J
LW2-C273	LW2-C273-D	274	355		5000	9000	5100	0.49 U	0.24 U	540	
LW2-C276	LW2-C276-B	30	153		11000	14000	9500	6.39 J	0.527 UJ	1500	1500 J
LW2-C276	LW2-C276-C	153	268		210000	260000	180000	43.4 J	24.8 NJ	21000	29000 J
LW2-C276	LW2-C276-D	268	319		94	140	80	0.83 U	0.4 U	12	
LW2-C278	LW2-C278-B	30	152		11000	17000	14000	8.97 NJ	1.1 UJ	1500	2850 JT
LW2-C278	LW2-C278-C	152	288		26000	33000	27000	12.1 NJ	0.949 U	2800	5200 J
LW2-C278	LW2-C278-D	288	350		24	34	29	0.0365 U	0.0772 U	4.7	9.6 U
LW2-C283	LW2-C283-B	30	151		30000 J	31000 J	28000 J	21.7 J	2.09 UJ	3200 J	4800 J
LW2-C283	LW2-C283-C	151	258		19000 J	25000 J	21000 J	0.843 U	1.78 UJ	2300 J	4200 J
LW2-C283	LW2-C283-E	380	430		33 J	26 J	27 J	1.06 J	0.0773 UJ	4 J	14 UT
LW2-C284	LW2-C284-B	30	104		21000	22000	15000	0.254 U	0.537 UJ	1900	3100 J
LW2-C284	LW2-C284-C	104	183		280000	340000	230000	45.8 J	2.27 U	30000	38000 J
LW2-C284	LW2-C284-D	183	292		2300	3000	1900	0.734 NJ	0.388 U	250	140 J
LW2-C284	LW2-C284-E	292	353		2.9	3.4	2.2			0.41 U	
LW2-C288	LW2-C288-B	30	153		56000	76000	69000	17.9 NJ	1.09 U	5400	5000 J
LW2-C288	LW2-C288-C	153	274		21000	29000	26000	0.474 U	1 U	2200	3800 J
LW2-C288	LW2-C288-D	274	389		14000	23000	19000	0.907 NJ	0.468 U	1500	1900 J
LW2-C289	LW2-C289-B	30	155		21000	21000	17000			2100	7100 J
LW2-C289	LW2-C289-C	155	206		17000	21000	17000			1900	4600 J
LW2-C289	LW2-C289-E	249	336		5.8	6.6	5.3			0.94 J	9.4 U
LW2-C294	LW2-C294-B	30	152		200000	260000	200000	25.6 J	3.8 J	27000	30000 J
LW2-C294	LW2-C294-C	152	272		18000	24000	20000	6.92 J	0.979 U	2000	2850 JT
LW2-C294	LW2-C294-D	272	376		800	1400	1100	0.412 U	0.871 U	150 J	270 J
LW2-C301	LW2-C301-B	30	153		150000 J	150000 J	130000 J	4.6 U	9.73 UJ	15000 J	30000 J
LW2-C301	LW2-C301-C	153	231		600000 J	690000 J	590000 J	15.1 U	32 UJ	66000 J	190000 J
LW2-C301	LW2-C301-D	231	358		180000 J	220000 J	170000 J	23.6	17 NJ	24000 J	30000 J
LW2-C301	LW2-C301-E	358	398		440000 J	470000 J	440000 J	12.6 U	26.6 UJ	37000 J	89000 J
LW2-C301	LW2-C301-G	428	516		46000 J	71000 J	60000 J	0.819 U	1.73 UJ	4300 J	3700 J
LW2-C302	LW2-C302-B	32	198		29000 J	28000 J	17000 J	1.12 U	2.38 UJ	3000 J	5000 J
LW2-C302	LW2-C302-C	198	288		760000	940000	580000	318 NJ	45.4 NJ	67000	130000 J
LW2-C302	LW2-C302-D	288	348		310000	370000	230000	41 U	21 U	24000	

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Table I-11a. iAOPC 11 Sediment Samples Summary Statistics.

Location	Sample	Upper cm	Lower cm	Ammonia mg/kg	Benzo(a)anthracene µg/kg	Benzo(a)pyrene µg/kg	Benzo(b)fluoranthene µg/kg	beta-Hexachlorocyclohexane µg/kg	delta-Hexachlorocyclohexane µg/kg	Dibenzo(a,h)anthracene µg/kg	Diesel Range Hydrocarbons mg/kg
LW2-C311	LW2-C311-B	30	153		10000 J	12000 J	10000 J	5.22 NJ	1.01 U	1100 J	2600 J
LW2-C311	LW2-C311-C	153	276		1400 J	2100 J	1900 J	2.17 J	1 U	180 J	870 J
LW2-C311	LW2-C311-E	398	533		740 J	1300 J	1000 J	0.86 J	0.871 U	98 J	365 JT
LW2-C312	LW2-C312-A	0	30		1800	1900	1100	0.24 U	0.16 U	140	560 J
LW2-C312	LW2-C312-B	30	152		490	540	310	0.38	0.081 U	45	110 J
LW2-C312	LW2-C312-C	152	245		1.8 J	2.7	1.6 J	0.79 U	0.073 U	0.33 U	4.3 UT
LW2-C521	LW2-C521-B	30	99		6400	8200	6600	4.4	2.1 U	840	3400 J
LW2-C521	LW2-C521-C	99	182		180000	220000	180000	1.7 U	2 U	21000	23000 J
LW2-C521	LW2-C521-D	182	280		18000	26000	14000	2 U	3.3	2000	
LW2-C521	LW2-C521-E	280	315		470	620	480			66	40 J
LW2-C525	LW2-C525-A	0	30		62000	85000	55000	3 U	5.7 U	7300	1800 J
LW2-C525	LW2-C525-B	30	127		4200	5900	3800	2.3 U	2.7 U	550	1200 J
LW2-C525	LW2-C525-C	127	236		3200	4400	2600	2.1 U	2.3 U	440	990 J
LW2-C525	LW2-C525-D	236	341		32000	44000	28000	6 U	15 U	3700	4400 J
LW2-C525	LW2-C525-E	341	427		550	800	470	0.81 U	0.4 U	63	74 J
LW2-C527	LW2-C527-A	0	30		2800	3900	2900	2.9 U	2 U	390	270 J
LW2-C527	LW2-C527-B	30	152		760	1000	800	2.4 U	1.2 U	130	160 J
LW2-C527	LW2-C527-C	152	250		1500	2000	1700	9.1	1.1 U	230	520 J
LW2-C527	LW2-C527-E	352	482		3000	3700	2900	4.4 U	6.7 U	370	1600 J
LW2-G259	LW2-G259	0	28		14000	21000	18000	4.04 J	0.107 UJ	2400	
LW2-G263	LW2-G263	0	25	115 J	3100	4700	4100	2 NJ	0.449 U	530	200 J
LW2-G264	LW2-G264	0	30	157 J	120000	140000	120000	5.97 J	0.658 UJ	14000	4700 J
LW2-G269	LW2-G269	0	26	334 J	13000	17000	16000	7.82 J	0.619 UJ	2000	1300 J
LW2-G270	LW2-G270-1	0	29	166 J	12000	17000	15000	2.14 NJ	0.123 UJ	2100	1100 J
LW2-G270-2	LW2-G270-2	0	29	140 J	22000	32000	28000	0.0624 UJ	0.132 UJ	3200	1700 J
LW2-G273	LW2-G273	0	28	248	9000	12000	12000	2.94 J	0.496 UJ	1300	620 J
LW2-G274	LW2-G274	0	22	49.9	12000	17000	16000	20.3 J	0.764 U	2200	940 J
LW2-G276	LW2-G276	0	29	227 J	2400	4100	3600	1.09 J	0.694 U	400	390 J
LW2-G278	LW2-G278	0	27	184 J	18000	27000	24000	3.2 J	0.696 U	2500	4200 J
LW2-G283	LW2-G283	0	27	152 J	110000	140000	130000	13.6 J	3.03 NJ	12000	14000 J
LW2-G284	LW2-G284	0	27	161 J	2200	3700	3100	2.59 NJ	0.698 U	350	500 JT
LW2-G288	LW2-G288	0	30	188	88000	100000	91000	17 J	0.912 NJ	8500	14000 J
LW2-G289	LW2-G289	0	27		11000	17000	15000			1700	630 J
LW2-G292	LW2-G292	0	28	122 T	21000	31000	27000	0.508 U	1.07 UJ	2600	1700 J
LW2-G294	LW2-G294-1	0	26	112 JT	40000	42000	40000	0.058 UJ	0.123 UJ	5400	20000 J
LW2-G294-2	LW2-G294-2	0	29	142 JT	41500 T	51500 T	48500 T	0.0601 UJT	0.127 UJT	5150 T	2600 JT
LW2-G297	LW2-G297	0	27		3400	4600	3900			370	630 J
LW2-G298	LW2-G298	0	27	120	200000	220000	190000	26.4	21.2 NJ	17000	39000 J
LW2-G301	LW2-G301	0	27	112	52000	47000	40000	0.488 U	1.03 UJ	4000	460 J
LW2-G302	LW2-G302	0	27	168	9300	17000	15000	0.574 U	1.21 UJ	1500	9000 J
LW2-G308	LW2-G308	0	27	88.4	1400	780	930	2.57 NJ	0.463 UJ	100	330 J
LW2-G311	LW2-G311-1	0	21	242 JT	3850 T	4800 T	4300 T	3.62 JT	0.109 UJT	425 T	1080 JT
LW2-G521	LW2-G521	0	28		2800	4600	3900	2.44 NJ	0.606 UJ	410	370 J
LWG0106B025SDS015C00	LWG0106B025SDS015C00	0	15		29000 T	41000 T	31000 T	42 U	3.9 U	9500 JT	
SL-02-A-PG	LWG2-PG-SL2A	0	29	165 T	7900	9800	5400			870 J	1150 JT
SL-04-A-PG	LWG2-PG-SL4A	0	20	71.3	580	790	500			80	150 J
SL-04-F-PG	LWG2-PG-SL4F	0	30	154	800	1000	680			110	130 J
SL-05-A-PG	LWG2-PG-SL5A	0	26	87.4	350	560	340			59	100 J
WLCASF97S017	WLCASF97S017W4149	0	10		459601	621300	342877			52802	
WLCDRD05PG050	WLCDRD05PG05050	0	30	196	5300	8400	4900	1.2 U	1 U	820	840 J
WLCDRD05PG052	WLCDRD05PG05252	0	28	171	5200	9700	6000	0.98 U	1 U	980	840 J
WLCDRD05VC050	WLCDRD05VC05050	0	140	283	27000	32000	18000	9.8 U	5.5 U	2600	6000 J

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Table I-11a. iAOPC 11 Sediment Samples Summary Statistics.

Location	Sample	Upper cm	Lower cm	Ammonia mg/kg	Benzo(a)anthracene µg/kg	Benzo(a)pyrene µg/kg	Benzo(b)fluoranthene µg/kg	beta-Hexachlorocyclohexane µg/kg	delta-Hexachlorocyclohexane µg/kg	Dibenzo(a,h)anthracene µg/kg	Diesel Range Hydrocarbons mg/kg
WLCDRD05VC052	WLCDRD05VC05252	0	88	204	20000	26000	15000	8.6 U	10 U	2000	2900 J
WLCGSD01AN0101	WLCGSD01AN0101_00-10	0	10		12000	18000	9300			1200	
WLCGSD01AN0101	WLCGSD01AN0101_10-20	10	20		15000	20000	8800			1600	
WLCGSD01AN0101	WLCGSD01AN0101_30-40	30	40		8300	10000	5100			730	
WLCGSD01AN0102	WLCGSD01AN0102_00-10	0	10		23000	37000	19000			2200	
WLCGSD01AN0102	WLCGSD01AN0102_10-20	10	20		48000	66000	33000			4800	
WLCGSD01AN0102	WLCGSD01AN0102_30-40	30	40		17000	19000	11000			1400	
WLCGSD01AN0103	WLCGSD01AN0103_00-10	0	10		100000	93000	46000			6400	
WLCGSD01AN0103	WLCGSD01AN0103_10-20	10	20		58000	58000	31000			5100	
WLCGSD01AN0103	WLCGSD01AN0103_30-40	30	40		120000	130000	65000			10000 J	
WLCGSD01AN0201	WLCGSD01AN0201_00-10	0	10		2000 J	3000 J	1600 J			220 J	
WLCGSD01AN0201	WLCGSD01AN0201_10-20	10	20		24000	29000	15000			2100	
WLCGSD01AN0201	WLCGSD01AN0201_30-40	30	40		9400	13000	7000			1100	
WLCGSD01AN0202	WLCGSD01AN0202_00-10	0	10		29000	23000	11000			1900	
WLCGSD01AN0202	WLCGSD01AN0202_10-20	10	20		20000	17000	7500			1300	
WLCGSD01AN0202	WLCGSD01AN0202_30-40	30	40		11000	13000	6400			1000	
WLCGSD01AN0203	WLCGSD01AN0203_00-10	0	10		35000	39000	20000			2500	
WLCGSD01AN0203	WLCGSD01AN0203_10-20	10	20		15000	18000	9300			1400	
WLCGSD01AN0203	WLCGSD01AN0203_30-40	30	40		10000	14000	7200			1200	
WLCGSD01AN0204	WLCGSD01AN0204_00-10	0	10		24000	31000	17000			2400	
WLCGSD01AN0204	WLCGSD01AN0204_10-20	10	20		26000	32000	16000			2200	
WLCGSD01AN0204	WLCGSD01AN0204_30-40	30	40		36000	37000	19000			2800	
WLCGSG04RAA02	WLCGSG04RAA02SD1019	304.8	579.12		89000	130000	110000			12000	8800
WLCGSG04RAA04	WLCGSG04RAA04SD0506	152.4	182.88		290000	340000	200000			22000	26000
WLCGSG04RAA05	WLCGSG04RAA05SD1020	304.8	609.6		940	1800	1100			110	190
WLCGSG04RAA06	WLCGSG04RAA06SD0415	121.92	457.2		24000	35000	20000			2000	2800
WLCGSG04RAA06	WLCGSG04RAA06SD1520	457.2	609.6		280	610	540			39 J	130
WLCGSG04RAA08	WLCGSG04RAA08SD0720	213.36	609.6		140	200	120			17	17 J
WLCGSG04RAA09	WLCGSG04RAA09SD0516	152.4	487.68		130000	170000	150000			17000	15000
WLCGSG04RAA10	WLCGSG04RAA10SD1020	304.8	609.6		50000	67000	58000			7100	2800
WLCGSG04RAA11	WLCGSG04RAA11SD1320	396.24	609.6		1010 T	1950 T	1150 T			104 T	175 T
WLCGSG04RAA12	WLCGSG04RAA12SD1820	548.64	609.6		7900	11000	9900			860 J	510
WLCGSG04RAA13	WLCGSG04RAA13SD1115	335.28	457.2		340000	450000	390000			48000	17000
WLCGSG04RAA14	WLCGSG04RAA14SD1014	304.8	426.72		410000	500000	290000			33000	51000
WLCGSG04RAA14	WLCGSG04RAA14SD1420	426.72	609.6		42	60	53			5.4 J	24 U
WLCGSG04RAA17	WLCGSG04RAA17SD0010	0	304.8		29000	43000	37000			4100	3400
WLCGSG04RAA17	WLCGSG04RAA17SD1420	426.72	609.6		78000	130000	110000			100	180
WLCMRI02CS001	WLCMRI02CS001CS001	0	91.44		10000	12000	8900	0.98 U		1500	2100 JT
WR-WSI98SD062	WR-WSI98SD0620	0	10		72000	57000	33000			9200	
WR-WSI98SD063	WR-WSI98SD0630	0	10		4000	5100	3100			1000	
WR-WSI98SD064	WR-WSI98SD0640	0	10		28000	40000	23000			6200	
WR-WSI98SD065	WR-WSI98SD0650	0	10		18000	23000	14000			3800	
WR-WSI98SD067	WR-WSI98SD0670	0	10		14000	15000	12000			2500	
WR-WSI98SD068	WR-WSI98SD0680	0	10		6300	8000	3900			1500	
WR-WSI98SD069	WR-WSI98SD0690	0	10		4800	2400	1900			390	
WR-WSI98SD070	WR-WSI98SD0700000CC	0	10		2250 T	1120 T	935 T	0.94 UT	0.94 UT	165 T	

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Table I-11a. iAOPC 11 Sediment Samples Summary Statistics.

Location	Sample	Upper cm	Lower cm	Dioxin-like PCB congener TCDD toxicity equivalent pg/g	Endrin ketone µg/kg	Indeno(1,2,3-cd)pyrene µg/kg	Residual Range Hydrocarbons mg/kg	Sulfide mg/kg	Total of 2,4' and 4,4'-DDD µg/kg	Total of 2,4' and 4,4'-DDT µg/kg	Total PCB Aroclors µg/kg	Total PCB Congeners µg/kg
GS-04-A-PG	LWG2-PG-GS4A	0	26			63000	13000 J	46 J				
GS-04-A-PG-2	LWG2-PG-GS4A-2	0	26			130000	11000 J	55 J				
GS-07-B-PG	LWG2-PG-GS7B	0	24			31000	2300 J	4.6 J				
GS-07-D-PG	LWG2-PG-GS7D	0	30			11000	1550 JT	7.3 J				
LW2-B016	LW2-B016	0	15		0.0265 U	8600			6.85 JT	1.76 JT	2.1 UT	
LW2-C263	LW2-C263-B	30	152		0.477 U	11000	1800 J		396 JT	36.6 JT	164 T	
LW2-C263	LW2-C263-C	152	277	7.43 JT							47 UT	50.5
LW2-C263	LW2-C263-D	277	376		0.438 U	20000	3000 J		251 JT	26.4 JT	7.36 UT	
LW2-C264	LW2-C264-B	30	156		0.203 U	70000	5500 J		106 JT	23.8 JT	31.7 UJT	
LW2-C264	LW2-C264-C	156	220		0.179 U	37000	3200 J		26.9 JT	1.67 JT	49.8 JT	
LW2-C264	LW2-C264-D	220	290		0.076 U	66			0.2 UT	0.19 UT	1.5 UT	
LW2-C269	LW2-C269-A	0	30								65 UT	
LW2-C269	LW2-C269-B	30	151		0.226 U	3400	1400 J		357 JT	232 JT	20.9 T	
LW2-C269	LW2-C269-C	151	272		0.21 U	3000	1400 J		205 JT	26.3 JT	219 JT	
LW2-C269	LW2-C269-D	272	395		7 U				219 JT	28 JT	180 UT	
LW2-C269	LW2-C269-F	509	541		0.184 U	12000	2100 J		5.1 JT	9.64 JT	2.95 UT	
LW2-C270	LW2-C270-B	30	87		1.09 U	29000	3900 J		229 JT	28.8 JT	184 UJT	
LW2-C270	LW2-C270-C	87	182		0.996 U	13000	2400 J		211 JT	164 T	23.7 UJT	
LW2-C270	LW2-C270-D	182	272		0.077 U	460			1.4 JT	0.36 UT		
LW2-C273	LW2-C273-B	30	153		0.461 U	97000	6000 J		23.3 T	52.6 JT	3.57 UJT	
LW2-C273	LW2-C273-C	153	274		0.385 U	36000	6000 J		0.63 UT	45.2 JT	3.08 UT	
LW2-C273	LW2-C273-D	274	355		0.81 U	7000			1.3 JT	1.1 UT		
LW2-C276	LW2-C276-B	30	153		0.217 U	11000	1700 J		91.8 JT	14.4 JT	253 JT	
LW2-C276	LW2-C276-C	153	268		0.849 U	170000	15000 J		138 JT	135 JT	2.81 UJT	
LW2-C276	LW2-C276-D	268	319		0.39 U	100			1.1 JT	0.97 UT		
LW2-C278	LW2-C278-B	30	152		0.451 UJ	13000	3250 JT		61.6 JT	17.1 JT	57.5 JT	
LW2-C278	LW2-C278-C	152	288		0.391 U	25000	3500 J		149 JT	7.04 JT	70.9 JT	
LW2-C278	LW2-C278-D	288	350		0.0318 U	34	17 J		0.128 JT	0.273 JT	2.7 UT	
LW2-C283	LW2-C283-B	30	151		0.861 U	22000 J	2500 J		588 JT	82.4 JT	105 JT	
LW2-C283	LW2-C283-C	151	258		0.734 U	19000 J	3700 J		145 JT	24.4 JT	2.93 UT	
LW2-C283	LW2-C283-E	380	430		0.0318 U	12 J	13.5 JT		0.0521 UT	0.0602 UJT	2.5 UJT	
LW2-C284	LW2-C284-B	30	104		0.221 U	15000	2300 J		42.9 JT	18.5 JT	128 JT	
LW2-C284	LW2-C284-C	104	183		0.935 U	240000	20000 J		193 JT	185 JT	6.2 UJT	
LW2-C284	LW2-C284-D	183	292		0.16 U	2100	110 J		2.15 JT	2.48 JT	2.5 UT	
LW2-C284	LW2-C284-E	292	353			1.8 J						
LW2-C288	LW2-C288-B	30	153		0.448 U	49000	5700 J		54.8 JT	26.8 JT	59.6 JT	
LW2-C288	LW2-C288-C	153	274		0.413 U	20000	4900 J		17.6 JT	30.4 JT	3.32 UT	
LW2-C288	LW2-C288-D	274	389		0.193 U	17000	2900 J		1.52 JT	0.365 UJT	3.09 UT	
LW2-C289	LW2-C289-B	30	155			14000	5100 J					
LW2-C289	LW2-C289-C	155	206			15000	3800 J					
LW2-C289	LW2-C289-E	249	336			5.6	14 J					
LW2-C294	LW2-C294-B	30	152		0.406 U	190000	17000 J		491 JT	23.9 JT	38.8 JT	
LW2-C294	LW2-C294-C	152	272		0.403 U	18000	3400 JT		10.6 JT	21.6 JT	3.18 UT	
LW2-C294	LW2-C294-D	272	376		0.358 U	1300	530 J		3.38 JT	0.679 UJT	2.77 UT	
LW2-C301	LW2-C301-B	30	153		4 U	93000 J	14000 J		448 JT	127 JT	10 UJT	
LW2-C301	LW2-C301-C	153	231		13.2 U	490000 J	110000 J		1110 JT	1110 JT	25.7 UT	
LW2-C301	LW2-C301-D	231	358		0.304 U	120000 J	14000 J		198 JT	103 JT	2.39 UT	
LW2-C301	LW2-C301-E	358	398		263 NJ	280000 J	68000 J		571 JT	649 JT	12.6 UT	
LW2-C301	LW2-C301-G	428	516		0.713 U	49000 J	2400 J		43.3 JT	61.5 JT	2.89 UT	
LW2-C302	LW2-C302-B	32	198	7.43 T	0.978 U	18000 J	3500 J		477 JT	41.7 JT	219 JT	223
LW2-C302	LW2-C302-C	198	288	0.117 T	6.7 U	610000	44000 J		780 JT	519 JT	846 UJT	13.6
LW2-C302	LW2-C302-D	288	348		220 U	270000			260 JT	250 UT	260 UT	

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Table I-11a. iAOPC 11 Sediment Samples Summary Statistics.

Location	Sample	Upper cm	Lower cm	Dioxin-like PCB congener TCDD toxicity equivalent pg/g	Endrin ketone µg/kg	Indeno(1,2,3-cd)pyrene µg/kg	Residual Range Hydrocarbons mg/kg	Sulfide mg/kg	Total of 2,4' and 4,4'-DDD µg/kg	Total of 2,4' and 4,4'-DDT µg/kg	Total PCB Aroclors µg/kg	Total PCB Congeners µg/kg
LW2-C311	LW2-C311-B	30	153		0.414 U	8700 J	2300 J		203 JT	31 JT	24.1 JT	
LW2-C311	LW2-C311-C	153	276		0.413 U	1700 J	1300 J		3.08 JT	1.42 JT	3.32 UT	
LW2-C311	LW2-C311-E	398	533		0.359 U	1000 J	715 JT		0.587 UT	0.679 UJT	2.85 UT	
LW2-C312	LW2-C312-A	0	30		2.1 NJ	1400	830 J		24 JT	245 JT	128 JT	
LW2-C312	LW2-C312-B	30	152		0.57 UJ	370	190 J		19.1 T	283 JT	19 UT	
LW2-C312	LW2-C312-C	152	245		0.2 UJ	1.7 J	4 UT		0.52 T	0.49 JT	1.4 UT	
LW2-C521	LW2-C521-B	30	99		13 U	6700	2000 J		48 T	17 UT	542 JT	
LW2-C521	LW2-C521-C	99	182		9.7 U	170000	11000 J		30 JT	16 JT		
LW2-C521	LW2-C521-D	182	280		5.8 U	17000			13 UT	5.7 UT	10 UT	
LW2-C521	LW2-C521-E	280	315			500	34 J					
LW2-C525	LW2-C525-A	0	30		28	59000	4400 J		40 JT	21 T	34 JT	
LW2-C525	LW2-C525-B	30	127		6.2 J	4600	1800 J		121 T	170 T	219 JT	
LW2-C525	LW2-C525-C	127	236		5.6	3200	1500 J		100 T	15 UT	71 T	
LW2-C525	LW2-C525-D	236	341		6.6 J	32000	5400 J		14 UT	20 UT	250 UT	
LW2-C525	LW2-C525-E	341	427		1.4 U	630	130 J		1 UT	1.1 UT	1.5 UT	
LW2-C527	LW2-C527-A	0	30		1.4 U	3300	1000 J		20 JT	193 JT	140 UT	
LW2-C527	LW2-C527-B	30	152		1.3 J	910	540 J		18 T	6.9 JT	20 JT	
LW2-C527	LW2-C527-C	152	250		1.7 J	1900	1300 J		22 T	9 T	32 T	
LW2-C527	LW2-C527-E	352	482		4 U	3900	2600 J		830 T	160 T	160 T	
LW2-G259	LW2-G259	0	28		0.0442 UJ	17000			80.4 JT	1.87 JT	3.8 UJT	
LW2-G263	LW2-G263	0	25		0.185 U	3800	400 J	28.6	13.9 JT	17.5 JT	3.17 UJT	
LW2-G264	LW2-G264	0	30		0.271 UJ	88000	10000 J	491	71.8 JT	19.9 JT	4.64 UJT	
LW2-G269	LW2-G269	0	26		0.255 UJ	13000	3600 J	998	81 JT	42.8 JT	R	
LW2-G270	LW2-G270-1	0	29		0.0507 U	14000	2000 J	59 J	19.3 JT	10.3 JT	4.3 UJT	
LW2-G270-2	LW2-G270-2	0	29		0.0543 U	24000	2200 J	121 J	112 JT	42.7 JT	4.5 UJT	
LW2-G273	LW2-G273	0	28	3.67 T	0.204 U	9800	1000 J	543 JT	25.6 JT	23.5 JT	122 JT	188
LW2-G274	LW2-G274	0	22		0.314 U	13000	1700 J	336	39.4 JT	23.7 JT	2.69 UJT	
LW2-G276	LW2-G276	0	29		0.286 U	3300	1100 J	15.7	39.8 JT	40.7 JT	4.94 UJT	
LW2-G278	LW2-G278	0	27		0.287 U	21000	4400 J	9	114 JT	32.5 JT	4.92 UJT	
LW2-G283	LW2-G283	0	27		0.224 UJ	100000	17000 J	103	444 JT	60.3 JT	3.81 UJT	
LW2-G284	LW2-G284	0	27		0.287 U	3200	1200 JT	13.9	49.8 JT	18.3 JT	4.92 UJT	
LW2-G288	LW2-G288	0	30		0.219 U	80000	7600 J	80.6 T	636 JT	22.4 JT	6.98 UT	
LW2-G289	LW2-G289	0	27			14000	1200 J					
LW2-G292	LW2-G292	0	28		0.442 U	24000	2600 J	1.4	64.6 JT	39.8 JT	14 JT	
LW2-G294	LW2-G294-1	0	26		0.0505 UJ	44000	13000 J	132 JT	838 JT	9.59 JT	80 JT	
LW2-G294-2	LW2-G294-2	0	29		0.0488 UJT	44500 T	3000 JT	11.7 JT	195 JT	36.5 JT	62.5 JT	
LW2-G297	LW2-G297	0	27			3500	730 J					
LW2-G298	LW2-G298	0	27	0.257 JT	0.429 U	140000	18000 J	40.6	2220 JT	60.4 JT	14.2 UJT	29.9
LW2-G301	LW2-G301	0	27		0.425 U	28000	1100 J	3.3	70 JT	41.6 JT	9.29 T	
LW2-G302	LW2-G302	0	27		0.5 U	13000	6000 J	10.1	163 JT	23.9 JT	163 JT	
LW2-G308	LW2-G308	0	27	1.49 T	0.191 U	600	310 J	2.9	16.2 JT	1.47 JT	68.1 JT	58.8
LW2-G311	LW2-G311-1	0	21		4.57 NJT	3150 T	1330 JT	17.4 JT	1360 JT	271 JT	170 JT	
LW2-G521	LW2-G521	0	28		0.249 U	3700	720 J		36.1 JT	38 JT	42.7 JT	
LWG0106B025SDS015C00	LWG0106B025SDS015C00	0	15		20 U	31000 T			9 UT	12 UT	29 T	
SL-02-A-PG	LWG2-PG-SL2A	0	29			6700	1400 JT	17.2 JT				
SL-04-A-PG	LWG2-PG-SL4A	0	20			590	290 J	3.4 J				
SL-04-F-PG	LWG2-PG-SL4F	0	30			870	320 J	5.6 J				
SL-05-A-PG	LWG2-PG-SL5A	0	26			450	250 J	4.7 J				
WLCASF97S017	WLCASF97S017W4149	0	10			440201						
WLCDRD05PG050	WLCDRD05PG05050	0	30		1 U	7700	1300 J	6.3 J	42 JT	34 JT	17 T	
WLCDRD05PG052	WLCDRD05PG05252	0	28		1.1 U	9100	1600 J	5.4 J	39 JT	9.9 JT	36 T	
WLCDRD05VC050	WLCDRD05VC05050	0	140		18 U	24000	3600 J	33.9	46 JT	27 T	175 T	

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Table I-11a. iAOPC 11 Sediment Samples Summary Statistics.

Location	Sample	Upper cm	Lower cm	Dioxin-like PCB congener TCDD toxicity equivalent pg/g	Endrin ketone µg/kg	Indeno(1,2,3-cd)pyrene µg/kg	Residual Range Hydrocarbons mg/kg	Sulfide mg/kg	Total of 2,4' and 4,4'-DDD µg/kg	Total of 2,4' and 4,4'-DDT µg/kg	Total PCB Aroclors µg/kg	Total PCB Congeners µg/kg
WLCDRD05VC052	WLCDRD05VC05252	0	88		12 U	19000	2100 J	7.1	30 T	27 UT	297 T	
WLCGSD01AN0101	WLCGSD01AN0101_00-10	0	10			10000						
WLCGSD01AN0101	WLCGSD01AN0101_10-20	10	20			11000						
WLCGSD01AN0101	WLCGSD01AN0101_30-40	30	40			6100						
WLCGSD01AN0102	WLCGSD01AN0102_00-10	0	10			26000						
WLCGSD01AN0102	WLCGSD01AN0102_10-20	10	20			41000						
WLCGSD01AN0102	WLCGSD01AN0102_30-40	30	40			12000						
WLCGSD01AN0103	WLCGSD01AN0103_00-10	0	10			46000						
WLCGSD01AN0103	WLCGSD01AN0103_10-20	10	20			32000						
WLCGSD01AN0103	WLCGSD01AN0103_30-40	30	40			76000						
WLCGSD01AN0201	WLCGSD01AN0201_00-10	0	10			1900						
WLCGSD01AN0201	WLCGSD01AN0201_10-20	10	20			17000						
WLCGSD01AN0201	WLCGSD01AN0201_30-40	30	40			8500						
WLCGSD01AN0202	WLCGSD01AN0202_00-10	0	10			9600						
WLCGSD01AN0202	WLCGSD01AN0202_10-20	10	20			8200						
WLCGSD01AN0202	WLCGSD01AN0202_30-40	30	40			7700						
WLCGSD01AN0203	WLCGSD01AN0203_00-10	0	10			22000						
WLCGSD01AN0203	WLCGSD01AN0203_10-20	10	20			11000						
WLCGSD01AN0203	WLCGSD01AN0203_30-40	30	40			9400						
WLCGSD01AN0204	WLCGSD01AN0204_00-10	0	10			20000						
WLCGSD01AN0204	WLCGSD01AN0204_10-20	10	20			19000						
WLCGSD01AN0204	WLCGSD01AN0204_30-40	30	40			20000						
WLCGSG04RAA02	WLCGSG04RAA02SD1019	304.8	579.12			100000	8100					
WLCGSG04RAA04	WLCGSG04RAA04SD0506	152.4	182.88			220000	14000					
WLCGSG04RAA05	WLCGSG04RAA05SD1020	304.8	609.6			1700	420					
WLCGSG04RAA06	WLCGSG04RAA06SD0415	121.92	457.2			28000	2800					
WLCGSG04RAA06	WLCGSG04RAA06SD1520	457.2	609.6			530	300					
WLCGSG04RAA08	WLCGSG04RAA08SD0720	213.36	609.6			160	39 J					
WLCGSG04RAA09	WLCGSG04RAA09SD0516	152.4	487.68			130000	9100					
WLCGSG04RAA10	WLCGSG04RAA10SD1020	304.8	609.6			52000	2700					
WLCGSG04RAA11	WLCGSG04RAA11SD1320	396.24	609.6			1950 T	320 T					
WLCGSG04RAA12	WLCGSG04RAA12SD1820	548.64	609.6			8900	760					
WLCGSG04RAA13	WLCGSG04RAA13SD1115	335.28	457.2			330000	11000					
WLCGSG04RAA14	WLCGSG04RAA14SD1014	304.8	426.72			330000	24000					
WLCGSG04RAA14	WLCGSG04RAA14SD1420	426.72	609.6			47	49 J					
WLCGSG04RAA17	WLCGSG04RAA17SD0010	0	304.8			31000	3600					
WLCGSG04RAA17	WLCGSG04RAA17SD1420	426.72	609.6			110000	370					
WLCMRI02CS001	WLCMRI02CS001CS001	0	91.44		2 U	9300			57 *	27 *	39 UT	
WR-WSI98SD062	WR-WSI98SD0620	0	10			12000						
WR-WSI98SD063	WR-WSI98SD0630	0	10			3000						
WR-WSI98SD064	WR-WSI98SD0640	0	10			19000						
WR-WSI98SD065	WR-WSI98SD0650	0	10			10000						
WR-WSI98SD067	WR-WSI98SD0670	0	10			9500						
WR-WSI98SD068	WR-WSI98SD0680	0	10			4200						
WR-WSI98SD069	WR-WSI98SD0690	0	10			1100						
WR-WSI98SD070	WR-WSI98SD0700000CC	0	10		2.8 UJT	405 T			12.5 T*	25.5 T*	51 T	

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Table I-11b. iAOPC 11 Surface Water Samples Data.

Location	Sampling Method	Sample	Benzo(a)anthracene µg/l	Benzo(a)pyrene µg/l	Benzo(b)fluoranthene µg/l	beta-Hexachlorocyclohexane µg/l	delta-Hexachlorocyclohexane µg/l	Dibenzo(a,h)anthracene µg/l	Endrin ketone µg/l	Indeno(1,2,3-cd)pyrene µg/l	Total of 2,4' and 4,4'-DDD µg/l	Total of 2,4' and 4,4'-DDT µg/l	Total PCB Aroclors µg/l
LW2-W012	bottle	LW2-W012	0.019	0.02	0.021	0.0005 U	0.0005 U	0.0033 U	0.0005 U	0.019	0.0005 UT	0.0005 UT	0.0025 UJT
LW2-W012	bottle	LW2-W2012	0.006 U	0.0082 U	0.0073 U	0.00051 U	0.00051 U	0.0033 U	0.00051 U	0.0094 J	0.00051 UT	0.00051 UT	0.0026 UT
LW2-W012	bottle	LW2-W3012	0.11	0.15	0.11	0.000481 U	0.000481 U	0.011 J	0.000481 U	0.11	0.000839 T	0.000481 UT	0.0025 UT

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Table I-11c. iAOPC 11 Tissue Samples Data.

Location	Sample	Species	Tissue	2-Methylnaphthalene µg/kg-Wet	Acenaphthene µg/kg-Wet	Anthracene µg/kg-Wet	Benzo(a)anthracene µg/kg-Wet	Benzo(a)pyrene µg/kg-Wet	Benzo(b)fluoranthene µg/kg-Wet	Benzo(g,h,i)perylene µg/kg-Wet	Benzo(k)fluoranthene µg/kg-Wet	beta-Hexachlorocyclohexane µg/kg-Wet	Chrysene µg/kg-Wet	delta-Hexachlorocyclohexane µg/kg-Wet	Dibenzo(a,h)anthracene µg/kg-Wet
LW2-BTFC015	LW2-BTFC015	clam	body without shell	20	61	78	630	490	460	230	310	0.0437 U	560	0.00193 U	43

Location	Sample	Species	Tissue	Dioxin-like PCB congener TCDD toxicity equivalent pg/g-Wet	Endrin ketone µg/kg-Wet	Fluoranthene µg/kg-Wet	Fluorene µg/kg-Wet	Indeno(1,2,3-cd)pyrene µg/kg-Wet	Naphthalene µg/kg-Wet	Phenanthrene µg/kg-Wet	Pyrene µg/kg-Wet	Total of 2,4' and 4,4'-DDT µg/kg-Wet	Total PCB Aroclors µg/kg-Wet	Total PCB Congeners µg/kg-Wet
LW2-BTFC015	LW2-BTFC015	clam	body without shell	1.55 T	0.00377 J	720	36	170	33	300	820	8.47 T	52.8 JT	78.2

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Table I-11d. iAOPC 11 Transition Zone Water Samples Data.

Location	Sample	Upper cm	Lower cm	Benzo(a)anthracene µg/l	Benzo(a)pyrene µg/l	Benzo(b)fluoranthene µg/l	Dibenzo(a,h)anthracene µg/l	Diesel Range Hydrocarbons mg/l	Indeno(1,2,3-cd)pyrene µg/l	Residual Range Hydrocarbons mg/l	Sulfide mg/l
GS-01-B-PR	LWG2-P-GSC1B	0	38	0.13	0.082	0.054	0.0047 J	0.84 J	0.051	0.07 U	
GS-02-A-TR	LWG2-T30-GS2A	30	30	3.2	3	2.1	0.34	3.3 J	2.7	0.81 J	
GS-02-A-TR	LWG2-T30-GS2A-D	30	30	1.8	1.2	0.93	0.12	3.6 J	0.93	0.8 J	
GS-02-A-TR	LWG2-T30-GS2A-D-FILT	30	30	0.22	0.11	0.081	0.0022 U	3.3 J	0.023 J	0.46 J	
GS-02-A-TR	LWG2-T30-GS2A-FILT	30	30	0.17	0.075	0.063	0.0024 J	3.6 J	0.019 J	0.5 J	
GS-07-B-TR	LWG2-T30-GS7B	30	30	2.4	2.7	1.5	0.21	6.1 J	1.9	1.2 J	
GS-07-D-PR	LWG2-P-GSC7D	0	38	0.042	0.016 J	0.012 J	0.0033 U	0.32 U	0.0098 U	0.059 U	
GS-07-D-PR	LWG2-P-GSC7D-2	0	38	0.039	0.0031 U	0.0038 U	0.0032 U	0.33 U	0.004 U	0.046 U	
GS-08-A-TR	LWG2-T30-GS8A	30	30	0.069 U	0.077	0.053 U	0.0087 J	0.37 JT	0.052	0.24 JT	
GS-08-A-TR	LWG2-T30-GS8A-FILT	30	30	0.0027 U	0.002 U	0.0025 U	0.0021 U	0.37	0.0026 U	0.24 J	
GS-08-D-TR	LWG2-T30-GS8D	30	30	0.21	0.11	0.073	0.0086 J	0.92 J	0.058	0.23 J	
GS-08-D-TR	LWG2-T30-GS8D-FILT	30	30	0.014 J	0.0063 J	0.0042 J	0.0021 U	0.7 J	0.0027 U	0.14 J	
GS-08-D-TR	LWG2-T90-GS8D	150	150	4.8	4.4	2.6	0.23	2.8 J	2.7	0.7 J	
SL-01-A-TR	LWG2-T30-SL1A	30	30	0.2 U	0.062 U	0.04 U	0.0033 U	2.3 J	0.023 J	0.5 J	
SL-01-A-TR	LWG2-T30-SL1A-FILT	30	30	0.01 J	0.0022 U	0.0026 U	0.0022 U	1.9 J	0.0028 U	0.43 J	
SL-02-A-TR	LWG2-T30-SL2A	30	30	0.048 U	0.069	0.047 U	0.0048 U	0.13 U	0.054	0.081 U	
SL-02-A-TR	LWG2-T30-SL2A-FILT	30	30	0.0029 U	0.0022 U	0.0027 U	0.0022 U	0.12 U	0.0029 U	0.07 U	
SL-03-A-TR	LWG2-T30-SL3A	30	30	0.092 U	0.066	0.046 U	0.0061 U	0.38 J	0.037	0.091 U	
SL-03-A-TR	LWG2-T30-SL3A-D	30	30	0.065 U	0.035	0.024 U	0.0049 U	0.35 J	0.023 J	0.074 U	
SL-03-A-TR	LWG2-T30-SL3A-D-FILT	30	30	0.003 U	0.0023 U	0.0028 U	0.0024 U	0.19 U	0.003 U	0.056 U	
SL-03-A-TR	LWG2-T30-SL3A-FILT	30	30	0.0035 U	0.0026 U	0.0032 U	0.0027 U	0.16 U	0.0035 U	0.057 U	
SL-04-A-TR	LWG2-T30-SL4A	30	30	0.14 U	0.076	0.053 U	0.008 U	0.495 JT	0.043	0.13 JT	
SL-04-A-TR	LWG2-T30-SL4A-FILT	30	30	0.003 U	0.0023 U	0.0028 U	0.0024 U	0.37 J	0.003 U	0.12 U	
SL-04-A-TR	LWG2-T90-SL4A	90	90	3.2	2.3	1.5	0.16	2.1 J	1.3	0.68 J	
SL-04-F-PR	LWG2-P-SLT4F	0	38	0.047	0.0076 J	0.021 J	0.003 U	1.3 J	0.0046 J	0.11 U	
SL-05-A-TR	LWG2-T30-SL5A	30	30	0.056 U	0.024 J	0.02 U	0.0022 U	0.24 J	0.015 J	0.11 U	
SL-05-A-TR	LWG2-T30-SL5A-FILT	30	30	0.0032 U	0.0024 U	0.003 U	0.0025 U	0.19 U	0.0032 U	0.09 U	
WLCSLH01GP56	WLCSLH01GP56W3	91.44	91.44								2 U
WLCSLH01GP67	WLCSLH01GP67W3	91.44	91.44								1 U
WLCSLH01GP68	WLCSLH01GP68W1	30.48	30.48	21.7	24.2	22.5	2.18		10.7		
WLCSLH01GP68	WLCSLH01GP68W3	91.44	91.44								2 U
WLCSLH01GP68	WLCSLH01GP68W5	152.4	152.4								2 U
WLCSLH01GP69	WLCSLH01GP69W1	30.48	30.48	12.5	15.2	12.9	1.54		7.72		
WLCSLH01GP69	WLCSLH01GP69W3	91.44	91.44								2 U
WLCSLH01GP69	WLCSLH01GP69W5	152.4	152.4								2 U
WLCSLH01GP73	WLCSLH01GP73W1	30.48	30.48	32.3	37.8	33.3	3.71		16.9		
WLCSLH01GP73	WLCSLH01GP73W3	91.44	91.44								1 U
WLCSLH01GP73	WLCSLH01GP73W5	152.4	152.4								1 U
WLCSLH01GP76	WLCSLH01GP76W1	30.48	30.48	0.84	0.81	0.68	0.1		0.46		
WLCSLH01GP76	WLCSLH01GP76W3	91.44	91.44								1 U
WLCSLH01GP80	WLCSLH01GP80W12	365.8	365.8								1 U
WLCSLH01GP80	WLCSLH01GP80W22	670.6	670.6								1 U
WLCSLH01GP80	WLCSLH01GP80W32	975.4	975.4								1 U
WLCSLH01GP82	WLCSLH01GP82W1	30.48	30.48	2.59	3.09	2.76	0.327		1.66		
WLCSLH01GP82	WLCSLH01GP82W3	91.44	91.44								2 U
WLCSLH01GP82	WLCSLH01GP82W5	152.4	152.4								2 U

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Table I-12. iAOPC 12 Sediment Samples Data.

Location	Sample	Upper cm	Lower cm	Dioxin-like PCB congener TCDD toxicity equivalent pg/g	Total PCB Aroclors µg/kg	Total PCB Congeners µg/kg
LW2-C300	LW2-C300-A	0	30		303 JT	
LW2-C300-2	LW2-C300-B	30	152		204 JT	
LW2-C300-2	LW2-C300-D	204	278		48.5 JT	
LW2-C313	LW2-C313-B	30	151		1.9 JT	
LW2-C313	LW2-C313-C	151	306		2.67 UT	
LW2-G307	LW2-G307	0	28	3.39 JT	270 JT	191
LW2-G313	LW2-G313	0	27		237 JT	
WLR0797WRGC25	WLR0797WRGC25RGC25A	0	61		78 T	

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Table I-13a. iAOPC 13 Sediment Samples Summary Statistics.

Location	Sample	Upper cm	Lower cm	Diesel Range Hydrocarbons mg/kg	Dioxin/furan TCDD toxicity equivalent pg/g	Dioxin-like PCB congener TCDD toxicity equivalent pg/g	Mercury mg/kg	Residual Range Hydrocarbons mg/kg	Total of 2,4' and 4,4'-DDT µg/kg	Total PCB Aroclors µg/kg	Total PCB Congeners µg/kg
LW2-C280	LW2-C280-B	30	137				3.06		0.399 UT	3.3 UT	
LW2-C280	LW2-C280-C	137	267				1.57		0.343 UT	2.85 UT	
LW2-C280	LW2-C280-D	267	321				0.735		0.302 UT	2.53 UT	
LW2-C282	LW2-C282-A	0	30	620 J				1600 J		5.4 JT	
LW2-C282	LW2-C282-B	30	155	24 J			0.07 T	57 J	0.085 JT	2.19 UT	
LW2-C282	LW2-C282-C	155	248				0.009 U		0.0505 UJT	2.13 UT	
LW2-C282	LW2-C282-D	248	344	4.4 UT			0.011 J	4.1 UT	0.054 UJT	2.27 UT	
LW2-C295	LW2-C295-B	30	153				0.152 T		1.36 JT	141 JT	
LW2-C295	LW2-C295-C	153	256				4.14		169 JT	85.7 JT	
LW2-C296	LW2-C296-B	30	152	800 J			0.967	1500 J	8.7 JT	119 JT	
LW2-C296	LW2-C296-C	152	216	120 J			0.219	280 J	0.23 UJT	1.8 UJT	
LW2-C303	LW2-C303-B	30	86	500 J			0.404	1100 J	110 JT	163 T	
LW2-C303	LW2-C303-C	86	210	5.85 JT			0.027	14 UT	0.19 UJT	1.5 UJT	
LW2-C524	LW2-C524-A	0	30	1900 J			0.489	4500 J	3.5 JT	22 T	
LW2-C524	LW2-C524-B	30	109	410 J			0.334	910 J	0.37 JT	3.7 JT	
LW2-C533	LW2-C533-A	0	30	2400 J			0.645	6000 J	7.7 JT	110 JT	
LW2-C533	LW2-C533-B	30	112	200 J			0.311	440 J	0.27 UJT	2.1 UT	
LW2-C533	LW2-C533-C	112	234	50 J			0.092	140 J	0.28 UT	1.8 UT	
LW2-C533	LW2-C533-D	234	336	6.5 J			0.027	26 J	0.19 UJT	1.5 UJT	
LW2-G280	LW2-G280	0	25			0.979 JT	0.176 J		1.05 JT	347 JT	41.6
LW2-G282	LW2-G282	0	23			14.9 JT	0.249		8.06 JT	3130 JT	1400
LW2-G295	LW2-G295	0	25				0.081 J		0.487 JT	110 JT	
LW2-G296	LW2-G296	0	27	66 J			0.077	320 J	3.41 JT	145 JT	
LW2-G303	LW2-G303	0	29	68 J			0.235	280 J	0.878 JT	112 JT	
LW2-G310	LW2-G310	0	28			3.61 T	0.138		0.422 JT	307 JT	185
LW2-GBT016	LW2-GBT016	0	10	100 J	1.69 JT	69.1 T	0.266 J	500 J	0.622 JT	850 T	8100
LWG0106B022SDS015C00	LWG0106B022SDS015C00	0	15				0.05 U		0.5 UT	2.5 JT	
LWG0106R002SDS015C10	LWG0106R002SDS015C10	0	15		57.5 JT	0.522 JT	0.54 JT		8.9 UT	75 UT	52.4 JT
LWG0106R002SDS015C20	LWG0106R002SDS015C20	0	15		102 JT	0.625 JT	0.64 J		3.8 UT	20 UT	80.8 JT
LWG0106R002SDS015C30	LWG0106R002SDS015C31	0	15		45.1 JT	0.474 T	0.94 JT		5.8 UT	24 UT	47.6 JT
LWG0106R031SDS015C00	LWG0106R031SDS015C00	0	15				0.09 U		42.1 T	14 UT	
WLCMBI02SED02	WLCMBI02SED02SED02	30	35				0.251				
WLCMBI02SED03	WLCMBI02SED03SED03	30	35				0.0435				
WLCMBJ99D09905	WLCMBJ99D09905D09905	0	15		9.89 JT						
WR-WSI98SD073	WR-WSI98SD0730	0	10				0.09				
WR-WSI98SD074	WR-WSI98SD0740	0	10				0.09		320 *	20 UT	
WR-WSI98SD074	WR-WSI98SD0740000A	0	90				0.56		15 J*	39 UT	
WR-WSI98SD076	WR-WSI98SD0760	0	10				0.08				

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Table I-13b. iAOPC 13 Surface Water Samples Data.

Location	Sampling Method	Sample	Mercury (dissolved) mg/l	Mercury mg/l	Total of 2,4' and 4,4'-DDT µg/l	Total PCB Aroclors µg/l
LW2-W013	bottle	LW2-W013-1	0.00004 U	0.00004 UT	0.000472 UT	0.0025 UT
LW2-W013	bottle	LW2-W2013-1	0.00004 UJ	0.00004 UJ		
LW2-W013	bottle	LW2-W3013-1	0.00008 U	0.00008 U		
LW2-W013-2	bottle	LW2-W013-2	0.00004 U	0.00004 U	0.000526 UT	0.0025 UT
LW2-W013-2	bottle	LW2-W2013-2	0.00004 UJ	0.00004 UJ		
LW2-W014	bottle	LW2-W014	0.00004 U	0.00004 U	0.00049 UT	0.0154 T
LW2-W014	bottle	LW2-W2014	0.00004 U	0.00004 U	0.000481 UT	0.0026 UT
LW2-W014	bottle	LW2-W3014	0.00008 U	0.00008 U	0.00049 UT	0.0025 UT
WLCMBI02SED03	bottle	WLCMBI02SED03SED03D		0.000187		

Location	Sampling Method	Sample	Dioxin/furan TCDD toxicity equivalent pg/l	Dioxin-like PCB congener TCDD toxicity equivalent pg/l	Total of 2,4' and 4,4'-DDT pg/l	Total PCB Aroclors pg/l	Total PCB Congeners pg/l
LW2-W013	XAD column	LW2-W013-1 C	0.00173 JT	0.000778 JT	4.97 JT	454 JT	720
LW2-W013	XAD column	LW2-W2013-1 C	0.00475 JT	0.00148 JT	6.03 T	1550 JT	2420
LW2-W013	XAD column	LW2-W3013-1 C	0.0113 JT	0.00212 T	10.6 JT	1436 JT	2060
LW2-W013	XAD filter	LW2-W013-1 F	0.12 JT	0.0109 JT	6.33 JT	2620 JT	2620
LW2-W013	XAD filter	LW2-W2013-1 F	0.105 JT	0.0456 JT	9.9 T	9950 JT	9550
LW2-W013	XAD filter	LW2-W3013-1 F	0.337 JT	0.0165 JT	12.6 JT	5660 JT	5920
LW2-W013-2	XAD column	LW2-W013-2 C	0.000903 T	0.000564 JT	3.4 JT	395 JT	624
LW2-W013-2	XAD column	LW2-W2013-2 C	0.0378 JT	0.000748 JT	0.744 JT	426 JT	681
LW2-W013-2	XAD column	LW2-W3013-2 C	0.00643 JT	0.00272 JT	3.89 JT	1603 JT	2160
LW2-W013-2	XAD filter	LW2-W013-2 F	0.103 JT	0.00774 JT	6.59 JT	1880 JT	1890
LW2-W013-2	XAD filter	LW2-W2013-2 F	0.114 JT	0.00431 JT	0.598 JT	1300 JT	1380
LW2-W013-2	XAD filter	LW2-W3013-2 F	0.91 JT		0.294 UT		

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Table I-13c. iAOPC 13 Tissue Samples Data.

Location	Sample	Species	Tissue	Dioxin/furan TCDD toxicity equivalent pg/g-Wet	Dioxin-like PCB congener TCDD toxicity equivalent pg/g-Wet	Mercury mg/kg-Wet	Total of 2,4' and 4,4'-DDT µg/kg-Wet	Total PCB Aroclors µg/kg-Wet	Total PCB Congeners µg/kg-Wet
LW2-BTFC016	LW2-BTFC016	clam	body without shell	0.515 T	6.96 T	0.011	1.6 T	1470 JT	2660
LW2-GBT016	LW2-BTLC016	lab clam	body without shell	0.18 JT	0.577 JT	0.0103	0.0927 JT	43 JT	81.8
LW2-GBT016	LW2-BTLW016	Lumbriculus variegatus	whole body	4.59 JT	11.4 JT	0.0105	0.501 JT	1860 JT	3910
LW2-MIT004	LW2-MIT004	multiplate invertebrates	whole body	0.323 JT	1.48 JT		0.356 JT	490 JT	498
LWG0106R002SDS015C10	LWG0106R002TSCAWBC00	clam	body without shell			0.012	8.3 UT	77 T	
LWG0106R002SP10	LWG0106R002TSSPWBC10	sculpin	whole body	2.84 T	4.82 T	0.047	6.9 UT	600 JT	382 JT
LWG0106R002SP20	LWG0106R002TSSPWBC20	sculpin	whole body	4.14 T	15.4 T	0.069	11 JT	2300 T	2450 JT
LWG0106R031CR00	LWG0106R031TSCRWBC00	crayfish	whole body	2.16 T	0.611 T	0.029	3 JT	4.2 UT	50.7 JT

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Table I-13d. iAOPC 13 Porewater Samples Data.

Location	Sample	Upper cm	Lower cm	Mercury mg/l
WR-WSI98SD074	WR-WSI98SD0740PW	0	10	0.0001 U

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Table I-14a. iAOPC 14 Sediment Samples Summary Statistics.

Location	Sample	Upper cm	Lower cm	Aldrin µg/kg	Arsenic mg/kg	beta-Hexachlorocyclohexane µg/kg	delta-Hexachlorocyclohexane µg/kg	Dibutyl phthalate µg/kg	Dioxin/furan TCDD toxicity equivalent pg/g	Dioxin-like PCB congener TCDD toxicity equivalent pg/g	Mercury mg/kg	Silver mg/kg	Sulfide mg/kg	Total of 2,4' and 4,4'-DDD µg/kg	Total of 2,4' and 4,4'-DDE µg/kg	Total of 2,4' and 4,4'-DDT µg/kg	Total PCB Aroclors µg/kg	Total PCB Congeners µg/kg
AP-02-A-PG	LWG2-PG-AP2A	0	24	2.2 UJ	5.97	6.5 J	2.6 NJ	15 U			0.036	0.057 J	0.56 J	310 JT	130 JT	7800 JT		
AP-02-D-PG	LWG2-PG-AP2D	0	30	2.1 UJ	3.47 T	2.7 U	1.3 UJ	12 U			0.08 T	0.251 JT	61.5 JT	206 JT	36 JT	1870 JT		
AP-04-C-PG	LWG2-PG-AP4C	0	29	4 UJ	3.62	5.2 U	3.7 J	45			0.074	0.18 J	0.09 UJ	350 JT	91 JT	2100 JT		
AP-04-C-PG-2	LWG2-PG-AP4C-2	0	29	3.9 UJ	3.41	5 U	2.5 UJ	55			0.088	0.183 J	1.2 J	450 JT	100 JT	937 JT		
CP-07-A-PG	LWG2-PG-CP7A	0	30	1.7 UJ	7.8	2.2 U	1.1 UJ	280			0.056	0.206 J	0.09 UJ	300 T	58 JT	2710 JT		
CP-07-D-PG	LWG2-PG-CP7D	0	30	2.5 UJ	3.54	3.3 U	1.6 UJ	7 U			0.066	0.25 J	0.09 UJ	12.5 JT	8.2 JT	67 JT		
CP-09-A-PG	LWG2-PG-CP9A	0	26	17 UJ	3.38	22 U	11 UJ	47 U			0.166	0.149 J	11.5 J	233 JT	169 JT	367 JT		
CP-09-D-PG	LWG2-PG-CP9D	0	30	2.3 UJ	3.41	2.9 U	1.4 UJ	6.3 U			0.06	0.181 J	61 J	9.7 JT	3.7 JT	42.1 JT		
LW2-B018	LW2-B018	0	15	0.932 J	5.43	0.358 NJ	0.0636 UJ	690	75.8 JT	1.05 T	0.024 J	0.087		48.3 JT	135 JT	307 JT	88 T	2.41 T
LW2-B050	LW2-B050	0	15	2.48 J	3.06 J	0.148 U	0.314 UJ	14 U			0.022	0.03		110 JT	38.8 JT	102 JT	64.5 T	
LW2-C321	LW2-C321-B1	30	138	0.65 UJ	3.09	0.84 UJ	0.41 UJ	7.1 U	0.836 T		0.133	0.507		3.3 JT	2.2 UJT	1.2 JT	66 JT	
LW2-C321	LW2-C321-C1	138	255	0.13 UJ	5.46	0.17 UJ	0.08 UJ	5.8 U	0.0151 T		0.026	0.364		0.35 JT	0.078 UT	0.2 UJT	1.6 UT	
LW2-C321-2	LW2-C321-B2	30	138	0.14 UJ	3.33	0.18 UJ	0.084 UJ	19 U	3.22 T		0.135	0.508		6.5 JT	4.5 JT	2 JT	103 JT	
LW2-C321-2	LW2-C321-C2	138	255	0.13 UJ	3.8	0.17 UJ	0.08 UJ	3.6 U			0.037	0.362		1.2 JT	0.45 JT	0.2 UJT	1.6 UT	
LW2-C321-2	LW2-C321-E2	394	465	0.12 UJ	1.28	0.16 UJ	0.074 UJ	5.2 U	0.0116 T		0.0125 JT	0.282		0.11 UJT	0.072 UT	0.18 UJT	1.4 UT	
LW2-C323	LW2-C323-B	30	119	1.46 J	3.14 JT	0.2 UJ	0.424 UJ	8.1 J	9.62 T		0.169 T	0.242 T		32.8 JT	4.96 JT	4.38 JT	241 JT	
LW2-C323	LW2-C323-C	119	198	0.034 UJ	2.36 J	1.62 NJ	0.0777 UJ	4.7 J	2.54 T		0.124	0.255		4.61 JT	2.22 JT	0.243 JT	53.2 JT	
LW2-C323	LW2-C323-D	198	321	0.325 J	2.52 J	3.54 NJ	0.0768 U	3.4 U	2.78 T		0.055	0.108		13.3 JT	1.46 T	1.4 JT	37 T	
LW2-C324	LW2-C324-B	30	91	0.037 UJ	3.31 J	0.0399 U	0.0845 U	4 J	1.48 T		0.126	0.201		4.38 JT	2.65 JT	1.58 JT	149 JT	
LW2-C324	LW2-C324-D	137	216	0.036 UJ	3.25 J	2.9 NJ	0.0822 U	7 U	2.53 T		0.134	0.285		9.36 JT	1.46 JT	1.25 JT	69.7 JT	
LW2-C324	LW2-C324-E	216	328	0.195 UJ	16.5 J	1.73 J	0.445 UJ	20 U	24.7 T		0.241	1.07		30.9 JT	8.02 JT	2.53 JT	154 T	
LW2-C327	LW2-C327-B	30	101	0.0325 UJ	5.77 J	2.98 NJ	0.0742 U	7.3 J	1.29 T		0.163	0.205		5.73 JT	1.45 T	0.885 JT	74.1 JT	
LW2-C327	LW2-C327-C	101	174	0.172 UJ	7.04 J	1.39 NJ	0.392 U	7.4 J	3.42 T		0.257	0.476		7.22 JT	2.36 T	1.01 JT	211 JT	
LW2-C327	LW2-C327-D	174	301	0.65 U	3.04	0.61 U	0.14 U	3.7 U	5.15 T	0.452 T	0.057 J	0.166		104 T	4.4 JT	14 T	33 JT	35.1 T
LW2-C329	LW2-C329-B	30	152	0.0333 UJ	2.23	1.16 NJ	0.076 UJ	7.5 U	3.61 T		0.02	0.067 J		22 JT	1.14 JT	0.95 JT	19.5 JT	
LW2-C329	LW2-C329-C	152	274	0.182 UJ	2.62	0.197 U	0.416 U	20 U	13.9 T		0.031	0.091 J		29.2 JT	7.64 JT	12.9 JT	193 JT	
LW2-C329	LW2-C329-D	274	359	0.17 UJ	5.2	6.82 NJ	0.388 U	18 U	3.18 T		0.008 J	0.054		10.4 JT	0.245 UT	18.5 JT	2.53 UT	
LW2-C331	LW2-C331-B	30	94	0.0313 U	3.31	0.607 NJ	0.0716 U	5.2 J	0.56 T		0.026	0.09		10.3 JT	1.15 JT	1.82 JT	11.9 JT	
LW2-C331	LW2-C331-C	94	137	0.163 U	7.21	0.176 U	0.372 U	3.8 J	1.89 T		0.016	0.083		26.2 JT	1.49 JT	12.2 JT	2.43 UT	
LW2-C331	LW2-C331-D	137	237	0.0345 U	2.85	0.076 J	0.0789 U	3.9 J	0.0052 T		0.013 J	0.033		0.176 JT	0.0499 UT	0.14 JT	2.57 UT	
LW2-C331	LW2-C331-E	237	280	0.0346 U	2.53	0.0373 U	0.0789 U	3.9 U	0 UT		0.022	0.08		0.093 JT	0.0499 UT	0.086 JT	2.6 UT	
LW2-C331	LW2-C331-G	346	490					23										
LW2-C332	LW2-C332-B	30	170	0.231 UJ	5.42	4.78 NJ	0.527 U	5.1 U	54.7 T		0.426	0.69		1310 JT	81.2 JT	979 JT	3.47 UJT	
LW2-C332	LW2-C332-C	170	243	0.0328 UJ	3.19	5.87 NJ	0.075 U	3.4 U	0.107 T		0.007 U	0.05		1.28 JT	0.0474 UT	0.47 T	2.37 UT	
LW2-C333	LW2-C333-B	30	103	0.178 UJ	2.84 T	2.76 NJ	0.406 UJ	3.7 U	5.91 T		0.07 T	0.098 T		54 JT	6.61 JT	2.34 JT	2.62 UJT	
LW2-C333	LW2-C333-C	103	153	0.0308 UJ	2.62	1.7 NJ	0.0704 U	3.5 U	0.0367 T		0.062	0.066		0.0475 UT	0.0445 UT	0.0548 UT	2.31 UT	
LW2-C333	LW2-C333-E	203	294	0.0358 UJ	2.48	0.0387 U	0.0818 U	3.7 U	0.197 T		0.011 J	0.028		0.0552 UT	0.0517 UT	0.0638 UT	2.64 UT	
LW2-C334	LW2-C334-B	30	110	0.224 UJ	4.3	0.242 U	0.513 U	11 J	200 T		0.159	0.34		399 JT	70.1 JT	256 JT	3.31 UT	
LW2-C334	LW2-C334-C	110	214	0.0334 UJ	1.44	1.29 NJ	0.0763 U	3.4 U	8.34 T		0.019	0.032		4.27 JT	0.366 JT	1.61 JT	2.55 UT	
LW2-C334	LW2-C334-D	214	308						5.32 T									
LW2-C335	LW2-C335-B	30	70	22.1 J	5.73	12.3 NJ	0.387 UJ	3.7 U	41 T		0.028	0.091		312 JT	48.4 JT	1020 JT	2.65 UJT	
LW2-C335	LW2-C335-C	70	127	0.028 UJ	4.64	0.0302 UJ	0.0639 UJ	4.5 U	11.9 T		0.185	0.231		0.0431 UJT	0.0404 UJT	0.0498 UJT	2.05 UT	
LW2-C335	LW2-C335-E	248	336					7.3 U	0 UT									
LW2-C341	LW2-C341-B	30	135	0.845 J	4.44	3.29 NJ	0.568 UJ	5.2 U			0.08	0.47		28.1 JT	6.79 JT	31.7 JT		
LW2-C348	LW2-C348-A	0	30						127 T									
LW2-C348	LW2-C348-B	30	153	54.5	4.26	0.241 U	0.509 U	10 U	677 T		0.162 T	0.353		277 JT	78.6 JT	342 JT	71.7 UT	
LW2-C348	LW2-C348-C	153	240	11.6 J	4.12	9.45 U	20 U	22 U			0.411	0.558		71100 JT	1300 JT	23000 JT	3.52 UT	
LW2-C348	LW2-C348-D	240	369	0.161 U	3.56	0.174 U	0.369 U	3.8 UJ			0.074	0.081		18.8 JT	0.551 JT	4.69 JT	2.59 UT	
LW2-C349	LW2-C349-B	30	62	0.62 NJ	3.78	1.31 NJ	0.116 UJ	11 U			0.15	0.214		26.9 JT	5.4 JT	1.49 JT		
LW2-C349	LW2-C349-C	62	159	0.0476 UJ	4.69	0.0514 UJ	0.109 UJ	9.9 U			0.251	0.498		17 JT	7.38 JT	2.95 JT		
LW2-C349	LW2-C349-D	159	307	0.31 U	2.05	0.15 U	0.071 U	4.6 U			0.023 J	0.038 J		0.3 UT	0.2 UT	0.17 UT		
LW2-C351	LW2-C351-B	30	80	2.33 J	5.59	1.03 U	2.19 U	27 U	145 T		0.319	0.491		5060 JT	140 JT	3220 JT	47.3 JT	
LW2-C351	LW2-C351-C	80	212	0.0319 U	3.38	0.106	0.0728 U	4.3 J	0.0867 T		0.026	0.026		1.99 JT	0.069 JT	1.3 JT	2.32 UT	
LW2-C351	LW2-C351-D	212	335	0.032 U	2.23	0.0346 U	0.0732 U	3.7 J	0.0012 T		0.009 U	0.027		0.243 JT	0.0462 UT	0.412 JT	2.37 UT	
LW2-C351	LW2-C351-E	335	399	0.0315 U	2.86	0.034 U	0.0719 U	3.5 UJ	0.0083 T		0.02	0.041		0.116 JT	0.0454 UT	0.125 JT	2.35 UT	
LW2-C356	LW2-C356-A	0	30														45 UT	
LW2-C356	LW2-C356-B	30	136	18.3 J	4.85	0.276 U	0.583 U	15 J			0.078	0.416		446 JT	33 JT	380 JT	1180 JT	
LW2-C356	LW2-C356-C	136	256	1340 J	4.98	2.49 U	5.26 U	26 U			0.169	0.456		44000 JT	1400 JT	26300 JT		
LW2-C356	LW2-C356-D	256	305														18000 UT	
LW2-C356	LW2-C356-E	305	336	2.64	2.17	0.225 J	0.355 U	7 J			0.017 J	0.021		282 JT	8.9 JT	43.5 JT		
LW2-C360	LW2-C360-B1	30	90	0.2 UJ	9.24	1.6 NJ	0.13 UJ	260			0.09	0.631		0.18 UJT	12 JT	380 JT	78 UT	
LW2-C360	LW2-C360-C1	90	213	3.4 UJ	3.83	4.4 UJ	2.1 UJ	24 U			0.168	0.81		169 JT	19 JT	366 JT	170 UT	
LW2-C360-2	LW2-C360-B2	30	90	4.1 UJT	5.15 T	5.3 UJT	2.6 UJT	245 T			0.101 T	0.722 T		455 JT	156 JT	1850 JT	92 UT	
LW2-C360-2	LW2-C360-C2	90	213	1.8 UJ	4.05	2.3 UJ	1.1 UJ	25 U			0.112	0.892		201 JT	23 JT	399 JT	200 UT	
LW2-C366	LW2-C366-B1	30	109	146 JT	5.01 T	1.02 UT	2.15 UT	155 T			0.106 T	0.779 T		615 JT	90.3 JT	846 JT	34.4 JT	
LW2-C366	LW2-C366-C1	109	217	111 JT	4.04 T	11.2 JT	0.482 UJT	24 UT	84 T	15.4 T	0.12 T	0.0825 T		701 JT	81.8 JT	661 JT	193 JT	695
LW2-C366	LW2-C366-D1	217	255	5.39 JT	2.85 T	2.87 JT	0.344 UT	6.9 UT			0.042 T	0.019 JT		64.7 JT	10.3 JT	43.6 JT	66.6 JT	
LW2-C366	LW2-C366-E1	255	316	9.81 JT	3.66 T	3.04 NJT	0.405 UT	4.65 JT			0.083 T	0.023 T		273 JT	16.1 JT	115 JT	187 JT	

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Table I-14a. iAOPC 14 Sediment Samples Summary Statistics.

Location	Sample	Upper cm	Lower cm	Aldrin µg/kg	Arsenic mg/kg	beta-Hexachlorocyclohexane µg/kg	delta-Hexachlorocyclohexane µg/kg	Dibutyl phthalate µg/kg	Dioxin/furan TCDD toxicity equivalent pg/g	Dioxin-like PCB congener TCDD toxicity equivalent pg/g	Mercury mg/kg	Silver mg/kg	Sulfide mg/kg	Total of 2,4' and 4,4'-DDD µg/kg	Total of 2,4' and 4,4'-DDE µg/kg	Total of 2,4' and 4,4'-DDT µg/kg	Total PCB Aroclors µg/kg	Total PCB Congeners µg/kg
LW2-C366	LW2-C366-F1	316	421														1.5 UT	
LW2-C366	LW2-C366-G1	421	464	0.0332 UJT	8.37 T	0.0359 UT	0.0759 UT	4.4 JT			0.0135 JT	0.0405 T		0.399 JT	0.195 T	0.189 T	832 JT	
LW2-C366-2	LW2-C366-B2	30	100	36.9 J	5.31	39.5 NJ	0.543 U	44 J			0.091	0.248		1210 JT	189 JT	436 JT	17.8 UT	
LW2-C366-2	LW2-C366-C2	100	202	92.7 NJ	4.54	17.8 J	0.492 U	9.4 UJ			0.118	0.081		479 JT	49.2 JT	304 JT	26.2 JT	
LW2-C366-2	LW2-C366-D2	202	288	11.9 NJ	3.86	6.18 J	0.423 U	20 U			0.074	0.02 J		226 JT	12.7 JT	152 JT	41 JT	
LW2-C366-2	LW2-C366-F2	348	388	0.0331 UJ	10.6 JT	0.28 NJ	0.0756 U	3.6 U			0.02 J	0.035 T		4.04 JT	0.789 JT	4.96 JT	2.43 UT	
LW2-C368	LW2-C368-B	30	136	1.61 J	4.34	0.263 U	0.556 U	31			0.058 T	0.306		132 JT	45.3 JT	218 T	36.1 UT	
LW2-C368	LW2-C368-C	136	241	3.42 J	3.82 T	2.15 NJ	0.425 U	21 U			0.196	0.062 T		51.1 JT	5.4 JT	41.9 JT	142 JT	
LW2-C368	LW2-C368-D	241	294	8.87 J	2.38	22.8 NJ	3.69 U	17 U			0.023	0.022		2.49 UT	8.47 JT	7.1 JT	2.37 UT	
LW2-C368	LW2-C368-E	294	375	2.19 NJ	3.4	0.168 U	0.356 U	19 U			0.056	0.03		2.28 JT	6.11 JT	4.84 JT	4.67 UT	
LW2-C371	LW2-C371-B	30	162	5.42 J	3.85 J	5.39 J	0.426 U	26 J		6.9 T	0.09 J	0.199		89.3 JT	16.2 JT	51.5 JT	446 T	425
LW2-C371	LW2-C371-C	162	275	0.16 UJ	2.64 J	0.172 U	0.365 U	3.5 U			0.021 J	0.032		40.5 JT	2.4 JT	0.231 UT	20.9 JT	
LW2-C371	LW2-C371-E	369	495	0.0315 UJ	2.96 J	1.04 NJ	0.072 U	3.5 U			0.035 J	0.032		1.17 JT	0.0455 UT	0.165 T	2.32 UT	
LW2-G320	LW2-G320	0	23	0.167 UJ	2.68 J	2.08 NJ	0.381 U	40 U		1.03 T	0.055	0.105	1.7	41.5 JT	4.87 T	19 JT	38.1 JT	50.6
LW2-G321	LW2-G321	0	27	0.0344 UJ	4.02	3.83 J	0.0786 UJ	21 U	7.83 T		0.242	0.254	5.8 T	4.24 JT	1.16 JT	3.39 JT	117 T	
LW2-G322	LW2-G322	0	21	0.216 UJ	4.5	3.12 J	0.493 UJ	4.7 U			0.074	0.317		23.5 JT	11.2 JT	7.78 JT	192 JT	
LW2-G323	LW2-G323	0	29	0.158 UJ	2.26 J	0.171 UJ	0.361 U	51	1.15 JT		0.014 J	0.028	5	9.41 JT	4.58 JT	51.6 JT	2.27 JT	
LW2-G324	LW2-G324-1	0	25	2.89 J	4.58 J	0.0358 UJ	0.0757 UJ	4.5 J	4.85 JT		0.038	0.049	0.3 J	9.17 JT	9.09 JT	29.6 JT	19.8 JT	
LW2-G324-2	LW2-G324-2	0	26	0.327 NJ	4.74 J	2.5 NJ	0.0716 UJ	3.5 U	2.87 JT		0.042	0.065	0.6 J	17.5 JT	12.7 JT	14.5 JT	14.3 JT	
LW2-G327	LW2-G327	0	27	0.177 UJ	6.68 J	0.798 NJ	0.405 U	8.3 U	2.17 JT	5.18 T	0.722	0.523	43.3	23.2 JT	5.68 T	2.12 JT	246 JT	224
LW2-G329	LW2-G329	0	25	0.0298 UJ	3.47	4.48 J	0.0682 UJ	3.5 U	2.11 JT		0.023	0.047	0.2 U	8.33 JT	3.42 JT	3.22 JT	4.92 UJT	
LW2-G330	LW2-G330	0	27	25.9 NJ	4.22	12.4 NJ	0.619 UJ	15	32.7 JT		0.189 J	0.241		49.6 JT	11.6 JT	32.4 JT	37 JT	
LW2-G331	LW2-G331	0	26	4.39 J	5.36 J	0.176 UJ	0.372 U	7 U	6.82 JT		0.017 J	0.038	0.2 U	61.3 JT	46 JT	40.1 JT	10.6 JT	
LW2-G332	LW2-G332	0	29	3.6 J	8.27	5.55	0.117 UJ	54 U	234 JT	2.6 JT	0.352	0.38		35.3 JT	18.9 JT	11 JT	41.9 UJT	480
LW2-G333	LW2-G333	0	27	10.6 J	4.09 J	0.904 NJ	0.529 U	22 U	66.4 JT		0.057	0.285	2.2	466 JT	42.7 T	71.6 JT	35.6 JT	
LW2-G334	LW2-G334	0	28	1.17 J	3.73 J	7.11 NJ	0.108 UJ	11 U	15.7 JT		0.066	0.18	87.5 J	300 JT	201 JT	236 JT	3.8 UJT	
LW2-G335	LW2-G335	0	26	0.158 UJ	3.9 J	0.171 UJ	0.361 U	10 J	7.15 JT	0.738 T	0.029	0.056	7	325 JT	61.8 T	118 JT	5.91 T	47.6
LW2-G336	LW2-G336	0	26	0.0322 UJ	4.27 J	0.0348 UJ	0.0736 U	9 U			0.057	0.072	0.9	75.7 JT	21.8 T	247 JT	19.3 T	
LW2-G339	LW2-G339	0	28	0.226 U	4.1	7.3 NJ	0.515 UJ	11 U		2.35 T	0.075	0.2	29.7	116 JT	23.2 JT	83.1 JT	71.6 T	38.7
LW2-G341	LW2-G341	0	29	0.0518 UJ	4.42	1.93 J	0.118 UJ	6.3 J			0.06	0.235		7.39 JT	2.61 JT	2.33 T		
LW2-G344	LW2-G344	0	28	1.51 J	4.53	4.52 J	0.123 UJ	6.3 U			0.069	0.188		9.72 JT	3.38 JT	9.05 JT		
LW2-G345	LW2-G345-1	0	27	1.91 JT	3.2 JT	0.0508 UJT	0.326 JT	8 JT			0.068 T	0.171 T	7.1 JT	165 JT	26.5 JT	572 JT	19.5 JT	
LW2-G345-2	LW2-G345-2	0	28	1.99 J	3.09 J	0.0493 UJ	0.104 UJ	8.5 J			0.069	0.172	0.2 J	129 JT	20.6 JT	381 JT	17 JT	
LW2-G348	LW2-G348	0	28	10.6 NJ	3.57 J	3.66 NJ	0.965 J	25 U			0.056	0.122	6.6	356 JT	148 T	568 JT	34.6 T	
LW2-G349	LW2-G349	0	28	0.0495 UJ	4.91	0.0534 U	0.113 UJ	51 U			0.357	0.553		14 JT	9.64 JT	2.01 JT		
LW2-G350	LW2-G350	0	29	6.23 J	4.09 J	0.049 UJ	0.104 U	27 U			0.092	0.223	0.8	331 JT	63.5 JT	859 JT	35.7 JT	
LW2-G351	LW2-G351	0	28	24.7 J	5.01	0.249 U	0.527 U	7.1 J	112 JT	3.62 T	0.128	0.243	3.1	255 JT	29.8 JT	176 JT	309 JT	122
LW2-G351-2	LW2-G351-2	0	28	15.8 JT	6.04 JT	0.517 UT	2.48 T	28 UT	322 JT		0.084 T	0.276 T	3.15 T	462 JT	55.6 JT	796 JT	171 JT	
LW2-G353	LW2-G353-1	0	26	25.9 J	4.24	0.267 U	0.565 U	30		3.94 T	0.076 J	0.238	1.9 JT	860 JT	175 JT	3530 JT	78 UJT	144
LW2-G353-2	LW2-G353-2	0	27	11.8 NJ	4.36	0.252 UJ	0.534 UJ	24			0.063 J	0.194	0.3 UJ	1100 JT	254 JT	4970 JT	76 UJT	
LW2-G355	LW2-G355	0	27	691 J	8.37	0.366 U	0.774 U	260 UJ		36.2 T	0.087	0.197	4.9	2460 JT	906 JT	8110 JT	1000 UT	972
LW2-G356	LW2-G356	0	29	1.64 J	5.58	0.815 NJ	0.694 U	25			0.067	0.234		65.4 JT	23.4 JT	183 JT		
LW2-G360	LW2-G360	0	29	4.5 J	7.43 J	0.508 UJ	1.07 U	1000		3.18 T	0.068	0.262	166	3040 JT	591 JT	12500 JT	151 JT	111
LW2-G362	LW2-G362-1	0	26	0.272 UJT	4.59 T	0.0587 UT	0.124 UT	9.3 UT			0.0573 T	0.216 T	5.4 T	19.4 JT	9.71 JT	53.2 JT	48.5 JT	
LW2-G366	LW2-G366	0	30	7.19 NJ	5.38 T	0.297 U	0.629 U	230			0.062	0.216 T	0.3 U	863 JT	1180 JT	3370 JT	13.8 JT	
LW2-G368	LW2-G368	0	26	0.279 UJ	3.7 J	0.301 U	0.638 UJ	14 UJ			0.055	0.198	445 J	14.9 JT	4.56 T	16.6 JT	13.9 JT	
LW2-G371	LW2-G371	0	23	0.18 UJ	2.29	0.195 U	0.412 U	94		1.83 T	0.106	0.092	9.7	108 JT	41.7 JT	111 JT	84.8 JT	59.6
LW2-GBT017	LW2-GBT017	0	10	0.047 J	5.56	0.0932 J	0.05 U	25 U	41.1 JT	4.14 T	0.137	0.206 J	3.2	231 T	36.2 T	152 T	170 UT	268
LW2-GBT018	LW2-GBT018	0	10	0.0811 J	4.18	0.109 J	0.153 J	7.8 U	248 JT	0.914 JT	0.313 J	0.204	0.08 U	296 T	21 T	640 T	80 UT	33.9
LWG0106R004SDS015C00	LWG0106R004SDS015C00	0	15	0.19 U	2.7	1.3 U	0.19 U	19 U	4.66 JT	0.885 T	0.05 UJ	0.03 U		17 T	12 T	15 JT	100 UT	47 JT
LWG0107B024SDS015C00	LWG0107B024SDS015C00	0	15	0.19 U	1.55 T	0.19 U	0.19 UJ	19 U			0.04 UT	0.02 UJT		129 T	104 T	139 T	46 UT	
LWG0107R003SDS015C00	LWG0107R003SDS015C00	0	15	65 U	1.8	65 U	65 UJ	22 U			0.08 UJ	0.03 U		130 UT	130 UT	200 T	2600 UT	
LWG0107R006SDS015C00	LWG0107R006SDS015C00	0	15	66 U	4.4	74 U	53 U	240	16600 JT	10.7 JT	0.07 UJ	0.08		1640 T	1330 T	9990 T	2200 UT	496 JT
LWP1-AP03B-1	LWP-TZSAP03B-1	0	30											420 *	150 *	1300 *		
LWP1-AP03B-2	LWP-TZSAP03B-2	0	30											650 *	300 *	6000 *		
LWP1-AP04B	LWP-TZSAP04B	0	30											1300 J*	1100 *	23000 *		
LWP1-AP04D	LWP-TZSAP04D	0	30											110 *	34 *	720 *		
R2-AP-02-PG	LWG2-PG-R2AP2	0	29	4 UJ	3.89	5.2 U	2.5 UJ	77			0.071	0.194 J	28 J	228 JT	66 JT	1270 JT		
R2-RP-03-PG	LWG2-PG-R2RP3	0	28	0.13 UJ	3.61	0.17 U	0.082 UJ	3.7 J			0.017 J	0.048 J	0.07 UJ	41 JT	912 JT	53 JT		
RP-03-C-PG	LWG2-PG-RP3C	0	24	0.63 J	3.36	0.32 U	2.2 J	4 J	15 JT		0.066	0.126 J	246 J	4.8 JT	0.84 JT	1.3 JT		
RP-07-B-PG	LWG2-PG-RP7B	0	30	2 UJ	3.45	2.6 U	1.3 UJ	28 U	45.1 JT		0.07	0.238 J	5.6 J	102 JT	18 JT	162 JT		
WLCDRD05PG060	WLCDRD05PG06060	0	20	1.1 U	3.97	0.89 U	0.3 U	4.8 U	21.1 J		0.169	0.415 J	53.1 J	11 JT	16 JT	16.3 JT	322 T	
WLCDRD05PG064	WLCDRD05PG06464	0	30	0.23 U	3.99	1.2 U	0.38 U	7.4 J	13.8 J		0.073	0.224 J	14.8 J	37 T	12 JT	333 T	37 UT	
WLCDRD05PG068	WLCDRD05PG06868	0	30	0.23 U	3.6	1.2 U	1.2 U	6.8 J	75.9 J		0.123	0.324 J	155 J	920 T	110 T	430 T	330 UT	
WLCDRD05PG070	WLCDRD05PG07070	0	30	0.66 J	4.31	1.1 U	0.37 U	6 U	15.2 J		0.093	0.219 J	20.6 J	286 T	30 JT	320 T	75 UT	
WLCDRD05PG072	WLCDRD05PG07272	0	28	0.47 U	4.9	1.3 U	0.99 U	28	15.3 J		0.07	0.201 J	355 J	88 T	26 T	833 T	96 UT	
WLCDRD05VC062	WLCDRD05VC06262	0	165	0.72 U	2.64	0.96 U	0.32 U	11 U			0.093	0.098 J	24.2 J	43 T	13.1 JT	8.3 T	102 T	
WLCDRD05VC064	WLCDRD05VC06464	0	186	0.22 U	4.01	1.1 U	0.37 U	8.4 U			0.215	0.41 J	18.4 J	16.9 JT	8.2 JT	38 JT	59 T	

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Table I-14a. iAOPC 14 Sediment Samples Summary Statistics.

Location	Sample	Upper cm	Lower cm	Aldrin µg/kg	Arsenic mg/kg	beta-Hexachlorocyclohexane µg/kg	delta-Hexachlorocyclohexane µg/kg	Dibutyl phthalate µg/kg	Dioxin/furan TCDD toxicity equivalent pg/g	Dioxin-like PCB congener TCDD toxicity equivalent pg/g	Mercury mg/kg	Silver mg/kg	Sulfide mg/kg	Total of 2,4' and 4,4'-DDD µg/kg	Total of 2,4' and 4,4'-DDE µg/kg	Total of 2,4' and 4,4'-DDT µg/kg	Total PCB Aroclors µg/kg	Total PCB Congeners µg/kg
WLCDRD05VC068	WLCDRD05VC06868	0	238	0.21 U	3.66	1.1 U	0.34 U	9.9 U			0.09	0.369 J	8.9	22.1 JT	8.7 JT	68.8 T	74 T	
WLCDRD05VC070	WLCDRD05VC07070	0	274	0.2 U	3.7	0.97 U	0.33 U	8.1 U			0.078	0.36 J	22.4	34.7 JT	60.5 JT	125 JT	36 T	
WLCEAF02WB08	WLCEAF02WB08SO1915	0	131.1	70 U		70 U	70 U							3800 *	570 J*	34000 *		
WLCEAF02WB08	WLCEAF02WB08SO1917	207.3	283.5	80 U		80 U	80 U							470000 *	9000 *	510000 T*		
WLCEAF02WB08	WLCEAF02WB08SO1919	435.9	496.8	7.1 U		7.1 U	7.1 U							95 *	7.1 U*	330 *		
WLCEAF02WB08	WLCEAF02WB08SO1929	1045.5	1106.4	7 U		7 U	7 U							26 *	7 U*	17 *		
WLCEAF02WB09	WLCEAF02WB09SO1931	0	121.9	64 U		64 U	64 U							1900 *	730 *	12000 *		
WLCEAF02WB09	WLCEAF02WB09SO1934	243.8	304.8	1800 U		1400 U	1400 U							240000 *	24000 *	2500000 T*		
WLCEAF02WB09	WLCEAF02WB09SO1938	548.6	609.6	130 U		130 U	130 U							130 U*	130 U*	1900 *		
WLCEAF02WB09	WLCEAF02WB09SO1945	975.4	1036.3	6.6 U		6.6 U	6.6 U							20 *	6.6 U*	240 *		
WLCEAF02WB10	WLCEAF02WB10SO1947	0	61	94 UT		94 UT	94 UT							890 JT*	175 T*	4000 T*		
WLCEAF02WB10	WLCEAF02WB10SO1952	213.4	274.3	180 U		180 U	180 U							4600 *	660 J*	15000 *		
WLCEAF02WB10	WLCEAF02WB10SO1956	457.2	518.2	170 U		170 U	170 U							640000 *	4300 U*	34500 T*		
WLCEAF02WB10	WLCEAF02WB10SO1961	762	823	6.6 U		6.6 U	6.6 U							28 *	6.6 U*	6.6 U*		
WLCEAF02WB11	WLCEAF02WB11SO1963	0	61	97 U		97 U	97 U							1300 J*	400 J*	3500 J*		
WLCEAF02WB11	WLCEAF02WB11SO1967	381	442	190 U		190 U	190 U							690000 *	5700 U*	110000 *		
WLCEAF02WB11	WLCEAF02WB11SO1971	624.8	679.7	6.4 U		6.4 U	6.4 U							36 *	6.4 U*	6.4 U*		
WLCEAF02WB13	WLCEAF02WB13SO1896	0	106.7	76 U		77	76 U							8200 *	780 *	26000 *		
WLCEAF02WB13	WLCEAF02WB13SO1901	426.7	518.2	75 U		75 U	75 U							460 *	75 U*	610 *		
WLCEAF02WB14	WLCEAF02WB14SO1906	0	61	97 U		97 U	97 U							810 *	150 J*	1400 *		
WLCEAF02WB14	WLCEAF02WB14SO1912	487.7	548.6	6.9 U		6.9 U	6.9 U							6.9 U*	6.9 U*	6.9 U*		
WLCEAF02WB16	WLCEAF02WB16SO1867	0	57.9	11 UJ		11 UJ	11 UJ							39 J*	11 UJ*	130 J*		
WLCEAF02WB17	WLCEAF02WB17SO1904	0	61	92 U		92 U	92 U							320 J*	92 U*	6100 *		
WLCEAF02WB18	WLCEAF02WB18SO1888	0	61	81 U		120	81 U							1200 *	350 *	8000 *		
WLCEAF02WB18	WLCEAF02WB18SO1890	182.9	243.8	150 U		150 U	150 U							3600 *	650 J*	33500 T*		
WLCEAF02WB18	WLCEAF02WB18SO1894	487.7	609.6	6.5 U		6.5 U	6.5 U							220 *	6.5 U*	150 *		
WLCEAF02WB19	WLCEAF02WB19SO1885	0	42.7	88 U		88 U	88 U							310 *	100 *	620 *		
WLCEAF02WB20	WLCEAF02WB20SO1882	0	61	11 UJ		11 UJ	11 UJ							24 J*	11 UJ*	67 J*		
WLCEAF02WB22	WLCEAF02WB22SO1879	106.7	161.5	7.1 U		7.1 U	7.1 U							14 U*	8.1 *	15 U*		
WLCEAF02WB23	WLCEAF02WB23SO1858	140.2	201.2	7.8 U		7.8 U	7.8 U							230 *	21 U*	450 *		
WLCEAF02WB23	WLCEAF02WB23SO1864	506	566.9	6.7 U		6.7 U	6.7 U							11 U*	6.7 U*	6.7 U*		
WLCEAF02WB24	WLCEAF02WB24SO1972	323.1	384	1800 U		1800 U	1800 U							130000 *	13000 *	3500000 *		
WLCEAF02WB24	WLCEAF02WB24SO1975	506	566.9	6.9 U		6.9 U	6.9 U							89 J*	6.9 U*	27000 *		
WLCEAF02WB25	WLCEAF02WB25SO1978	0	51.8	110 UJT		110 UJT	110 UJT							350 JT*	110 UJT*			
WLCEAF02WB25	WLCEAF02WB25SO1983	326.1	387.1	7.4 U		7.4 U	7.4 U							10 *	7.4 U*	24 *		
WLCEAF02WB25	WLCEAF02WB25SO1985	448.1	509	6.9 UT		6.9 UT	6.9 UT							6.9 UT*	6.9 UT*	12.5 T*		
WLCEAF02WB25	WLCEAF02WB25SO1988	615.7	661.4	6.2 U		6.2 U	6.2 U							6.2 U*	6.2 U*	6.2 U*		
WLCOFJ0222B01	WLCOFJ0222B0122B010	0	8	1.08 U	3.55	1.06 U	0.96 U	16.9 U			0.0207 J	0.136		469 T	70 T	88.1 T		10.7 JT
WLCOFJ0222B02	WLCOFJ0222B0222B020	0	8	1.25 U	20.8	15.2	1.11 U	18.2 U			0.0409	0.701		194 T	32.7 T	46.4 T		8.17 JT
WLCOFJ0222B03	WLCOFJ0222B0322B030	0	9	1.61 U	22.9	1.58 U	1.44 U	24.3 U			0.625	4.24		365 T	34.8 T	70.3 T		25.4 JT
WLCOFJ0222C01	WLCOFJ0222C0122C010	0	9	2.28 U	27.7	2.24 U	2.03 U	341 U			0.101	1.3		458 T	81.8 T	73.4 T		32.2 JT
WLCOFJ0222C02	WLCOFJ0222C0222C020	0	13	1.09 U	19.7	1.07 U	0.969 U	15.3 UJ			0.012 J	0.744		32.3 T	23.8 JT	45.3 T		4.14 JT
WLCOFJ0222C03	WLCOFJ0222C0322C030	0	8	0.923 UT	5.26 T	0.905 UT	0.821 UT	15.3 UT			0.0193 JT	3.14 T		60.3 T	34.9 JT	193 T		7.63 JT
WLRELF99OSS001	WLRELF99OSS001SD0001	0	10	40 U		40 U	40 U	12						115 *	54 *	1250 J*		
WLRELF99OSS001	WLRELF99OSS001SD0004	50	70	50 U		40 U	40 U	10 U						1770 *	226 *	1060 *		
WLRELF99OSS002	WLRELF99OSS002SD0006	0	10	50 U		40 U	40 U	52						3400 *	509 *	81000 *		
WLRELF99OSS002	WLRELF99OSS002SDC001	10	90	61 U		40 U	40 U	20						5200 *	356 *	17000 *		
WLRELF99OSS003	WLRELF99OSS003SD0021	0	10	10 U		10 U	10 U	10 UG						49 *	10 U*	17 *		
WLRELF99OSS003	WLRELF99OSS003SD0022	10	30	25 U		25 U	25 U	10 U						735 *	25 U*	2800 *		
WLRELF99OSS004	WLRELF99OSS004SD0011	0	10	70 U		40 U	52 U	110						11000 *	1480 *	18000 *		
WLRELF99OSS004	WLRELF99OSS004SD0013	30	50	3600 U		400 U	400 U	10 U						16000 *	1840 *	400 U*		
WLRELF99OSS005	WLRELF99OSS005SD0024	0	10	10 U		10 U	10 U	15 UG						194 *	32 *	360 *		
WLRELF99OSS005	WLRELF99OSS005SDC002	10	90	10 U		10 U	10 U	12 G						147 *	10 U*	216 *		
WLRELF99OSS006	WLRELF99OSS006SD0016	0	10	40 U		40 U	40 U	640						2300 *	522 *	10000 *		
WLRELF99OSS006	WLRELF99OSS006SD0017	10	30	40 U		40 U	40 U	1500						4100 *	1180 *	11000 *		
WLRELF99RB2	WLRELF99RB2SD1003	0	10	10 U		10 U	10 U	10 U						100 *	130 *	700 *		
WLRELF99RB2	WLRELF99RB2SD1004	10	23	10 U		10 U	10 U	10 U						360 *	310 *	1300 *		
WLRELF99RB6	WLRELF99RB6SD1011	0	10	10 U		10 U	10 U	10 U						26 J*	11 J*	64 *		
WLRELF99RB6	WLRELF99RB6SD1012	10	58	10 U		10 U	10 U	10 U						28 *	71 *	360 *		
WLRELF99RB6	WLRELF99RB6SD1013	0	10	10 U		10 U	10 U	10 U						10 U*	50 J*	62 *		
WLRELF99RB6	WLRELF99RB6SD1014	10	58	10 U		10 U	10 U	10 U						35 *	100 *	390 *		
WR-WSI98SD077	WR-WSI98SD0770	0	10	19 U	10 U	19 U	19 U	19 U			0.03	1.6		100 *	38 U*	63 *	760 UT	
WR-WSI98SD078	WR-WSI98SD0780	0	10	48 U	8 U	48 U	48 U	19 U			0.1	1		100 *	95 U*	280 *		
WR-WSI98SD080	WR-WSI98SD0800	0	10	48 U	5 U	48 U	48 U	21			0.06	1.2		110 *	96 U*	470 *		
WR-WSI98SD081	WR-WSI98SD0810	0	10	50 U	8 U	50 U	50 U	20 U			0.05	1		76 J*	99 U*	490 *	2000 UT	
WR-WSI98SD081C	WR-WSI98SD081C0000A	0	90	0.96 U	4 U	0.96 U	0.96 U	35 U	57 JT		0.12	0.7		82 *	5.4 UI*	48 *		
WR-WSI98SD083	WR-WSI98SD0830	0	10	48 U	6 U	48 U	48 U	23			0.08	1.4		120 *	97 U*	620 *		
WR-WSI98SD084	WR-WSI98SD0840	0	10	49 U	5 U	49 U	49 U	20 U			0.05	1.1		59 J*	98 U*	620 *	2000 UT	

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Table I-14a. iAOPC 14 Sediment Samples Summary Statistics.

Location	Sample	Upper cm	Lower cm	Aldrin µg/kg	Arsenic mg/kg	beta-Hexachlorocyclohexane µg/kg	delta-Hexachlorocyclohexane µg/kg	Dibutyl phthalate µg/kg	Dioxin/furan TCDD toxicity equivalent pg/g	Dioxin-like PCB congener TCDD toxicity equivalent pg/g	Mercury mg/kg	Silver mg/kg	Sulfide mg/kg	Total of 2,4' and 4,4'-DDD µg/kg	Total of 2,4' and 4,4'-DDE µg/kg	Total of 2,4' and 4,4'-DDT µg/kg	Total PCB Aroclors µg/kg	Total PCB Congeners µg/kg
WR-WSI98SD084	WR-WSI98SD0840000ACC	0	90	380 UT	5 UT	380 UT	380 UJT	20 UT			0.17 T	1.1 T		4550 T*	750 UT*	1800 T*	15000 UT	
WR-WSI98SD085	WR-WSI98SD0850	0	10	9.9 U	5 U	9.9 U	9.9 U	20 U			0.07	1.2		110 *	26 *	370 *		
WR-WSI98SD087	WR-WSI98SD0870	0	10	50 U	5 U	50 U	50 U	39			0.06	1.2		110 *	100 U*	810 *	2000 UT	
WR-WSI98SD088	WR-WSI98SD0880	0	10	97 U	5 U	97 U	97 U	19 U			0.08	1.3		100 J*	190 U*	930 *		
WR-WSI98SD090	WR-WSI98SD0900	0	10	99 U	5 U	99 U	99 U	20 U			0.09	1		160 J*	200 U*	2100 *	4000 UT	
WR-WSI98SD090	WR-WSI98SD0900000A	0	90	78 U	5 U	78 U	78 UJ	19 U			0.23	1.1		170 *	160 U*	1100 *	3100 UT	
WR-WSI98SD092	WR-WSI98SD0920000A	0	90	3800 U	5 U	3800 U	3800 UJ	47 U	9680 JT		0.28	1.5		29000 *	7500 U*	22000 *	150000 UT	
WR-WSI98SD092	WR-WSI98SD0920000CC	0	10	19 UT	4 UT	19 UT	19 UT	19 UT			0.045 T	0.8 T		375 T*	20 JT*	280 T*	750 UT	
WR-WSI98SD093	WR-WSI98SD0930	0	10	9.6 U	5 U	9.6 U	9.6 U	19 U			0.06	1.2		16 J*	19 U*	70 *		
WR-WSI98SD097	WR-WSI98SD0970	0	10	99 U	5 U	99 U	99 U	180			0.12	1.2		420 *	220 *	3100 *		
WR-WSI98SD100	WR-WSI98SD1000	0	10		4 U			19 U			0.04	0.8						
WR-WSI98SD100	WR-WSI98SD1000000A	0	90		5 U			20 U			0.06	1.1						

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Table I-14b. iAOPC 14 Surface Water Samples Data.

Location	Sampling Method	Sample	Arsenic (dissolved) mg/l	Arsenic mg/l	Dibutyl phthalate µg/l	Mercury (dissolved) mg/l	Mercury mg/l	Silver (dissolved) mg/l	Silver mg/l
LW2-W015	bottle	LW2-W015	0.000353	0.000399 T	0.076 U	0.00004 U	0.00004 U	0.000009 U	0.000009 UT
LW2-W015	bottle	LW2-W2015	0.000372	0.000435	0.068 U	0.00004 U	0.00004 U	0.000009 U	0.000009 U
LW2-W015	bottle	LW2-W3015	0.00045	0.00052	0.17 U	0.00008 U	0.00008 U	0.000005 UJ	0.000005 UJ
LW2-W016	bottle	LW2-W016-1	0.000333	0.000386	0.063 U	0.00004 U	0.00004 U	0.000009 U	0.000009 U
LW2-W016	bottle	LW2-W2016-1	0.000376	0.000437	0.062 U	0.00004 U	0.00004 U	0.000009 U	0.000009 U
LW2-W016	bottle	LW2-W3016-1	0.00045	0.0005	0.071 U	0.00008 U	0.00008 UT	0.000005 U	0.000005 U
LW2-W016-2	bottle	LW2-W016-2	0.00033	0.000373	0.086 UJ	0.00004 U	0.00004 U	0.000009 U	0.000009 U

Location	Sampling Method	Sample	Aldrin pg/l	beta-Hexachlorocyclohexane pg/l	delta-Hexachlorocyclohexane pg/l	Dibutyl phthalate pg/l	Dioxin/furan TCDD toxicity equivalent pg/l	Dioxin-like PCB congener TCDD toxicity equivalent pg/l	Total of 2,4' and 4,4'-DDD pg/l	Total of 2,4' and 4,4'-DDE pg/l	Total of 2,4' and 4,4'-DDT pg/l	Total PCB Aroclors pg/l	Total PCB Congeners pg/l
LW2-W015	XAD column	LW2-W015 C	3.27 J	33.7	6.25	5980 J	0.0404 JT	0.00306 JT	2560 T	349 T	547 T	604 JT	639
LW2-W015	XAD column	LW2-W2015 C	1.42 J	23.4	1.38 J	1420 U	0.0275 JT	0.00261 JT	1760 T	136 T	200 T	151 JT	255
LW2-W015	XAD column	LW2-W3015 C	1.15 J	15.9	3.24 J	1810 J	0.0278 JT	0.00104 JT	1750 T	129 T	104 T	241.1 JT	404
LW2-W015	XAD filter	LW2-W015 F	13	1.04 J	0.432 U	801 U	0.528 JT	0.0193 JT	2610 T	299 T	1300 T	1030 JT	1290
LW2-W015	XAD filter	LW2-W2015 F	0.693 J	0.597 J	1.58 U	550 U	0.476 JT	0.00777 JT	1760 T	290 T	1070 T	228 JT	285
LW2-W015	XAD filter	LW2-W3015 F	1.26 J	0.254 U	0.13 UJ	303 U	0.373 JT	0.0095 JT	1420 T	193 T	0.982 UT	331.3 JT	398
LW2-W016	XAD column	LW2-W016 C	0.702 J	5.91 J	1.52 UJ	1600 U		0.00141 JT	539 T	70.8 T	171 T	112 JT	137
LW2-W016	XAD column	LW2-W2016 C	1.4 J	8.96	1.53 U	1430 U		0.000605 T	368 T	55.8 JT	70.2 T	171 JT	248
LW2-W016	XAD column	LW2-W3016 C	1.44 U	19.4	3.31 J	1690 J		0.00401 JT	2380 T	233 T	355 T	516.3 JT	581
LW2-W016	XAD filter	LW2-W016 F	0.504 UJ	0.288 U	0.168 U	413 U		0.00571 JT	656 T	152 T	1380 T	206 JT	241
LW2-W016	XAD filter	LW2-W2016 F	0.652 J	0.499 J	1.52 U	507 U		0.00535 T	350 T	117 JT	277 T	158 JT	201
LW2-W016	XAD filter	LW2-W3016 F	0.979 J	1.24 J	0.508 J	368 U		0.0159 T	2240 T	520 T	4030 T	647 JT	695

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Table I-14c. iAOPC 14 Tissue Samples Data.

Location	Sample	Species	Tissue	Aldrin µg/kg-Wet	Arsenic mg/kg-Wet	beta-Hexachlorocyclohexane µg/kg-Wet	delta-Hexachlorocyclohexane µg/kg-Wet	Dibutyl phthalate µg/kg-Wet	Dioxin/furan TCDD toxicity equivalent pg/g-Wet	Dioxin-like PCB congener TCDD toxicity equivalent pg/g-Wet	Mercury mg/kg-Wet	Silver mg/kg-Wet	Total of 2,4' and 4,4'-DDD µg/kg-Wet	Total of 2,4' and 4,4'-DDE µg/kg-Wet	Total of 2,4' and 4,4'-DDT µg/kg-Wet	Total PCB Aroclors µg/kg-Wet	Total PCB Congeners µg/kg-Wet
LW2-BTFC017	LW2-BTFC017	clam	body without shell	0.36	1.05	0.0421 U	0.00425 J	16 U	4.65 T	1.98 T	0.013 J	0.0752	196 T	63.2 T	44.4 T	75 JT	111
LW2-BTFC018	LW2-BTFC018	clam	body without shell	0.261 J		0.00418 U	0.00153 U		6.76 T	1.63 T			116 T	41.1 T	24.4 T	63.1 JT	91
LW2-GBT017	LW2-BTLC017	lab clam	body without shell	0.0399 J	0.421 J	0.0441 U	0.007 J	16 U	42.5 T	2.27 T	0.0094	0.014	103 T	9.64 T	3.34 T	124 JT	167
LW2-GBT017	LW2-BTLW017	Lumbriculus variegatus	whole body	0.34 J	1.13	0.0415 U	0.0181 U	280 U	472 JT	21.5 JT	0.006 J	0.0062	1260 T	188 T	34.2 T	1870 JT	1890
LW2-GBT018	LW2-BTLC018	lab clam	body without shell	0.0146 J	0.429	0.00318 U	0.004 U	170 U	1.49 JT	0.443 JT	0.011	0.0108	941 T	11.2 T	87.1 T	19.7 JT	24.6
LW2-GBT018	LW2-BTLW018	Lumbriculus variegatus	whole body	0.555	1.7	0.0493 J	0.0161 J	16 U	29.5 JT	2.61 JT	0.0063	0.0069	896 T	83.9 JT	37.9 T	136 JT	208
LW2-MIT356	LW2-MIT003/005/006	multiplate invertebrates	whole body	0.0828		0.00933 U	0.004 U		4 JT	0.296 JT			44.4 T	30.7 T	19.7 T	34.8 JT	45.6
LW2-T02	LW2-T02 SC	chinook	stomach contents	0.0426 J		0.215 J	0.0972 J			2.29 T			137 JT	147 JT	43.9 JT	52.1 JT	59.8
LW2-T02	LW2-T02-NOAA SC	chinook	stomach contents	0.0333 U		0.0742 U	0.023 U			0.889 T			27.8 T	77.8 T	69.4 T	55.1 JT	57.1
LW2-T02	LW2-T02-REP1	chinook	whole body	1.2 U	0.0663	0.33 U	0.22 U		3.61 JT	2.31 JT	0.01131	0.00273 U	120 T	87 T	42.6 T	92.8 JT	97.1
LW2-T02	LW2-T02-REP2	chinook	whole body	0.16 U	0.05684	0.33 U	0.26 U		2.48 JT	4.54 JT	0.011172 J	0.00196 U	132 T	92 T	48 T	100 JT	100
LW2-T02	LW2-T02-REP3	chinook	whole body	0.16 U	0.07178	1.1 U	1.1 U		4.63 JT	2.54 JT	0.010864 J	0.002522 U	143 T	93 T	48 T	101 JT	111
LWG0106R004CR10	LWG0106R004TSCRWBC10	crayfish	whole body	1 U	0.38 J	1 U	1 U	330 U	1.69 T	0.59 T	0.034	0.0306 J	2.9 JT	8.8 T	3.1 T	5.8 UT	14.2 JT
LWG0106R004CR20	LWG0106R004TSCRWBC20	crayfish	whole body	1 U	0.35 J	1 U	1 U	330 U	1.35 JT	0.488 T	0.029	0.03 J	9.6 JT	3.3 T	1.1 JT	2.6 UT	16.5 JT
LWG0106R004SP00	LWG0106R004TSSPWBC00	sculpin	whole body	4 UJT	0.18	8.5 UT	4 UT	300 U	5.52 JT	4.98 T	0.031	0.0015 U	173 JT	244 JT	153 JT	400 JT	203 JT
LWG0107R003CR00	LWG0107R003TSCRWBC00	crayfish	whole body	2 U	0.3 J	2 UJ	2 U	330 U			0.03	0.019 J	3.1 JT	15 JT	17.5 JT	39 T	
LWG0107R003SDS015C00	LWG0107R003TSCAWBC00	clam	body without shell	1.1 U	0.802	1 UJ	1 U	400 UT			0.011	0.0399	44 JT	28.5 JT	69 T	62 JT	
LWG0107R003SP00	LWG0107R003TSSPWBC00	sculpin	whole body	1 UT	0.17	8.5 UT	1 UT	290 U			0.086	0.0009 U	102 JT	168 JT	313 T	226 JT	
LWG0107R006CR00	LWG0107R006TSCRWBC00	crayfish	whole body	1 U	0.32	1 UJ	1 U	330 U	22.7 T	1.13 T	0.024	0.0315	21.3 JT	51 T	12.6 T	45 JT	27.8 JT
LWG0107R006SDS015C00	LWG0107R006TSCAWBC00	clam	body without shell	1 UT	0.923	8.5 UT	1 UT	480 U			0.006 T	0.0371	242 T	107 JT	114 T	120 T	
LWG0107R006SP00	LWG0107R006TSSPWBC00	sculpin	whole body	1 UT	0.28	1 UJT	1 UT	300 U	38.6 T	15.5 T	0.066	0.0011 U	376 T	657 T	2030 T	430 JT	692 JT

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Table I-14d. iAOPC 14 Porewater Samples Data.

Location	Sample	Upper cm	Lower cm	Arsenic mg/l	Mercury mg/l	Silver mg/l
WR-WSI98SD077	WR-WSI98SD0770PW	0	10	0.002	0.0001 U	0.0002 U

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Table I-14e. iAOPC 14 Transition Zone Water Samples Data.

Location	Sample	Upper cm	Lower cm	Arsenic (dissolved) mg/l	Arsenic mg/l	Dioxin/furan TCDD toxicity equivalent pg/l	Mercury (dissolved) mg/l	Mercury mg/l	Silver (dissolved) mg/l	Silver mg/l	Total of 2,4' and 4,4'-DDD µg/l	Total of 2,4' and 4,4'-DDE µg/l	Total of 2,4' and 4,4'-DDT µg/l
AP-02-A-TR	LWG2-T30-AP2A	30	30		0.0376			0.00008 U		0.00002 U	0.2 JT	0.038 UT	1.1 JT
AP-02-A-TR	LWG2-T30-AP2A-Filt	30	30	0.027			0.00008 U		0.000004 U		0.036 JT	0.0045 UT	0.015 UT
AP-02-D-TR	LWG2-T30-AP2D	30	30		0.00207 J			0.000116 J		0.000106 U	2.4 JT	0.93 UT	0.15 UT
AP-03-A-TR	LWG2-T30-AP3A	30	30		0.00788			0.000085 J		0.000008 U	1.04 T	0.12 JT	1.89 JT
AP-03-A-TR	LWG2-T30-AP3A-D	30	30		0.00863			0.00008 U		0.000009 U	0.69 T	0.043 JT	0.84 T
AP-03-A-TR	LWG2-T30-AP3A-D-Filt	30	30	0.00855			0.00008 U		0.00001 U		0.04 JT	0.021 UT	0.028 UT
AP-03-A-TR	LWG2-T30-AP3A-Filt	30	30	0.00793			0.00008 U		0.000009 U		0.029 JT	0.024 UT	0.031 UT
AP-03-A-TR	LWG2-T90-AP3A	150	150		0.0142			0.000246		0.000152	2.37 T	0.19 JT	3.17 T
AP-03-D-PR	LWG2-P-AP03D	0	38								0.0055 UT	0.0046 UT	0.016 UJT
AP-03-D-TR	LWG2-T90-AP3D	150	150		0.00693			0.00008 U		0.000025 U	0.169 JT	0.064 UT	0.026 UT
AP-04-C-PR	LWG2-P-AP04C	0	38		0.00091 J			0.00008 U		0.000004 U	0.0074 UT	0.0062 UT	0.008 UT
CP-06-A-TR	LWG2-T30-CP6A	30	30		0.0016			0.000495		0.000058 U			
CP-06-A-TR	LWG2-T30-CP6A-FILT	30	30	0.00021 U			0.000228		0.000002 U				
CP-06-A-TR	LWG2-T90-CP6A	150	150		0.00585			0.000293		0.000102 U			
CP-07-A-TR	LWG2-T30-CP7A	30	30		0.00522			0.000101 J		0.000011 U			
CP-07-A-TR	LWG2-T30-CP7A-FILT	30	30	0.0065			0.0001 J		0.000007 U				
CP-07-B-TR	LWG2-T30-CP7B	30	30		0.0005 U			0.00008 U		0.000062 U			
CP-07-B-TR	LWG2-T30-CP7B-FILT	30	30	0.00043 U			0.00008 U		0.000049 U				
CP-07-B-TR	LWG2-T90-CP7B	150	150		0.00953			0.000198 J		0.000386 U			
CP-07-D-PR	LWG2-P-CP07D	0	38		0.00046 UJ			0.00009 U		0.0026			
CP-07-D-TR	LWG2-T90-CP7D	150	150		0.00031 U			0.000092 U		0.000359			
CP-08-B-TR	LWG2-T30-CP8B	30	30		0.00072			0.000148 J		0.000004 U			
CP-08-B-TR	LWG2-T30-CP8B-FILT	30	30	0.00055 U			0.000134 J		0.000002 U				
CP-09-A-TR	LWG2-T30-CP9A	30	30		0.00066 U			0.00008 U		0.000034 U			
CP-09-A-TR	LWG2-T30-CP9A-D	30	30		0.00069 U			0.00008 U		0.000016 J			
CP-09-A-TR	LWG2-T30-CP9A-D-filt	30	30	0.0007 U			0.00008 U		0.000005 U				
CP-09-A-TR	LWG2-T30-CP9A-filt	30	30	0.00069 U			0.00008 U		0.000008 U				
CP-09-D-PR	LWG2-P-CP09D	0	38		0.0107 J			0.00009 U		0.000036 U			
CP-09-D-PR	LWG2-P-CP09D-2	0	38		0.00948 J			0.00009 U		0.000035 U			
LWP1-AP03B-1	LWP1-T-AP03BDupfilt	30	30								0.017 U*	0.0084 NJ*	0.0096 U*
LWP1-AP03B-1	LWP1-T-AP03BDupunfilt	30	30								0.42 *	0.092 *	1.1 *
LWP1-AP03B-1	LWP1-T-AP03Bfilt	30	30								0.032 U*	0.0015 U*	0.035 U*
LWP1-AP03B-1	LWP1-T-AP03Bunfilt	30	30								0.88 *	0.24 *	1.3 *
LWP1-AP03B-1	LWP-TZW3-AP03B-1	0	38								0.032 NJ*	0.0091 U*	0.026 U*
LWP1-AP03B-2	LWP-TZW3-AP03B-2	0	38								0.0015 U*	0.0024 U*	0.019 U*
LWP1-AP04B	LWP1-T-AP04Bfilt	30	30								0.0019 U*	0.0015 U*	0.0042 U*
LWP1-AP04B	LWP1-T-AP04Bunfilt	30	30								0.0019 U*	0.018 *	0.66 *
LWP1-AP04B	LWP-TZW3AP04B	0	38								0.017 U*	0.0012 U*	0.015 U*
LWP1-AP04D	LWP1-T-AP04Dfilt	30	30								0.008 U*	0.0015 U*	0.0072 U*
LWP1-AP04D	LWP1-T-AP04Dunfilt	30	30								0.015 U*	0.0015 U*	0.0075 J*
LWP1-AP04D	LWP-TZW3AP04D	0	38								0.0015 U*	0.0039 NJ*	0.0096 J*
R2-AP-01-PR	LWG2-P-R2AP1	0	38		0.00073 J			0.00008 U		0.000064 U	0.0087 UT	0.0073 UT	0.0094 UT
R2-AP-01-PR	LWG2-P-R2AP1-2	0	38		0.00117 J			0.00008 U		0.000004 U	0.0072 UT	0.006 UT	0.0077 UT
R2-AP-02-TR	LWG2-T30-R2AP2	30	30		0.00595			0.00008 J		0.000061 U	0.066 JT	0.045 UT	0.058 UT
R2-AP-02-TR	LWG2-T30-R2AP2-filt	30	30	0.00522			0.00008 J		0.000023 U				
R2-AP-02-TR	LWG2-T90-R2AP2	150	150		0.00317			0.00021		0.000222 U	2.46 JT	0.2 JT	0.946 JT
R2-CP-01-PR	LWG2-P-R2CP1	0	38		0.00409 J			0.00009 U		0.000624			
R2-RP-01-TR	LWG2-T30-R2RP1	30	30		0.0111 J			0.00008 U		0.0001			
R2-RP-01-TR	LWG2-T30-R2RP1-FILT	30	30	0.0112 J			0.00008 U		0.000007 U				
R2-RP-02-TR	LWG2-T30-R2RP2	30	30		0.00571 JT			0.00008 UT		0.000034 UT			
R2-RP-02-TR	LWG2-T30-R2RP2-FILT	30	30	0.00591 J			0.00008 U		0.000005 U				
R2-RP-03-TR	LWG2-T30-R2RP3	30	30		0.00596			0.00008 U		0.000103			
R2-RP-03-TR	LWG2-T30-R2RP3-Filt	30	30	0.00383			0.00008 U		0.000024 U				
RP-03-C-TR	LWG2-T30-RP3C	30	30		0.0207 J	0 UT		0.000115 JT		0.000143	0.185 JT	0.015 JT	0.0098 JT
RP-03-C-TR	LWG2-T30-RP3C Filt	30	30	0.0224 J		0 UT	0.00008 U		0.000016 U		0.15 T	0.013 UT	0.0078 JT
RP-03-C-TR	LWG2-T90-RP3C	150	150		0.0211 J			0.00009 J		0.000092	0.16 T	0.014 UT	0.01 JT
RP-03-C-TR	LWG2-T90-RP3C-Filt	150	150	0.021 J			0.00008 U		0.000009 U		0.16 T	0.014 UT	0.019 JT
RP-03-E-TR	LWG2-T30-RP3E	30	30		0.0192 J			0.00011 J		0.000234			
RP-03-E-TR	LWG2-T90-RP3E	90	90		0.008 J			0.00011 J		0.000244			
RP-03-E-TR	LWG2-T90-RP3E-FILT	90	90	0.0021 J			0.00008 U		0.000005 U				
RP-07-B-TR	LWG2-T30-RP7B	30	30		0.00522 J	1.79 JT		0.00008 U		0.000034 U			
RP-07-B-TR	LWG2-T30-RP7B-D	30	30		0.00535 J	1.63 JT		0.00008 U		0.000022 U			
RP-07-B-TR	LWG2-T30-RP7B-D-FILT	30	30	0.00457 J		0 UT	0.00008 U		0.000026 U				
RP-07-B-TR	LWG2-T30-RP7B-FILT	30	30	0.00433 J		0 UT	0.00008 U		0.000015 U				
WLCSLH01P9	WLCSLH01P9	1006	1006	0.03					0.002 U				

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Table I-15a. iAOPC 15 Sediment Samples Data.

Location	Sample	Upper cm	Lower cm	Dioxin-like PCB congener TCDD toxicity equivalent mg/kg	Dioxin/furan TCDD toxicity equivalent pg/g
LWG0107R004SDS015C00	LWG0107R004SDS015C00	0	15	6.1	
WLCMBJ99D09934	WLCMBJ99D09934D09934	0	15	5.9	
WLCMBJ99D09937	WLCMBJ99D09937D09937	0	15	7.8	28 JT
WLCMBJ99D09938	WLCMBJ99D09938D09938	0	15	5.7	
WLCMBJ99D09939	WLCMBJ99D09939D09939	0	15	4	
WLCOFJ024803	WLCOFJ02480348030	0	15	75.6	
WLCOFJ024804	WLCOFJ02480448040	0	15	83.5	
WLCOFJ024805	WLCOFJ02480548050	0	15	27.5	
WLCOFJ024806	WLCOFJ02480648060	0	15	54	
WR-WSI98SD086	WR-WSI98SD0860	0	10	5 U	39 T*

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Table I-15b. iAOPC 15 Tissue Samples Data.

Location	Sample	Species	Tissue	Arsenic mg/kg-Wet
LWG0107R004CR00	LWG0107R004TSCRWBC00	crayfish	whole body	0.5 J

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Table I-16. iAOPC 16 Sediment Samples Data.

Location	Sample	Upper cm	Lower cm	Dioxin-like PCB congener TCDD toxicity equivalent µg/kg
WR-WSI98SD096	WR-WSI98SD0960	0	10	200 T
WR-WSI98SD096	WR-WSI98SD0960000A	0	90	230 T

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Table I-17a. iAOPC 17 Sediment Samples Summary Statistics.

Location	Sample	Upper cm	Lower cm	Dioxin/furan TCDD toxicity equivalent pg/g	Dioxin-like PCB congener TCDD toxicity equivalent pg/g	Total of 2,4' and 4,4'-DDD µg/kg	Total of 2,4' and 4,4'-DDT µg/kg	Total PCB Aroclors µg/kg	Total PCB Congeners µg/kg
LW2-C377	LW2-C377-B	30	153	0.41 T		29.1 JT	27.7 JT	33.7 JT	
LW2-C377	LW2-C377-C	153	273	1.86 T		69 JT	19.7 JT	267 T	
LW2-C377	LW2-C377-D	273	369	15.2 T					
LW2-C377	LW2-C377-E	369	482	13.7 T	1.14 T	241 JT	2.9 JT	26.6 T	64.3
LW2-G377	LW2-G377	0	26	0.771 JT		6.23 JT	0.819 JT	0.851 JT	
LW2-G389	LW2-G389	0	20			0.233 JT	0.501 JT	2.73 UT	
LW2-G394	LW2-G394	0	25			385 JT	5.12 JT	703 T	
LW2-GBT020	LW2-GBT020	0	10	3.48 JT	0.598 JT	23.8 T	125 T	33 T	19.4
LWG0107B022SDS015C00	LWG0107B022SDS015C00	0	15			1.1 T	0.84 T	7.9 UT	
LWG0107R030SDS015C00	LWG0107R030SDS015C00	0	15			20.9 T	4.2 UT	8.4 T	
TOSCO99DMMU1	TOSCO99DMMU1SDO1	0	304			11 E*	2 UE*	240 T	
TOSCO99DMMU1	TOSCO99DMMU1SDO3	0	304			12 EG*	13 EG*	324 T	
WLCCPF01SD0101	WLCCPF01SD0101SD139F	183	213			0.8 U*	0.8 U*	205 T	
WLCCPF01SD0101	WLCCPF01SD0101SD141F	213	244			0.8 U*	0.8 U*	12 UT	
WLCCPF01SD0101	WLCCPF01SD0101SD1S1C	91	183			1.65 U*	1.65 U*	24.8 UT	
WLCCPF01SD0103	WLCCPF01SD0103SD339F	152	183			0.8 U*	0.8 U*	19.1 T	
WLCCPF01SD0103	WLCCPF01SD0103SD341F	183	213			0.8 U*	0.8 U*	58 T	
WLCCPF01SD0103	WLCCPF01SD0103SD3S1C	0	152			1.7 U*	1.7 U*	25.5 UT	
WLCCPF01SD0104	WLCCPF01SD0104SD439F	91	122			0.8 U*	0.8 U*	14.3 T	
WLCCPF01SD0104	WLCCPF01SD0104SD441F	122	152			0.8 U*	0.8 U*	12 UT	
WLCCPF01SD0104	WLCCPF01SD0104SD4S1C	0	91			0.8 U*	0.8 U*	12.4 T	
WLCCPF01SD0105	WLCCPF01SD0105D5SC1C	0	30			0.8 U*	0.8 U*	79.1 T	
WLCCPF01SD0105	WLCCPF01SD0105SD539F	30	61			0.8 U*	0.8 U*	49.6 T	
WLCCPF01SD0105	WLCCPF01SD0105SD541F	61	91			0.8 U*	0.8 U*	12 UT	
WLRWTF98ATXSD1	WLRWTF98ATXSD1ATXSD1	0	12.7			3.35 U*	3.35 U*		
WLRWTF98ATXSD1	WLRWTF98ATXSD1TXSD1D	0	12.7			3.35 U*	3.35 U*		
WLRWTF98ATXSD2	WLRWTF98ATXSD2ATXSD2	0	12.7			3.35 U*	3.35 U*		
WLRWTF98ATXSD2	WLRWTF98ATXSD2TXSD2D	0	12.7			3.35 U*	3.35 U*		
WLRWTF98ATXSD3	WLRWTF98ATXSD3ATXSD3	0	12.7			10.6 *	3.35 U*		
WLRWTF98ATXSD4	WLRWTF98ATXSD4ATXSD4	0	12.7			6.7 U*	3.35 U*		
WLRWTF98ATXSD5	WLRWTF98ATXSD5ATXSD5	0	12.7			6.7 U*	3.35 U*		
WLRWTF98HEVSD2	WLRWTF98HEVSD2HEVSD2	0	12.7			3.35 U*	3.35 U*		
WLRWTF98HEVSD3	WLRWTF98HEVSD3HEVSD3	0	12.7			3.35 U*	3.35 U*		

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Table I-17b. iAOPC 17 Surface Water Samples Data.

Location	Sampling Method	Sample	Total of 2,4' and 4,4'-DDD µg/l	Total of 2,4' and 4,4'-DDT µg/l	Total PCB Aroclors µg/l
LW2-W017	bottle	LW2-W017	0.00051 UT	0.00051 UT	RT
LW2-W017	bottle	LW2-W2017	0.00051 UT	0.00051 UT	0.00256 UT
LW2-W017	bottle	LW2-W3017	0.000481 UT	0.000693 JT	0.0025 UT

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Table I-17c. iAOPC 17 Tissue Samples Data.

Location	Sample	Species	Tissue	Dioxin/furan TCDD toxicity equivalent pg/g-Wet	Dioxin-like PCB congener TCDD toxicity equivalent pg/g-Wet	Total of 2,4' and 4,4'-DDD µg/kg-Wet	Total of 2,4' and 4,4'-DDT µg/kg-Wet	Total PCB Aroclors µg/kg-Wet	Total PCB Congeners µg/kg-Wet
LW2-BTFC020	LW2-BTFC020	clam	body without shell	0.816 JT	1.57 JT	28.5 T	11.6 T	71.1 JT	99
LW2-GBT020	LW2-BTLC020	lab clam	body without shell	0.279 T	1.36 T	6.26 T	0.405 JT	44.3 JT	50.7
LW2-GBT020	LW2-BTLW020	Lumbriculus variegatus	whole body	2.35 T	1.73 T	64.2 T	0.831 JT	60.8 JT	91.4

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Table I-18. iAOPC 18 Sediment Samples Data.

Location	Sample	Upper cm	Lower cm	Dioxin-like PCB congener TCDD toxicity equivalent mg/kg	Dioxin-like PCB congener TCDD toxicity equivalent pg/g	Total PCB Aroclors µg/kg	Total PCB Congeners µg/kg
GN-01-E-PG	LWG2-PG-GN1E	0	21	481			
LW2-B022	LW2-B022-1	0	15		2.51 T	119 T	4.92 T
LW2-B022-2	LW2-B022-2	0	15		2.63 T	71 JT	5.37 T
LW2-C431	LW2-C431-B	30	131		11 T	1430 JT	1120
LW2-C431	LW2-C431-C	131	175			2.63 UT	
LW2-C431	LW2-C431-D	175	281			2.01 JT	
LW2-C434	LW2-C434-B	30	144			88.9 JT	
LW2-C434	LW2-C434-C	144	175			2.49 UT	
LW2-C434	LW2-C434-D	175	250			2.43 UT	
LW2-G427	LW2-G427	0	29			80 T	
LW2-G431	LW2-G431	0	30			127 JT	
LW2-G432	LW2-G432	0	26			590 JT	
LW2-G434	LW2-G434	0	26		6.52 JT	245 JT	101
WLCOFJ021901	WLCOFJ02190119010	0	15				42.9 JT
WLCOFJ021902	WLCOFJ02190219020	0	15				164 T
WLCOFJ021903	WLCOFJ02190319030	0	15				29.9 JT
WLCOFJ0219A01	WLCOFJ0219A0119A010	0	8				74.2 T
WLCOFJ0219A02	WLCOFJ0219A0219A020	0	12				22.3 JT
WLCOFJ0219A03	WLCOFJ0219A0319A030	0	10				54.6 JT

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Table I-19a. iAOPC 19 Sediment Samples Summary Statistics.

Location	Sample	Upper cm	Lower cm	Aldrin µg/kg	alpha-Hexachlorocyclohexane µg/kg	Ammonia mg/kg	Cadmium mg/kg	Dibutyl phthalate µg/kg	Dieldrin µg/kg	Diesel Range Hydrocarbons mg/kg	Dioxin-like PCB congener TCDD toxicity equivalent pg/g	Endrin ketone µg/kg	Mercury mg/kg	Residual Range Hydrocarbons mg/kg	Silver mg/kg	Total of 2,4' and 4,4'-DDD µg/kg	Total of 2,4' and 4,4'-DDE µg/kg	Total of 2,4' and 4,4'-DDT µg/kg	Total PCB Aroclors µg/kg	Total PCB Congeners µg/kg
LW2-C444	LW2-C444-B	30	152	2.77 NJ	1.8 NJ		0.467	26 U	0.0877 UJ			0.0504 UJ	0.156		0.517	3.15 JT	13.6 JT	1.2 JT	685 JT	
LW2-C444	LW2-C444-C	152	206	0.21 U	0.224 U		0.376	22 U	0.343 U			0.197 U	0.289		0.316	12.7 JT	21.1 JT	0.374 UT	253 JT	
LW2-C444	LW2-C444-D	206	263										0.019							
LW2-C444	LW2-C444-E	263	388	0.14 U	0.11 U		0.191	4.5 J	0.12 U			0.079 U			0.078 J	0.3 UT	0.35 UT	0.2 UT	2.3 UT	
LW2-C447	LW2-C447-A	0	30	0.51 U	0.14 U				0.15 U			0.3 U				2.1 T	4.6 T	3.7 T		
LW2-C447	LW2-C447-B	30	112				0.389	42 U		340 JT			0.191	740 JT	0.406				755 JT	
LW2-C447	LW2-C447-C	112	189	0.32 U	0.13 U		0.214	21 U	0.13 U	120 J		0.16 J	0.109	320 J	0.183	11.3 T	2.54 JT	0.31 T	2.91 JT	
LW2-C447	LW2-C447-D	189	239				0.088	3.6 U		14 U			0.024	68 J	0.036				2.51 UT	
LW2-C447	LW2-C447-F	311	382					3.7 U												
LW2-C448	LW2-C448-A	0	30	1.1 J	0.17 U				0.17 U			0.22 U				3.3 JT	4.8 T	2.17 JT		
LW2-C448	LW2-C448-B	30	152				0.243	5 U		68 J			0.063	290 J	0.216				30.7 JT	
LW2-C448	LW2-C448-C	152	272	0.18 U	0.15 U		0.458	7.3 J	0.16 U	340 J		0.3 U	0.114	1100 J	0.484	2.3 JT	6.2 T	4.6 T	241 JT	
LW2-C448	LW2-C448-D	272	365				0.403	12 U		460 J				1300 J	0.377 J				399 JT	
LW2-C450	LW2-C450-B	30	148	2.44 J	0.0516 U		0.252	4.9 U	0.0791 U	110 J		0.0455 U	0.065	410 J	0.207	8.21 JT	7.74 JT	0.859 JT	81.9 JT	
LW2-C450	LW2-C450-C	148	245	0.442 U	0.472 U		0.675	93 U	0.723 U	1200 J		0.415 U	0.312	2700 J	0.633	31.6 JT	71.7 JT	18 JT	2110 JT	
LW2-C453	LW2-C453-B	30	152	31.3	2.9 J		1.93	240 U	51 J	2700 J	48.8 T	0.422 U	1.23	5000 J	1.05	88.9 JT	380 JT	9.74 JT	3600 T	5990
LW2-C453	LW2-C453-C	152	270	0.428 U	1.83 J		0.653	88 U	0.699 U	1900 J		0.402 U	1.01	3200 J	0.741	102 JT	242 JT	2.82 JT	299 JT	
LW2-C453	LW2-C453-D	270	382	0.0407 U	0.0434 U		0.358	21 U	0.0665 U	280 J		0.0382 U	0.196	720 J	0.44	0.748 JT	2.36 JT	0.0724 UT	5.84 JT	
LW2-C455	LW2-C455-B	30	152	637 J	98.9 NJ		4.36 J	240 U	7.31 UJ	12000 J	318 T	55.9 NJ	1.3	25000 J	2.47	2980 JT	2830 JT	31.5 JT	21900 JT	36800
LW2-C455	LW2-C455-C	152	274	2.19 J	0.225 U		0.923 J	90 U	0.344 UJ	2000 J	10.4 T	0.198 UJ	0.845	3500 J	1.01	151 JT	384 JT	2.46 JT	432 JT	591
LW2-C455	LW2-C455-D	274	395	0.204 UJ	0.218 U		0.314 J	21 U	0.333 UJ	420 J		0.192 UJ	0.165	890 J	0.401	1.65 JT	1.98 JT	0.294 UJT	36 JT	
LW2-C455	LW2-C455-F	430	494					19 U											9.7 T	
LW2-C456	LW2-C456-B	30	137	0.631 NJ	0.0481 U		0.255 J	4.9 U	0.0737 U	88 J		0.0423 U	0.067	400 J	0.198	4.27 JT	3.51 JT	0.661 JT	29.4 JT	
LW2-C456	LW2-C456-C	137	222	1.01 NJ	0.194 U		0.207 J	91	0.298 U	410 J		1.03 NJ	0.129	1200 J	0.551	11.4 JT	8.96 JT	0.998 JT	258 JT	
LW2-C456	LW2-C456-D	222	254	0.0418 UJ	0.0447 U		0.587 J	14 J	0.0684 U			0.0393 U	0.247		0.735	0.638 JT	0.493 JT	0.0604 UJT	10.3 JT	
LW2-C456	LW2-C456-F	377	414	0.0405 UJ	0.0433 U		0.279 J	13 J	0.0663 U			0.0381 U	0.197		0.398	0.349 JT	0.382 JT	0.562 JT	2.97 UJT	
LW2-C457	LW2-C457-B	30	108	0.0475 U	0.0507 U		0.227	4.8 U	0.0777 U			0.0446 U	0.062		0.217	3.81 JT	3.72 JT	0.899 JT	53 JT	
LW2-C457	LW2-C457-C	108	173	0.201 U	0.214 U		0.452	43 U	0.328 U			0.189 U	0.11		0.525	6.46 JT	5.39 JT	1.88 JT	139 JT	
LW2-C457	LW2-C457-D	173	291				0.557	47 U							0.801 J				12 UT	
LW2-C457	LW2-C457-E	291	357	0.0406 UJ	0.0434 UJ		0.388	21 U	0.0664 UJ			0.0382 UJ	0.215		0.522	0.0625 UJT	0.0586 UJT	0.74 JT	2.99 UT	
LW2-C458	LW2-C458-B	30	151	0.0515 UJ	0.055 U		0.195 T	5 U	0.0843 U			0.0484 U	0.054 T		0.204 T	1.8 JT	2.63 JT	0.0917 UJT	29.1 JT	
LW2-C458	LW2-C458-C	151	273	0.0467 U	0.0499 U		0.219	4.8 U	0.0764 U			0.0439 U	0.11		0.256	3.79 JT	3.25 JT	0.402 JT	58 JT	
LW2-C458	LW2-C458-D	237	342	0.17 U	0.14 U				0.15 U			0.23 U				1 JT	2.1 JT	1.85 JT		
LW2-C458-2	LW2-C458-B2	30	152	0.0477 UJT	0.0509 UT		0.195 T	4.8 UT	0.078 UJT			0.0448 UJT	0.058 T		0.21 T	1.98 JT	2.66 JT	0.483 JT	53.7 JT	
LW2-C458-2	LW2-C458-C2	152	274	0.048 UJT	0.0506 UT		0.244 T	4.9 JT	0.0775 UT			0.0445 UT	0.0745 T		0.297 T	3.7 JT	3.1 JT	0.214 JT	78.6 JT	
LW2-C458-2	LW2-C458-D2	274	341																52 JT	
LW2-C461	LW2-C461-A	0	30							160 J				770 J						
LW2-C461	LW2-C461-B	30	152	0.0507 UJ	0.0541 UJ		0.269	5 U	0.0829 UJ	150 J		0.0476 UJ	0.095	580 J	0.263	2.39 JT	3.04 JT	0.0902 UJT	104 JT	
LW2-C461	LW2-C461-C	152	279	0.0448 UJ	0.0478 UJ		0.361	5.8 J	0.0733 UJ			0.771 NJ	0.178		0.435	2.37 JT	2.84 JT	0.535 JT	224 JT	
LW2-C461	LW2-C461-D	279	361				0.4	17 U		180 J				540 J	0.218 J				185 T	
LW2-C468	LW2-C468-B	30	152	0.0445 U	0.0475 U		0.229 T	9.2 U	0.0728 U			0.0418 U	0.0795 T		0.187 T	2.41 JT	1.96 JT	0.529 JT	79.5 JT	
LW2-C468	LW2-C468-C	152	272	0.0466 U	0.0498 U		0.291	9.6 U	0.0762 U			0.0438 U	0.097		0.405	2.9 JT	3.19 JT	0.425 JT	111 JT	
LW2-C468	LW2-C468-D	272	342					30 J											57 JT	
LW2-C471	LW2-C471-B	30	152				0.185	5.4 J					0.048		0.189				14.1 JT	
LW2-C471	LW2-C471-C	152	274				0.165	4.6 J					0.047		0.14				15.9 JT	
LW2-C471	LW2-C471-D	274	364																40.9 JT	
LW2-C474	LW2-C474-B	30	152	0.05 UJ	1.47 NJ		0.218	5.6 J	0.0818 U	65 J		0.621 NJ	0.057	350 J	0.196	1.7 JT	1.81 JT	0.68 JT	65.5 JT	
LW2-C474	LW2-C474-C	152	275	0.0441 UJ	7.37 NJ		0.21	4.6 U	0.0722 U	51 J		0.0415 U	0.065	240 J	0.202	2.96 JT	2.54 JT	0.0786 UJT	33.2 JT	
LW2-C477	LW2-C477-B	30	123	0.0446 UJ	0.0476 U		0.439 J	24 U	0.828 NJ	63 J	14 JT	0.0419 U	0.101	300 J	0.504	7.53 JT	3.32 JT	2.34 JT	684 JT	506
LW2-C477	LW2-C477-C	123	208	0.0329 UJ	0.0351 U		0.751 J	8.8 J	0.0538 U	130 J		1.5 NJ	0.089	330 J	0.168	3.14 JT	3.29 JT	1.73 JT	140 JT	
LW2-G444	LW2-G444	0	27	30 J	2.24 J	117	0.296 J	11 U	21.5 J			0.0457 U	0.098		0.226	93.2 JT	123 JT	1.71 JT	82.8 JT	
LW2-G445	LW2-G445	0	25	0.407 J	0.0435 U	13.6	0.769 J	160	3.96 J	610 J		0.0383 U	0.455	1300 J	1.13	50.2 JT	18.1 JT	66.8 JT	271 T	
LW2-G447	LW2-G447	0	25				0.27	5.2 UJ		90 J	1.3 T		0.087	400 J	0.241				67 JT	50.4
LW2-G448	LW2-G448	0	30				0.28	6.5 UJ		160 J	1.63 T		0.086	740 J	0.233				90 JT	90.7
LW2-G450	LW2-G450-1	0	27	1.98 J	0.192 U	182	0.338 J	32 U	0.192 U	150 J		0.192 U	0.08	760 J	0.22	6.91 JT	9.72 JT	2.55 JT	94 JT	
LW2-G450-2	LW2-G450-2	0	28	0.198 UJ	0.198 U	188	0.352 J	13 U	0.198 U	170 J		0.198 U	0.076	760 J	0.222	2.45 JT	6.02 JT	5.2 JT	98 T	
LW2-G453	LW2-G453	0	26	132 J	10 J	352	5.41	57 U	356 J	8400 J	324 T	90.1 NJ	2.01	18000 J	4.44	1370 JT	2530 JT	28.8 JT	27400 JT	35400
LW2-G455	LW2-G455	0	24	2.19 J	0.0336 UJ	91	0.95 J	18 U	3.03 J	350 J		0.0296 UJ	0.151	1200 J	0.349	18.1 JT	20.7 JT	2.36 JT	795 T	
LW2-G456	LW2-G456	0	24	3.97 NJ	0.199 UJ	135	0.34	61	0.305 UJ			0.175 UJ	0.067		0.342	10.7 JT	9.94 JT	7.3 JT	189 JT	
LW2-G457	LW2-G457	0	27	0.868 J	0.091 NJ	171	0.29	12 J	0.905 NJ		2.38 JT	1.18 NJ	0.085		0.207	4.02 JT	6.84 JT	2.43 JT	142 JT	115
LW2-G458	LW2-G458	0	27	0.187 UJ	2.98 J	148 T	0.25	14 U	0.187 U			0.187 U	0.085		0.186	1.11 JT	1.36 T	0.187 UT	23.6 JT	
LW2-G460	LW2-G460	0	26				0.24	130					0.057		0.167				9.1 T	
LW2-G461	LW2-G461	0	27	0.478 J	0.0592 UJ	170	0.27	7.6 J	0.542 NJ		1.52 T	1.05 NJ	0.081		0.219	2.2 JT	5.39 JT	0.734 JT	79.1 JT	65.7
LW2-G464	LW2-G464	0	25				0.243 J	6.3 U					0.061		0.149				10 T	
LW2-G466	LW2-G466	0	27	0.0464 UJ	0.0495 UJ		0.2	5.6 UJ	0.292 NJ			0.0436 UJ	0.039		0.237	1.31 JT	1.45 T	0.0826 UJT	11.7 JT	
LW2-G467	LW2-G467	0	24	0.159 UJ	0.17 U	58.9	0.94	81 J	0.26 UJ			3.92 NJ	0.114		0.169	39.5 JT	7.35 JT	8.81 JT	1270 T	
LW2-G468	LW2-G468	0	28	0.0557 UJ	0.0595 UJ	170	0.24	8.5 J	0.415 NJ			0.479 NJ	0.065		0.2	1.62 JT	3.44 JT	1.13 JT	46.6 JT	
LW2-G469	LW2-G469	0	28	0.182 UJ	0.776 J	195	0.241 J	6 U	0.182 UJ			0.182 UJ	0.054		0.156	0.915 JT	1.09 JT	0.919 JT	13 T	
LW2-G471	LW2-G471	0	28				0.2	6.2 UJ					0.053		0.195				14.7 JT	

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Table I-19a. iAOPC 19 Sediment Samples Summary Statistics.

Location	Sample	Upper cm	Lower cm	Aldrin µg/kg	alpha-Hexachlorocyclohexane µg/kg	Ammonia mg/kg	Cadmium mg/kg	Dibutyl phthalate µg/kg	Dieldrin µg/kg	Diesel Range Hydrocarbons mg/kg	Dioxin-like PCB congener TCDD toxicity equivalent pg/g	Endrin ketone µg/kg	Mercury mg/kg	Residual Range Hydrocarbons mg/kg	Silver mg/kg	Total of 2,4' and 4,4'-DDD µg/kg	Total of 2,4' and 4,4'-DDE µg/kg	Total of 2,4' and 4,4'-DDT µg/kg	Total PCB Aroclors µg/kg	Total PCB Congeners µg/kg
LW2-G473	LW2-G473	0	29	0.227 U	0.427 J	154 T	1.21	46 J	0.372 U	120 J	41.7 T	8.5 NJ	0.407 T	590 J	0.328	51.2 JT	13.7 JT	10.6 JT	1470 T	2510
LW2-G474	LW2-G474	0	26	0.195 U	0.379 J	180	0.235 J	6.5 U	0.195 U	63 J		0.129 NJ	0.054	420 J	0.134	2 JT	3.09 JT	0.785 JT	16 T	
LW2-G477	LW2-G477	0	28	0.214 U	0.228 U	111	1.07	39	0.35 U	130 J	61.6 T	3.86 NJ	0.289	670 J	0.216	44.2 JT	10.2 T	8.95 JT	2360 T	1880
LW2-G480	LW2-G480	0	24	1.42 J	0.212 NJ	83.5	0.2	7.5 U	0.267 U			1.33 NJ	0.068		0.123	13.8 JT	21.2 JT	2.06 JT	145 T	
LW2-GBT028	LW2-GBT028	0	10	11.4	0.0361 J	108 J	0.729	36 U	9.17	670 J	21.9 T	0.0195 J	0.159	2300 J	0.374 J	35.2 T	50 T	3.1 JT	1190 T	1540
LWG0108R041SDS015C00	LWG0108R041SDS015C00	0	15	3.9 U	0.19 U		0.24	20 U	1.6 U			0.39 U	0.1		0.14	6.9 T	18 T	3.2 UT	77 JT	
WLCDRD05PG094	WLCDRD05PG09494	0	26	0.39 U	0.42 U	217	0.249	12 U	1.1 U	110 J		1.3 U	0.056	720 J	0.177 J	1.1 UT	1.7 T	1.1 JT	38 T	
WLCDRD05PG096	WLCDRD05PG09696	0	20	0.42 U	0.47 U	240	0.249	23 U	0.15 U	120 J		1.3 U	0.061	800 J	0.171 J	0.92 JT	1.8 JT	0.74 JT	19.2 T	
WLCGNG03A2GS09	WLCGNG03A2GS09A2GS09	0	15				0.442 U	10000 U		50 U			0.116		0.442 U				134 UT	
WLCGNG03A2GS10	WLCGNG03A2GS10A2GS10	0	15				0.417 U	5000 U		25 U			0.0833 U		0.417 U				146 T	
WLCOFH021802	WLCOFH0218021802	0	15	7.77 P	0.832 U		0.46 J	153 U	0.878 U	16.2 JV		0.752 U	0.189		0.149 J	46.1 T	65.8 T	5.36 UT	273 T	
WLCOFH021803	WLCOFH0218031803	0	15	5.11 JT	0.732 UT		0.551 JT	142 UT	0.773 UT	98.8 JT		0.662 UT	0.187 T		0.183 JT	24 JT	33.5 T	4.71 UT	237 T	
WLCOFH021805	WLCOFH0218051805	0	15	24.2 P	0.9 U		0.626 J	185 J	0.95 U	369 V		0.814 U	0.204		0.205 J	41.8 T	72.9 T	5.79 UT	237.2 T	
WLCOFH021806	WLCOFH0218061806	0	15	28.6 P	1.03 J		0.897	137 U	0.854 U	194 JV		0.732 U	0.318 J		0.349 J	78.5 T	124 T	5.21 UT	640 T	
WLCOFH021807	WLCOFH0218071807	0	15	8.38 P	0.727 U		0.664	133 U	0.768 U	265 JV		0.658 U	0.245 J		0.165 J	100 T	75.4 T	4.68 UT	478.5 T	
WLCOFH021808	WLCOFH0218081808	0	15	5.03 P	0.731 U		0.713	147 U	0.772 U	166 V		0.661 U	0.334 J		0.174 J	10.6 T	27.9 T	4.71 UT	357 T	
WLCOFH021809	WLCOFH0218091809	0	15	13.6 P	0.711 U		0.759	139 U	0.751 U	200 V		0.643 U	0.453		0.337 J	57.8 T	78.9 T	4.58 UT	163.9 T	
WLCOFH021810	WLCOFH0218101810	0	15	6.48 P	1.16 U		0.077 J	197 U	1.22 U	73.1 V		1.05 U	0.128		0.387 J	14.1 T	65.1 T	7.46 UT	93.3 T	
WR-WSI98SD140	WR-WSI98SD1400	0	10				0.6	20 U					0.08		0.7					
WR-WSI98SD142	WR-WSI98SD1420	0	10				0.5 J	19 U					0.06		0.8					
WR-WSI98SD143	WR-WSI98SD1430	0	10				0.5	19 U					0.04		0.6					
WR-WSI98SD143	WR-WSI98SD1430000A	0	90				5.3	910 U					0.37		3.4					
WR-WSI98SD144	WR-WSI98SD1440	0	10				0.5	19 U					0.06		0.8					
WR-WSI98SD146	WR-WSI98SD1460	0	10				0.4	19 U					0.05		0.7					
WR-WSI98SD149	WR-WSI98SD1490	0	10				0.6	20 U					0.1		0.9					
WR-WSI98SD151	WR-WSI98SD1510000A	0	90	0.97 U	0.97 U		0.5	19 U	1.9 U			2.2 UIJ	0.11		1	3.5 UI*	2.3 UI*	7.2 UI*	101 T	
WR-WSI98SD151	WR-WSI98SD1510000CC	0	10	9.7 UT	9.7 UT		0.7 T	23.5 NT	19 UT			19 UT	0.265 T		0.8 T	19 UT*	19 UT*	19 UT*	500 T	

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Table I-19b. iAOPC 19 Surface Water Samples Data.

Location	Sampling Method	Sample	Aldrin µg/l	alpha-Hexachlorocyclohexane µg/l	Cadmium (dissolved) mg/l	Cadmium mg/l	Dibutyl phthalate µg/l	Dieldrin µg/l	Endrin ketone µg/l	Mercury (dissolved) mg/l	Mercury mg/l	Silver (dissolved) mg/l	Silver mg/l	Total of 2,4' and 4,4'-DDD µg/l	Total of 2,4' and 4,4'-DDE µg/l	Total of 2,4' and 4,4'-DDT µg/l	Total PCB Aroclors µg/l
LW2-W019	bottle	LW2-W019	0.000481 U	0.000481 U	0.00003	0.00003	0.08 U	0.000481 U	0.000481 U	0.00004 U	0.00004 U	0.000009 U	0.000009 U	0.000481 UT	0.000481 UT	0.000481 UT	0.00253 UT
LW2-W019	bottle	LW2-W2019	0.0005 U	0.0005 U	0.00002 U	0.00002 UT	0.067 U	0.0005 U	0.0005 U	0.00004 U	0.00004 UT	0.000009 U	0.000009 UT	0.0005 UT	0.0005 UT	0.00115 T	0.00263 UT
LW2-W019	bottle	LW2-W3019	0.000485 U	0.000485 U	0.00002	0.00002	0.097 U	0.000485 U	0.000485 U	0.00008 U	0.00008 U	0.000005 UJ	0.000005 UJ	0.000485 UT	0.000485 UT	0.000485 UJT	0.0025 UT

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Table I-19c. iAOPC 19 Tissue Samples Data.

Location	Sample	Species	Tissue	Aldrin µg/kg-Wet	alpha-Hexachlorocyclohexane µg/kg-Wet	Cadmium mg/kg-Wet	Dibutyl phthalate µg/kg-Wet	Dieldrin µg/kg-Wet	Dioxin-like PCB congener TCDD toxicity equivalent pg/g-Wet	Endrin ketone µg/kg-Wet	Mercury mg/kg-Wet	Silver mg/kg-Wet	Total of 2,4' and 4,4'-DDD µg/kg-Wet	Total of 2,4' and 4,4'-DDE µg/kg-Wet	Total of 2,4' and 4,4'-DDT µg/kg-Wet	Total PCB Aroclors µg/kg-Wet	Total PCB Congeners µg/kg-Wet
LW2-BTFC028	LW2-BTFC028	clam	body without shell	5.07	0.0128 J	0.0925	16 U	2.62	5.52 T	0.00464 J	0.011 J	0.053	29.7 T	66.8 T	1.63 T	299 JT	421
LW2-GBT028	LW2-BTLC028	lab clam	body without shell	2.14	0.00798 J	0.0582	16 U	4.14	1.82 JT	0.0108 J	0.0116	0.0155	10.6 T	7.11 T	0.146 JT	128 JT	189
LW2-GBT028	LW2-BTLW028	Lumbriculus variegatus	whole body	37	0.0149 J	0.0488	320 U	26.7	33.9 JT	0.0171 J	0.01 J	0.0133	131 T	153 T	0.0873 JT	3230 JT	4310

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Table I-19d. iAOPC 19 Tissue Samples Data.

Location	Sample	Upper cm	Lower cm	Cadmium mg/l	Mercury mg/l	Silver mg/l
WR-WSI98SD143	WR-WSI98SD1430PW	0	10	0.002 U	0.0001 U	0.0002 U
WR-WSI98SD146	WR-WSI98SD14600CCPW	0	10	0.002 U	0.0001 U	0.0002 U

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Table I-20. iAOPC 20 Sediment Samples Data.

Location	Sample	Upper cm	Lower cm	Dioxin-like PCB congener TCDD toxicity equivalent pg/g	Total PCB Aroclors µg/kg	Total PCB Congeners µg/kg
LW2-G446	LW2-G446	0	28	0.916 JT	183 JT	108
WR-WSI98SD150	WR-WSI98SD1500	0	10		156 T	
WR-WSI98SD150	WR-WSI98SD1500000A	0	90		48 T	

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Table I-21a. iAOPC 21 Sediment Samples Data.

Location	Sample	Upper cm	Lower cm	Dioxin-like PCB congener TCDD toxicity equivalent mg/kg	Dibutyl phthalate µg/kg	Diesel Range Hydrocarbons mg/kg	Dioxin-like PCB congener TCDD toxicity equivalent pg/g	Total PCB Aroclors µg/kg	Total PCB Congeners µg/kg	Zinc mg/kg
LW2-C364	LW2-C364-B	30	75	2.98 J	26 U			376 JT		98.7
LW2-C364	LW2-C364-C	75	183	3.43 J	4.3 U			2.93 UT		89.2
LW2-C364	LW2-C364-D	183	225		7.7 U					
LW2-C372	LW2-C372-B	30	94	3.74	9.3 J	440 J		177 JT		127
LW2-C372	LW2-C372-C	94	141	2.62	7.4 U	150 J		37.1 T		81
LW2-C372	LW2-C372-E	263	363		23 U			2.8 UT		
LW2-C384	LW2-C384-B	30	128	44.5 J	230	880 J		3840 JT		1930
LW2-C384	LW2-C384-C	128	207	2.3 J	3.5 U	21 J		60.1 JT		72.9
LW2-C384	LW2-C384-E	274	334					2.2 UT		
LW2-C384	LW2-C384-F	334	357	2.62						61.2
LW2-C392	LW2-C392-B	30	76	6.7	39	210 J		843 JT		383
LW2-C392	LW2-C392-C	76	199	1.71 T	5.5 J	94.5 JT		55.5 JT		60.4 T
LW2-C392	LW2-C392-D	199	337					19.8 JT		
LW2-G364	LW2-G364	0	27	3.5 J	11 J		1.55 JT	148 JT	97.2	136
LW2-G367	LW2-G367	0	26	6.7	41 UJ	140 J		981 T		262
LW2-G372	LW2-G372-1	0	29	4.89 T	13 JT	99.5 JT	0.845 T	179 JT	23.6	168 T
LW2-G372-2	LW2-G372-2	0	30	4.78	15 J	110 J		95 T		174
LW2-G376	LW2-G376	0	29	7.27	29	180 J		216 T		299
LW2-G384	LW2-G384-1	0	27	6.22 T	21.5 T	160 JT		44 JT		241 T
LW2-G384-2	LW2-G384-2	0	29	5.36	26	150 J		91 JT		260
LW2-G390	LW2-G390	0	28	16.5	120	406 JT	23.1 T	1430 T	725	731
LW2-G392	LW2-G392	0	30	5.99 J	66 J	150 J	1.35 JT	74.5 JT	40.5 T	218
LW2-GBT022	LW2-GBT022	0	10	5.25	9.3 U	180 J	7.2 T	106 T	218	219
LW2-GBT023	LW2-GBT023	0	10	6.76	22	130 J	2.92 JT	104 JT	81.7 T	220
LWG0107B023SDS015C00	LWG0107B023SDS015C00	0	15	0.7	27			25 UT		97
LWG0108R003SDS015C00	LWG0108R003SDS015C00	0	15	2.4	27 U		3.52 T	37 T	92.6 JT	149
PSYSEA98PSY15	PSYSEA98PSY15PSY15S	0	10	8	37			116 T		271
PSYSEA98PSY18	PSYSEA98PSY18PSY18S	0	10	7	68			253 T		375
PSYSEA98PSY18C	PSYSEA98PSY18CPSY18A	0	121	4	16			635 T		159
PSYSEA98PSY18C	PSYSEA98PSY18CPSY18B	121	243	3	24			110 UT		121
PSYSEA98PSY18C	PSYSEA98PSY18CPSY18C	243	344	2	10 U			10 UT		49
PSYSEA98PSY19	PSYSEA98PSY19PSY19S	0	10	7	34			82 T		212
PSYSEA98PSY20	PSYSEA98PSY20PSY20S	0	10	13	22			257 T		359
PSYSEA98PSY20C	PSYSEA98PSY20CPSY20A	0	121	6	20			2290 T		347 G
PSYSEA98PSY20C	PSYSEA98PSY20CPSY20B	121	243	2 U	10 U			10 UT		52 G
PSYSEA98PSY20C	PSYSEA98PSY20CPSY20C	243	365	2	10 U			10 UT		50 G
PSYSEA98PSY20C	PSYSEA98PSY20CPSY20D	365	487	2	10 U			10 UT		47 G
PSYSEA98PSY21	PSYSEA98PSY21PSY21S	0	10	6	41			69 T		190
PSYSEA98PSY22	PSYSEA98PSY22PSY22S	0	10	8	24			108 T		203
PSYSEA98PSY23	PSYSEA98PSY23PSY23S	0	10	6	23			43 T		173

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Table I-21a. iAOPC 21 Sediment Samples Data.

Location	Sample	Upper cm	Lower cm	Dioxin-like PCB congener TCDD toxicity equivalent mg/kg	Dibutyl phthalate µg/kg	Diesel Range Hydrocarbons mg/kg	Dioxin-like PCB congener TCDD toxicity equivalent pg/g	Total PCB Aroclors µg/kg	Total PCB Congeners µg/kg	Zinc mg/kg
PSYSEA98PSY23C	PSYSEA98PSY23CPSY23A	0	121	6	39			1640 T		257 G
PSYSEA98PSY23C	PSYSEA98PSY23CPSY23B	121	243	2 U	10 U			10 UT		44 G
PSYSEA98PSY23C	PSYSEA98PSY23CPSY23C	243	365	3	10 U			10 UT		44 G
PSYSEA98PSY23C	PSYSEA98PSY23CPSY23D	365	490	2 U	10 U			10 UT		35 G
PSYSEA98PSY26	PSYSEA98PSY26PSY26S	0	10	6	90			379 T		314
PSYSEA98PSY27	PSYSEA98PSY27PSY27S	0	10	17	350			284 T		593
PSYSEA98PSY27C	PSYSEA98PSY27CPSY27A	0	121	2	10 U			10 UT		42 G
PSYSEA98PSY27C	PSYSEA98PSY27CPSY27B	121	243	3	10 U			10 UT		43 G
PSYSEA98PSY27C	PSYSEA98PSY27CPSY27C	243	338	2	10 U			10 UT		45
PSYSEA98PSY27C	PSYSEA98PSY27CY27A01	0	30	3						68 G
PSYSEA98PSY27C	PSYSEA98PSY27CY27A02	30	60	2						41 G
PSYSEA98PSY27C	PSYSEA98PSY27CY27A03	60	91	2						38 G
PSYSEA98PSY27C	PSYSEA98PSY27CY27A04	91	121	2						52
PSYSEA98PSY27C	PSYSEA98PSY27CY27B05	121	152	3						49
PSYSEA98PSY27C	PSYSEA98PSY27CY27B06	152	182	3						47
PSYSEA98PSY27C	PSYSEA98PSY27CY27B07	182	213	3						51
PSYSEA98PSY27C	PSYSEA98PSY27CY27B08	213	243	3						52
PSYSEA98PSY27C	PSYSEA98PSY27CY27C09	243	274	2 U						35
PSYSEA98PSY27C	PSYSEA98PSY27CY27C10	274	304	2						43
PSYSEA98PSY27C	PSYSEA98PSY27CY27C11	304	338	3						53
PSYSEA98PSY29	PSYSEA98PSY29PSY29S	0	10	8	103			300 T		296
PSYSEA98PSY30	PSYSEA98PSY30PSY30S	0	10	5	67			16 T		238 E
PSYSEA98PSY30C	PSYSEA98PSY30CPSY30A	0	121	6	135			22 T		327
PSYSEA98PSY30C	PSYSEA98PSY30CPSY30B	121	243	5	11			10 UT		91
PSYSEA98PSY30C	PSYSEA98PSY30CY30A01	0	30	6						183
PSYSEA98PSY30C	PSYSEA98PSY30CY30A02	30	60	6						222
PSYSEA98PSY30C	PSYSEA98PSY30CY30A03	60	91	5						251
PSYSEA98PSY30C	PSYSEA98PSY30CY30A04	91	121	7						1340
PSYSEA98PSY30C	PSYSEA98PSY30CY30B05	121	152	21						872
PSYSEA98PSY30C	PSYSEA98PSY30CY30B06	152	182	4						85
PSYSEA98PSY30C	PSYSEA98PSY30CY30B07	182	213	2 U						35
PSYSEA98PSY30C	PSYSEA98PSY30CY30B08	213	243	2 U						26
WR-WSI98SD128	WR-WSI98SD1280	0	10	8	26			380 T		361
WR-WSI98SD129	WR-WSI98SD1290	0	10	6 U	51					279
WR-WSI98SD133	WR-WSI98SD1330	0	10	16	37			580 T		539
WR-WSI98SD133	WR-WSI98SD1330000A	0	90	14	88			2379 T		598

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Table I-21b. iAOPC 21 Tissue Samples Data.

Location	Sample	Species	Tissue	Arsenic mg/kg-Wet	Dibutyl phthalate µg/kg-Wet	Dioxin-like PCB congener TCDD toxicity equivalent pg/g-Wet	Total PCB Aroclors µg/kg-Wet	Total PCB Congeners µg/kg-Wet	Zinc mg/kg-Wet
LW2-BTFC022	LW2-BTFC022	clam	body without shell	0.83	1300	3 T	166 JT	240	42.4
LW2-BTFC023	LW2-BTFC023	clam	body without shell	0.694					54
LW2-GBT022	LW2-BTLC022	lab clam	body without shell	0.406 J	16 U	1.63 JT	63.7 JT	74.4	16.2
LW2-GBT022	LW2-BTLW022	Lumbriculus variegatus	whole body	0.985	280 U	5.91 JT	312 JT	449	25.1
LW2-GBT023	LW2-BTLC023	lab clam	body without shell	0.548	190 U	0.358 JT	26.8 JT	34.1	15.2
LW2-GBT023	LW2-BTLW023	Lumbriculus variegatus	whole body	0.659	16 U	7.44 JT	394 JT	475	29.4
LW2-MIT007	LW2-MIT007	multiplate invertebrates	whole body			0.425 JT	29.4 JT	33.1	
LWG0108R003SP00	LWG0108R003TSSPWBC00	sculpin	whole body	0.15	330 U	6.06 T	480 JT	352 JT	14.5

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Table I-21c. iAOPC 21 Transition Zone Water Samples Data.

Location	Sample	Upper cm	Lower cm	Arsenic mg/l	Zinc mg/l
WR-WSI98SD128	WR-WSI98SD1280PW	0	10	0.007	0.179
WR-WSI98SD133	WR-WSI98SD1330PW	0	10	0.004	0.073

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Table I-22a. iAOPC 22 Sediment Samples Data.

Location	Sample	Upper cm	Lower cm	Dioxin-like PCB congener TCDD toxicity equivalent pg/g	Total PCB Aroclors µg/kg	Total PCB Congeners µg/kg
LW2-C379	LW2-C379-B	30	152		908 JT	
LW2-C379	LW2-C379-C	152	196		425 JT	
LW2-C379	LW2-C379-D	196	318		2.68 UT	
LW2-C380	LW2-C380-B	30	153		2.96 UT	
LW2-C380	LW2-C380-C	153	275		2.93 UT	
LW2-C382	LW2-C382-B	30	153	7.47 T	1340 JT	291
LW2-C382	LW2-C382-C	153	284		2.72 UT	
LW2-C383	LW2-C383-B	30	63		204 T	
LW2-C383	LW2-C383-C	63	160		2.81 UT	
LW2-C388	LW2-C388-B	30	154		2.91 UT	
LW2-C388	LW2-C388-C	154	276		3 UT	
LW2-C393	LW2-C393-B	30	152		1220 JT	
LW2-C393	LW2-C393-C	152	282		2.28 UT	
LW2-C396	LW2-C396-B	30	153		2.75 UT	
LW2-C396	LW2-C396-C	153	277		3.09 UT	
LW2-C397	LW2-C397-B	30	153		568 JT	
LW2-C397	LW2-C397-C	153	271	15.1 T	595 JT	571
LW2-C397	LW2-C397-D	271	341		384 T	
LW2-C402	LW2-C402-B	30	65		417 JT	
LW2-C402	LW2-C402-C	65	183		6.24 JT	
LW2-G379	LW2-G379	0	28		380 T	
LW2-G380	LW2-G380	0	22	4.19 T	175 T	130
LW2-G382	LW2-G382	0	29	15.7 T	446 JT	466
LW2-G383	LW2-G383	0	20		35.6 JT	
LW2-G385	LW2-G385	0	29		983 T	
LW2-G388	LW2-G388	0	26		115 JT	
LW2-G393	LW2-G393	0	26		2310 T	
LW2-G396	LW2-G396	0	23		2.82 UT	
LW2-G397	LW2-G397	0	29		330 T	
LW2-G402	LW2-G402	0	30	12 T	679 JT	656
LW2-GBT026	LW2-GBT026	0	10	11.8 T	210 T	596
LWG0108R040SDS015C00	LWG0108R040SDS015C00	0	15		360 T	
PSYD&M97DM01	PSYD&M97DM01DM01	0	10		168 T	
PSYD&M97DM24	PSYD&M97DM24DM24C1	121	152		40 UT	
PSYD&M97DM24	PSYD&M97DM24DM24C2	167	198		40 UT	
PSYSEA98PSY08	PSYSEA98PSY08PSY08S	0	10		144 T	

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Table I-22a. iAOPC 22 Sediment Samples Data.

Location	Sample	Upper cm	Lower cm	Dioxin-like PCB congener TCDD toxicity equivalent pg/g	Total PCB Aroclors µg/kg	Total PCB Congeners µg/kg
PSYSEA98PSY08	PSYSEA98PSY08PSY52S	0	10		231 T	
PSYSEA98PSY08	PSYSEA98PSY08PSY53S	0	10		101 T	
PSYSEA98PSY11	PSYSEA98PSY11PSY11S	0	10		354 T	
PSYSEA98PSY11C	PSYSEA98PSY11CPSY11A	0	121		80 T	
PSYSEA98PSY11C	PSYSEA98PSY11CPSY11B	121	243		10 UT	
PSYSEA98PSY11C	PSYSEA98PSY11CPSY11C	243	365		10 UT	
PSYSEA98PSY11C	PSYSEA98PSY11CPSY11D	365	423		10 UT	
PSYSEA98PSY12	PSYSEA98PSY12PSY12S	0	10		57 T	
PSYSEA98PSY14	PSYSEA98PSY14PSY14S	0	10		2500 T	
PSYSEA98PSY16	PSYSEA98PSY16PSY16S	0	10		108 T	
PSYSEA98PSY16C	PSYSEA98PSY16CPSY16A	0	121		799 T	
PSYSEA98PSY16C	PSYSEA98PSY16CPSY16B	121	243		108 T	
PSYSEA98PSY16C	PSYSEA98PSY16CPSY16C	243	323		10 UT	
PSYSEA98PSY17	PSYSEA98PSY17PSY17S	0	10		394 T	
PSYSEA98PSY28	PSYSEA98PSY28PSY28S	0	10		62 T	
WLCOFH02M101	WLCOFH02M101M101	0	15		271 T	
WLCOFH02M103	WLCOFH02M103M103	0	15		121 T	
WLCOFH02M104	WLCOFH02M104M104	0	15		6.8 UT	
WLCOFH02M105	WLCOFH02M105M105	0	15		338.2 T	
WLCOFH02M106	WLCOFH02M106M106	0	15		34.5 T	
WLCOFH02M107	WLCOFH02M107M107	0	15		6.18 UT	
WLCOFH02M108	WLCOFH02M108M108	0	15		13.5 T	
WLCOFH02M109	WLCOFH02M109M109	0	15		191.1 T	
WLCOFH02M110	WLCOFH02M110M110	0	15		8.79 T	

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Table I-22b. iAOPC 22 Surface Water Samples Data.

Location	Sampling Method	Sample	Dioxin-like PCB congener TCDD toxicity equivalent pg/l	Total PCB Aroclors pg/l	Total PCB Congeners pg/l
LW2-W018	XAD column	LW2-W018 C	0.00197 JT	111 JT	162
LW2-W018	XAD column	LW2-W2018 C	0.00385 JT	335 JT	567
LW2-W018	XAD column	LW2-W3018 C	0.00165 T	288.9 JT	487
LW2-W018	XAD filter	LW2-W018 F	0.00547 T	251 JT	277
LW2-W018	XAD filter	LW2-W2018 F	0.0176 T	872 JT	1120
LW2-W018	XAD filter	LW2-W3018 F	0.00765 T	314.64 JT	341

Location	Sampling Method	Sample	Total PCB Aroclors µg/l
LW2-W018	bottle	LW2-W018	0.0025 UT

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Table I-22c. iAOPC 22 Tissue Samples Data.

Location	Sample	Species	Tissue	Dioxin-like PCB congener TCDD toxicity equivalent pg/g-Wet	Total PCB Aroclors µg/kg-Wet	Total PCB Congeners µg/kg-Wet
LW2-BTFC026	LW2-BTFC026	clam	body without shell	3.48 T	246 JT	386
LW2-GBT026	LW2-BTLC026	lab clam	body without shell	0.62 T	23.9 JT	32.3
LW2-GBT026	LW2-BTLW026	Lumbriculus variegatus	whole body	6.51 JT	413 JT	730
LWG0108R010Zone	LWG0108R010TSLSWBC00	largescale sucker	whole body		320 T	
LWG0108R010Zone	LWG0108R010TSNPWBC00	northern pikeminnow	whole body		670 T	
LWG0108R010Zone	LWG0108R010TSPMWBC00	peamouth	whole body		138 T	
LWG0108R010Zone	LWG0108R010TSSBWBC10	smallmouth bass	whole body	33.9 T	4500 JT	4530 JT
LWG0108R010Zone	LWG0108R010TSSBWBC20	smallmouth bass	whole body	13.7 T	3300 JT	1070 JT
LWG0108R010Zone	LWG0108R010TSSBWBC30	smallmouth bass	whole body	26.5 T	1000 T	3480 JT

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Table I-23a. iAOPC 23 Sediment Samples Data.

Location	Sample	Upper cm	Lower cm	Dioxin-like PCB congener TCDD toxicity equivalent pg/g	Total PCB Aroclors µg/kg	Total PCB Congeners µg/kg
LW2-B020	LW2-B020	0	15	0.339 T	29 T	0.629 T
LW2-C405	LW2-C405-B	30	134		479 JT	
LW2-C405	LW2-C405-C	134	171		70.1 JT	
LW2-C405	LW2-C405-E	292	328		1.7 UT	
LW2-C415	LW2-C415-B	23	175		22.2 JT	
LW2-C415	LW2-C415-C	175	262		2.34 UT	
LW2-C415	LW2-C415-D	262	337		2.42 UT	
LW2-C417	LW2-C417-B	30	152		199 JT	
LW2-C417	LW2-C417-D	298	353		167 JT	
LW2-C421	LW2-C421-B	30	61		1230 JT	
LW2-C421	LW2-C421-C	61	123		313 JT	
LW2-C421	LW2-C421-E	240	318		2.3 UT	
LW2-C425	LW2-C425-B1	30	165		64.6 JT	
LW2-C425	LW2-C425-C1	165	217		108 JT	
LW2-C425	LW2-C425-E1	257	295		172 JT	
LW2-C425	LW2-C425-F1	295	324		2.8 UT	
LW2-C425-2	LW2-C425-B2	30	102		88.5 JT	
LW2-C425-2	LW2-C425-C2	102	253		37.4 JT	
LW2-C425-2	LW2-C425-D2	253	300		109 JT	
LW2-C426	LW2-C426-B	30	132		196 JT	
LW2-C426	LW2-C426-C	135	220		2.45 UT	
LW2-C430	LW2-C430-A	0	30		133 T	
LW2-C430	LW2-C430-B	30	155		141 JT	
LW2-C430	LW2-C430-C	155	278		278 T	
LW2-C430	LW2-C430-E	400	520		547 JT	
LW2-G405	LW2-G405	0	25		14.7 T	
LW2-G408	LW2-G408	0	24		124 JT	
LW2-G411	LW2-G411	0	30		16.1 JT	
LW2-G415	LW2-G415	0	25		880 JT	
LW2-G416	LW2-G416	0	29	2.83 T	333 JT	124
LW2-G417	LW2-G417	0	26	3.37 JT	107 T	90.1
LW2-G421	LW2-G421	0	30		555 JT	
LW2-G425	LW2-G425	0	24		14.9 JT	
LW2-G426	LW2-G426	0	27	10.5 T	293 JT	256 T
LW2-G430	LW2-G430	0	25		2.39 JT	
LW2-GBT029	LW2-GBT029	0	10	1.83 JT	53 JT	52.5 T
LW2-NA4B	NA-4B-0024	0	24		159 JT	
LW2-NA4B	NA-4B-2450	24	50		178 JT	

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Table I-23a. iAOPC 23 Sediment Samples Data.

Location	Sample	Upper cm	Lower cm	Dioxin-like PCB congener TCDD toxicity equivalent pg/g	Total PCB Aroclors µg/kg	Total PCB Congeners µg/kg
LW2-NA4B	NA-4B-5094	50	94		124 JT	
LWG0108B032SDS015C00	LWG0108B032SDS015C00	0	15		16.8 JT	
LWG0109B028SDS015C00	LWG0109B028SDS015C00	0	15		3.7 JT	
LWG0109R001SDS015C10	LWG0109R001SDS015C10	0	15		31 UT	
LWG0109R001SDS015C20	LWG0109R001SDS015C20	0	15		21 T	
LWG0109R001SDS015C30	LWG0109R001SDS015C31	0	15		145 JT	
PSYD&M97DM16	PSYD&M97DM16DM16	0	10		70.1 T	
PSYSEA98PSY01	PSYSEA98PSY01PSY01S	0	10		112 T	
PSYSEA98PSY01C	PSYSEA98PSY01CPSY01A	0	121		151 T	
PSYSEA98PSY01C	PSYSEA98PSY01CPSY01B	121	219		403 T	
PSYSEA98PSY03	PSYSEA98PSY03PSY03S	0	10		10 UT	
PSYSEA98PSY04	PSYSEA98PSY04PSY04S	0	10		116 T	
PSYSEA98PSY05	PSYSEA98PSY05PSY05S	0	10		53 T	
PSYSEA98PSY06	PSYSEA98PSY06PSY06S	0	10		10 UT	
PSYSEA98PSY07	PSYSEA98PSY07PSY07S	0	10		116 T	
PSYSEA98PSY07C	PSYSEA98PSY07CPSY07A	0	121		306 T	
PSYSEA98PSY07C	PSYSEA98PSY07CPSY07B	121	222		351 T	
PSYSEA98PSY10	PSYSEA98PSY10PSY10S	0	10		129 T	
WLCOFJ02M0201	WLCOFJ02M0201M2010	0	5			18.1 JT
WLCOFJ02M0202	WLCOFJ02M0202M2020	0	10			10.2 JT
WLCOFJ02M0203	WLCOFJ02M0203M2030	0	15			1.62 JT
WLCOFJ02M02031	WLCOFJ02M02031M2031	0	15			4.63 JT
WLCOFJ02M0204	WLCOFJ02M0204M2040	0	5			1.24 JT
WLCOFJ02M0205	WLCOFJ02M0205M2050	0	8			0.39 UT
WLCOFJ02M0302	WLCOFJ02M0302M3020	0	6			0.31 UT
WLCOFJ02M0303	WLCOFJ02M0303M3030	0	12			18.9 JT
WLCOFJ02M0304	WLCOFJ02M0304M3040	0	15			18 JT
WLCOFJ02M0305	WLCOFJ02M0305M3050	0	14.5			21.9 T
WLCOFJ02S0201	WLCOFJ02S0201S2010	0	15			1.15 JT
WLCOFJ02S0202	WLCOFJ02S0202S2020	0	15			0.31 UT
WLCOFJ02S0203	WLCOFJ02S0203S2030	0	15			4.24 JT
WLCOFJ02S0204	WLCOFJ02S0204S2040	0	15			0.73 JT
WLCOFJ02S0205	WLCOFJ02S0205S2050	0	15			0.31 UT
WR-WSI98SD141	WR-WSI98SD1410000A	0	90		140 T	
WR-WSI98SD141	WR-WSI98SD1410000CC	0	10		31 T	

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Table I-23b. iAOPC 23 Surface Water Samples Data.

Location	Sampling Method	Sample	Total PCB Aroclors µg/l
LW2-W020	bottle	LW2-W020	0.0025 UT
LW2-W020	bottle	LW2-W2020	0.0025 UT
LW2-W020	bottle	LW2-W3020	0.0025 UT
LW2-W021	bottle	LW2-W021	0.0025 UT
LW2-W021	bottle	LW2-W2021	0.0026 UT
LW2-W021	bottle	LW2-W3021	0.0025 UT

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Table I-23c. iAOPC 23 Tissue Samples Data.

Location	Sample	Species	Tissue	Dioxin-like PCB congener TCDD toxicity equivalent pg/g-Wet	Total PCB Aroclors µg/kg-Wet	Total PCB Congeners µg/kg-Wet
LW2-BTFC029	LW2-BTFC029	clam	body without shell	4.33 T	189 JT	281
LW2-GBT029	LW2-BTLC029	lab clam	body without shell	0.644 T	20.8 JT	25
LW2-GBT029	LW2-BTLW029	Lumbriculus variegatus	whole body	3.74 JT	102 JT	168
LWG0109R001CR10	LWG0109R001TSCRWBC10	crayfish	whole body		46 T	
LWG0109R001CR20	LWG0109R001TSCRWBC20	crayfish	whole body		49 T	
LWG0109R001SP00	LWG0109R001TSSPWBC00	sculpin	whole body		510 JT	

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Table I-24a. iAOPC 24 Sediment Samples Data.

Location	Sample	Upper cm	Lower cm	Dioxin-like PCB congener TCDD toxicity equivalent pg/g	Total PCB Aroclors µg/kg	Total PCB Congeners µg/kg
LW2-B026	LW2-B026	0	15	4.31 T	322 T	7.01 T
LW2-C492	LW2-C492-B	30	154		33 T	
LW2-C492	LW2-C492-C	154	274		1.4 UT	
LW2-C494	LW2-C494-A	0	30		233 JT	
LW2-C494	LW2-C494-B	30	118		489 JT	
LW2-C494	LW2-C494-C	118	221	16.3 T	971 JT	953
LW2-C494	LW2-C494-D	221	338		627 JT	
LW2-C494	LW2-C494-E	338	382		2.84 UJT	
LW2-G492	LW2-G492-1	0	27	2.61 T	173 T	188
LW2-G492-2	LW2-G492-2	0	28		110 T	
LW2-G494	LW2-G494	0	26	8.09 JT	600 JT	524
LW2-G497	LW2-G497	0	27		271 T	
LW2-GBT032	LW2-GBT032	0	10	4.4 T	304 JT	366
LWG0109R002SDS015C00	LWG0109R002SDS015C00	0	15	3.87 T	98 T	192 JT
PPTLDT24T2U2	PPTLDT24T2U2B203C1	0	91		26 T	
WLCT0F01T20101	WLCT0F01T20101T2011A	0	121		142 T	
WLCT0F01T20101	WLCT0F01T20101T2011B	121	152		770 T	
WLCT0F01T20101	WLCT0F01T20101T2011C	152	182		74 T	

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Table I-24b. iAOPC 24 Surface Water Samples Data.

Location	Sampling Method	Sample	Total PCB Aroclors µg/l
LW2-W022	bottle	LW2-W022	0.0025 UT
LW2-W022	bottle	LW2-W2022	0.0025 UT
LW2-W022	bottle	LW2-W3022	0.00467 JT

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Table I-24c. iAOPC 24 Tissue Samples Data.

Location	Sample	Species	Tissue	Dioxin-like PCB congener TCDD toxicity equivalent pg/g-Wet	Total PCB Aroclors µg/kg-Wet	Total PCB Congeners µg/kg-Wet
LW2-BTFC032	LW2-BTFC032	clam	body without shell	4.29 T	243 JT	459
LW2-GBT032	LW2-BTLC032	lab clam	body without shell	0.753 JT	43.2 JT	60
LW2-GBT032	LW2-BTLW032	Lumbriculus variegatus	whole body	9.69 JT	930 JT	1450
LW2-MIT009	LW2-MIT009	multiplate invertebrates	whole body	0.776 JT	73.8 JT	78.7
LW2-MIT810	LW2-MIT008/010	multiplate invertebrates	whole body	0.524 JT	27.6 JT	37.1
LW2-T03	LW2-T03 SC	chinook	stomach contents	1.77 T	163 JT	162
LW2-T03	LW2-T03-REP1	chinook	whole body	3.2 JT	253 JT	246
LW2-T03	LW2-T03-REP2	chinook	whole body	1.85 JT	141 JT	136
LW2-T03	LW2-T03-REP3	chinook	whole body	3.37 JT	199 JT	198
LWG0109R002CR00	LWG0109R002TSCRWBC00	crayfish	whole body	1.41 T	110 T	82.6 JT
LWG0109R002SP00	LWG0109R002TSSPWBC00	sculpin	whole body	13.9 T	670 T	818 JT

BZTO104(e)031436

Table I-25. iAOPC 25 Sediment Samples Data.

Location	Sample	Upper cm	Lower cm	Dioxin-like PCB congener TCDD toxicity equivalent µg/kg
LW2-G487	LW2-G487	0	21	46.1 JT
WLCDRD05VC045	WLCDRD05VC04545	0	207	60 T
WRD&M98DMF	WRD&M98DMFDMF	0	10	109 T

BZTO104(e)031437

Table I-26. iAOPC 26 Sediment Samples Data.

Location	Sample	Upper cm	Lower cm	Dioxin-like PCB congener TCDD toxicity equivalent pg/g	Total PCB Aroclors µg/kg	Total PCB Congeners µg/kg
LW2-G503	LW2-G503	0	23	4.02 T	898 T	338
WLCDRD05PG106	WLCDRD05PG106106	0	30		146 T	
WLCDRD05VC106	WLCDRD05VC106106	0	229		880 T	
WLCT1F00T1S01	WLCT1F00T1S01T1S01	0	10		41 T	

BZTO104(e)031438

Table I-27. iAOPC 27 Sediment Samples Data.

Location	Sample	Upper cm	Lower cm	Dioxin-like PCB congener TCDD toxicity equivalent pg/g	Total PCB Aroclors µg/kg	Total PCB Congeners µg/kg
LW2-G516	LW2-G516	0	25	0.512 JT	28.1 T	32.2
WLCDRD05PG063	WLCDRD05PG06363	0	24		190 T	
WLCT0I98GRAB12	WLCT0I98GRAB12GRAB12	0	10		14 T	

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COMPREHENSIVE ROUND 2 SITE CHARACTERIZATION SUMMARY AND DATA GAPS ANALYSIS REPORT

APPENDIX J
UPLAND CSM SITE SUMMARY TABLE

February 21, 2007

Table J-1. Site Summary Publication Dates

ECSI	Site	Original	Revision	Addendum
1528	ARCO Bulk Terminal	July 28, 2004		August 30, 2006
134	McCall Oil	August 2, 2004		
2013	Premier Edible Oils (Schnitzer Investment)	August 4, 2004		
2352	Marine Finance Corporation (Hendren Tow Boats)	August 13, 2004		July 25, 2006
2350	Mar Com	September 3, 2004	October 10, 2005	October 12, 2006
74	McCormick & Baxter Creosoting	September 3, 2004		
2364	Foss Maritime/Brix Marine	September 7, 2004	October 10, 2005	
1096	Kinder Morgan Linnton Terminal (GATX)	September 8, 2004		
178	UPRR Albina Railyard	September 10, 2004		July 30, 2006
137	ExxonMobil Oil Terminal	September 15, 2004	October 10, 2005	October 16, 2006
1155	Gunderson	September 15, 2004	October 10, 2005	August 18, 2006
277	Triangle Park (Riedel Environmental)	September 15, 2004	October 10, 2005	
1549	Willbridge Bulk Fuel Facility	September 15, 2004		November 17, 2006
271	Cascade General (Portland Shipyard)	September 16, 2004	June 28, 2006	
272	Port of Portland - Terminal 4, Slip 3	September 16, 2004	October 13, 2006	
183	Siltronics	September 16, 2004	December 14, 2006	
398	Arkema	September 17, 2004	October 10, 2005 October 12, 2006	
84	Gasco (NW Natural, Koppers, Pacific Northern Oil)	September 17, 2004	October 10, 2005	July 14, 2006
141	Oregon Steel Mills	September 17, 2004	July 28, 2006	
155	Rhone Poulenc (SLLI)	September 17, 2004	November 1, 2006	
170	Time Oil	September 17, 2004	January 3, 2007	
2361	Babcock Land Company	March 4, 2005		
2362	Burgard Industrial Park - Boydstun Metals	March 4, 2005		
	Burgard Industrial Park - Noncontiguous	March 4, 2005		
2375	Burgard Industrial Park - Portland Container Repair	March 4, 2005		
2355	Burgard Industrial Park - Schnitzer Steel	March 4, 2005		
138	Burgard Industrial Park (NW Pipe)	March 4, 2005		
2454	Calbag Metals - Front Avenue	March 4, 2005		July 28, 2006
2424	Chase Bag	March 4, 2005		
3295	Consolidated Metco	March 4, 2005		
2363	Crawford Street Corp	March 4, 2005		
2370	Georgia Pacific - Linnton (Morse Bros.)	March 4, 2005		
2371	Jefferson-Smurfit	March 4, 2005		
2373	Linnton Plywood	March 4, 2005		
1036	Owens Corning - Linnton	March 4, 2005		
2117	Texaco/Equilon Enterprises - Pipeline	March 4, 2005		
169	Texaco/Equilon Enterprises-Bulk Terminal	March 4, 2005		
1641	USACE - Portland Moorings	March 4, 2005		
2353	Portland General Electric - Harborton	March 31, 2005		
2437	RoMar Transportation Systems	March 31, 2005		
2365	Fred Devine Diving and Salvage	April 14, 2005		
794	ACF Industries	April 26, 2005		August 30, 2006
2446	Alder Creek Lumber Company	April 26, 2005		
2426	Christenson Oil	April 26, 2005		
29	Columbia American Plating	April 26, 2005		
115	Freightliner TMP2 (Parts Plant)	April 26, 2005		
117	GS Roofing Products (Genstar)	April 26, 2005		
2372	Lakeside Industries	April 26, 2005		
135	McWhorter Technologies	April 26, 2005		
1160	Trumbull Asphalt Plant	April 26, 2005		
1338	U.S. Coast Guard - Marine Safety Station	April 26, 2005		
970	Anderson Brothers Property	May 31, 2005		
2452	City of Portland - BES Water Pollution Control Lab	May 31, 2005		
2366	Freightliner TMP	May 31, 2005		
2441	Joseph T. Ryerson & Son	May 31, 2005		
2374	Olympic Pipeline Co.	May 31, 2005		
395	Schnitzer Investment - Doane Lake (Air Liquide American Corp.)	May 31, 2005		
2980	South Rivergate Industrial Park	May 31, 2005		
1235	Sulzer Bingham Pumps	May 31, 2005		November 1, 2006

Table J-1. Site Summary Publication Dates

ECSI	Site	Original	Revision	Addendum
330	Van Water and Rogers	May 31, 2005		
1281	Chevron Asphalt Refinery	June 6, 2005		
1239	Front Avenue LP Properties	August 31, 2005		June 30, 2006
49	Gould Electronics, Inc./ NL Industries	August 31, 2005		
1189	Linnton Oil Fire Training Grounds	August 31, 2005		
2376	RK Storage and Warehousing	August 31, 2005		
2104	Santa Fe Pacific Pipeline	August 31, 2005		
2442	Schnitzer Investment - Kittridge	August 31, 2005		
2377	Shaver Transportation	August 31, 2005		
1989	ST Services/Shore Terminal	August 31, 2005		
2367	Transloader International (General Construction)	August 31, 2005		
2356	Port of Portland - Terminal 4, Slip 1	June 6, 2006		
2642	Port of Portland - Terminal 1 North	June 22, 2006		
2642	Port of Portland - Terminal 1 South	June 22, 2006		
172	Port of Portland - Terminal 4, Toyota Auto Storage	June 30, 2006		
2769	Port of Portland - Terminal 2	July 27, 2006		
4003	GE Decommisioning	August 4, 2006		
3395	BNSF (Willbridge Railyard, Kleenblast)	September 11, 2006		
2066	Willamette Cove	November 1, 2006		
2440	Goldendale Aluminum	November 29, 2006		

FIGURE 3.0-1
Human Health Conceptual Site Model

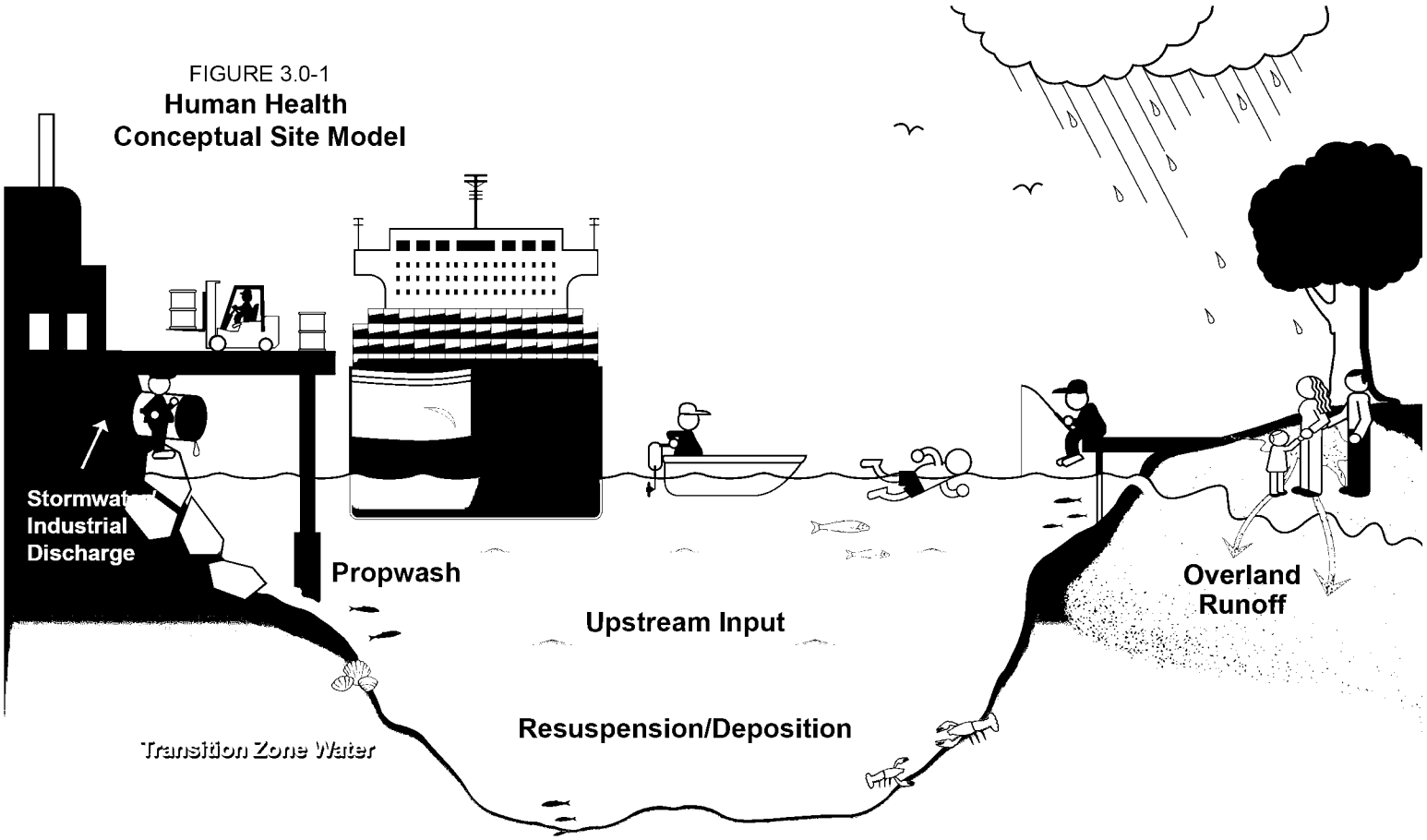
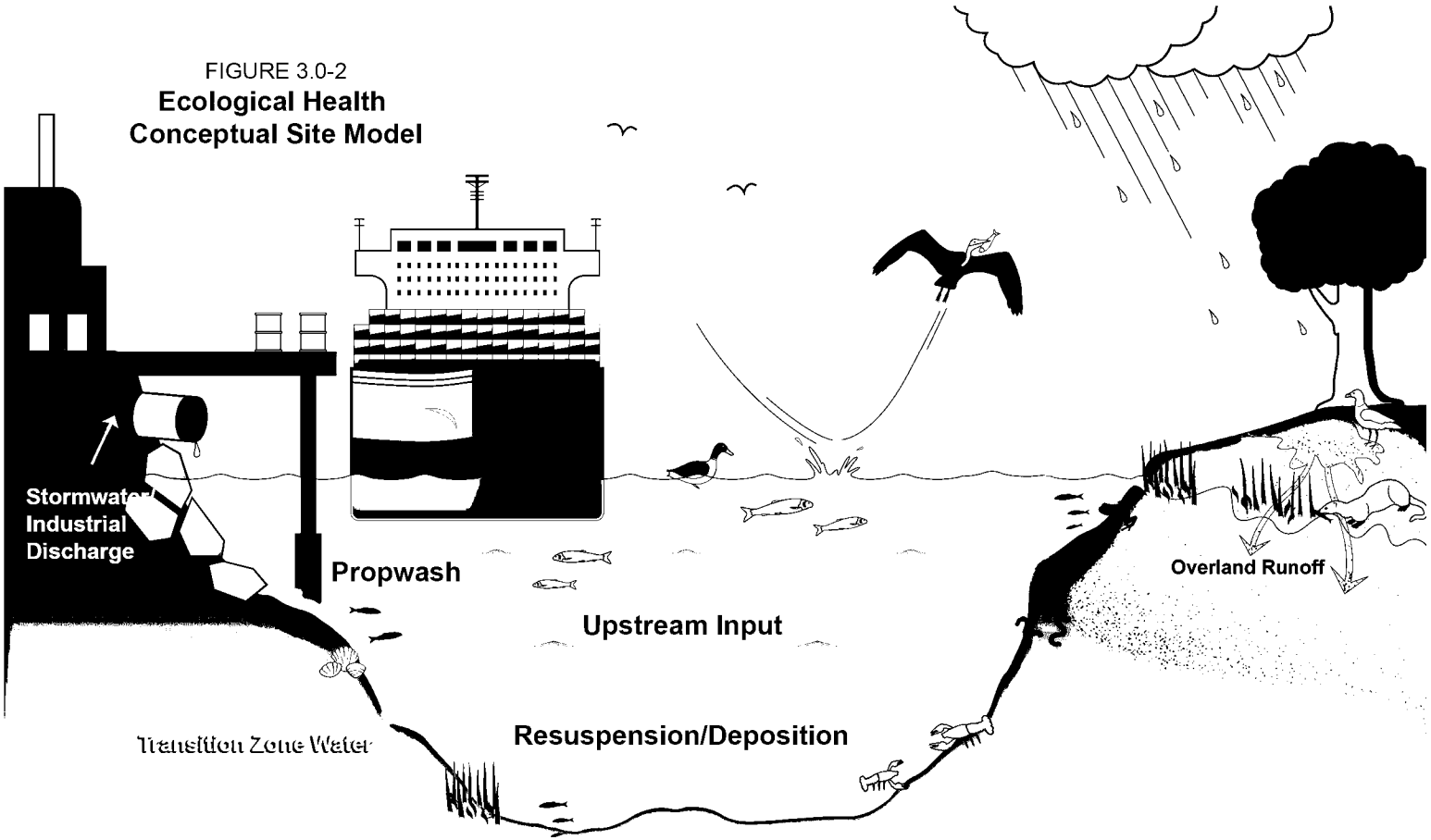
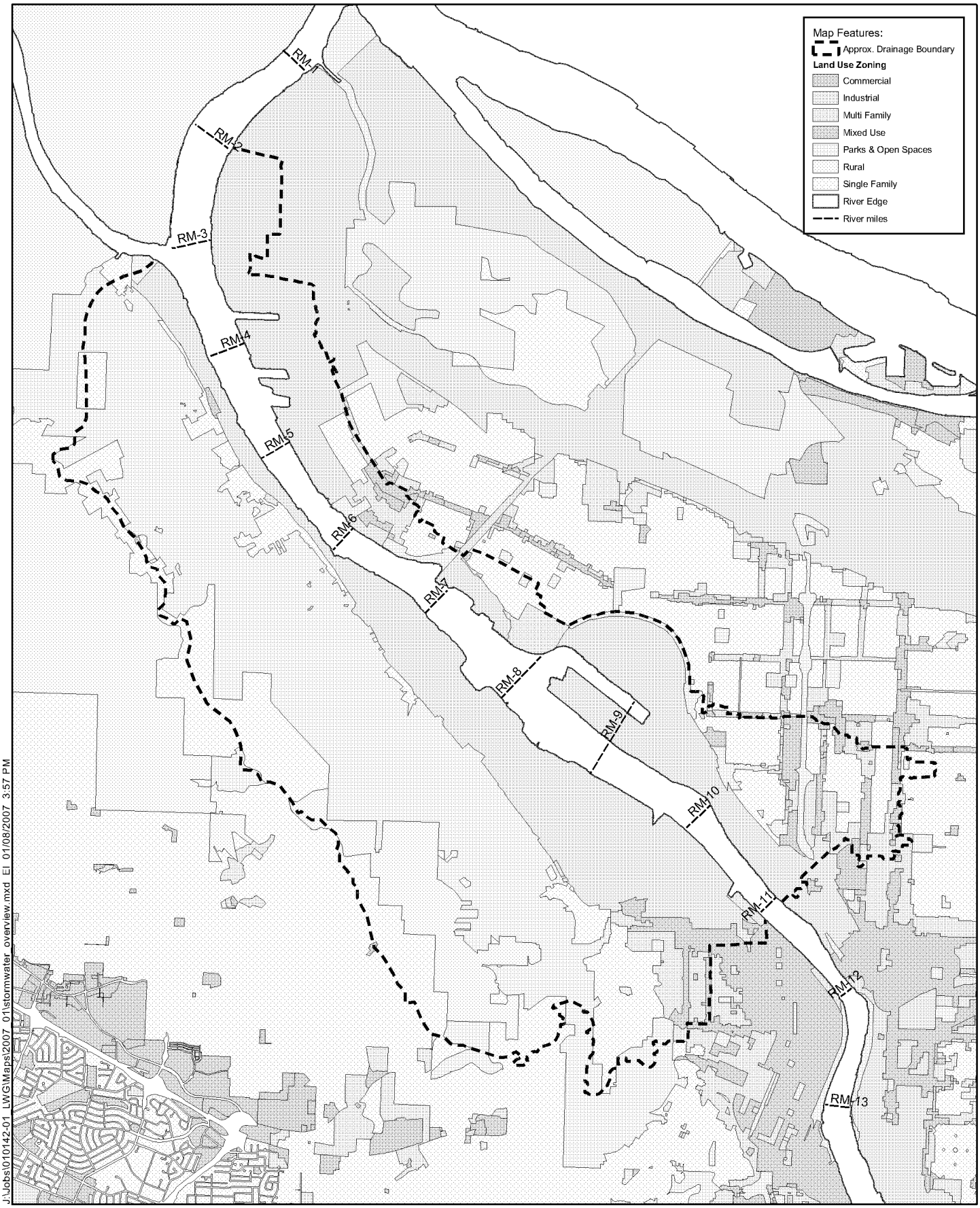


FIGURE 3.0-2
Ecological Health Conceptual Site Model





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ANCHOR ENVIRONMENTAL, L.L.C.

N

FEATURE SOURCES:
Land Use/Zoning, Streams, Water Bodies: Metro RLIS.
Channel & River miles: US Army Corps of Engineers.

0 2,000 4,000 Feet

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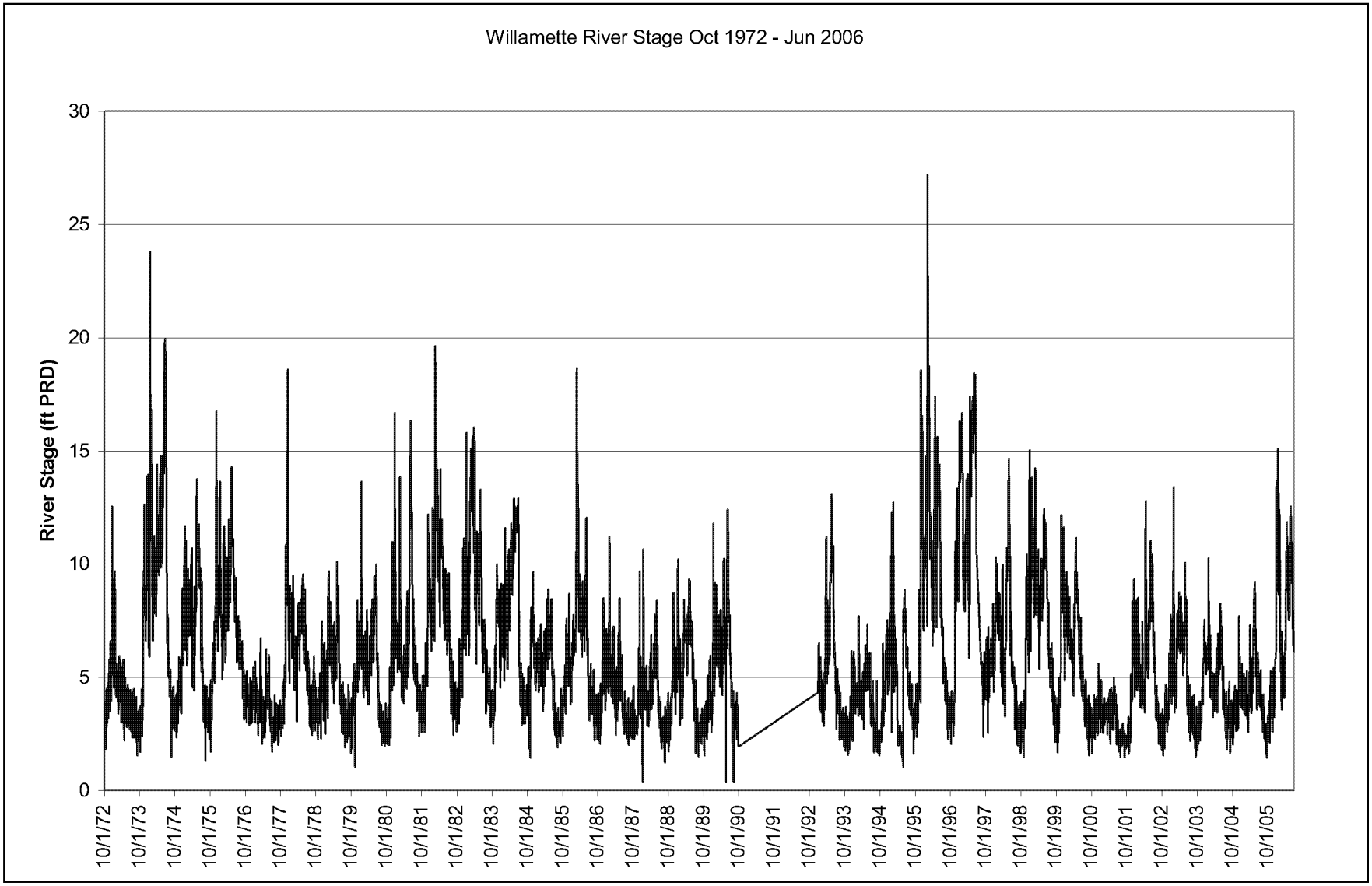
Figure 4-1.1
Portland Harbor RI/FS
Comprehensive Round 2 Site Characterization Report
LWR Stormwater Basin
River Miles 2 to 11

BZTO104(e)031445



integral LWG LOWER WILLAMETTE GROUP

Figure 4.3-1
Portland Harbor RI/FS
Comprehensive Round 2 Report
Willamette River Stage Data
October 1972- June 2006

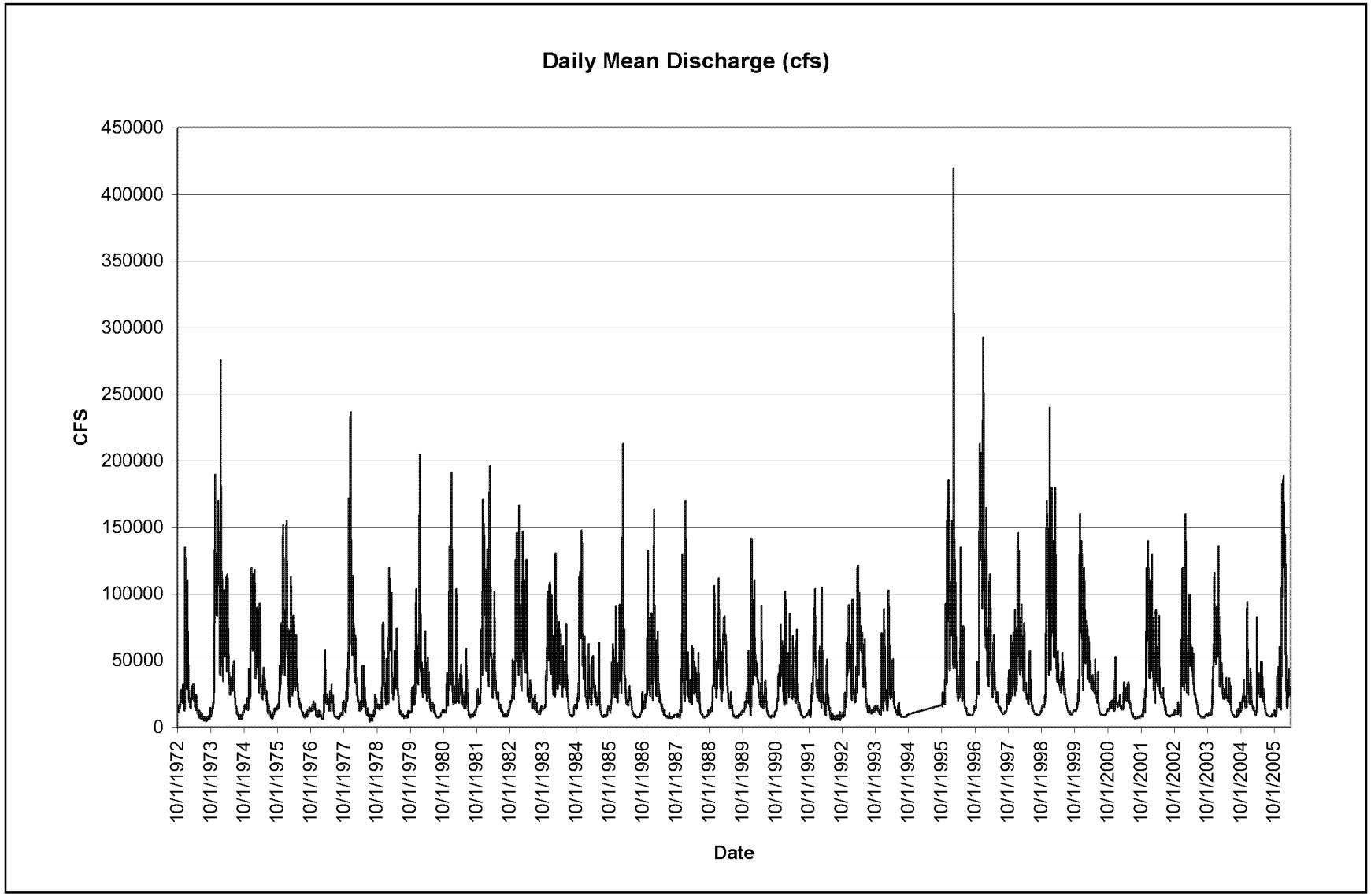


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Figure 4.3-2
Portland Harbor RI/FS
Comprehensive Round 2 Report
Daily Mean Willamette River Discharge
October 1, 1972 through June 30, 2006

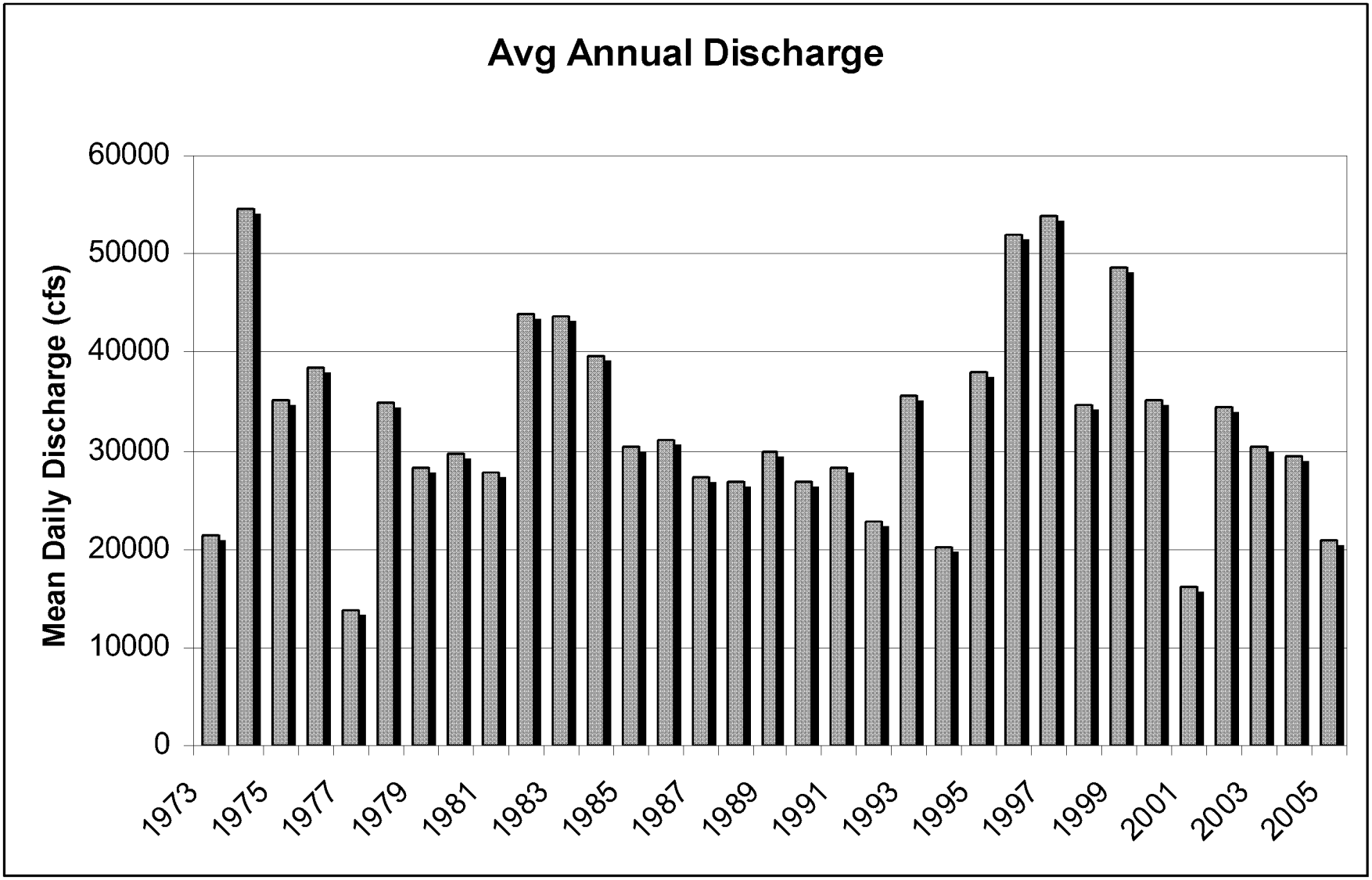

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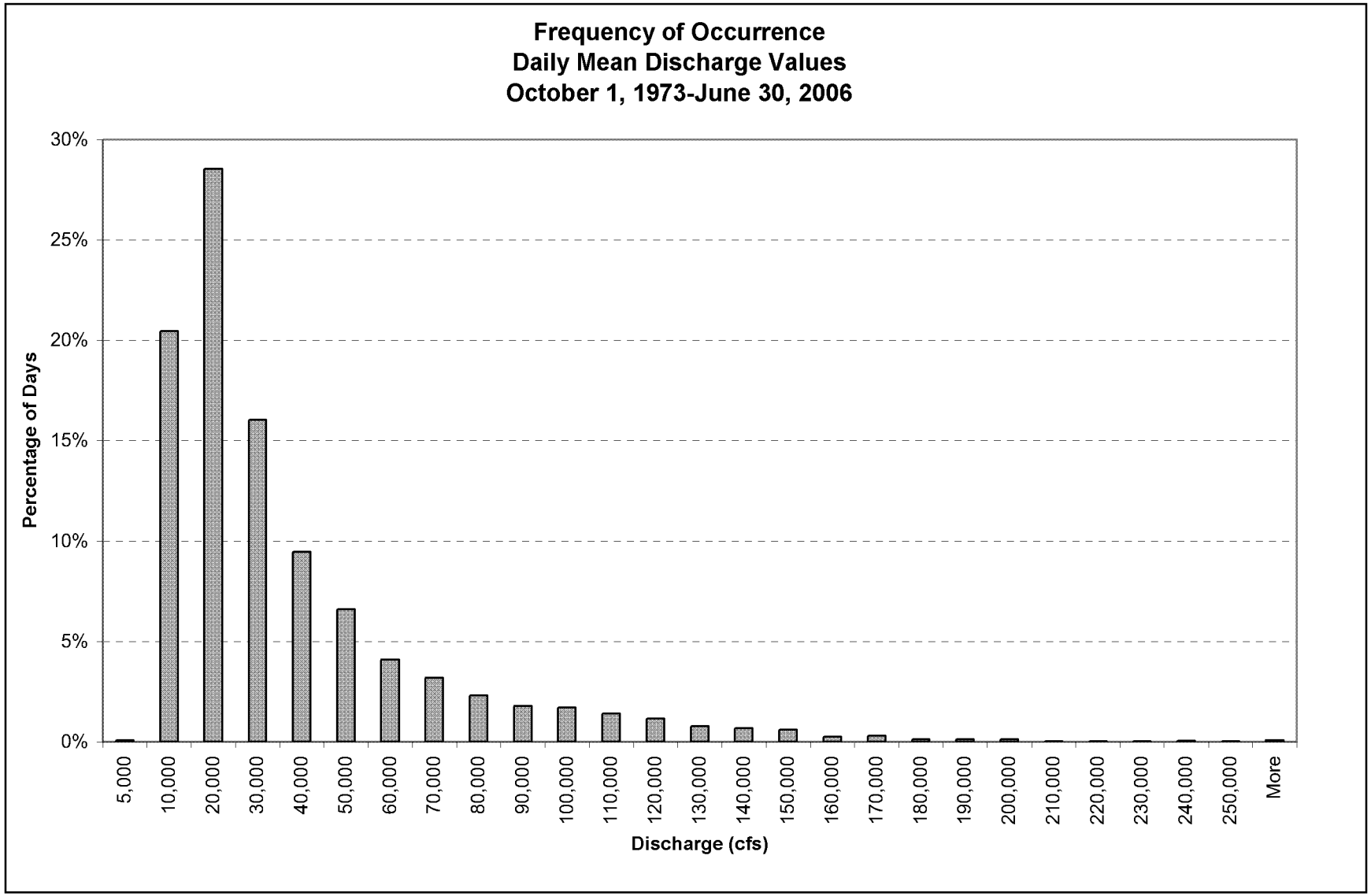
Figure 4.3-3
Portland Harbor RI/FS
Comprehensive Round 2 Report
Average Mean Daily Discharge Values for
the Water Years 1973 to 2005



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Figures 4.3-4
Portland Harbor RI/FS
Round 2 Comprehensive Report
Frequency of Daily Mean Discharge Values
October 1, 1973-June 30, 2006

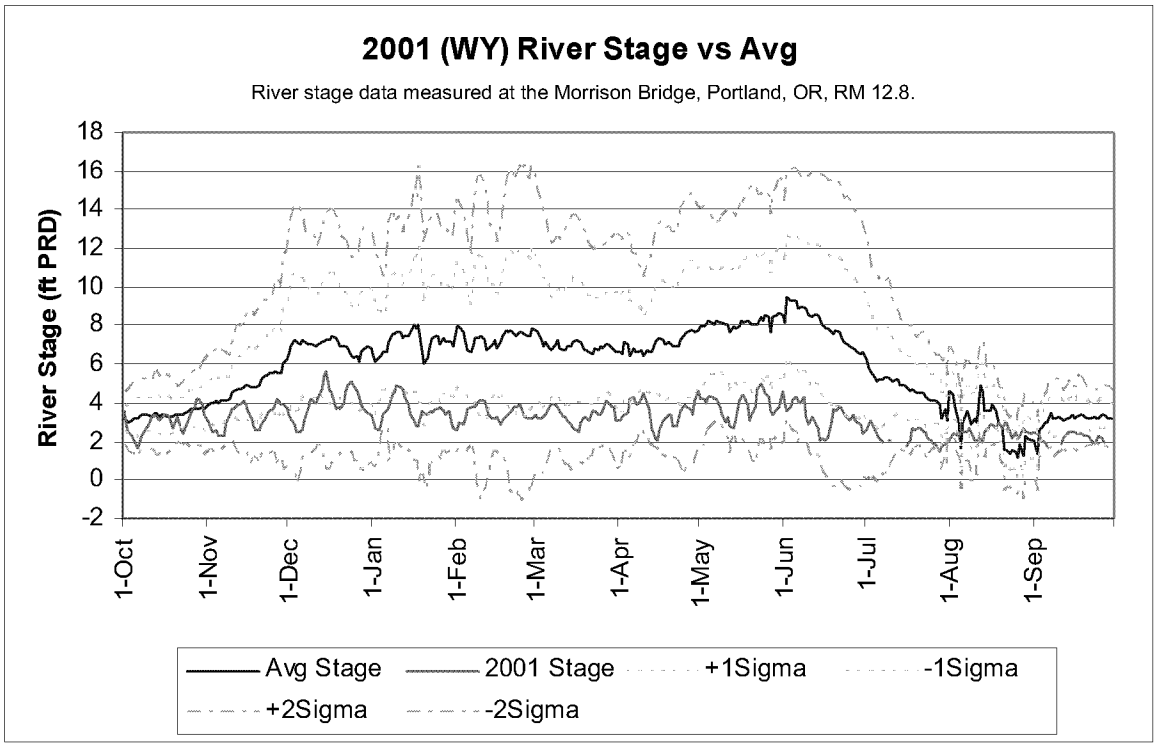


Figure 4.3-5a. Water Year 2001 Willamette River Stage Data versus Average Annual Values (October 1972-June 2006).

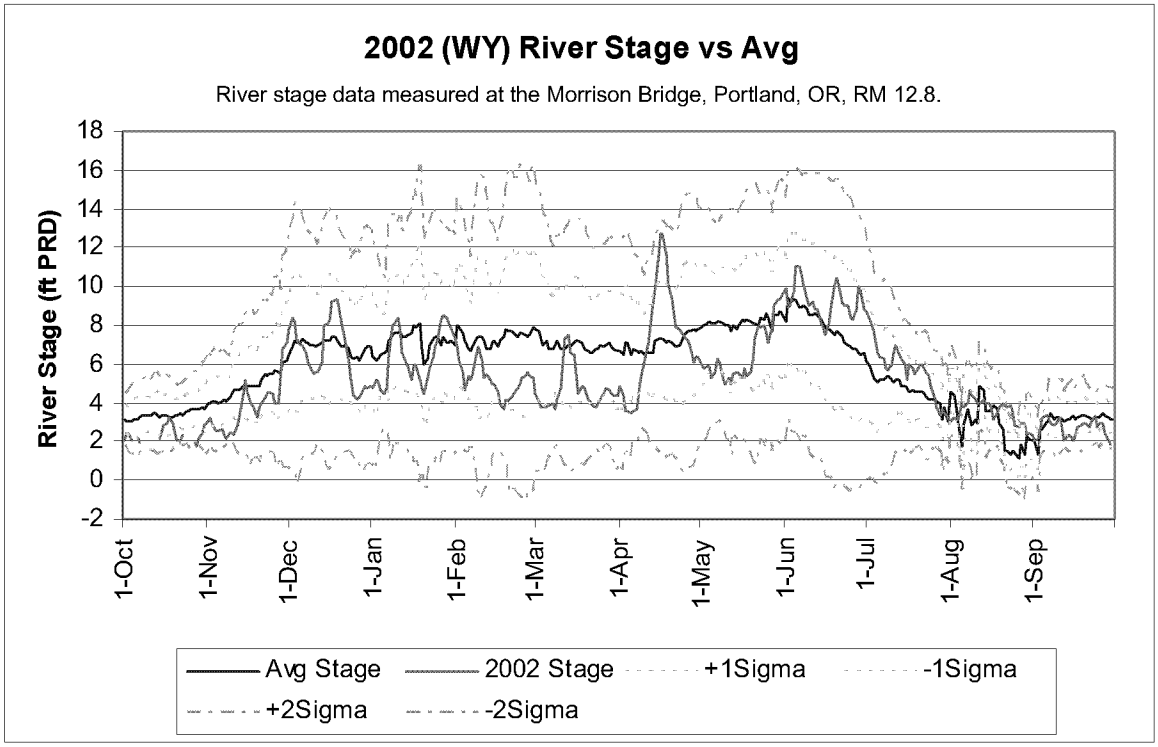


Figure 4.3-5b. Water Year 2002 Willamette River Stage Data versus Average Annual Values (October 1972-June 2006).

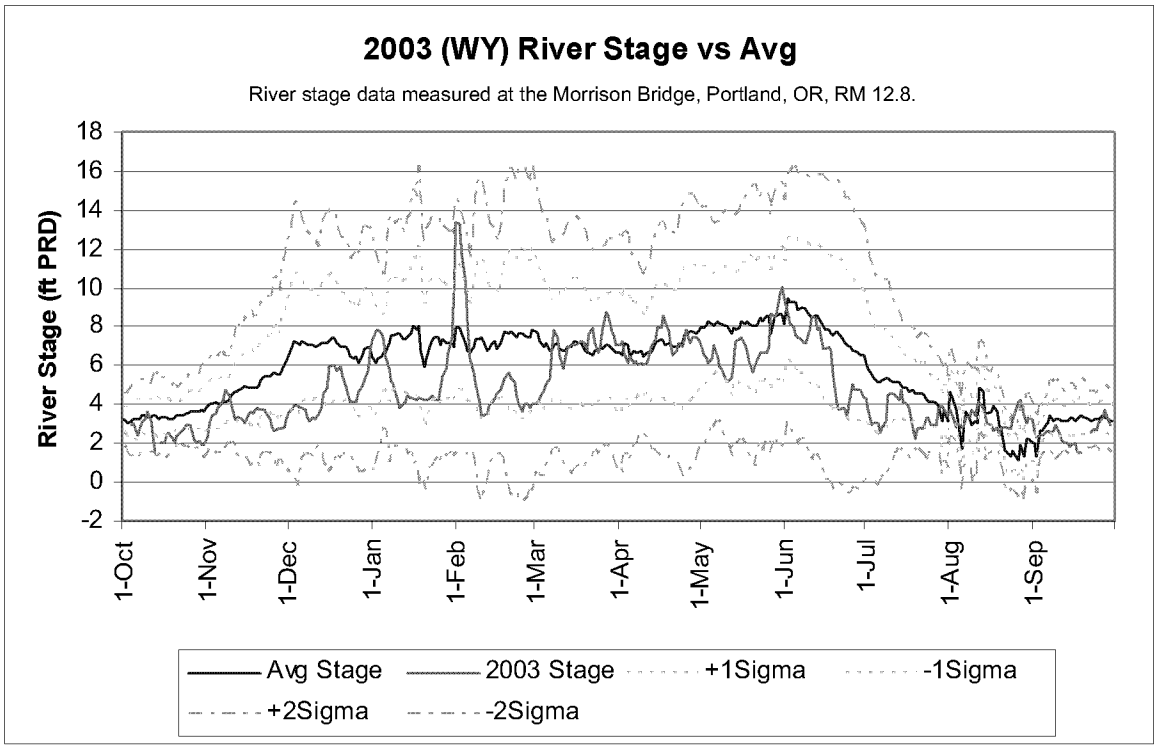


Figure 4.3-5c. Water Year 2003 Willamette River Stage Data versus Average Annual Values (October 1972-June 2006).

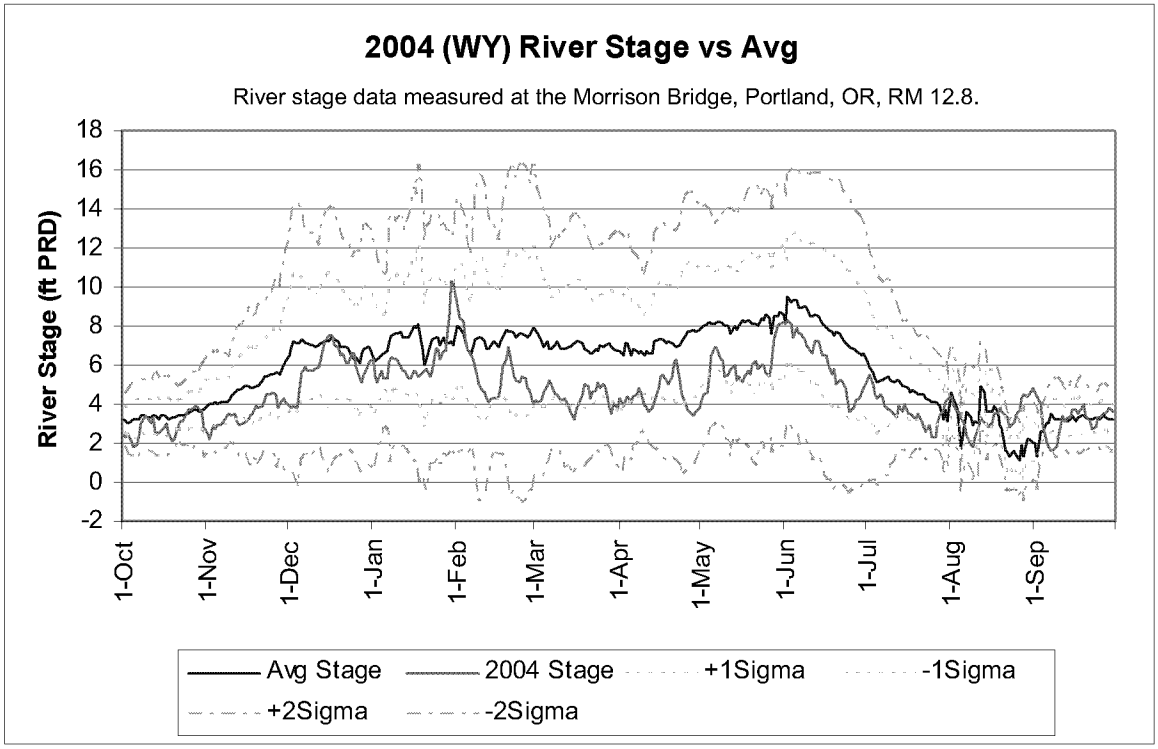


Figure 4.3-5d. Water Year 2004 Willamette River Stage Data versus Average Annual Values (October 1972-June 2006).

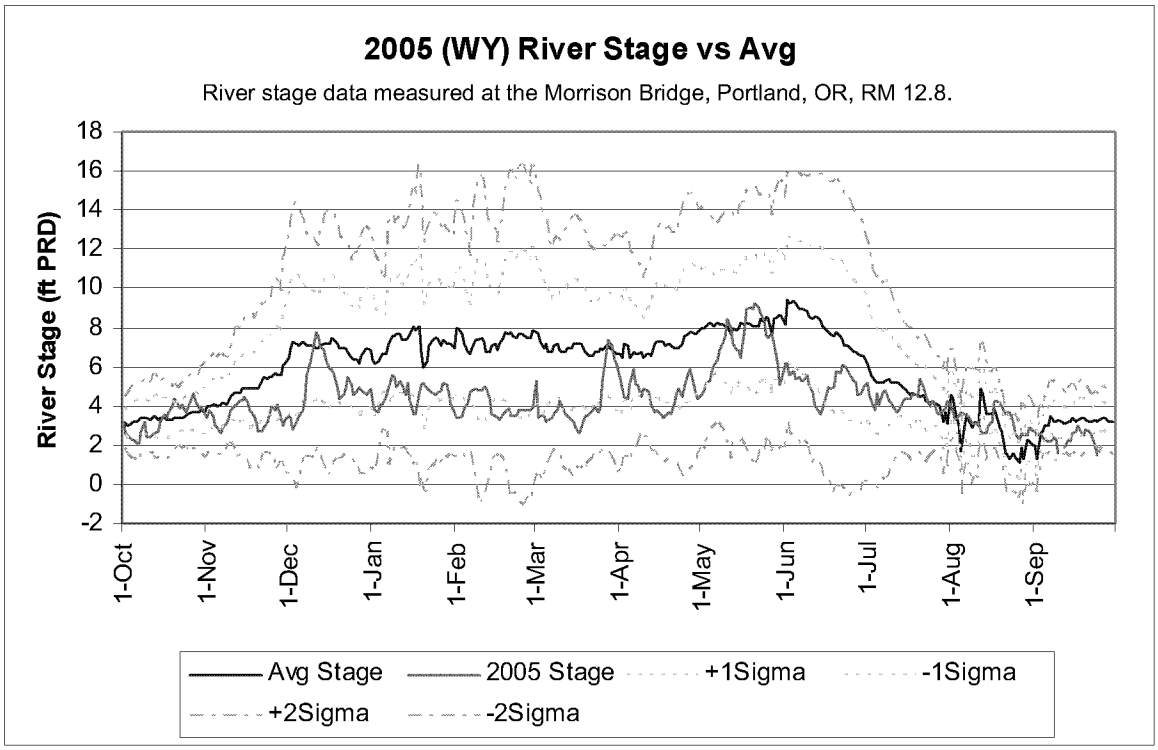


Figure 4.3-5e. Water Year 2005 Willamette River Stage Data versus Average Annual Values (October 1972-June 2006).

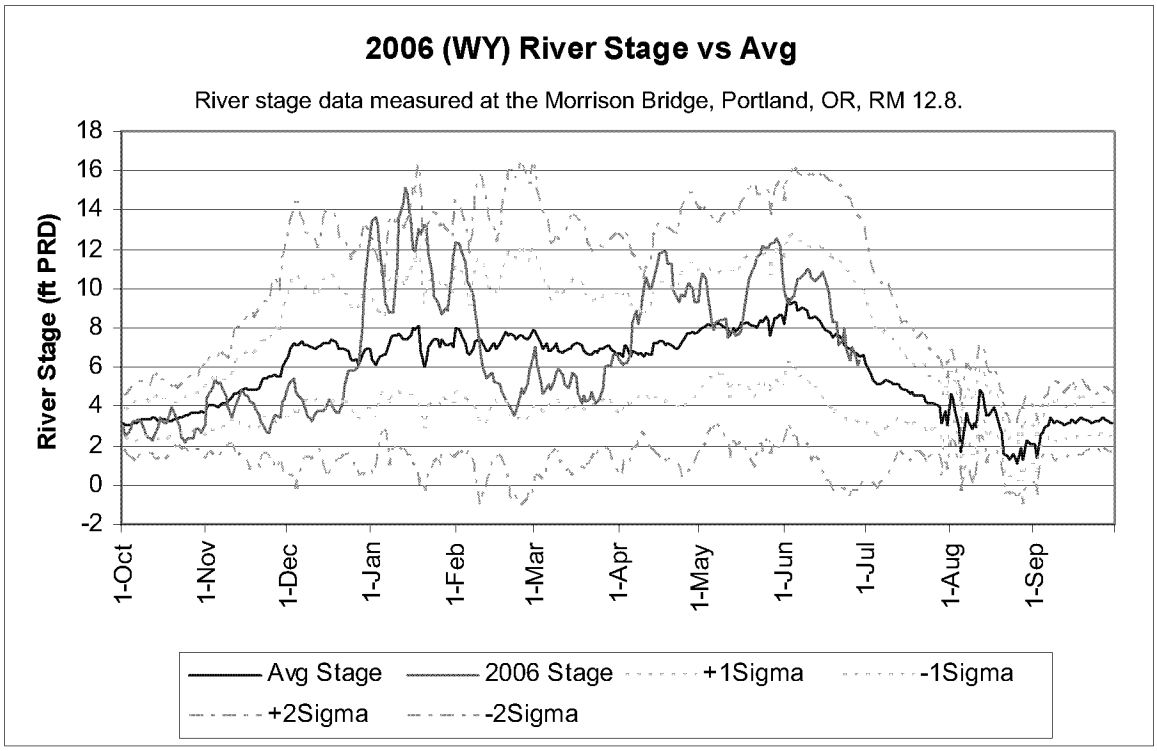


Figure 4.3-5f. Water Year 2006 Willamette River Stage Data versus Average Annual Values (October 1972-June 2006).

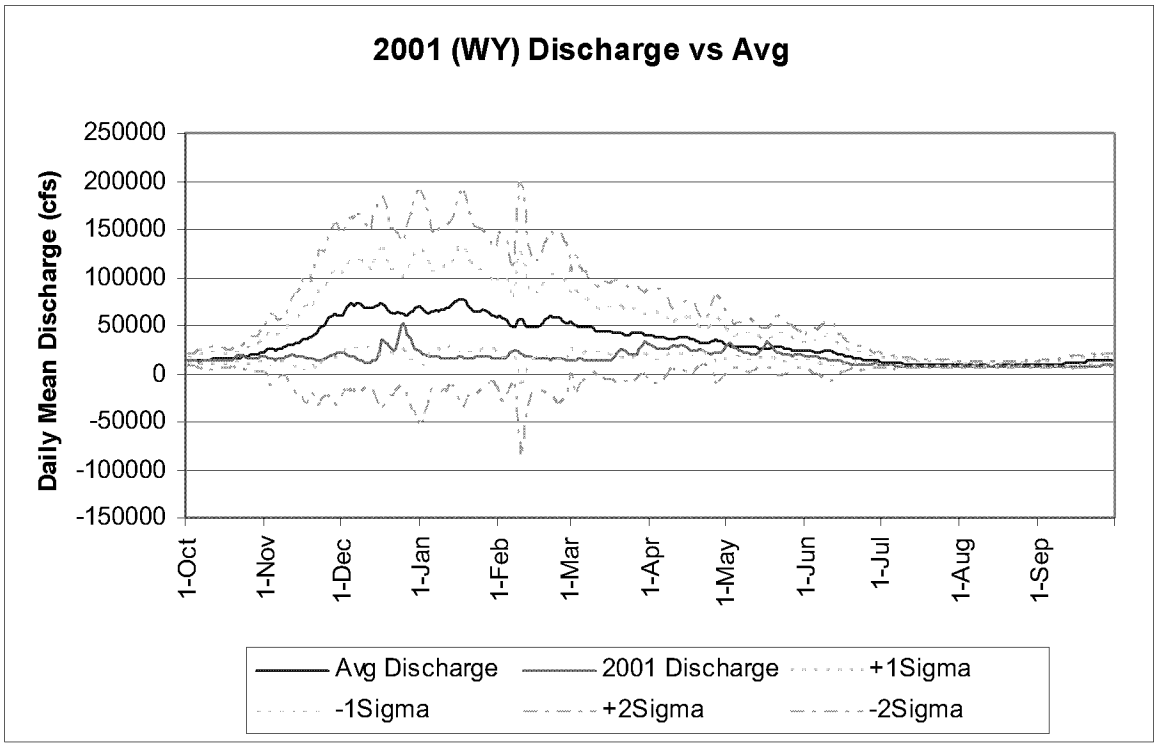


Figure 4.3-6a. Water Year 2001 Willamette River Daily Mean Discharge versus Averaged Daily Discharge (October 1972-June 2006).

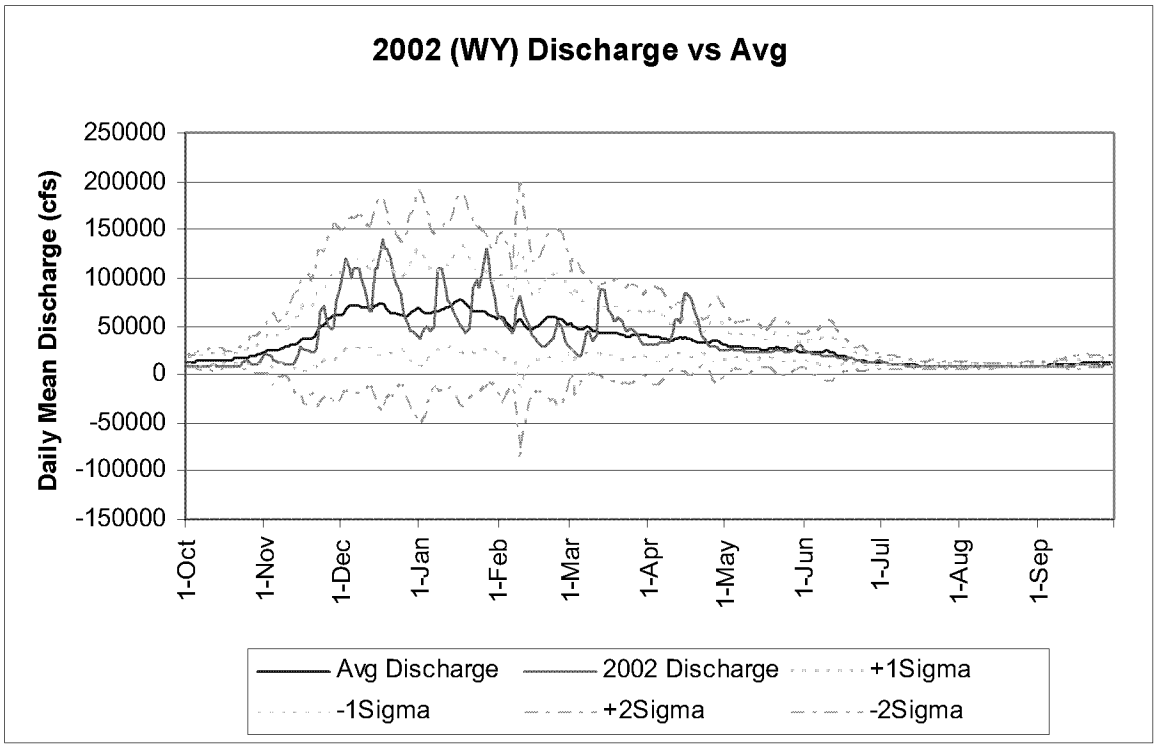


Figure 4.3-6b. Water Year 2002 Willamette River Daily Mean Discharge versus Averaged Daily Discharge (October 1972-June 2006).

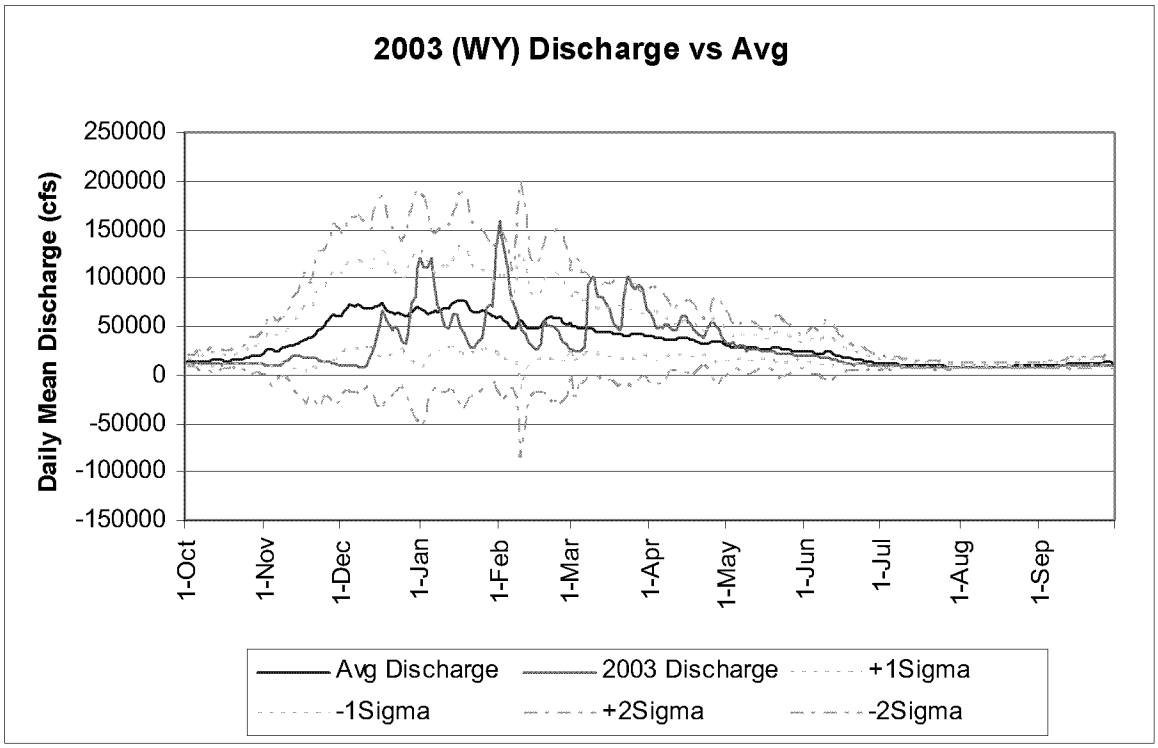


Figure 4.3-6c. Water Year 2003 Willamette River Daily Mean Discharge versus Averaged Daily Discharge (October 1972-June 2006).

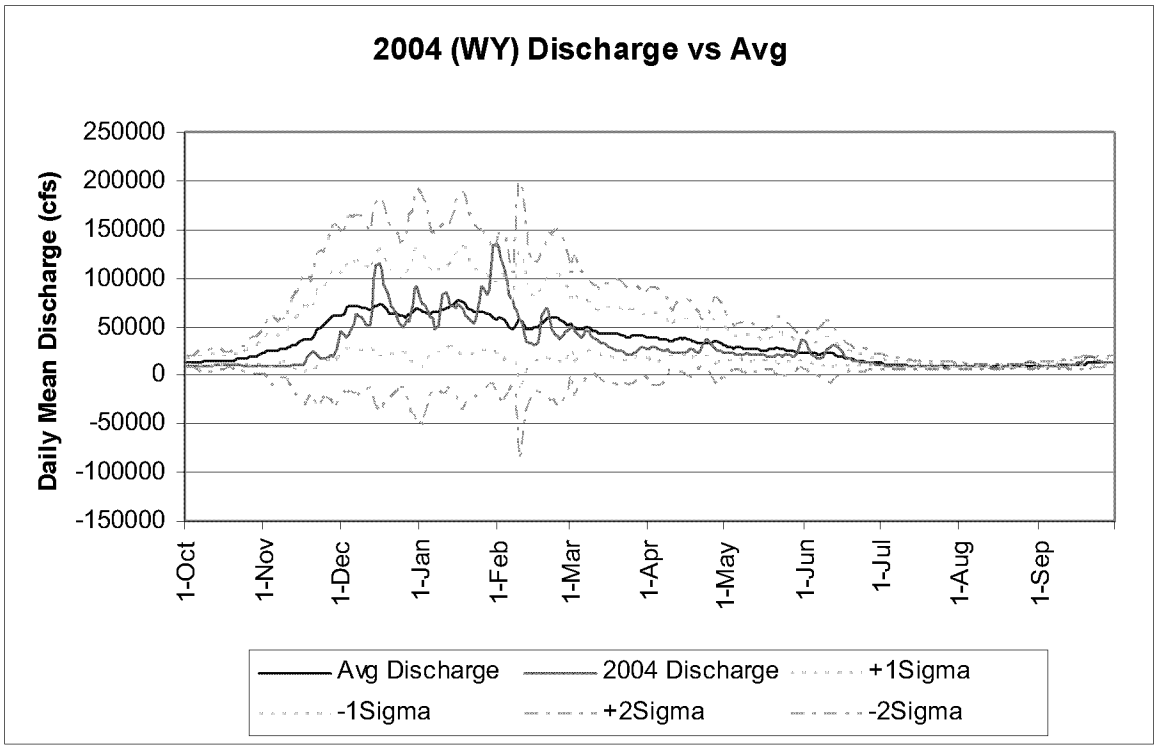


Figure 4.3-6d. Water Year 2004 Willamette River Daily Mean Discharge versus Averaged Daily Discharge (October 1972-June 2006).

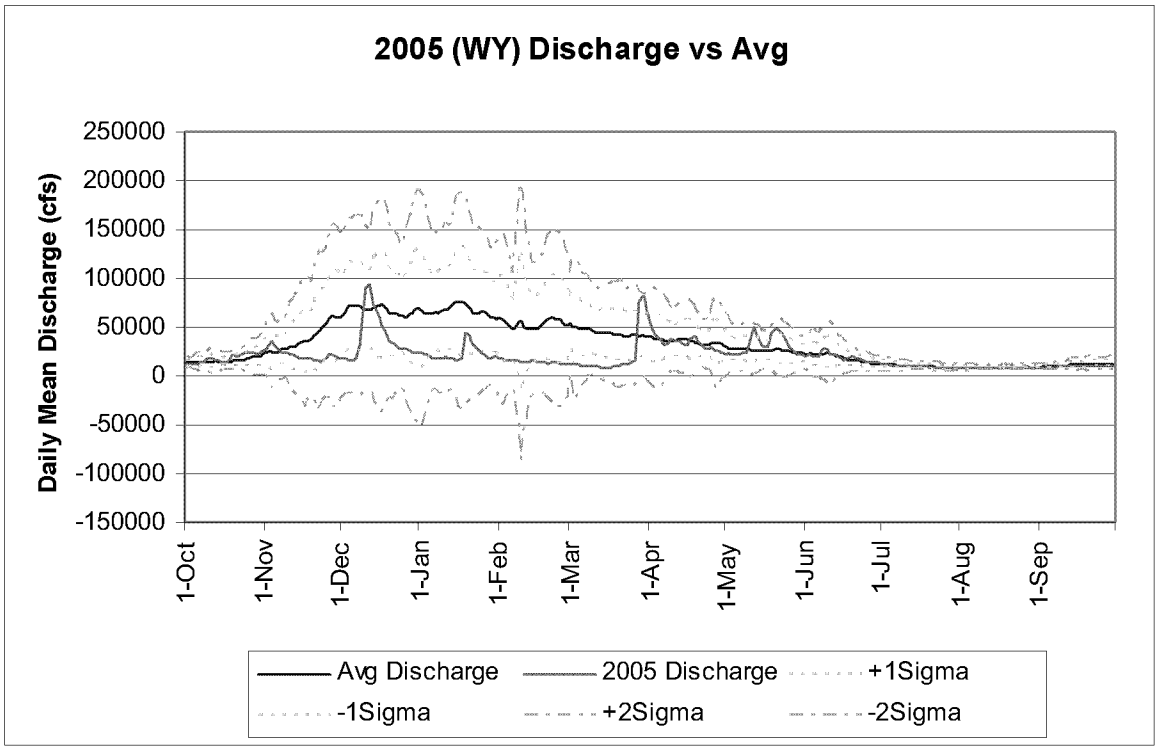


Figure 4.3-6e. Water Year 2005 Willamette River Daily Mean Discharge versus Averaged Daily Discharge (October 1972-June 2006).

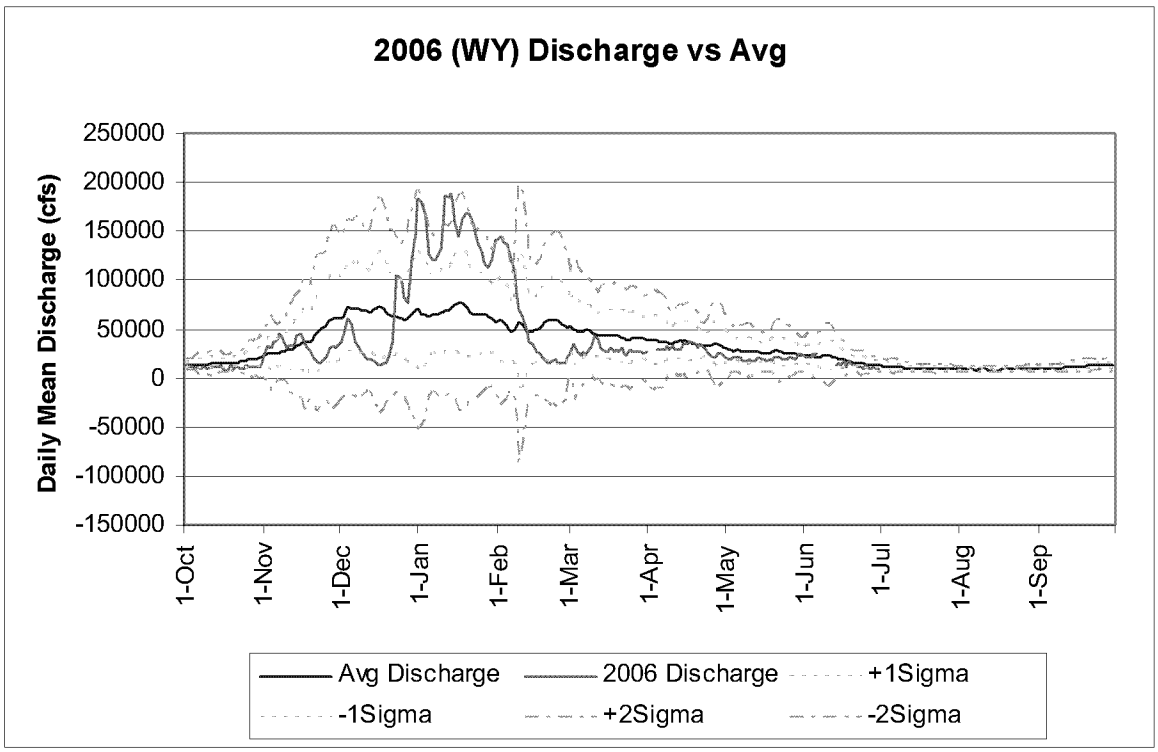
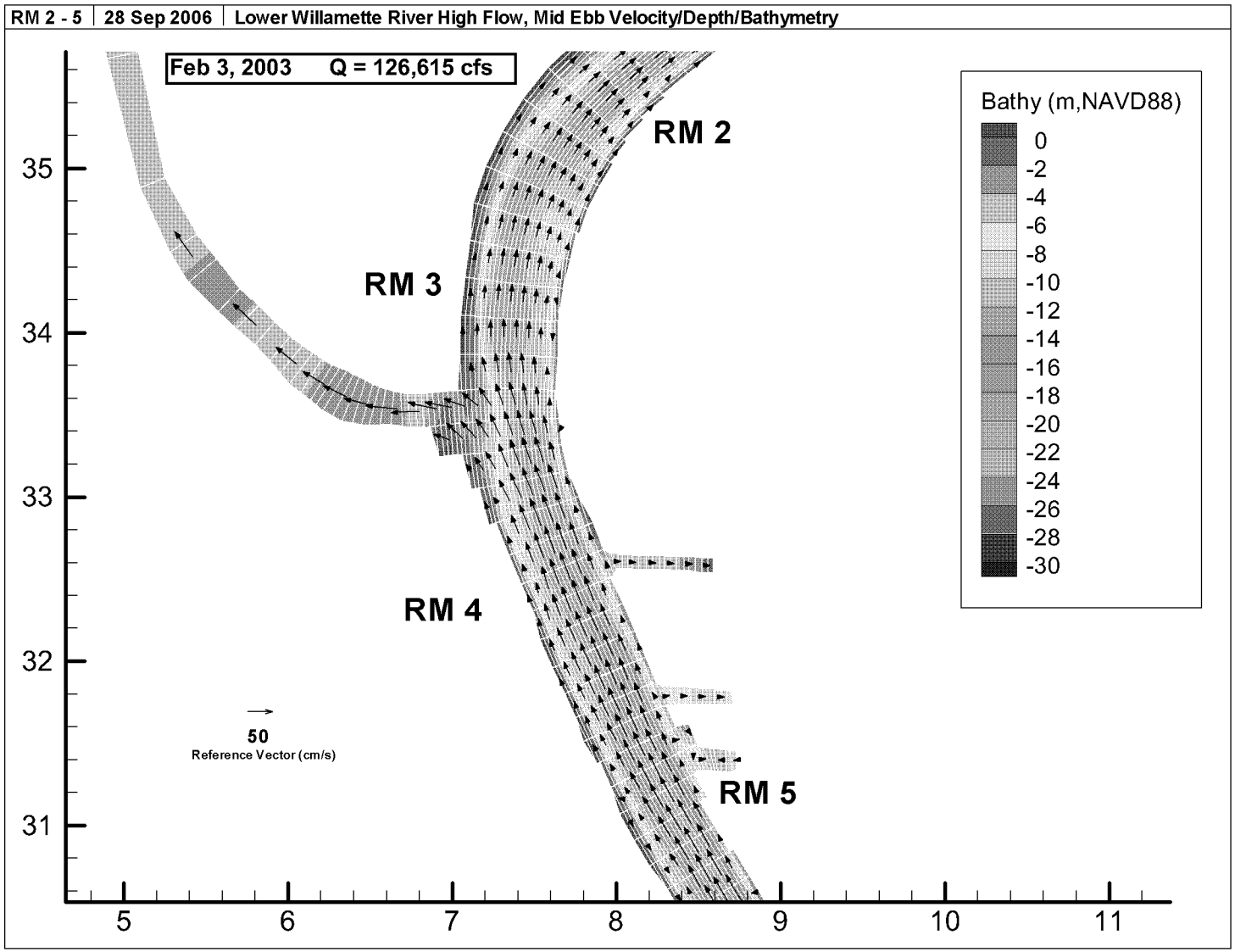
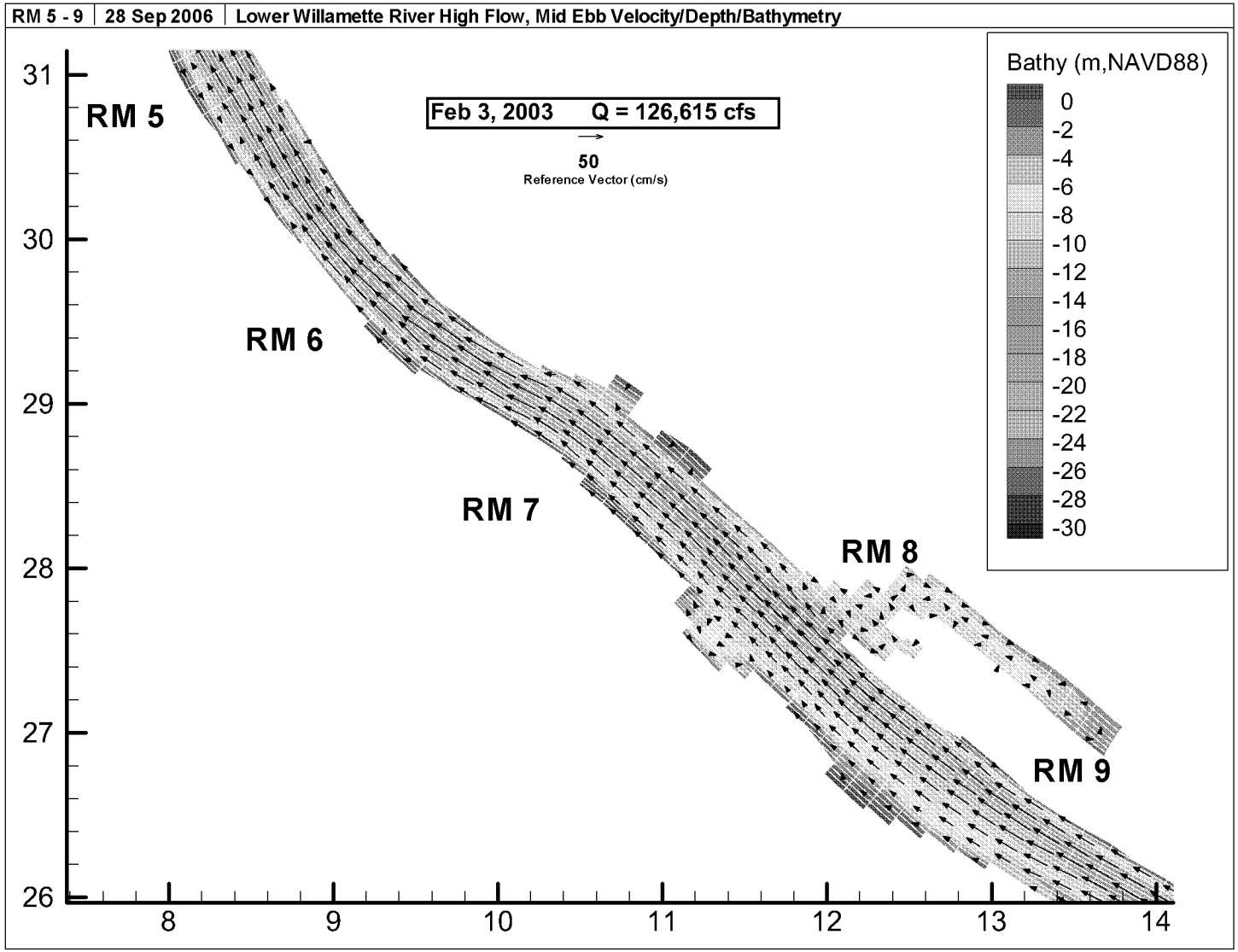


Figure 4.3-6f. Water Year 2006 Willamette River Daily Mean Discharge versus Averaged Daily Discharge (October 1972-June 2006).



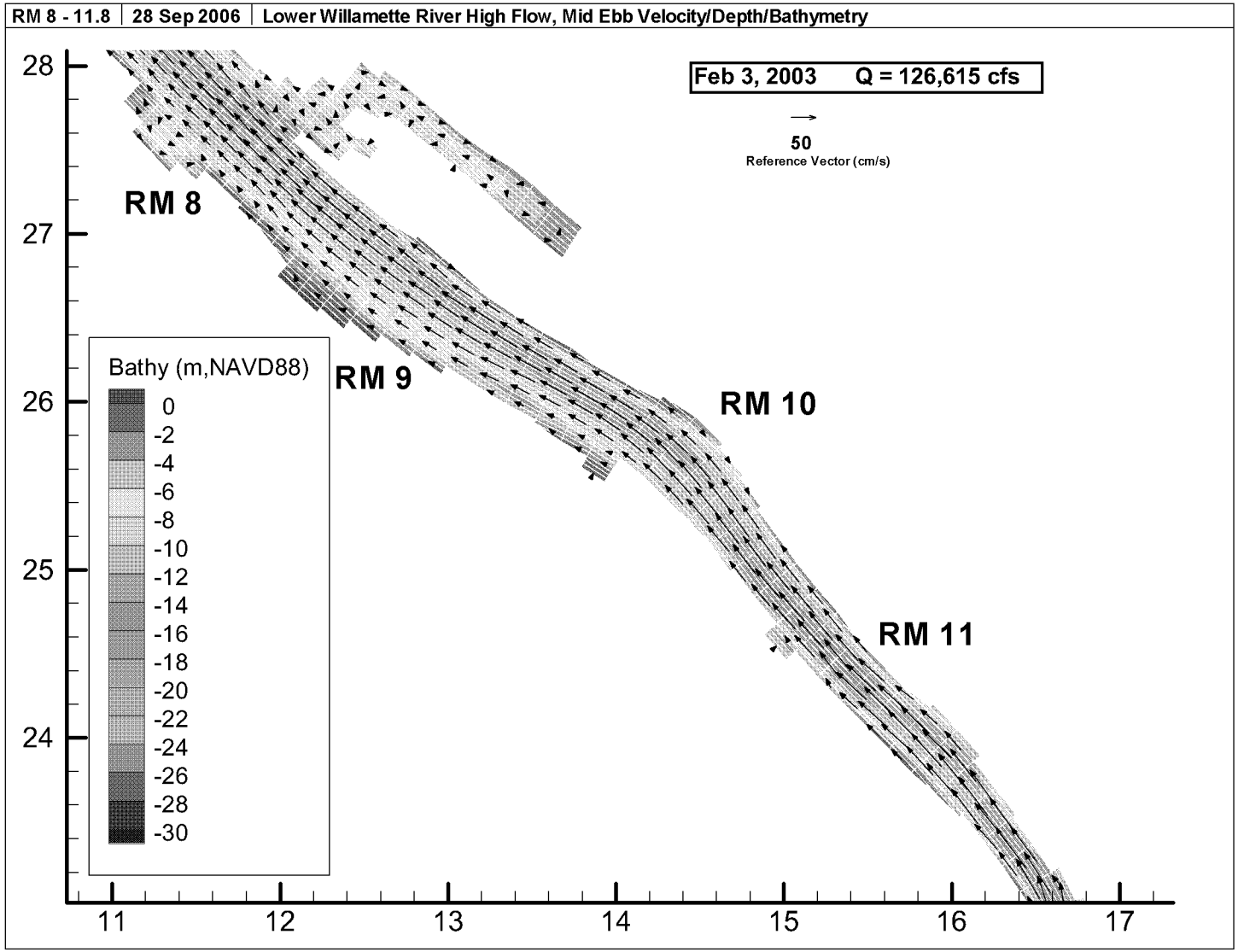
integral LWG LOWER WILLAMETTE GROUP

Figure 4.3-7a
Portland Harbor RI/FS
Comprehensive Round 2 Report
Velocity Vector Plot, High Flow
Mid Ebb, RM 2-5



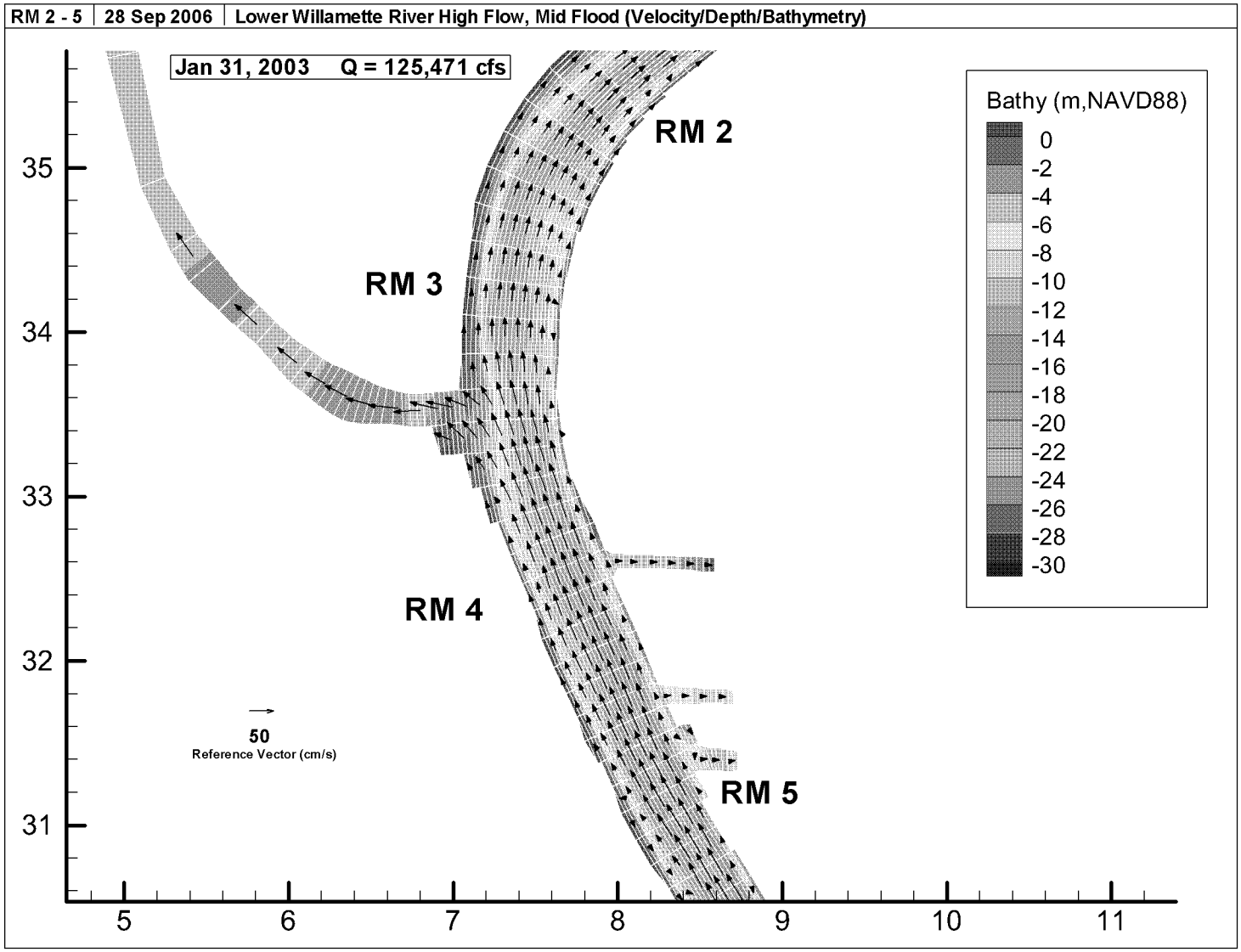
integral LWG Lower Willamette Group

Figure 4.3-7b
Portland Harbor RI/FS
Comprehensive Round 2 Report
Velocity Vector Plot, High Flow
Mid Ebb, RM 5-9



integral LWG LOWER WILLAMETTE GROUP

Figure 4.3-7c
Portland Harbor RI/FS
Comprehensive Round 2 Report
Velocity Vector Plot, High Flow
Mid Ebb, RM 8-11.8



integral LWG LOWER WILLAMETTE GROUP

Figure 4.3-8a
Portland Harbor RI/FS
Comprehensive Round 2 Report
Velocity Vector Plot, High Flow
Mid Flood, RM 2-5

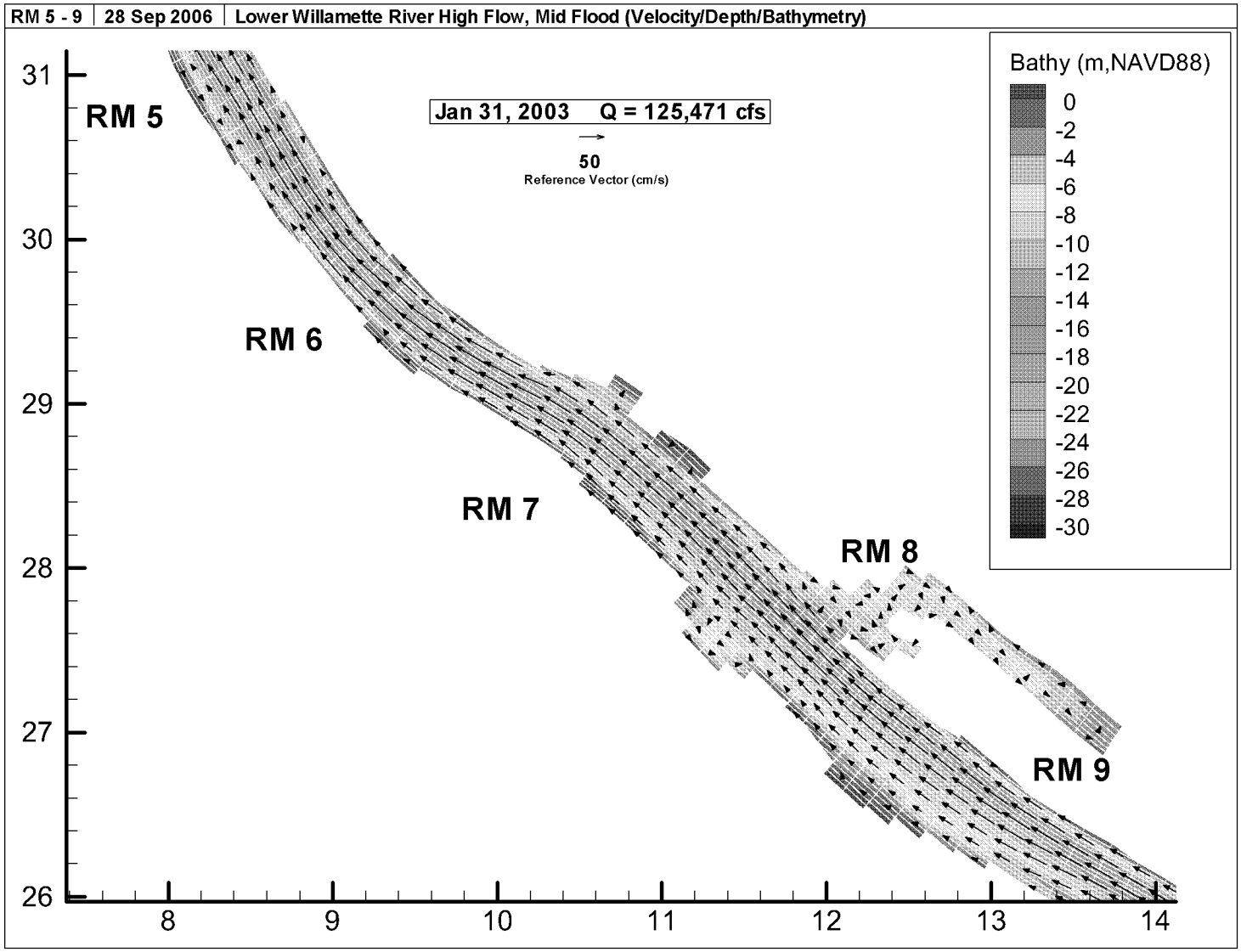


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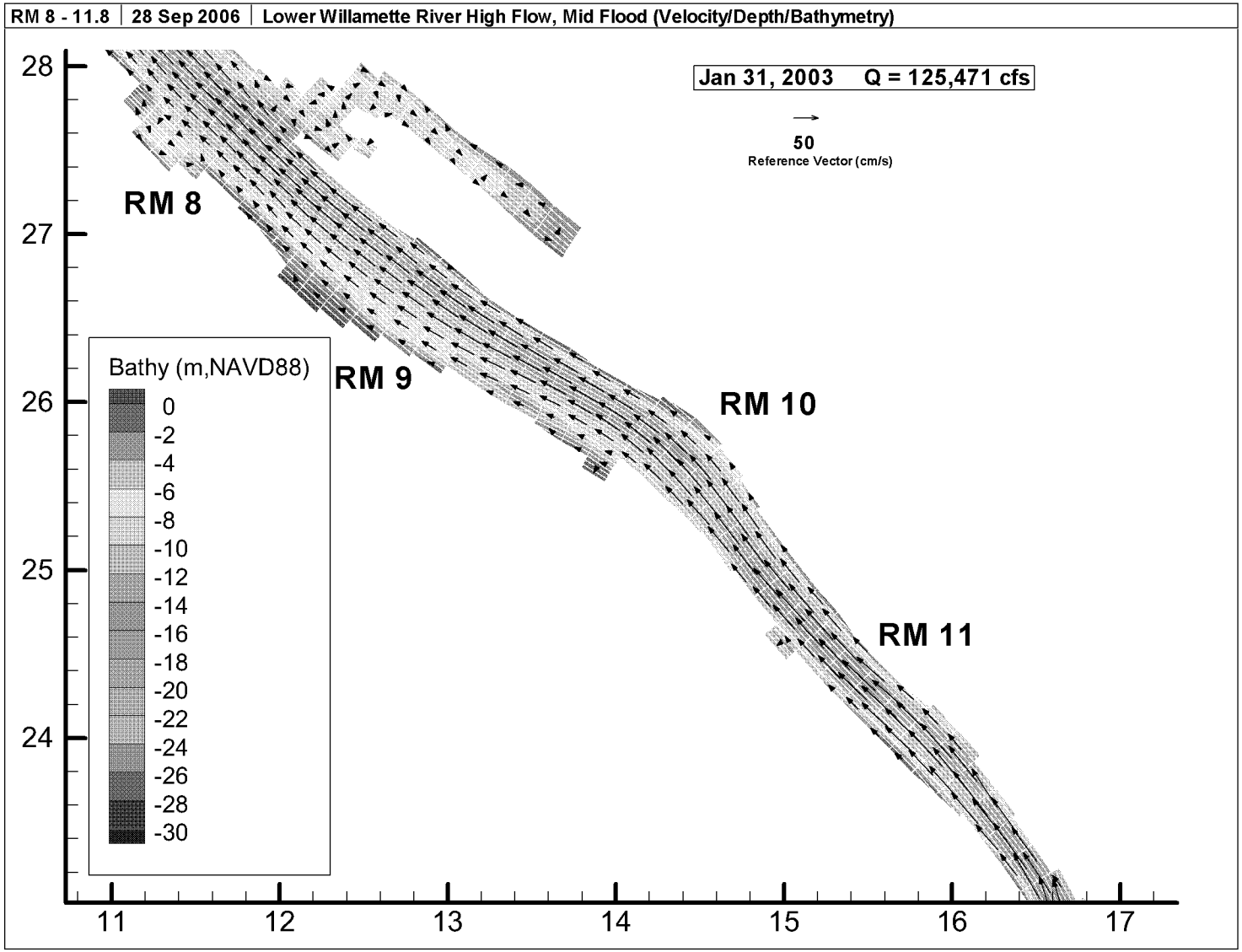
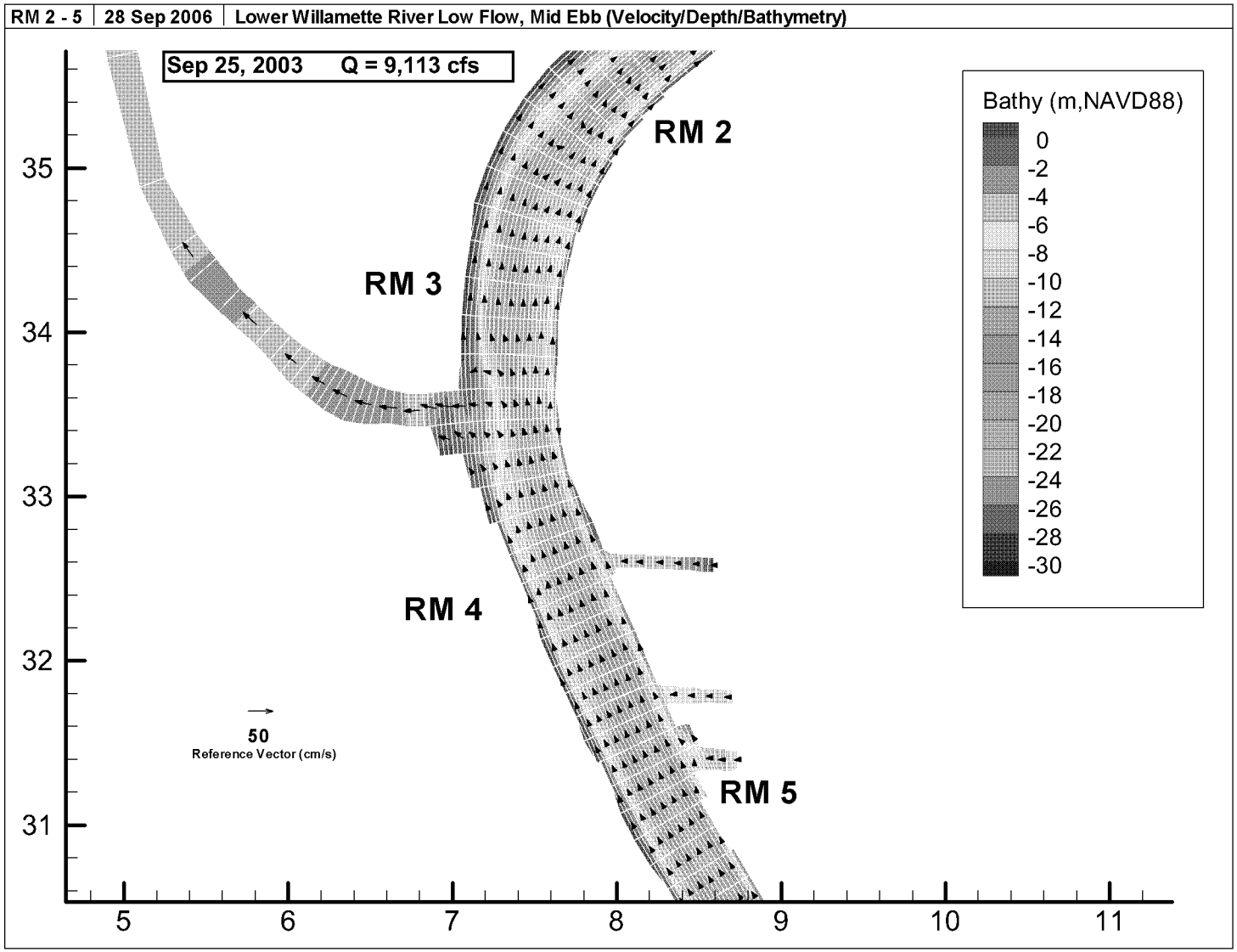
Figure 4.3-8b
Portland Harbor RI/FS
Comprehensive Round 2 Report
Velocity Vector Plot, High Flow
Mid Flood, RM 5-9



integral LWG LOWER WILLAMETTE GROUP

Figure 4.3-8c
Portland Harbor RI/FS
Comprehensive Round 2 Report
Velocity Vector Plot, High Flow
Mid Flood, RM 8-11.8



integral LWG LOWER WILLAMETTE GROUP

Figure 4.3-9a
Portland Harbor RI/FS
Comprehensive Round 2 Report
Velocity Vector Plot, Low Flow
Mid Ebb, RM 2-5

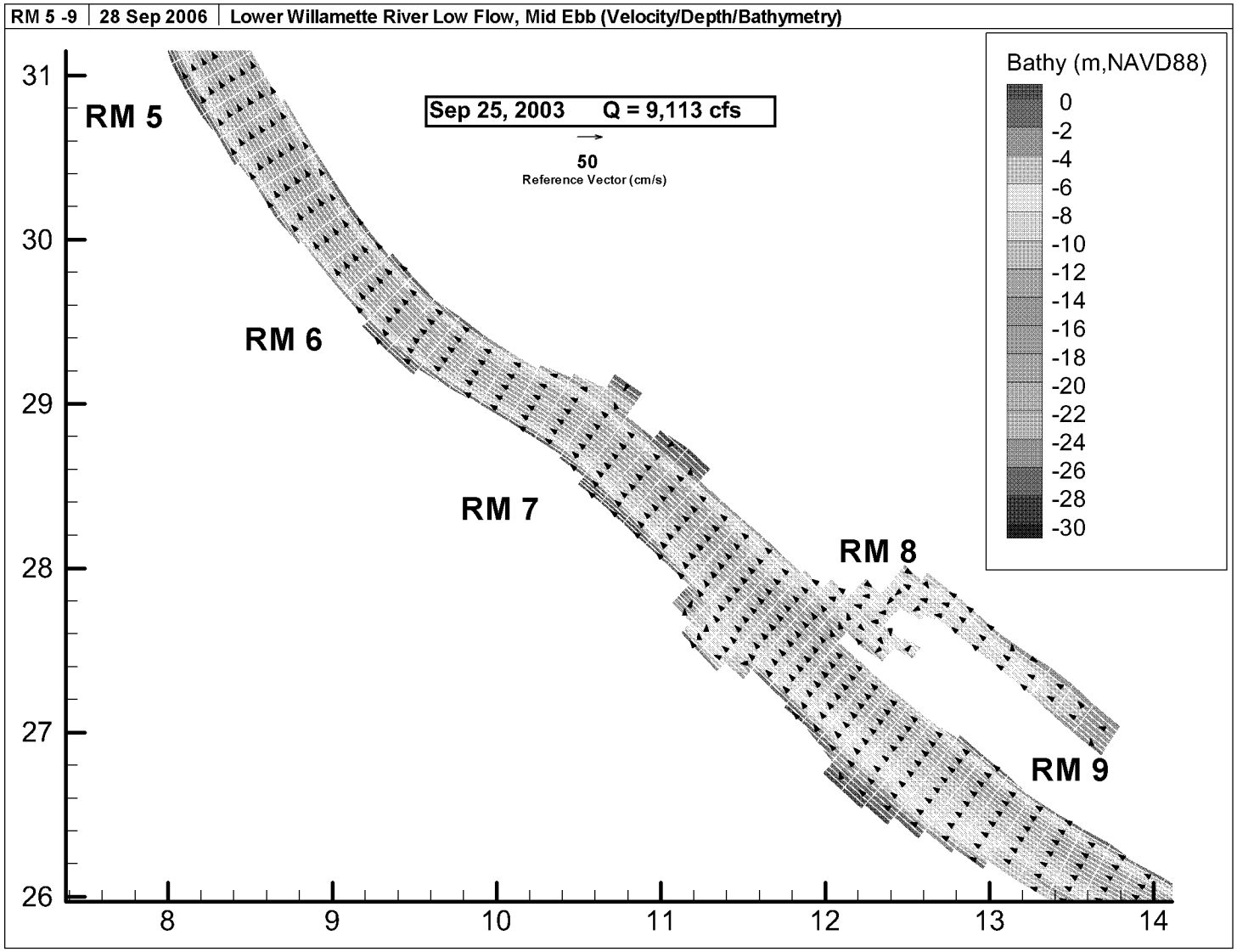


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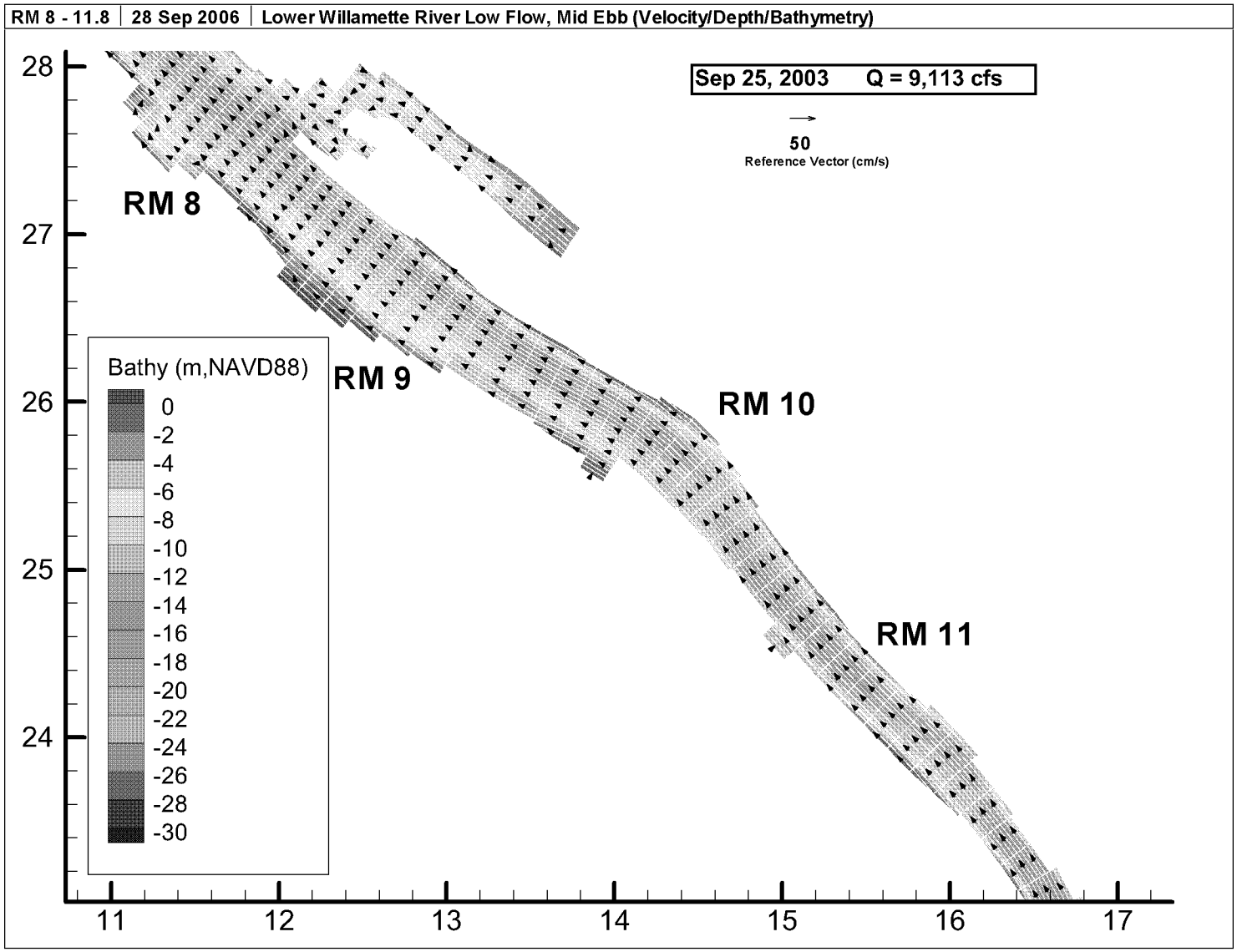
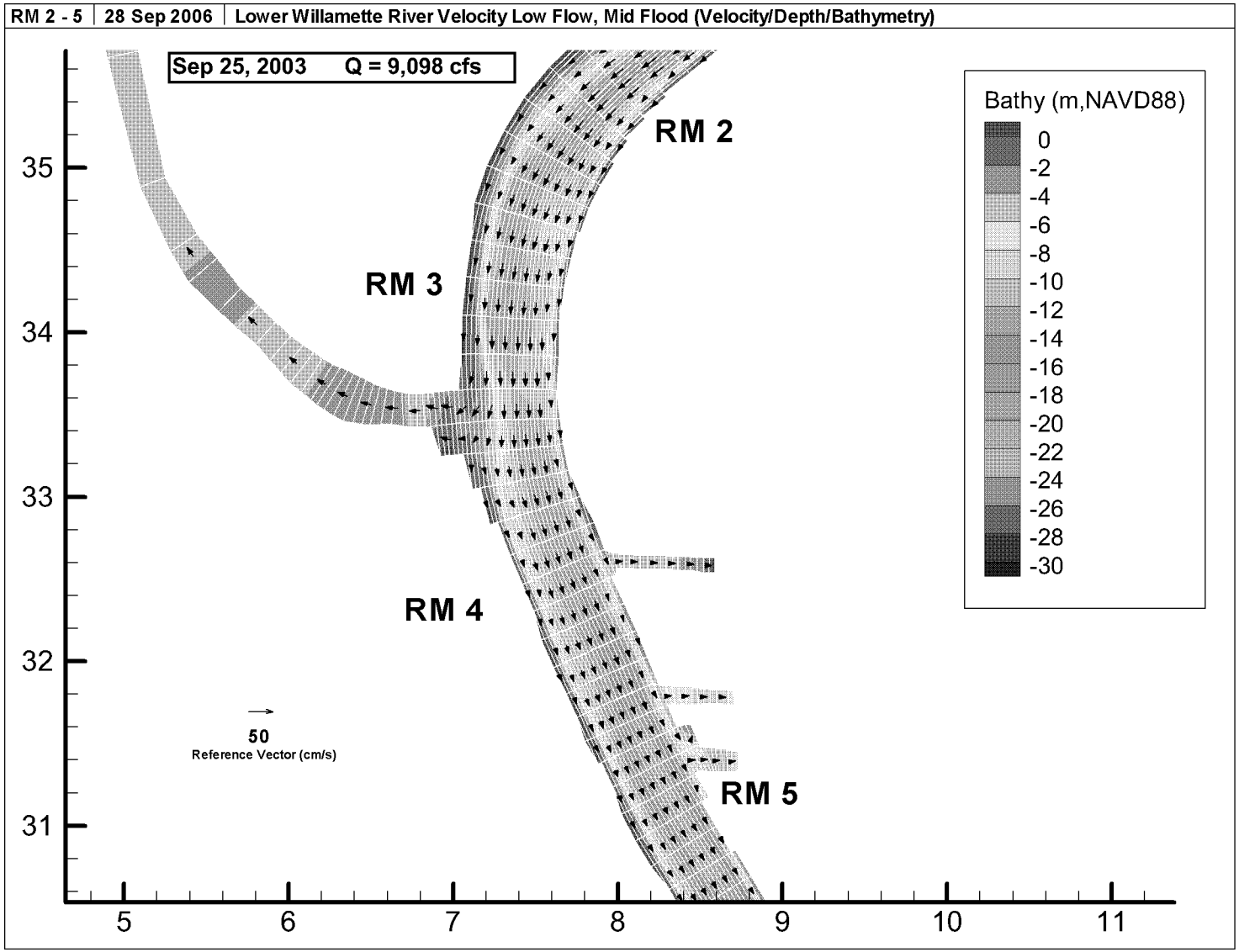
Figure 4.3-9b
Portland Harbor RI/FS
Comprehensive Round 2 Report
Velocity Vector Plot, Low Flow
Mid Ebb, RM 5-9



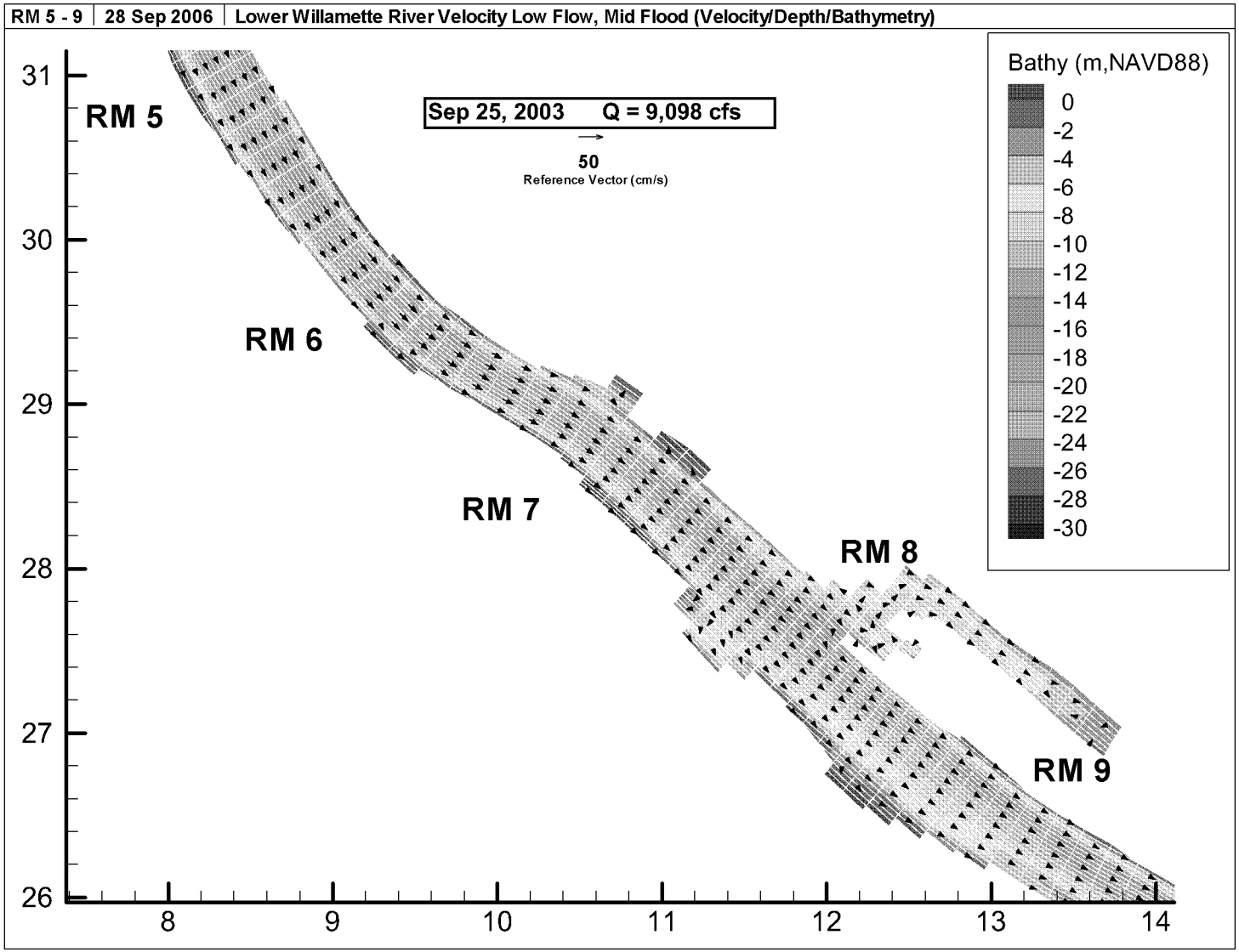
integral LWG LOWER WILLAMETTE GROUP

Figure 4.3-9c
Portland Harbor RI/FS
Comprehensive Round 2 Report
Velocity Vector Plot, Low Flow
Mid Ebb, RM 8-11.8



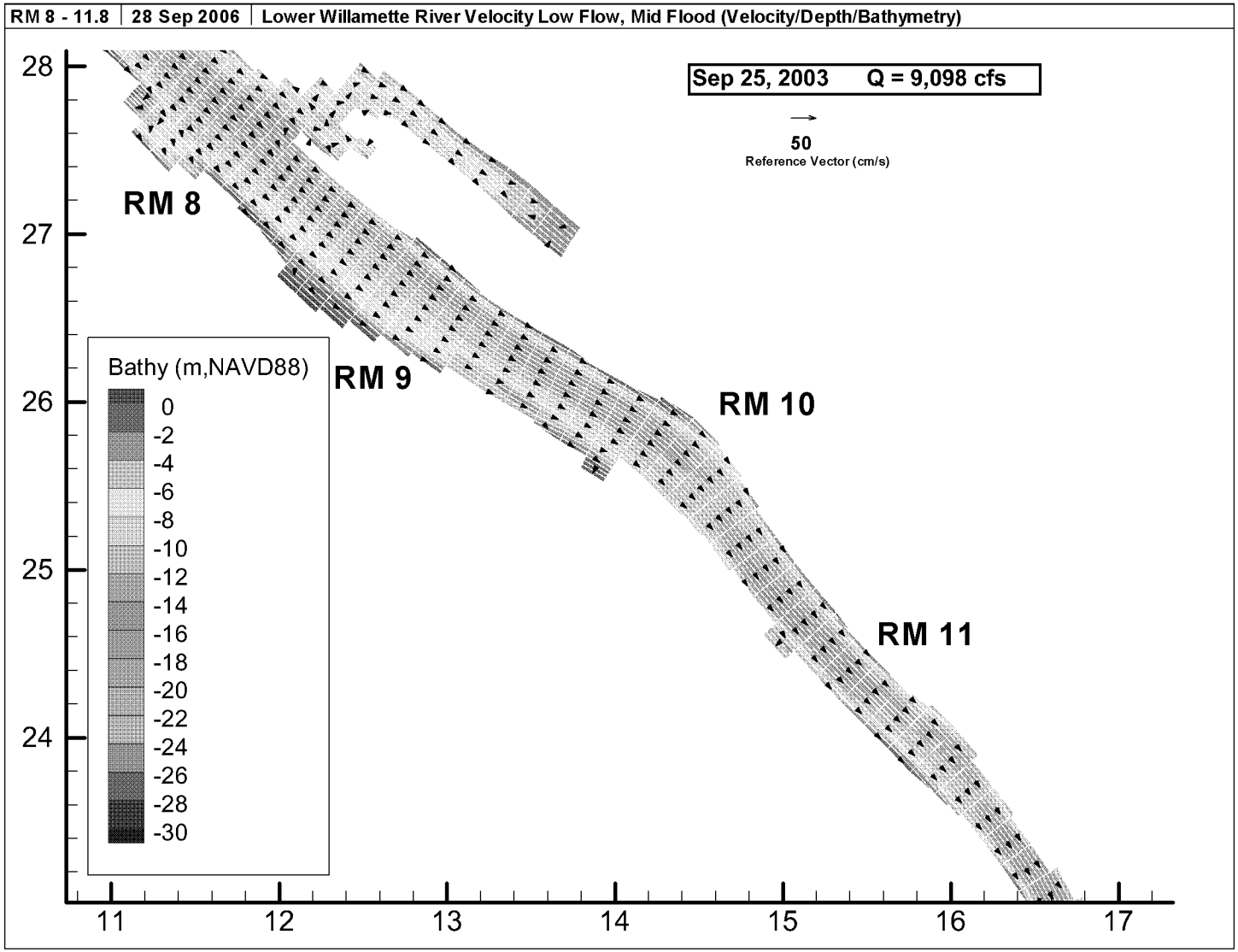
integral LWG LOWER WILLAMETTE GROUP

Figure 4.3-10a
Portland Harbor RI/FS
Comprehensive Round 2 Report
Velocity Vector Plot, Low Flow
Mid Flood, RM 2-5



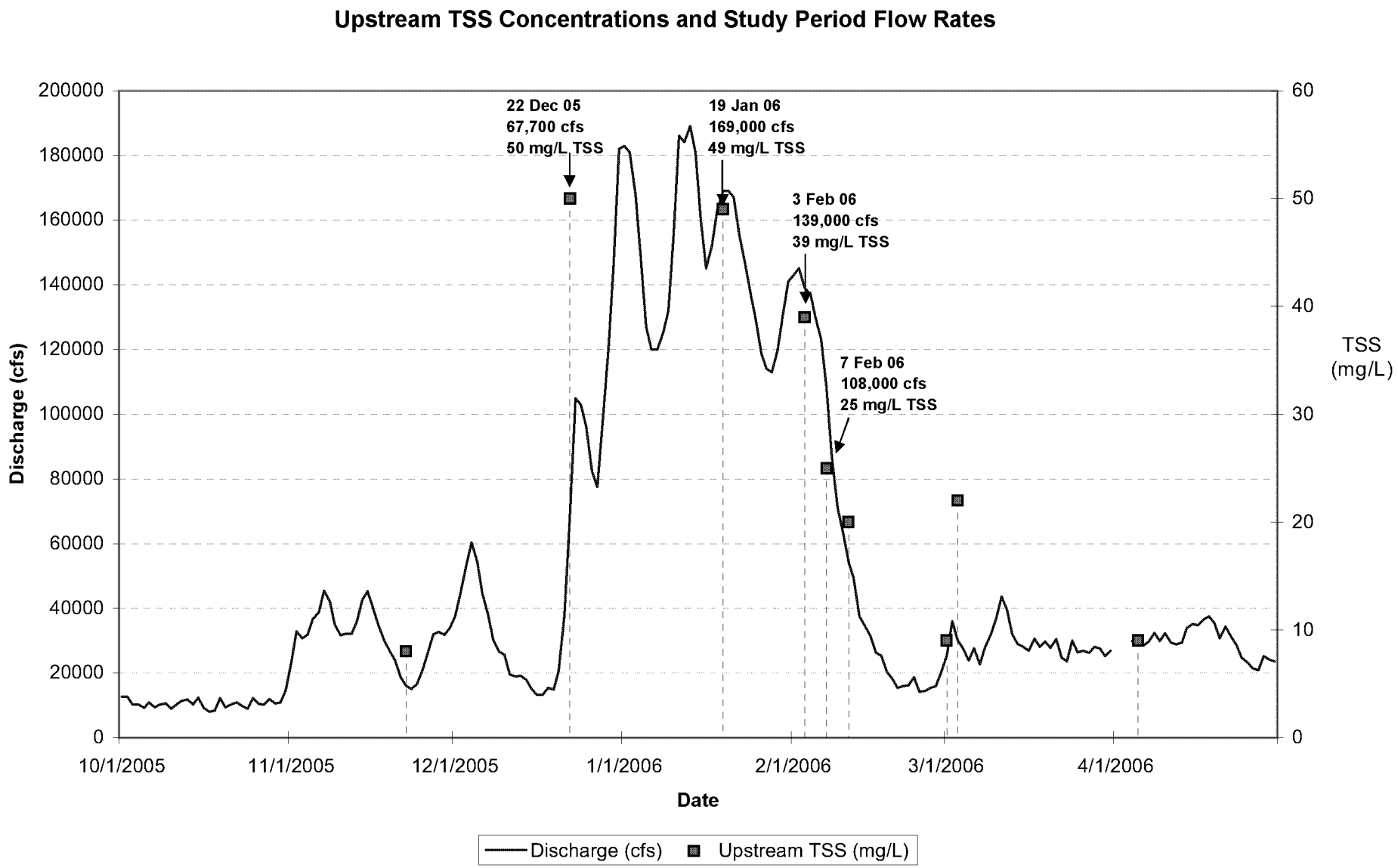
integral LWG LOWER WILLAMETTE GROUP

Figure 4.3-10b
Portland Harbor RI/FS
Comprehensive Round 2 Report
Velocity Vector Plot, Low Flow
Mid Flood, RM 5-9



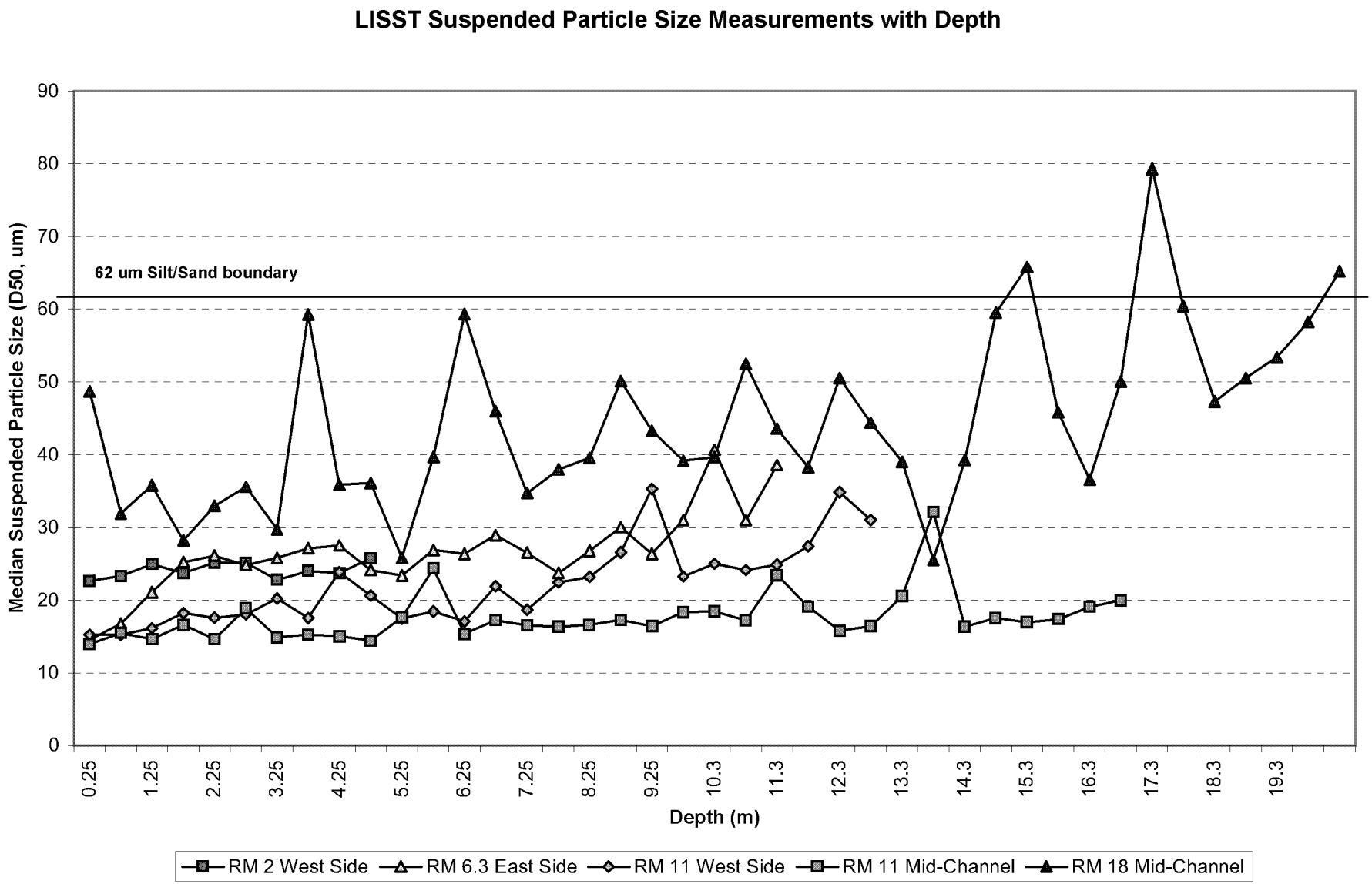
integral LWG LOWER WILLAMETTE GROUP

Figure 4.3-10c
Portland Harbor RI/FS
Comprehensive Round 2 Report
Velocity Vector Plot, Low Flow
Mid Flood, RM 8-11



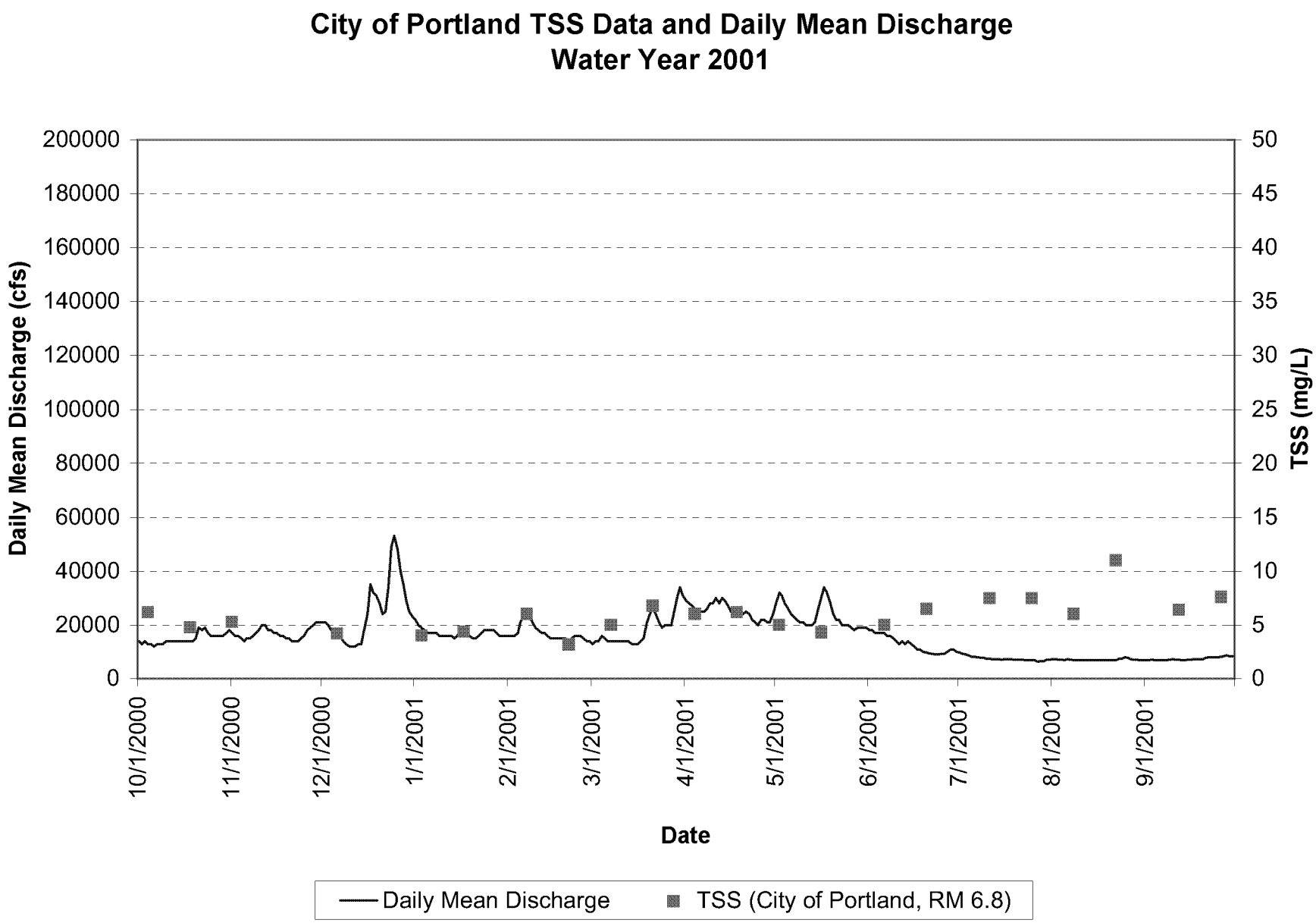
integral LWG LOWER WILLAMETTE GROUP

Figure 4.4-1
Portland Harbor RI/FS
Comprehensive Round 2 Report
Upstream TSS Concentrations and
Study Period Flow Rates



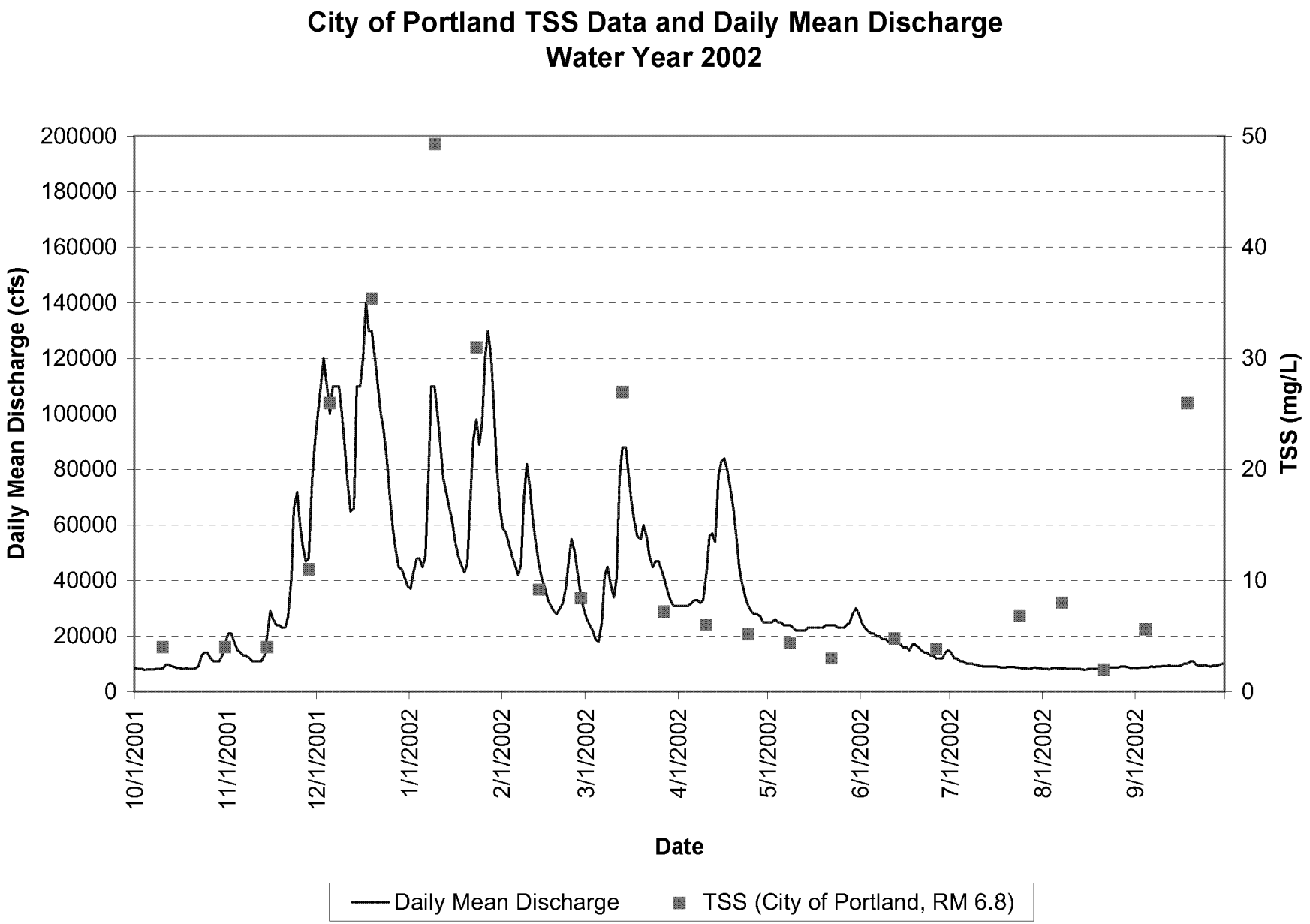
integral LWG LOWER WILLAMETTE GROUP

Figure 4.4-2
Portland Harbor RI/FS
Comprehensive Round 2 Report
LISST Suspended Particle Size
Measurements with Depth



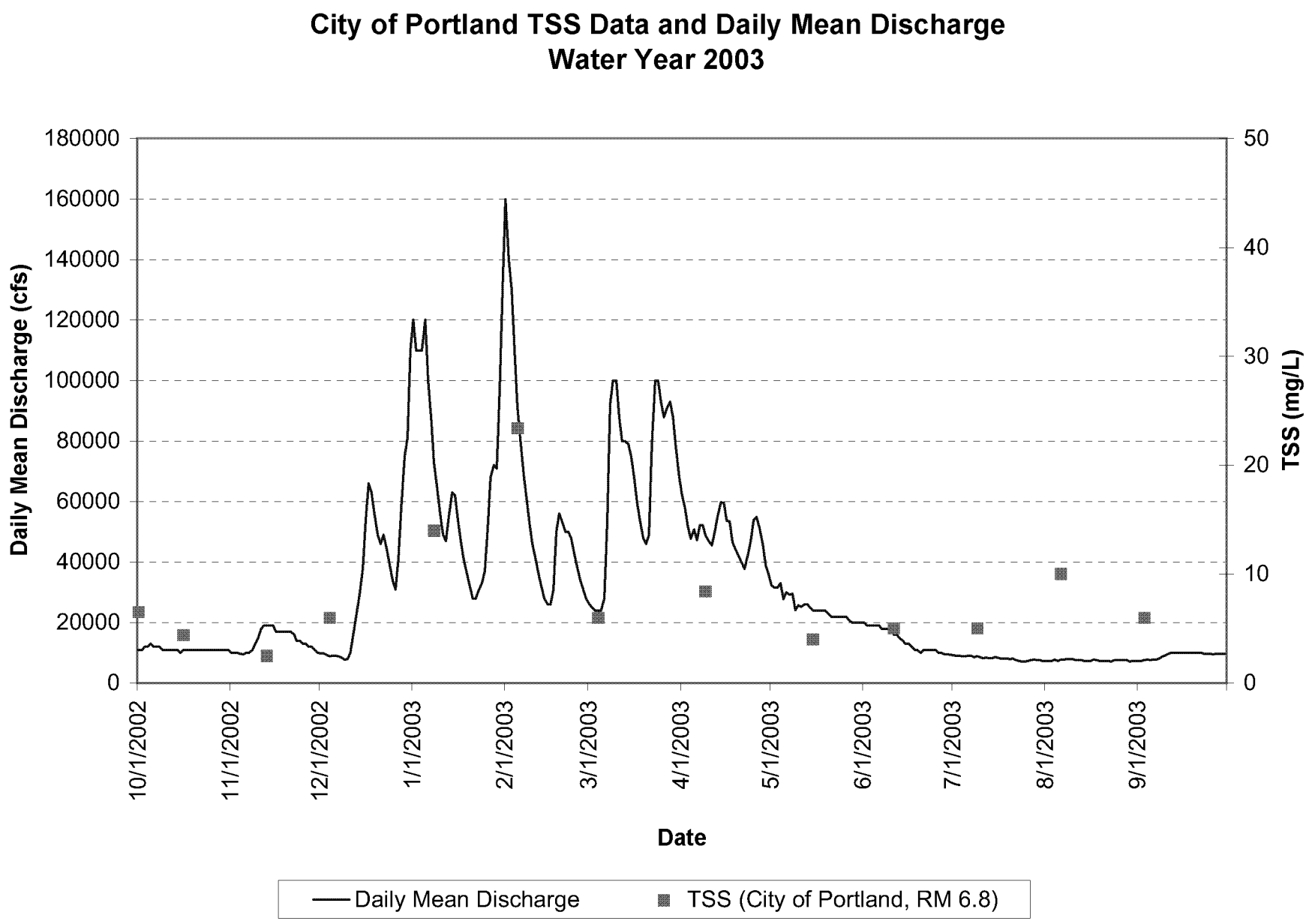
integral LWG LOWER WILLAMETTE GROUP

Figure 4.4-3a
Portland Harbor RI/FS
Round 2 Comprehensive Report
City of Portland TSS Data and
Daily Mean Discharge Water Year 2001



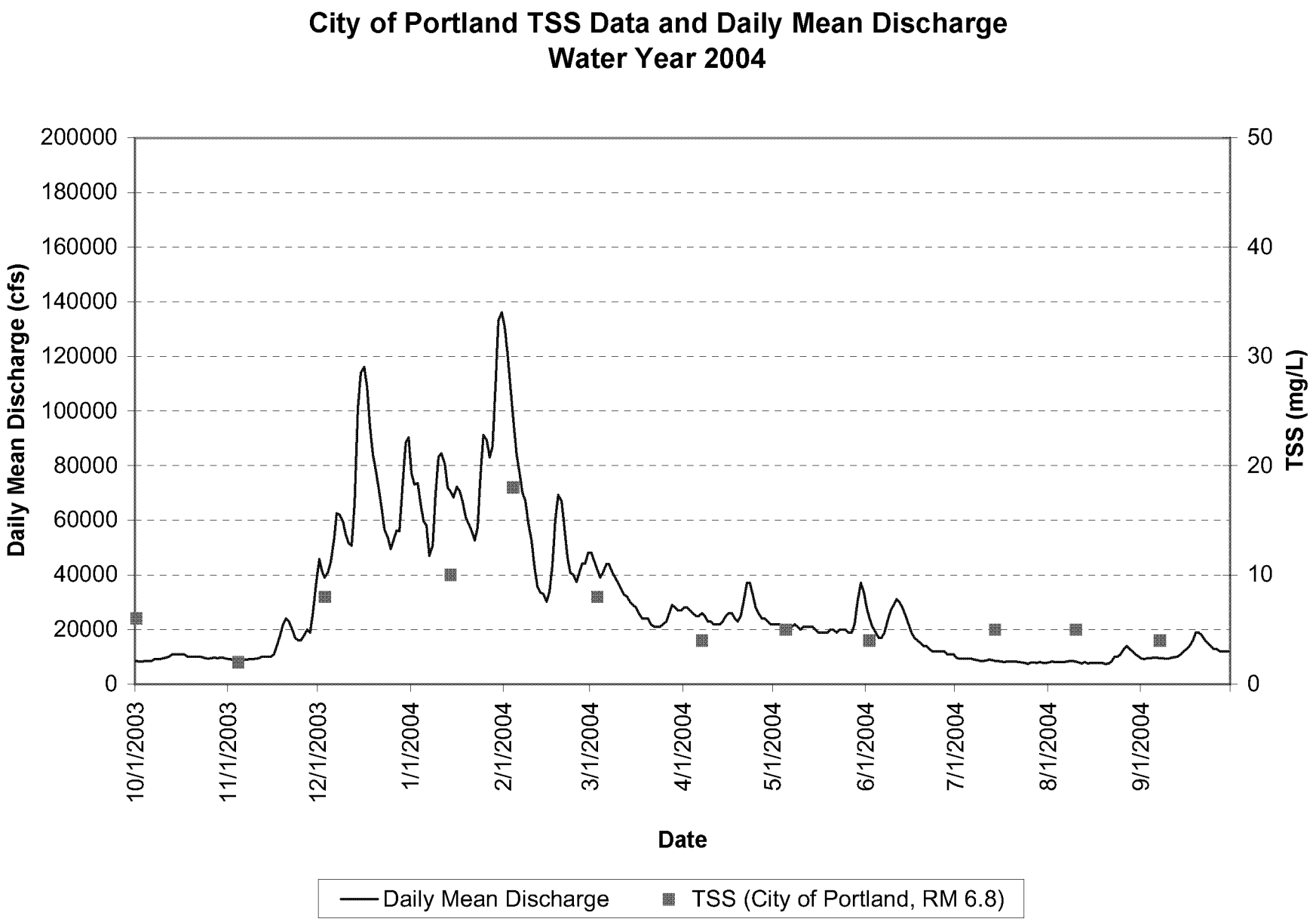
integral LWG Lower Willamette Group

Figure 4.4-3b
Portland Harbor RI/FS
Round 2 Comprehensive Report
City of Portland TSS Data and
Daily Mean Discharge Water Year 2002



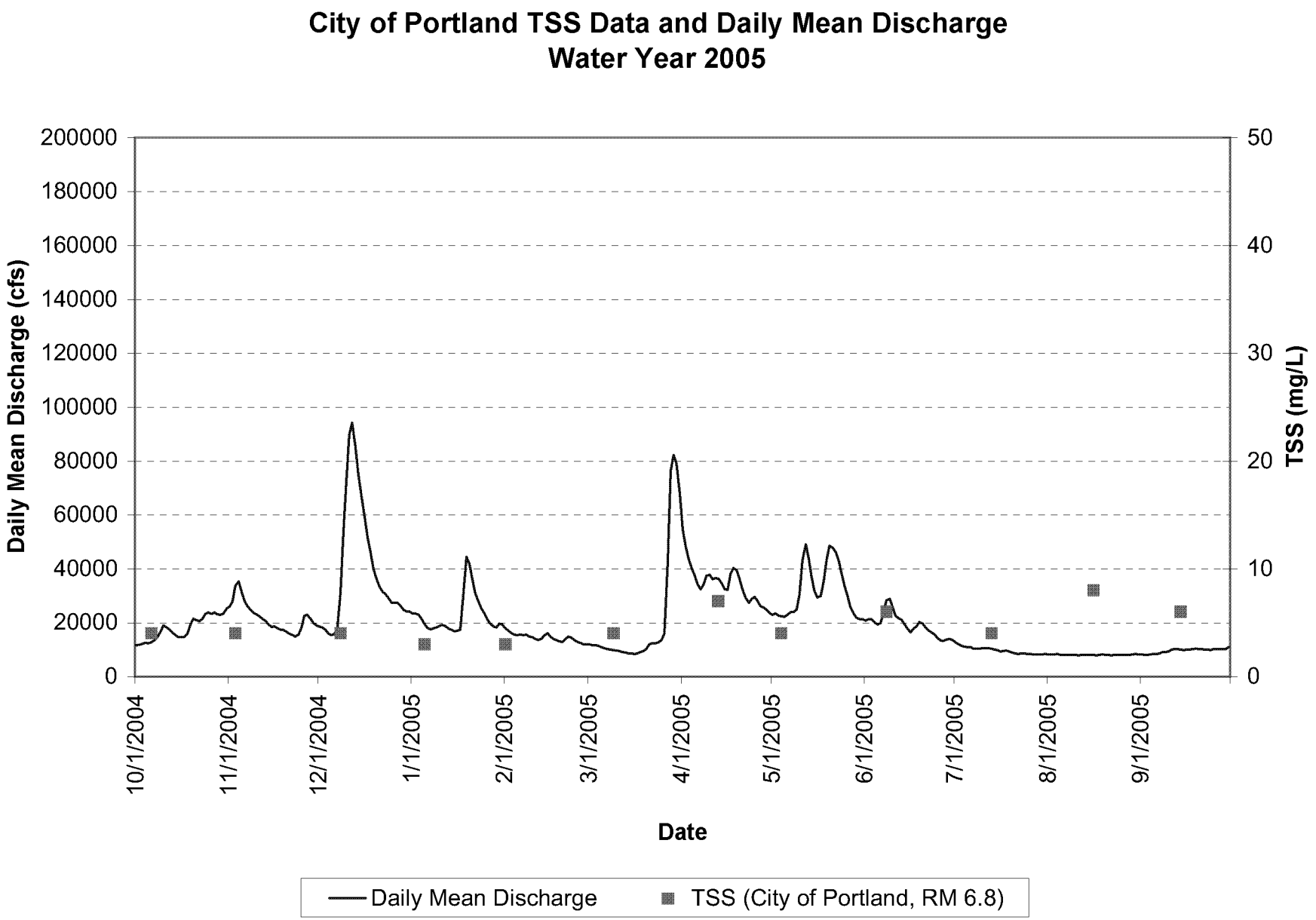
integral LWG Lower Willamette Group

Figure 4.4-3c
Portland Harbor RI/FS
Round 2 Comprehensive Report
City of Portland TSS Data and
Daily Mean Discharge Water Year 2003



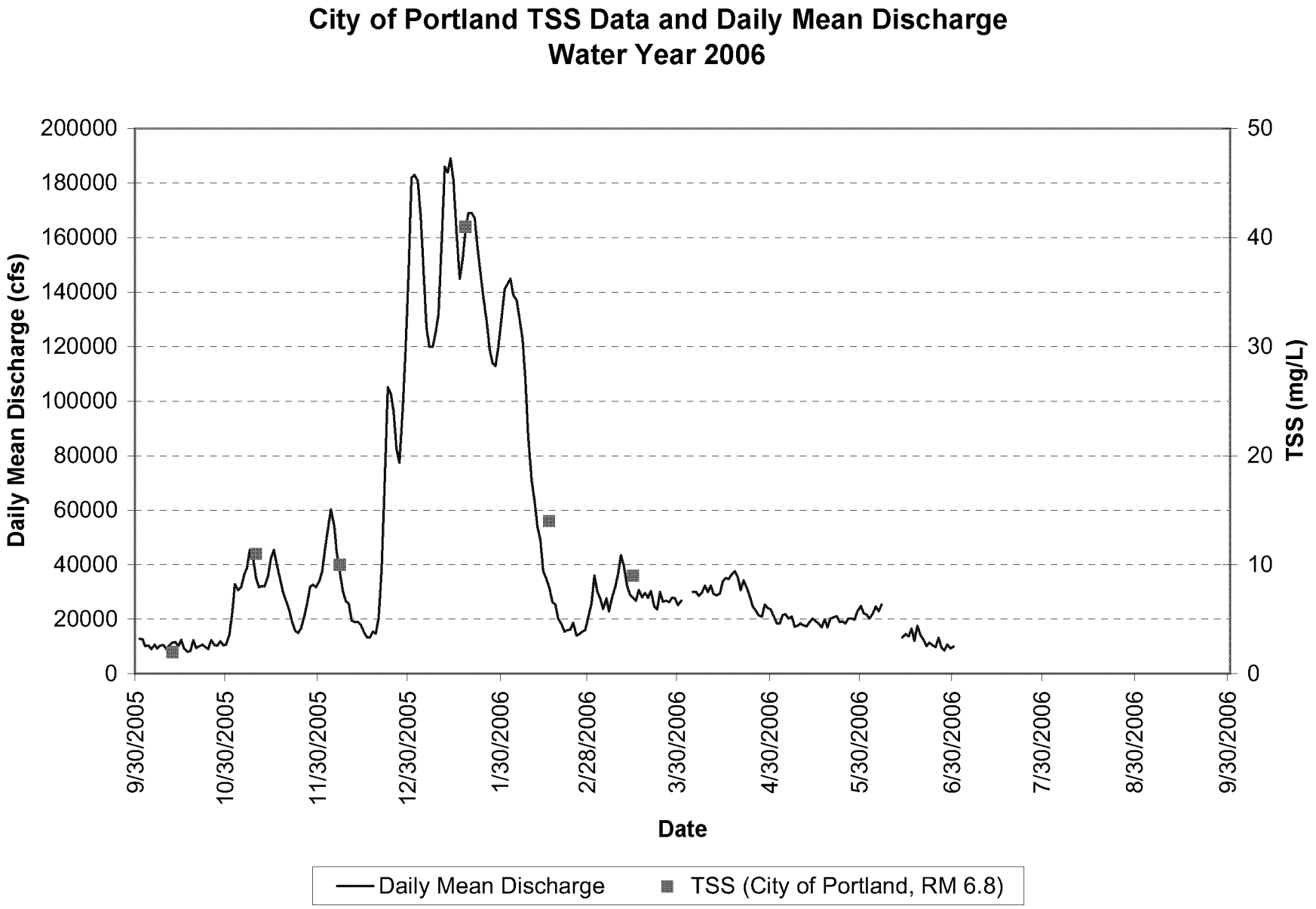
integral LWG Lower Willamette Group

Figure 4.4-3d
Portland Harbor RI/FS
Round 2 Comprehensive Report
City of Portland TSS Data and
Daily Mean Discharge Water Year 2004



integral LWG Lower Willamette Group

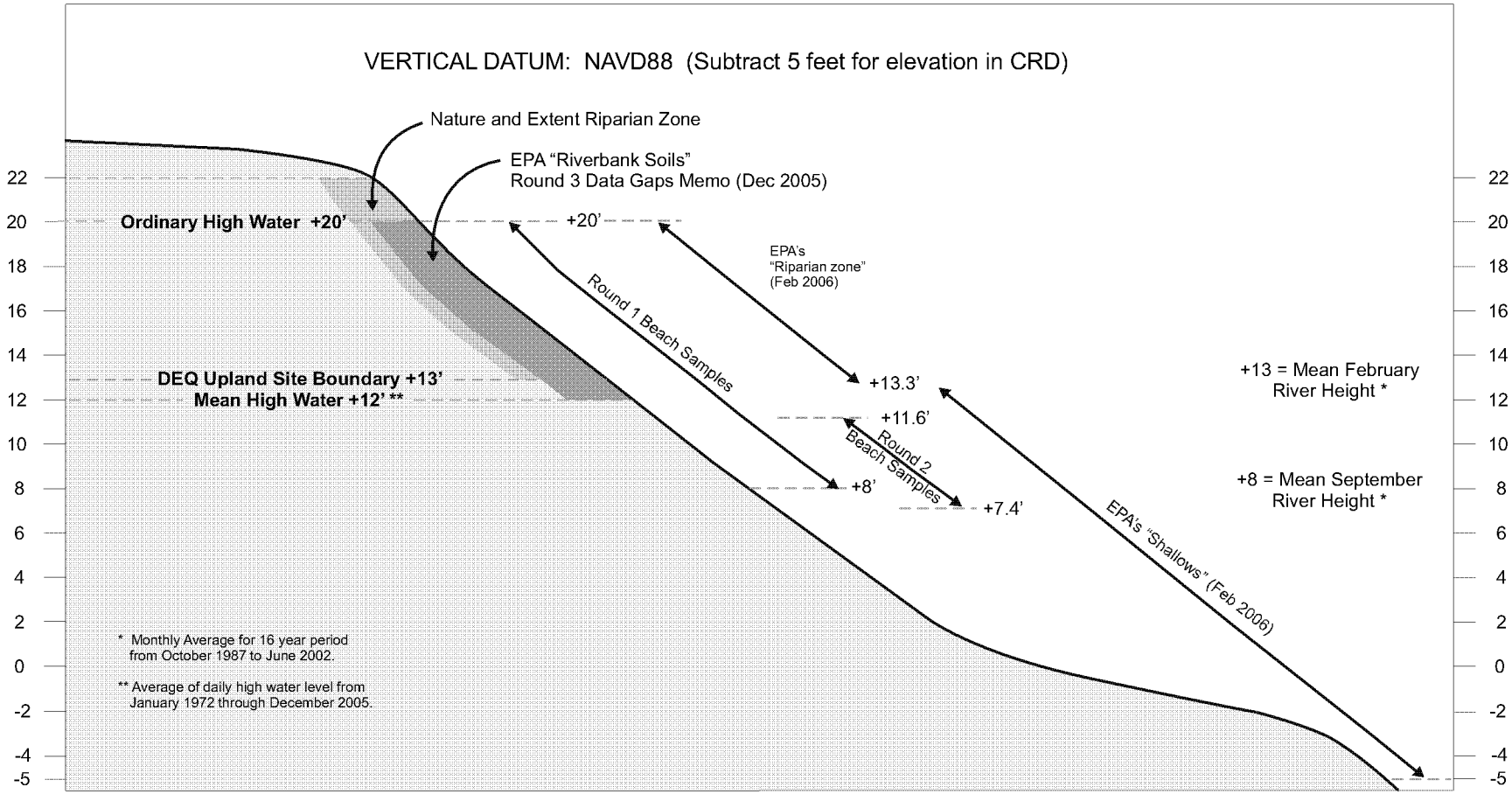
Figure 4.4-3e
Portland Harbor RI/FS
Round 2 Comprehensive Report
City of Portland TSS Data and
Daily Mean Discharge Water Year 2005



integral LWG Lower Willamette Group

Figure 4.4-3f
Portland Harbor RI/FS
Round 2 Comprehensive Report
City of Portland TSS Data and
Daily Mean Discharge Water Year 2006

Schematic Willamette River Bank Cross Section
(River mile 2 to 11)

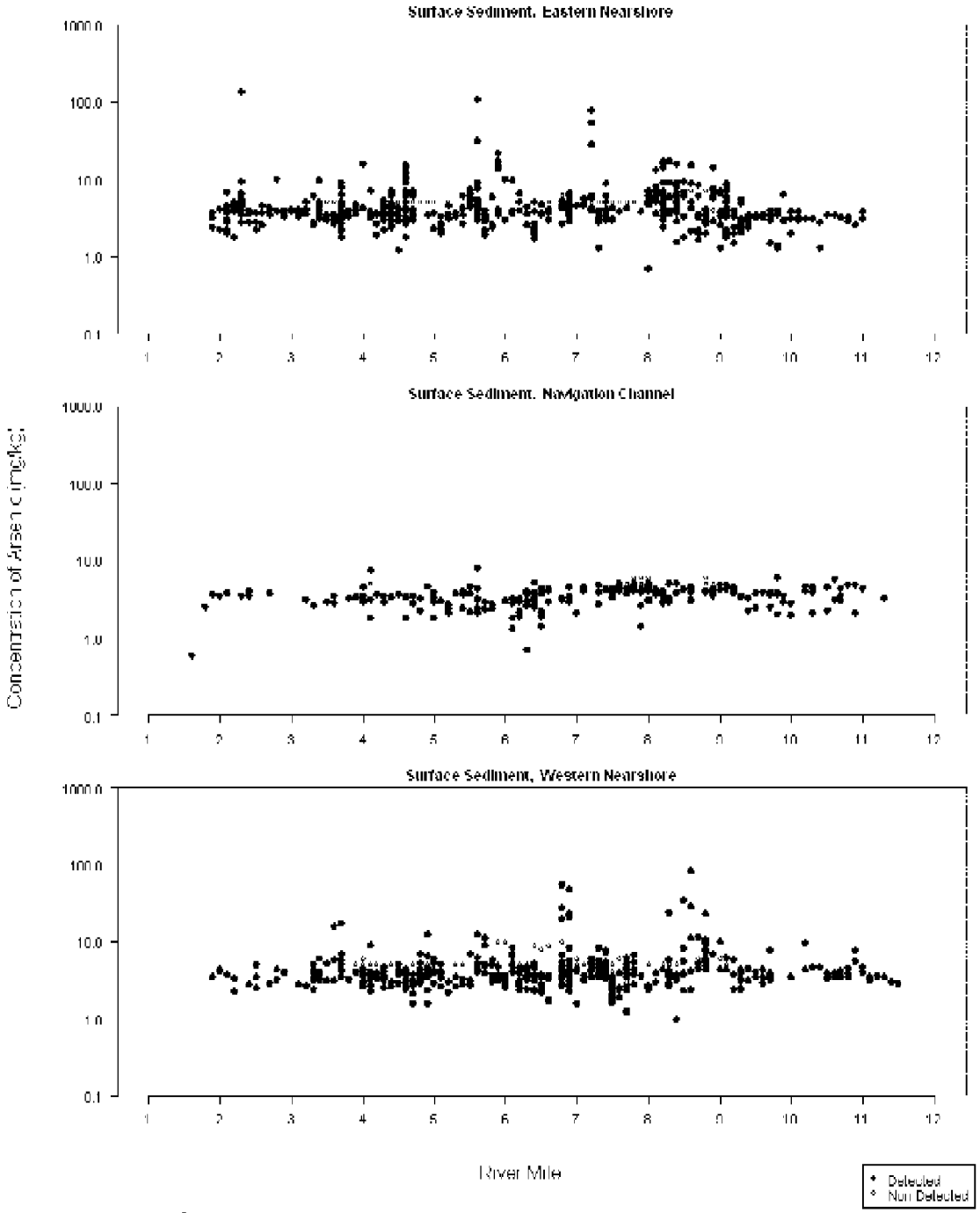


File name: Beach_Cross Section_v3.cdr

PRIVILEGED AND CONFIDENTIAL: WORK PRODUCT
PREPARED IN ANTICIPATION OF LITIGATION.

integral consulting inc.

Figure 6.1-1
Portland Harbor RI/FS
Comprehensive Round 2 Report



integral

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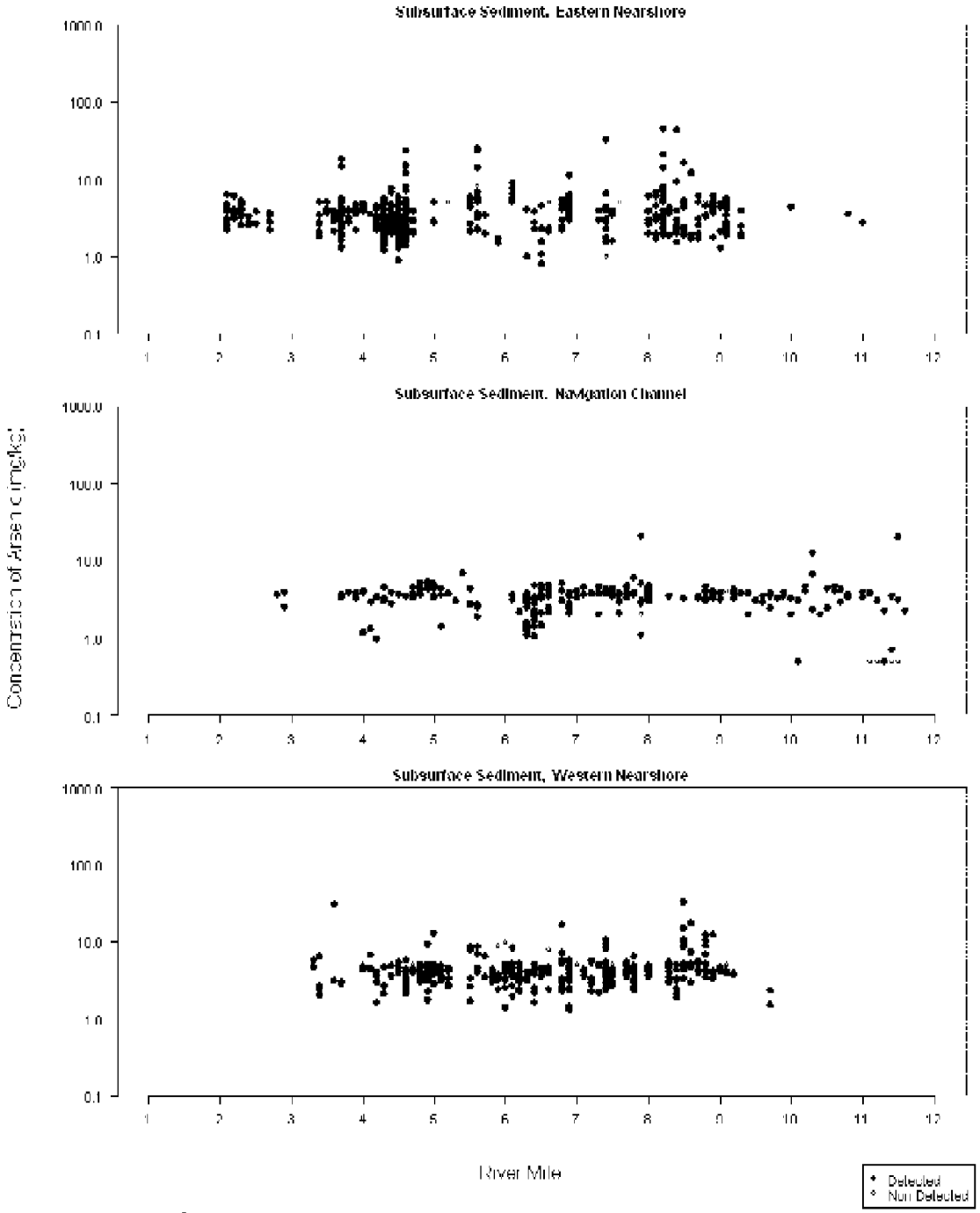
Figure 6.1-2
Portland Harbor RI/FS
Comprehensive Round 2 Report
Scatter Plot of Arsenic Concentrations (mg/kg)
in Surface Sediment, RM 2-11, Eastern Nearshore (top plot),
Navigation Channel (center plot), and Western Nearshore (bottom plot)

BZTO104(e)031477



integral

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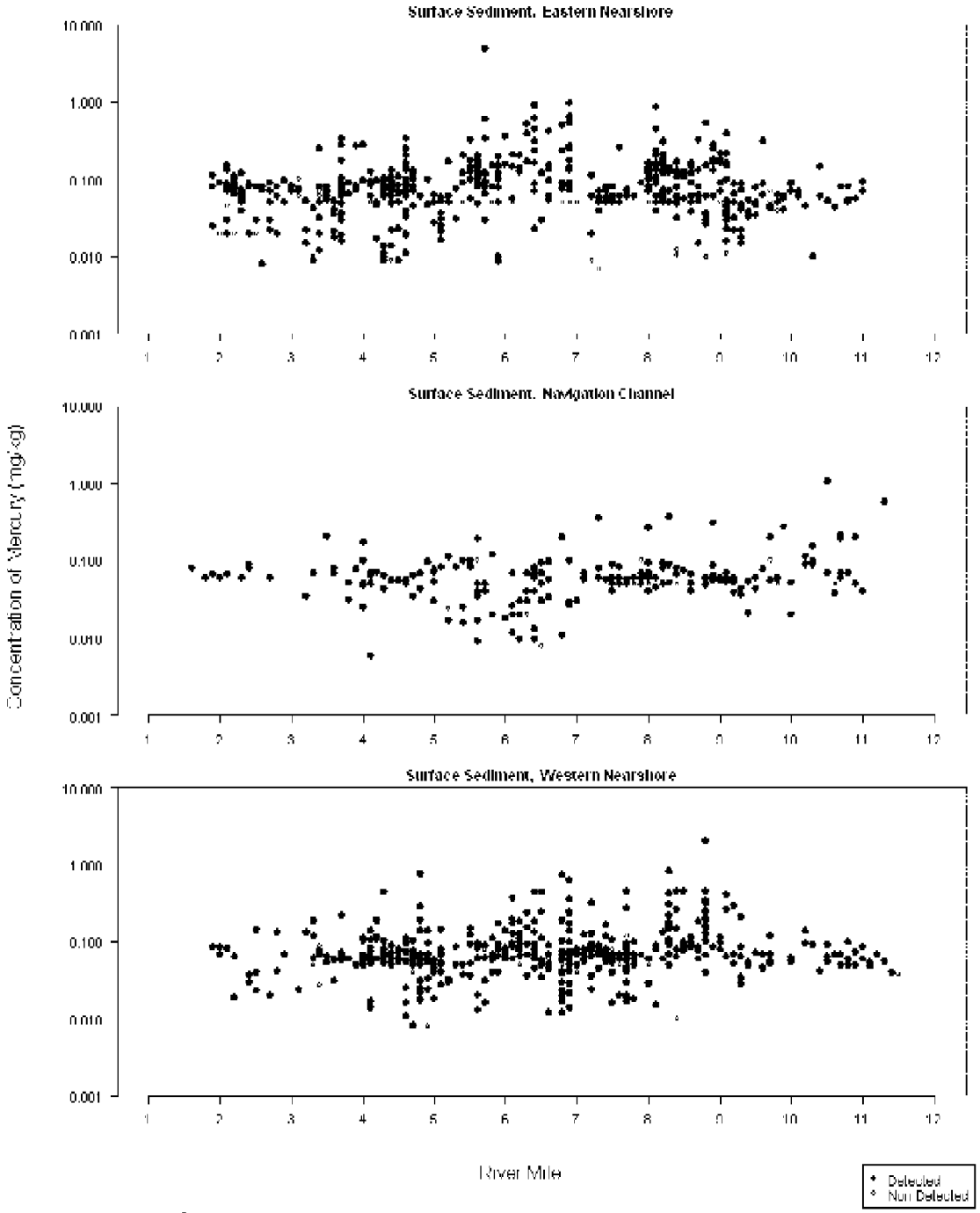
Figure 6.1-3
Portland Harbor RI/FS
Comprehensive Round 2 Report
Scatter Plot of Arsenic Concentrations (mg/kg)
in Subsurface Sediment, RM 2-11, Eastern Nearshore (top plot),
Navigation Channel (center plot), and Western Nearshore (bottom plot)

BZTO104(e)031478



integral

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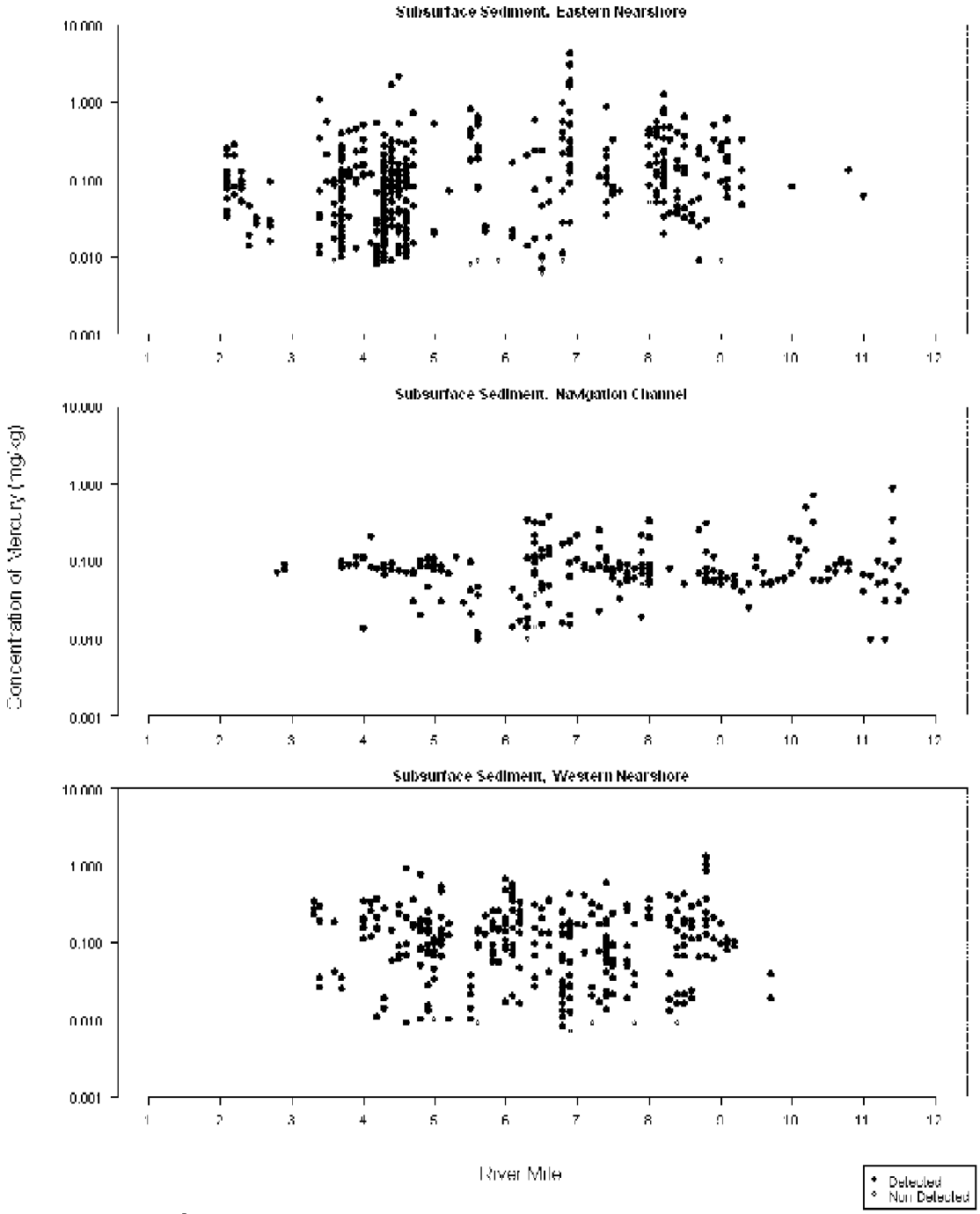
Figure 6.1-4
Portland Harbor RI/FS
Comprehensive Round 2 Report
Scatter Plot of Mercury Concentrations (mg/kg)
in Surface Sediment, RM 2-11, Eastern Nearshore (top plot),
Navigation Channel (center plot), and Western Nearshore (bottom plot)

BZTO104(e)031479



integral

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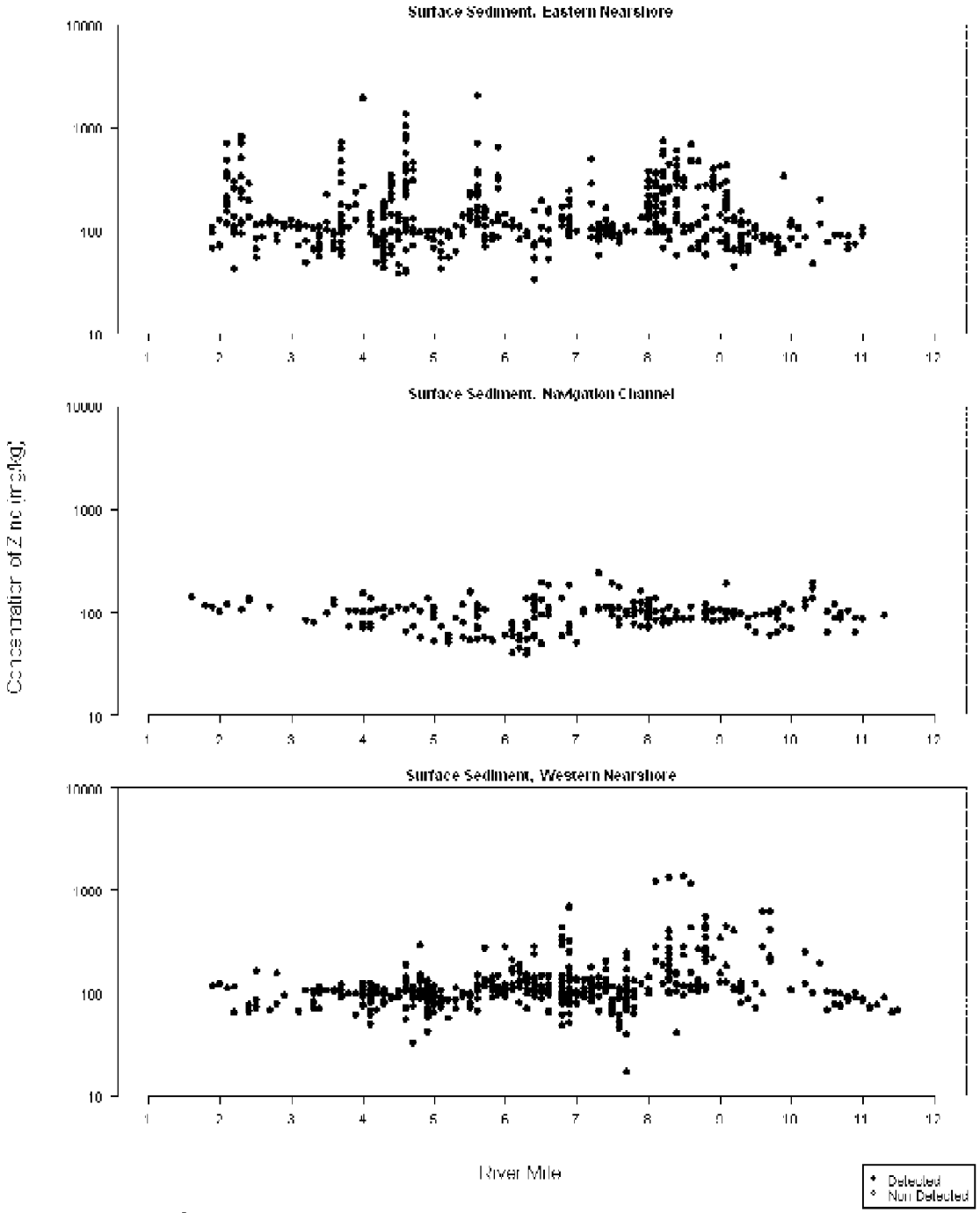
Figure 6.1-5
Portland Harbor RI/FS
Comprehensive Round 2 Report
Scatter Plot of Mercury Concentrations (mg/kg)
in Subsurface Sediment, RM 2-11, Eastern Nearshore (top plot),
Navigation Channel (center plot), and Western Nearshore (bottom plot)

BZTO104(e)031480



integral

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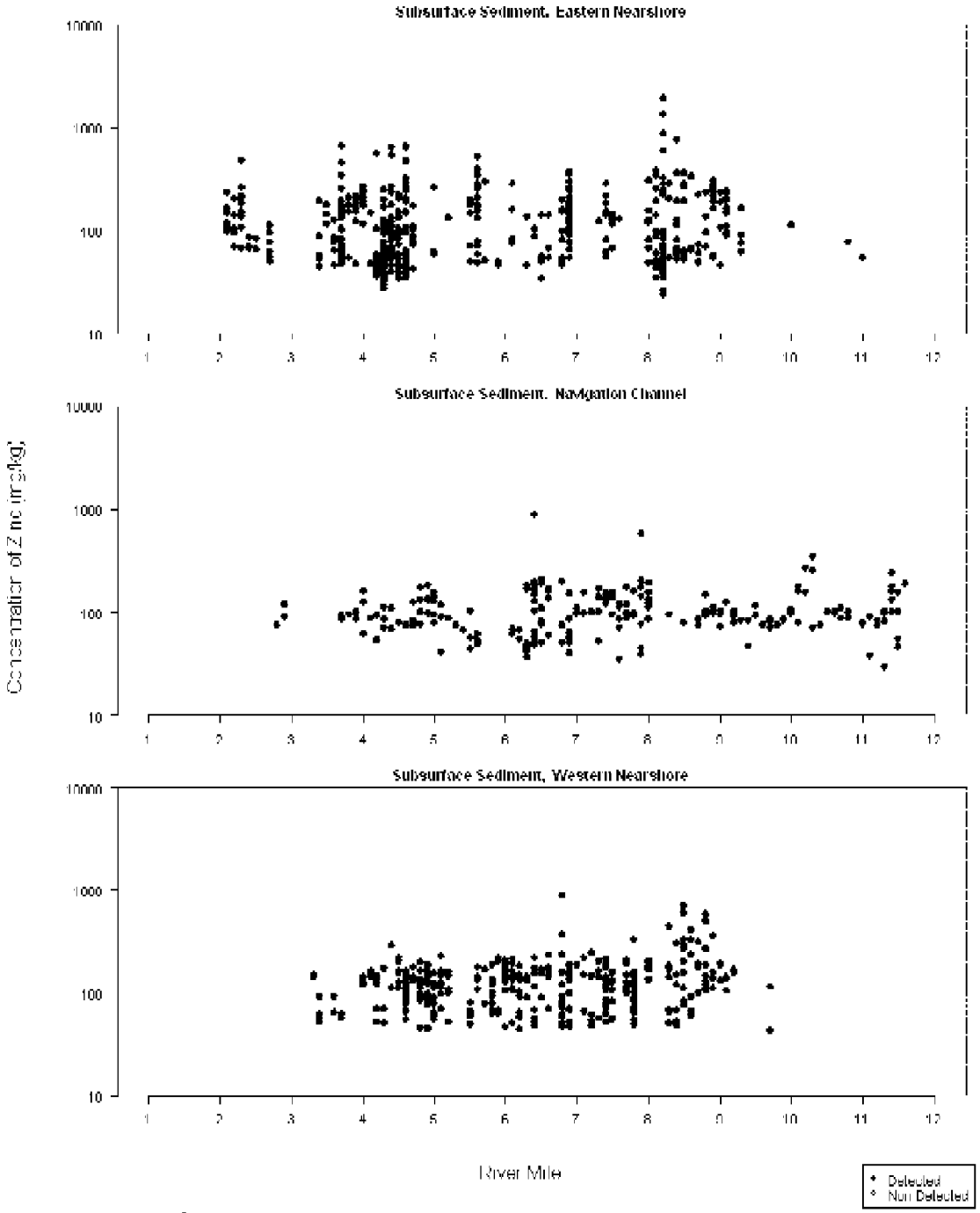
Figure 6.1-6
Portland Harbor RI/FS
Comprehensive Round 2 Report
Scatter Plot of Zinc Concentrations (mg/kg)
in Surface Sediment, RM 2-11, Eastern Nearshore (top plot),
Navigation Channel (center plot), and Western Nearshore (bottom plot)

BZTO104(e)031481



integral

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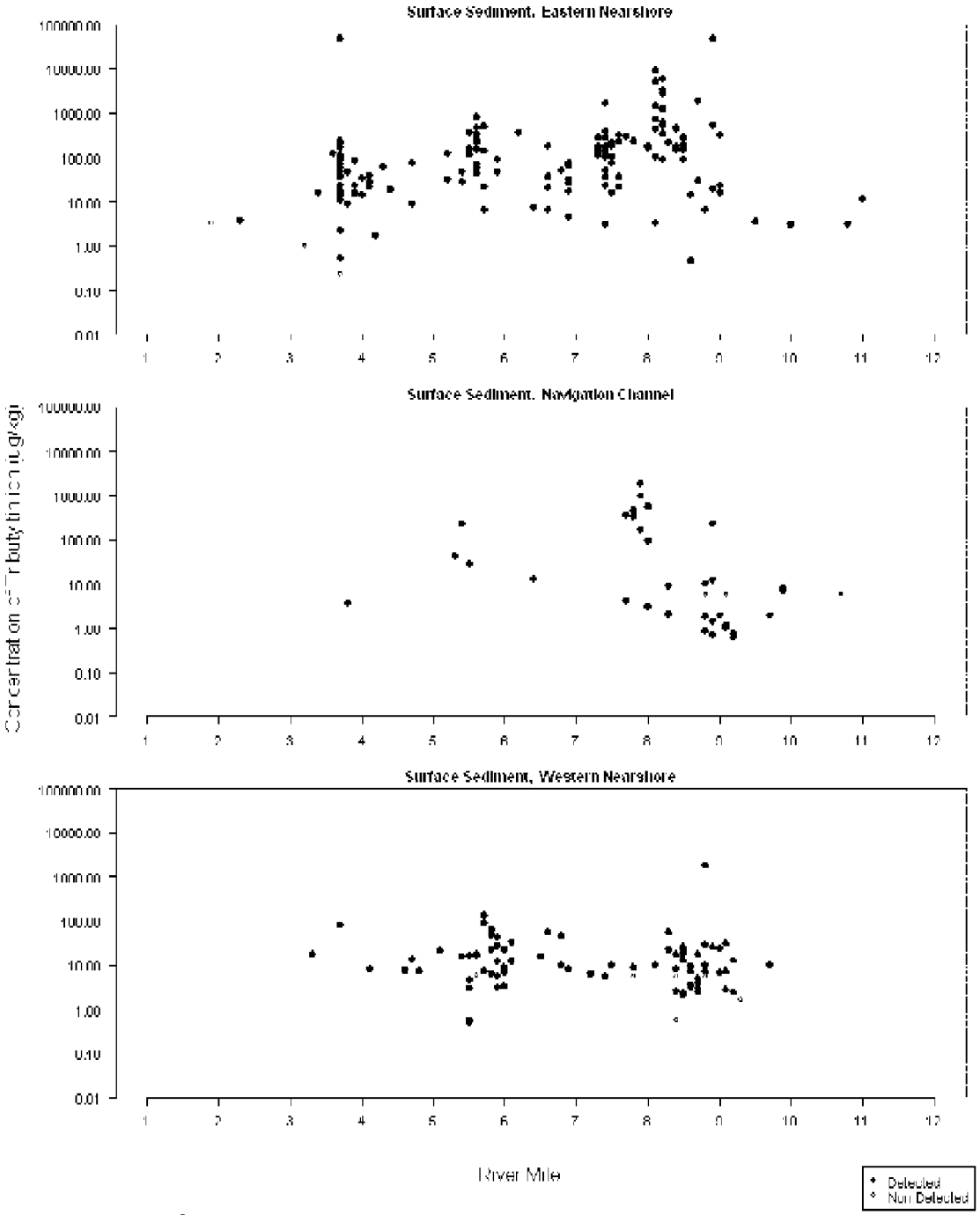
Figure 6.1-7
Portland Harbor RI/FS
Comprehensive Round 2 Report
Scatter Plot of Zinc Concentrations (mg/kg)
in Subsurface Sediment, RM 2-11, Eastern Nearshore (top plot),
Navigation Channel (center plot), and Western Nearshore (bottom plot)

BZTO104(e)031482



integral

LWG
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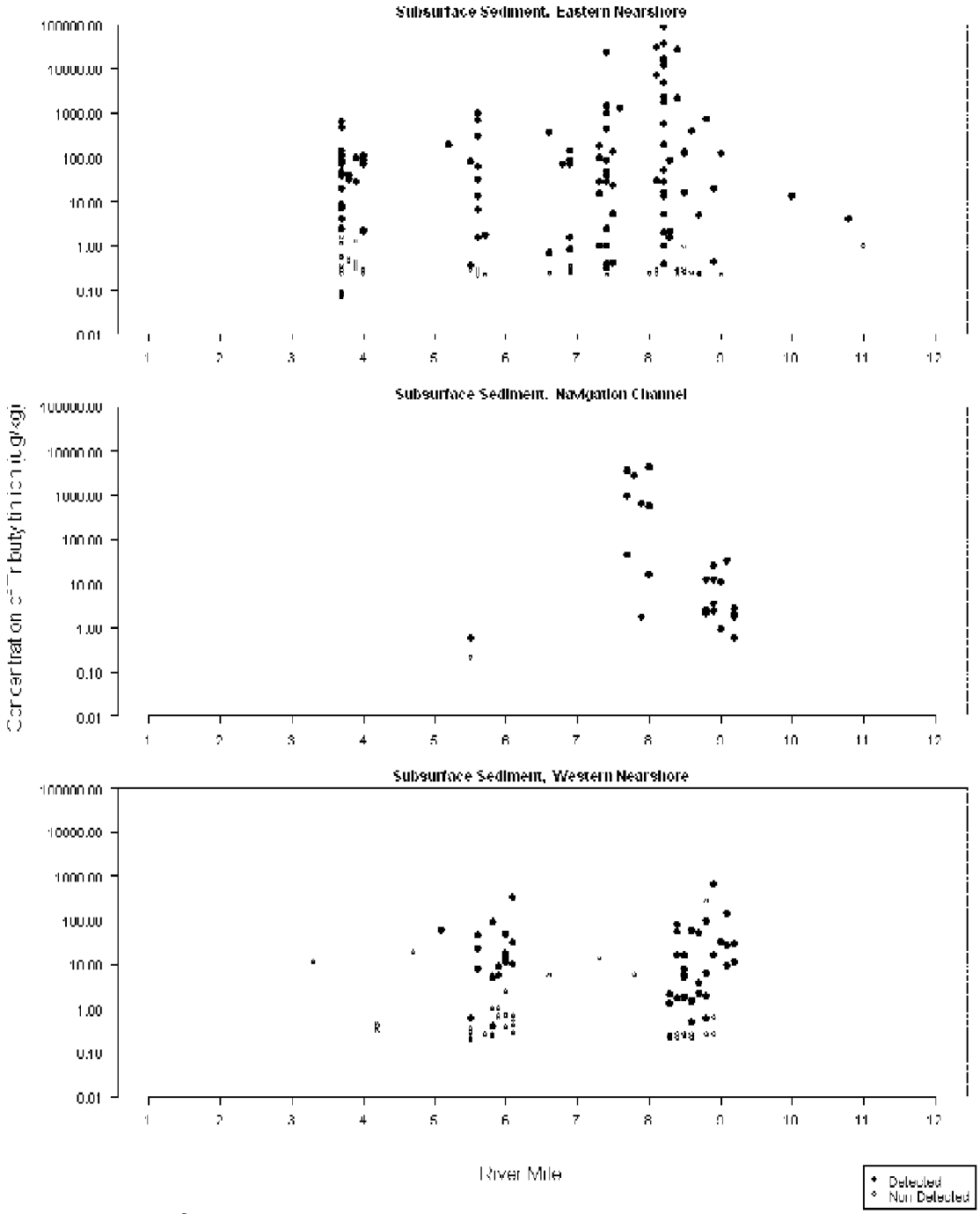
Figure 6.1-8
Portland Harbor RI/FS
Comprehensive Round 2 Report
Scatter Plot of Tributyltin Ion Concentrations (ug/kg)
in Surface Sediment, RM 2-11, Eastern Nearshore (top plot),
Navigation Channel (center plot), and Western Nearshore (bottom plot)

BZTO104(e)031483



integral

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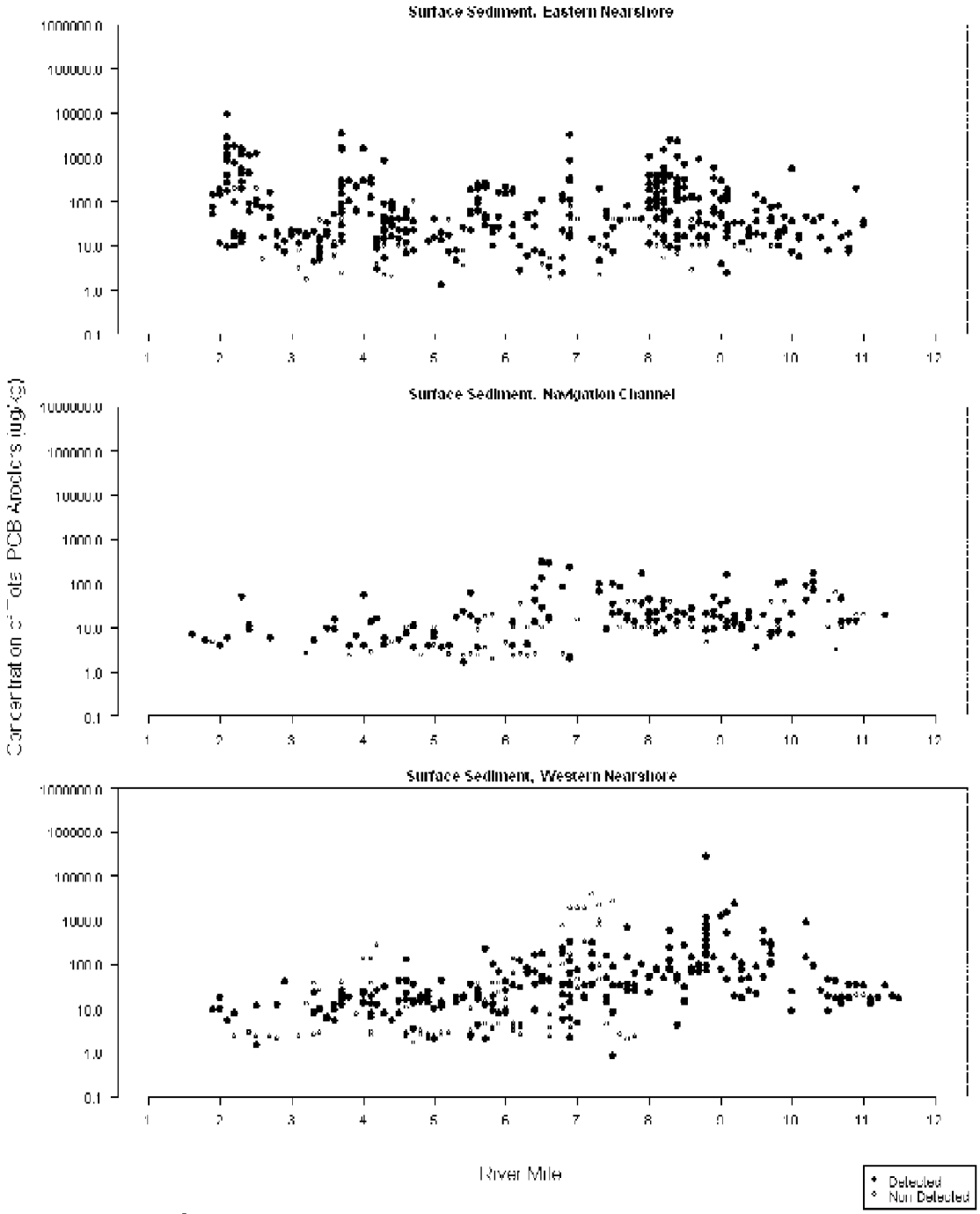
Figure 6.1-9
Portland Harbor RI/FS
Comprehensive Round 2 Report
Scatter Plot of Tributyltin Ion Concentrations (ug/kg)
in Subsurface Sediment, RM 2-11, Eastern Nearshore (top plot),
Navigation Channel (center plot), and Western Nearshore (bottom plot)

BZTO104(e)031484



integral

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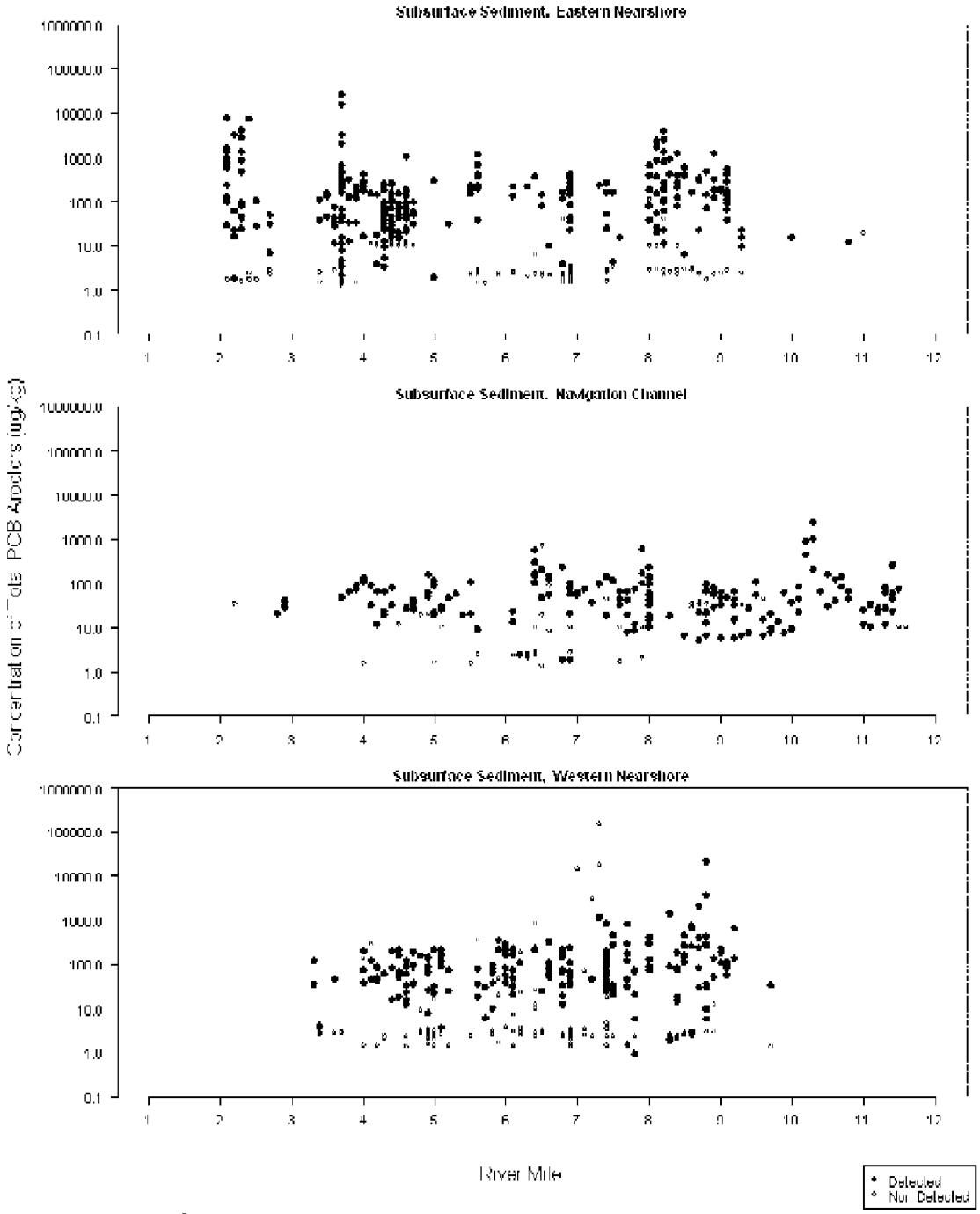
Figure 6.1-10
Portland Harbor RI/FS
Comprehensive Round 2 Report
Scatter Plot of Total PCB Aroclors Concentrations (ug/kg)
in Surface Sediment, RM 2-11, Eastern Nearshore (top plot),
Navigation Channel (center plot), and Western Nearshore (bottom plot)

BZTO104(e)031485



integral

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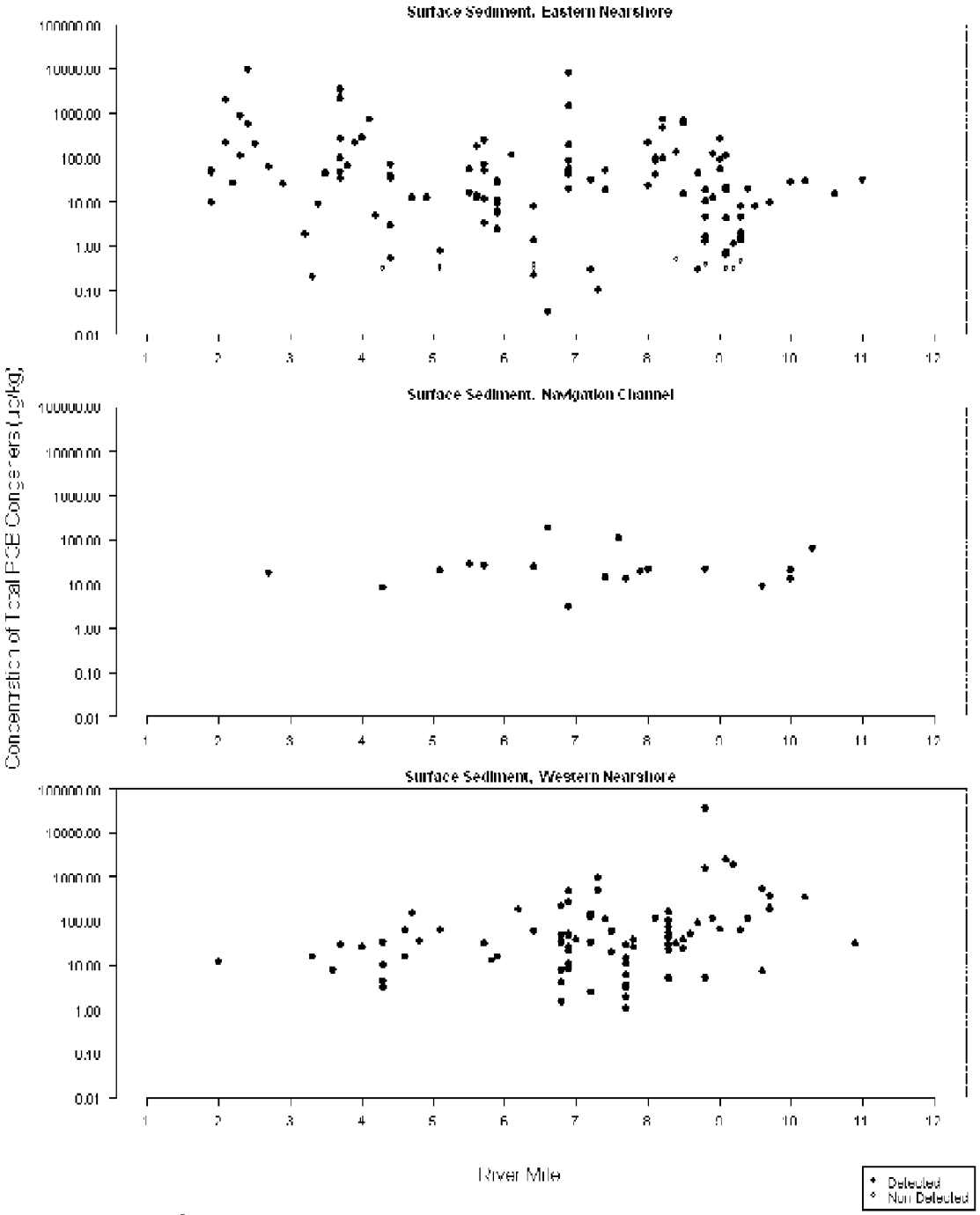
Figure 6.1-11
Portland Harbor RI/FS
Comprehensive Round 2 Report
Scatter Plot of Total PCB Aroclors Concentrations (ug/kg)
in Subsurface Sediment, RM 2-11, Eastern Nearshore (top plot),
Navigation Channel (center plot), and Western Nearshore (bottom plot)

BZTO104(e)031486



integral

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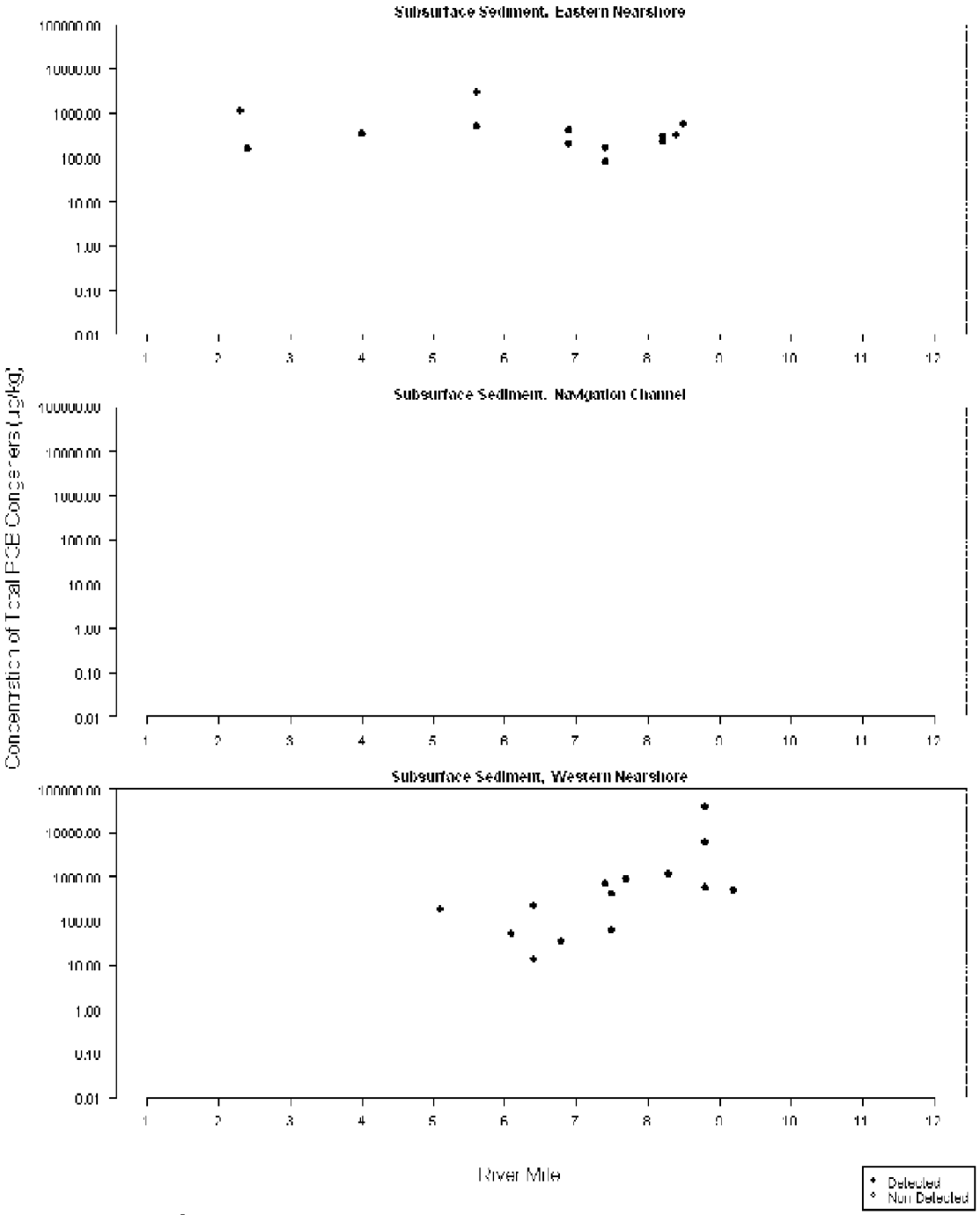
Figure 6.1-12
Portland Harbor RI/FS
Comprehensive Round 2 Report
Scatter Plot of Total PCB Congeners Concentrations (ug/kg)
in Surface Sediment, RM 2-11, Eastern Nearshore (top plot),
Navigation Channel (center plot), and Western Nearshore (bottom plot)

BZTO104(e)031487



integral

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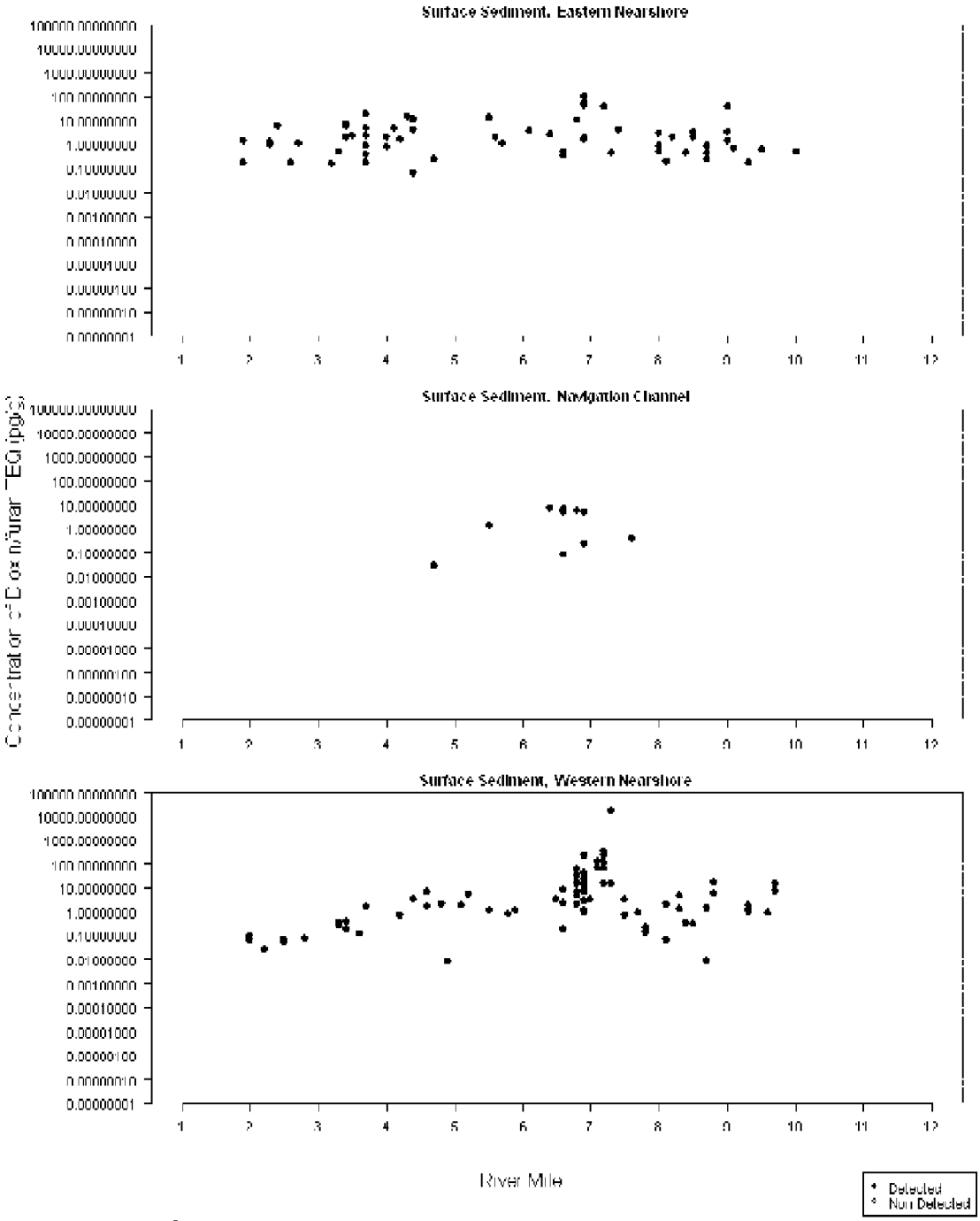
Figure 6.1-13
Portland Harbor RI/FS
Comprehensive Round 2 Report
Scatter Plot of Total PCB Congeners Concentrations (ug/kg)
in Subsurface Sediment, RM 2-11, Eastern Nearshore (top plot),
Navigation Channel (center plot), and Western Nearshore (bottom plot)

BZTO104(e)031488



Note Y-axis is linear.

integral

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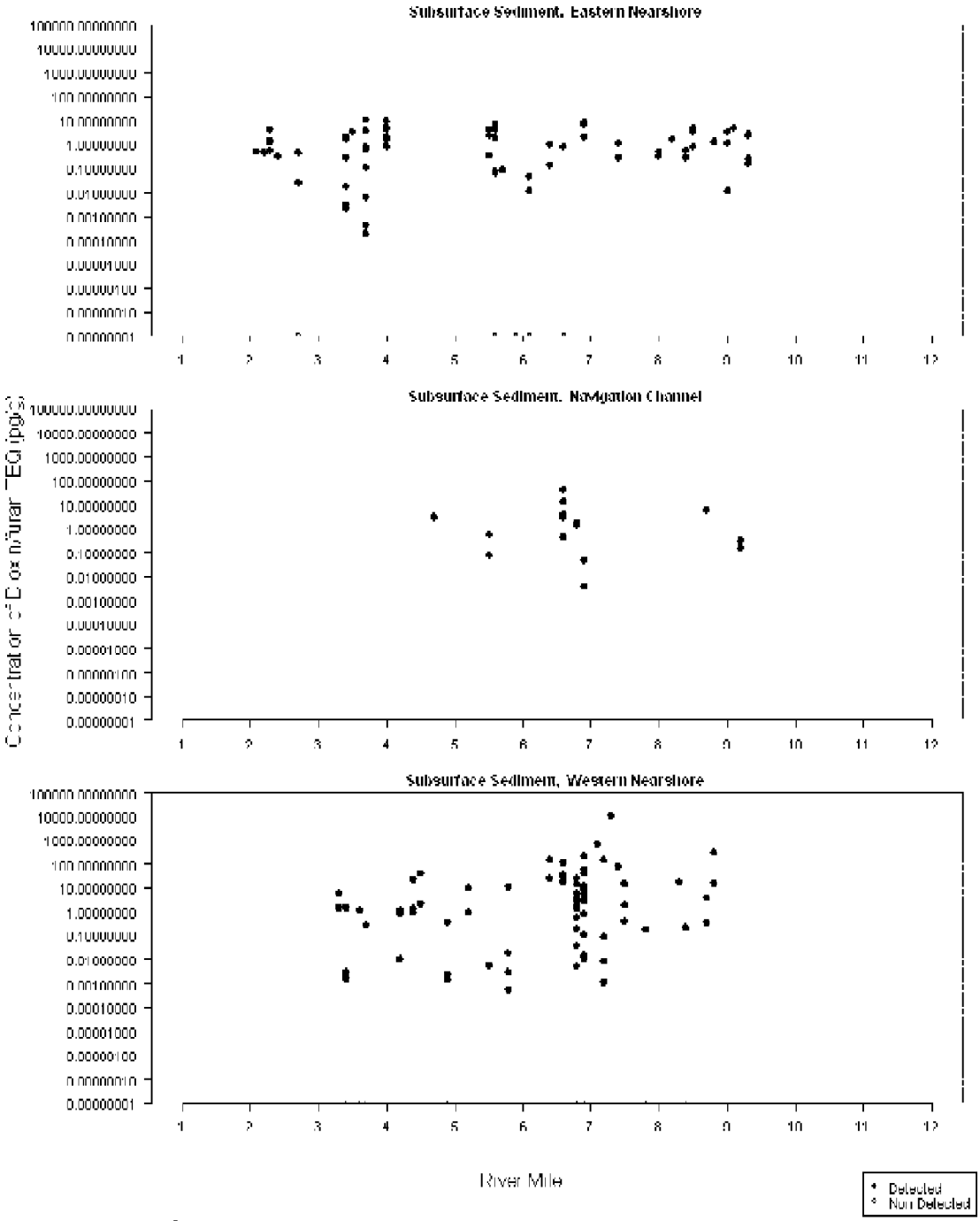
Figure 6.1-14
Portland Harbor RI/FS
Comprehensive Round 2 Report
Scatter Plot of Dioxin/furan TEQ Concentrations (pg/g)
in Surface Sediment, RM 2-11, Eastern Nearshore (top plot),
Navigation Channel (center plot), and Western Nearshore (bottom plot)

BZTO104(e)031489



Note Y-axis is linear.

integral

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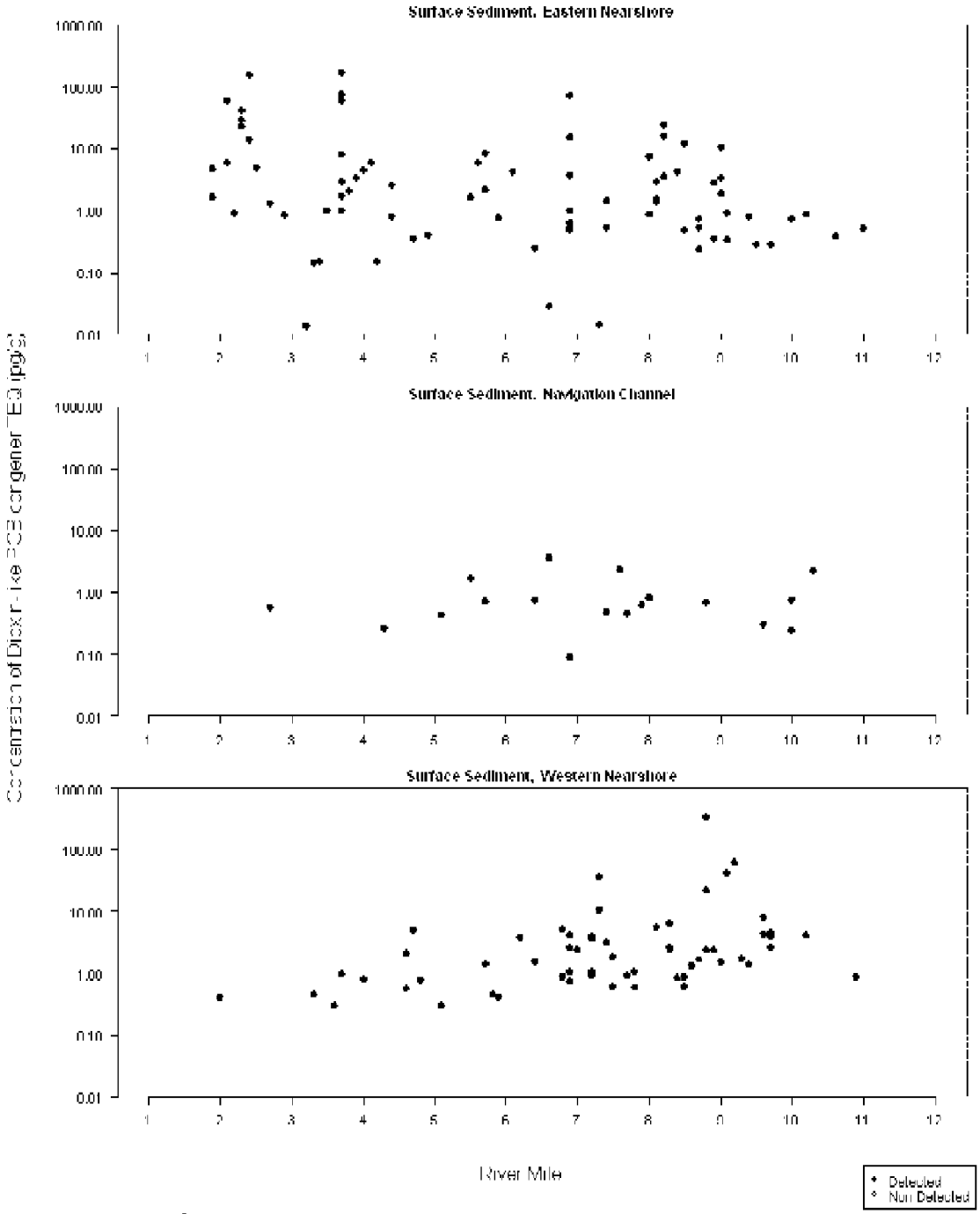
Figure 6.1-15
Portland Harbor RI/FS
Comprehensive Round 2 Report
Scatter Plot of Dioxin/furan TEQ Concentrations (pg/g)
in Subsurface Sediment, RM 2-11, Eastern Nearshore (top plot),
Navigation Channel (center plot), and Western Nearshore (bottom plot)

BZTO104(e)031490



integral

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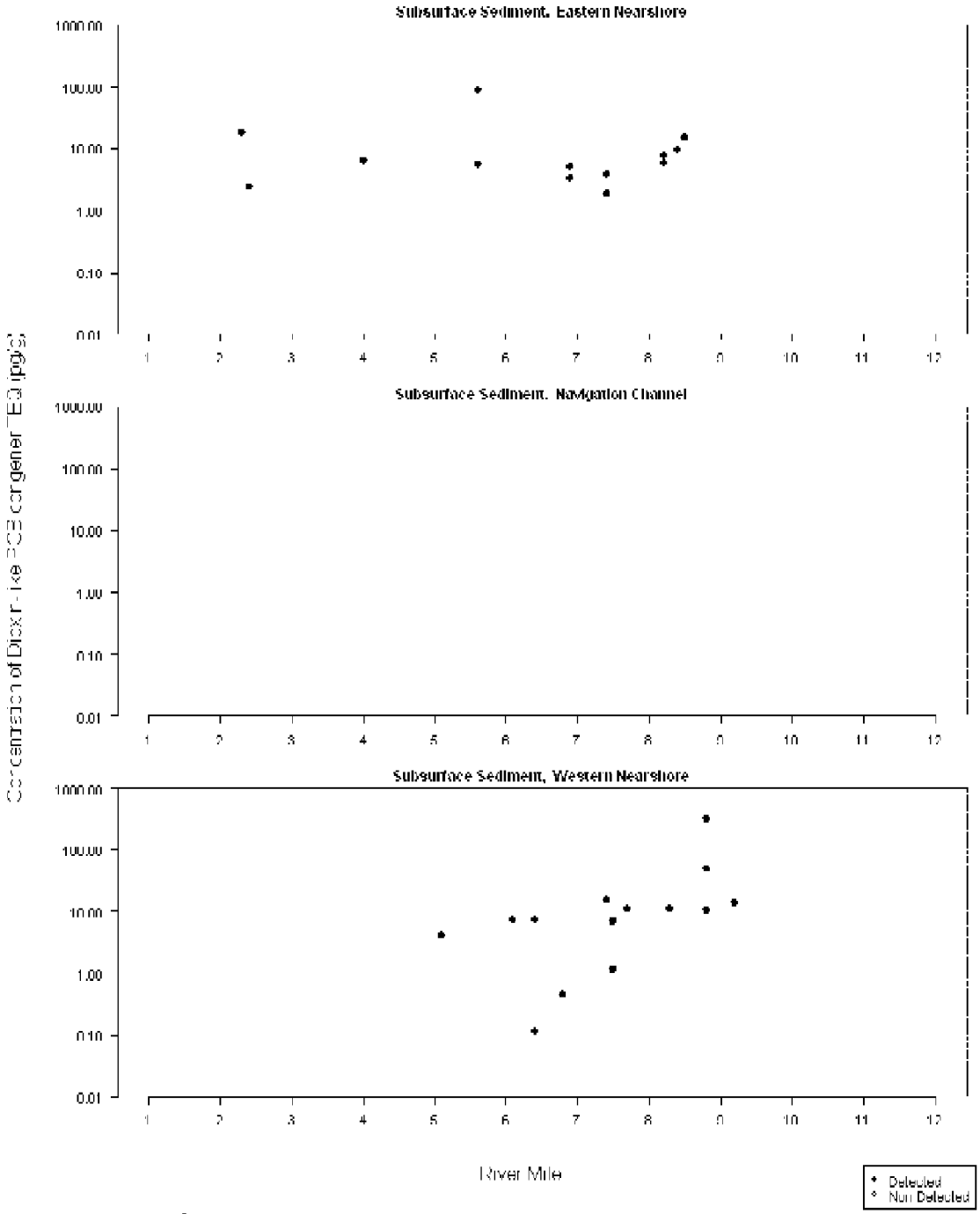
Figure 6.1-16
Portland Harbor RI/FS
Comprehensive Round 2 Report
Scatter Plot of Dioxin-like PCB congener TEQ Concentrations (pg/g)
in Surface Sediment, RM 2-11, Eastern Nearshore (top plot),
Navigation Channel (center plot), and Western Nearshore (bottom plot)

BZTO104(e)031491



integral

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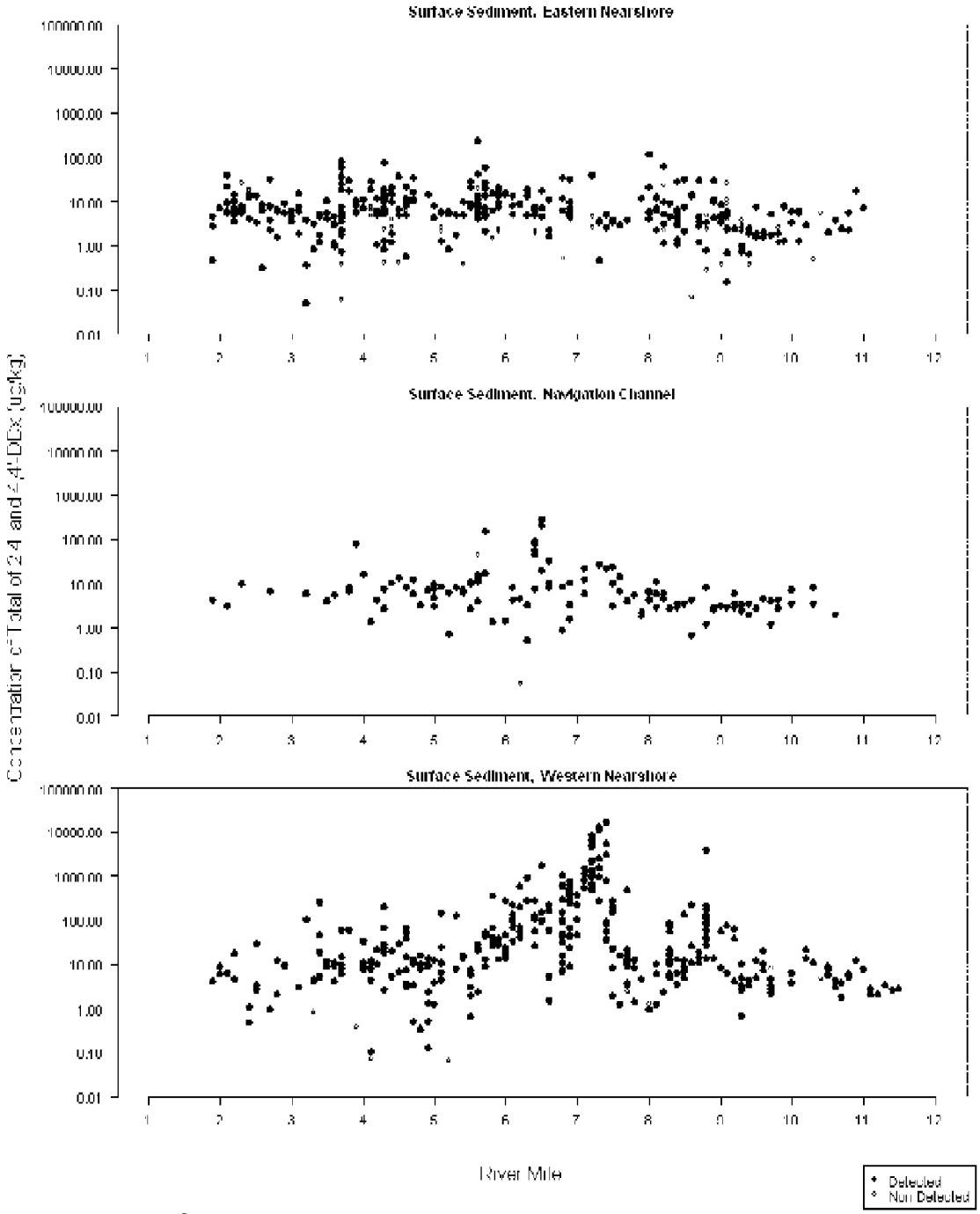
Figure 6.1-17
Portland Harbor RI/FS
Comprehensive Round 2 Report
Scatter Plot of Dioxin-like PCB congener TEQ Concentrations (pg/g)
in Subsurface Sediment, RM 2-11, Eastern Nearshore (top plot),
Navigation Channel (center plot), and Western Nearshore (bottom plot)

BZTO104(e)031492



integral

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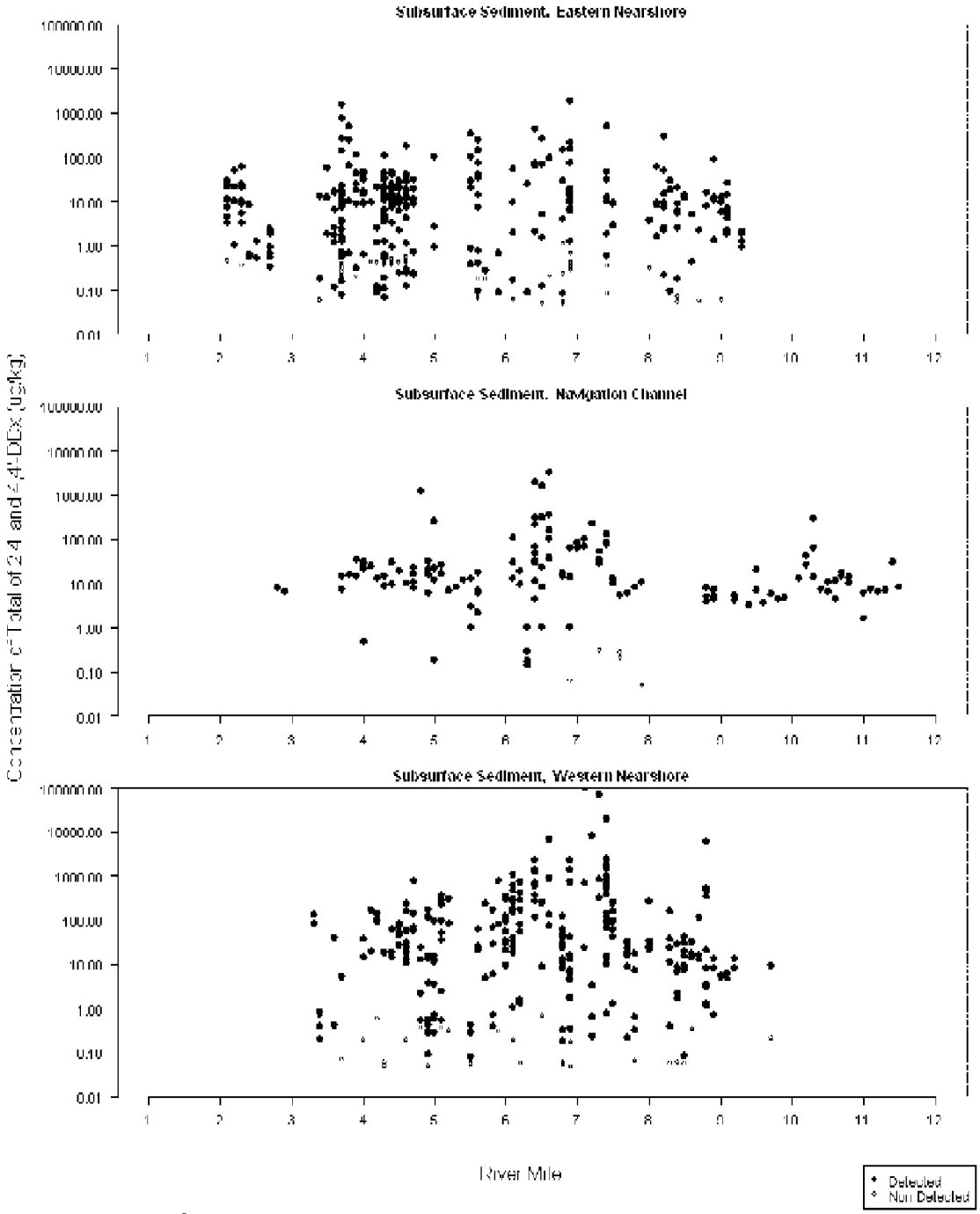
Figure 6.1-18
Portland Harbor RI/FS
Comprehensive Round 2 Report
Scatter Plot of Total of 2,4' and 4,4'-DDx Concentrations (ug/kg)
in Surface Sediment, RM 2-11, Eastern Nearshore (top plot),
Navigation Channel (center plot), and Western Nearshore (bottom plot)

BZTO104(e)031493



integral

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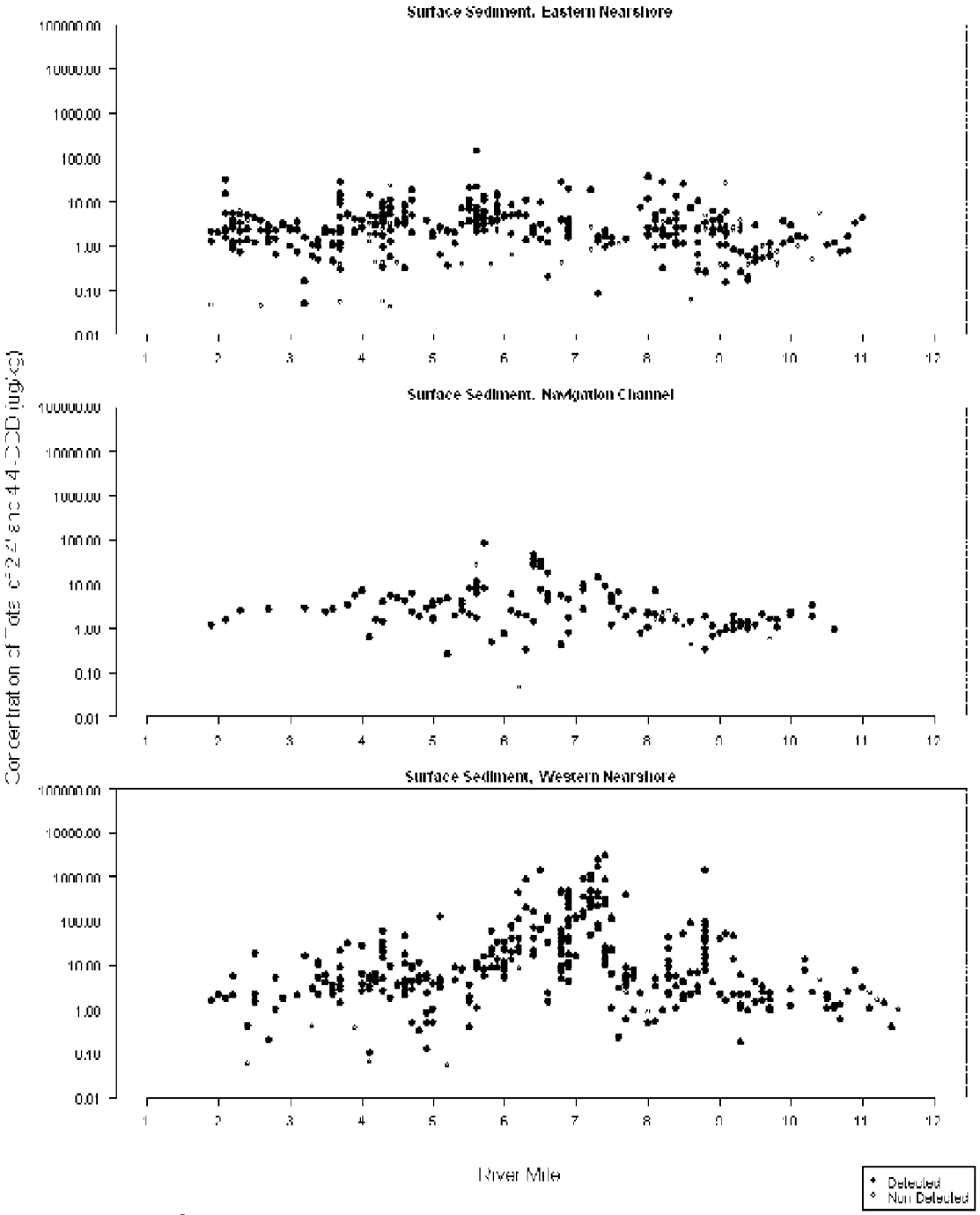
Figure 6.1-19
Portland Harbor RI/FS
Comprehensive Round 2 Report
Scatter Plot of Total of 2,4' and 4,4'-DDx Concentrations (ug/kg)
in Subsurface Sediment, RM 2-11, Eastern Nearshore (top plot),
Navigation Channel (center plot), and Western Nearshore (bottom plot)

BZTO104(e)031494



integral

LWG
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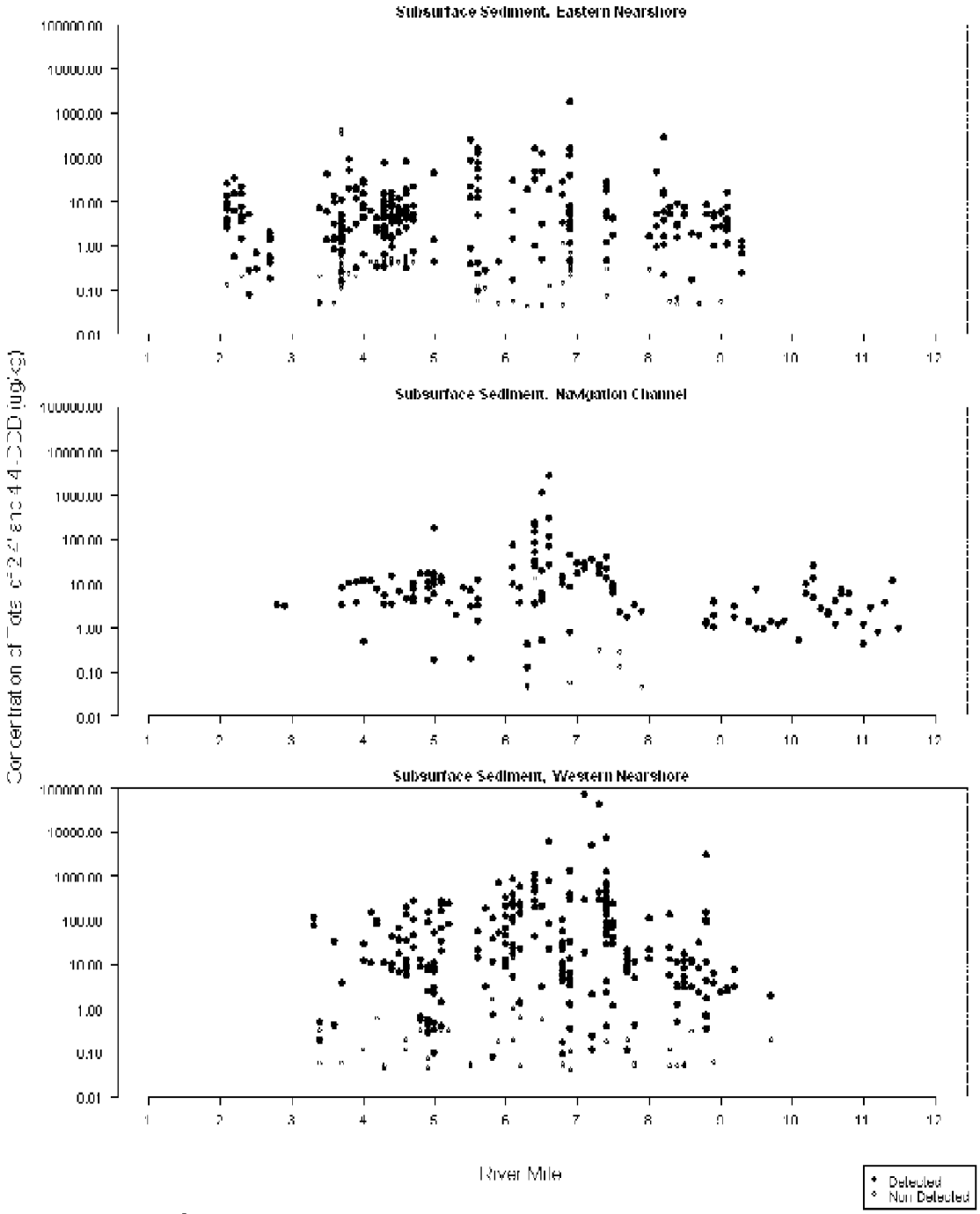
Figure 6.1-20
Portland Harbor RI/FS
Comprehensive Round 2 Report
Scatter Plot of Total of 2,4' and 4,4'-DDD Concentrations (ug/kg)
in Surface Sediment, RM 2-11, Eastern Nearshore (top plot),
Navigation Channel (center plot), and Western Nearshore (bottom plot)

BZTO104(e)031495



integral

LWG
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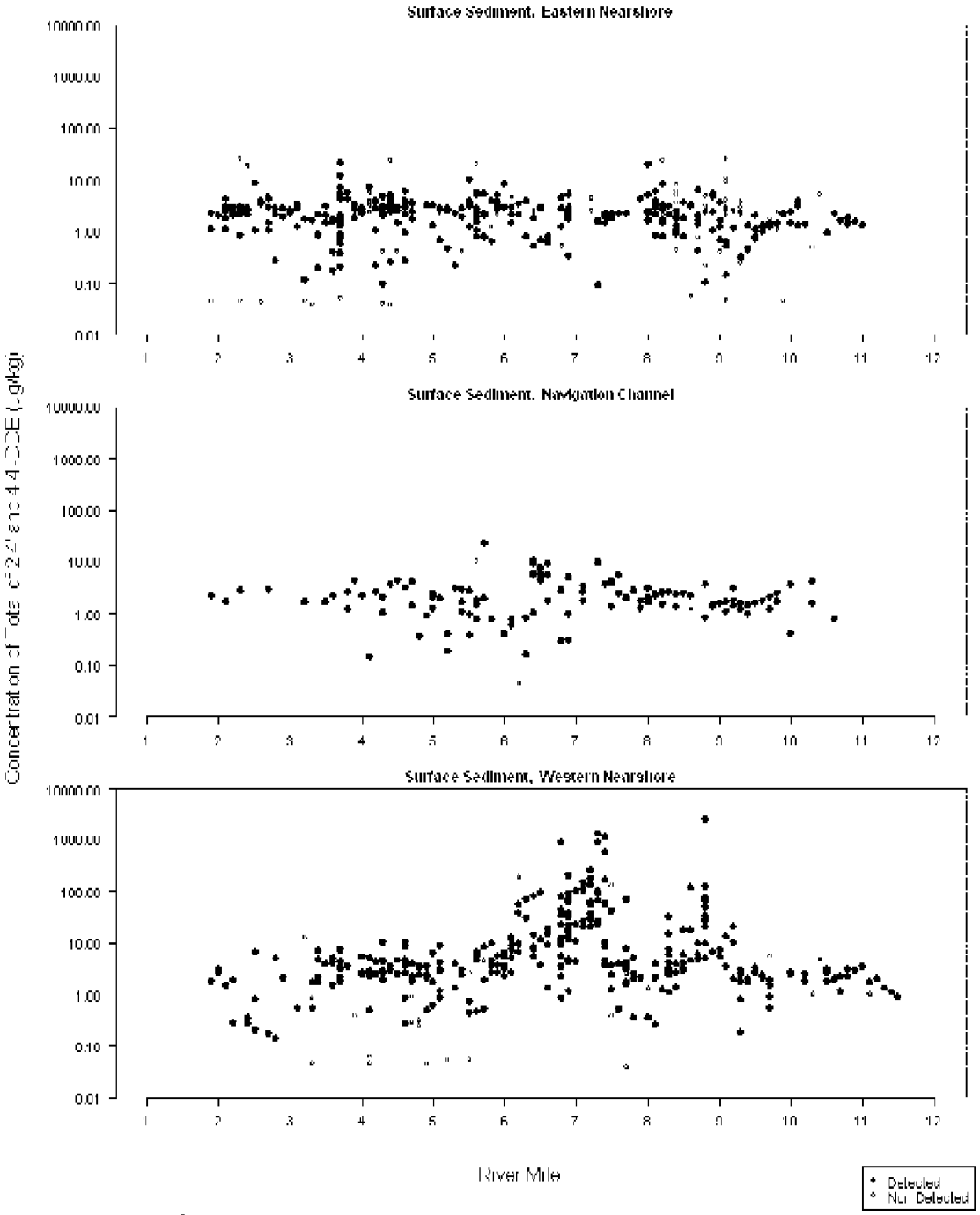
Figure 6.1-21
Portland Harbor RI/FS
Comprehensive Round 2 Report
Scatter Plot of Total of 2,4' and 4,4'-DDD Concentrations (ug/kg)
in Subsurface Sediment, RM 2-11, Eastern Nearshore (top plot),
Navigation Channel (center plot), and Western Nearshore (bottom plot)

BZTO104(e)031496



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LWG
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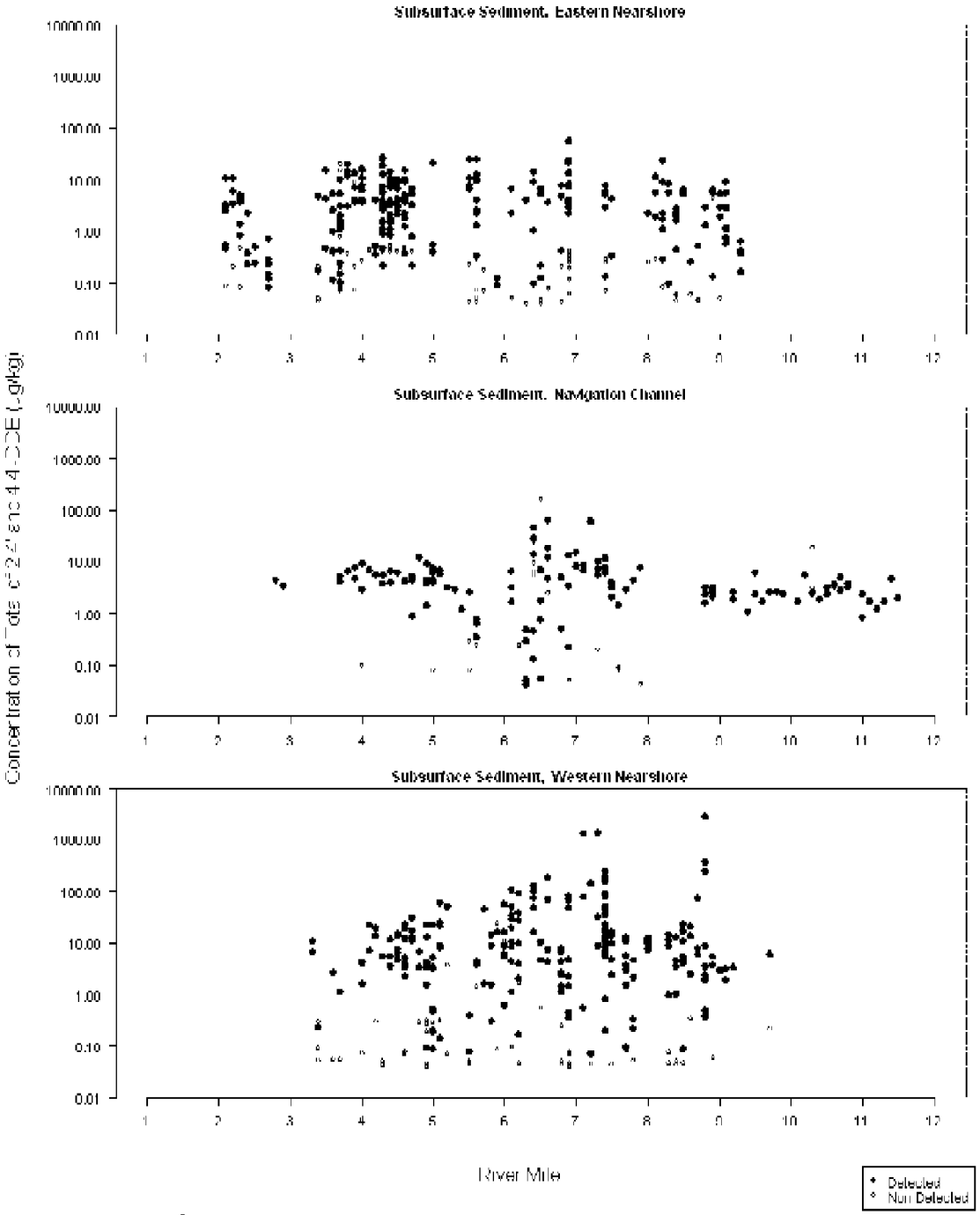
Figure 6.1-22
Portland Harbor RI/FS
Comprehensive Round 2 Report
Scatter Plot of Total of 2,4' and 4,4'-DDE Concentrations (ug/kg)
in Surface Sediment, RM 2-11, Eastern Nearshore (top plot),
Navigation Channel (center plot), and Western Nearshore (bottom plot)

BZTO104(e)031497



integral

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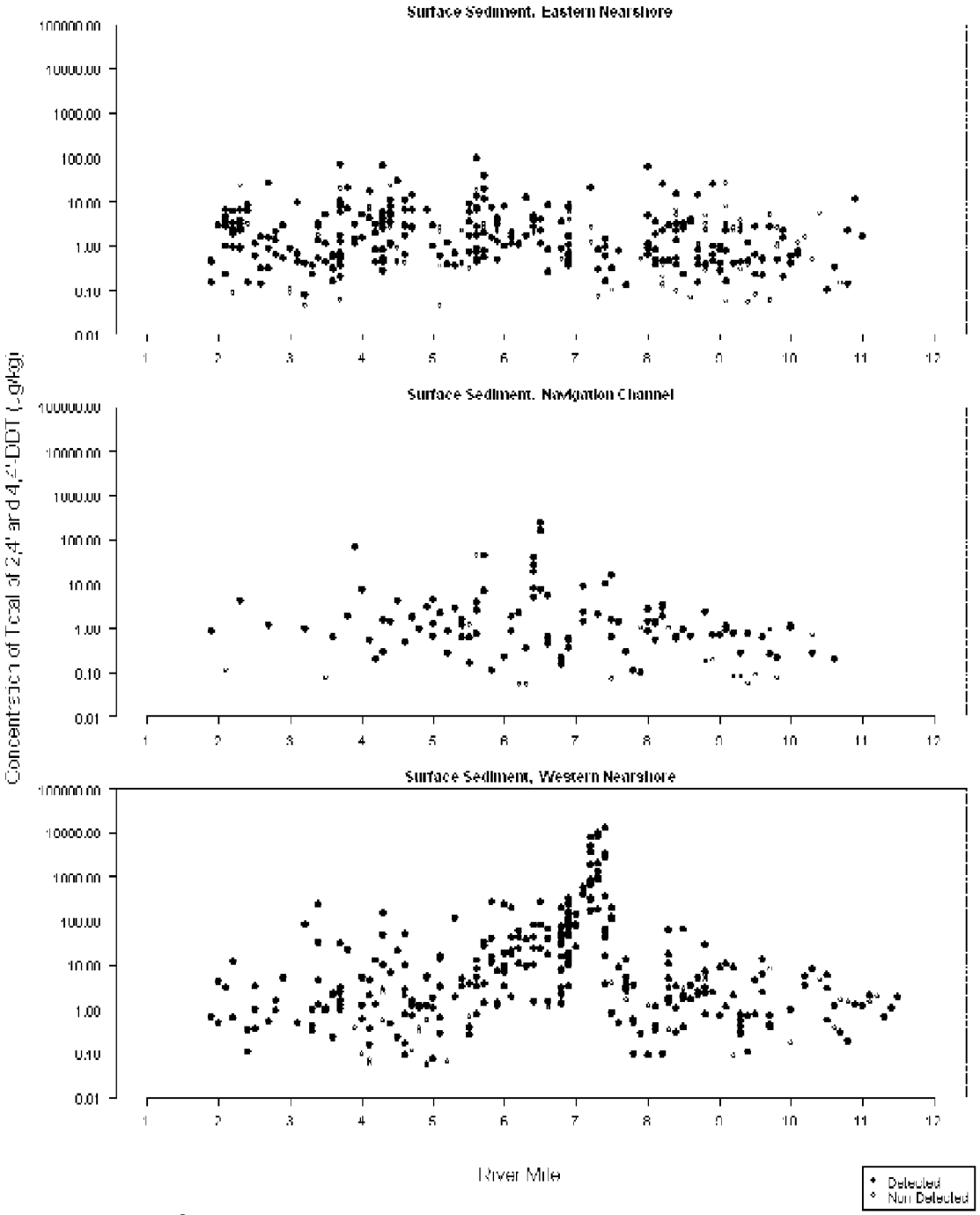
Figure 6.1-23
Portland Harbor RI/FS
Comprehensive Round 2 Report
Scatter Plot of Total of 2,4' and 4,4'-DDE Concentrations (ug/kg)
in Subsurface Sediment, RM 2-11, Eastern Nearshore (top plot),
Navigation Channel (center plot), and Western Nearshore (bottom plot)

BZTO104(e)031498



integral

LWG
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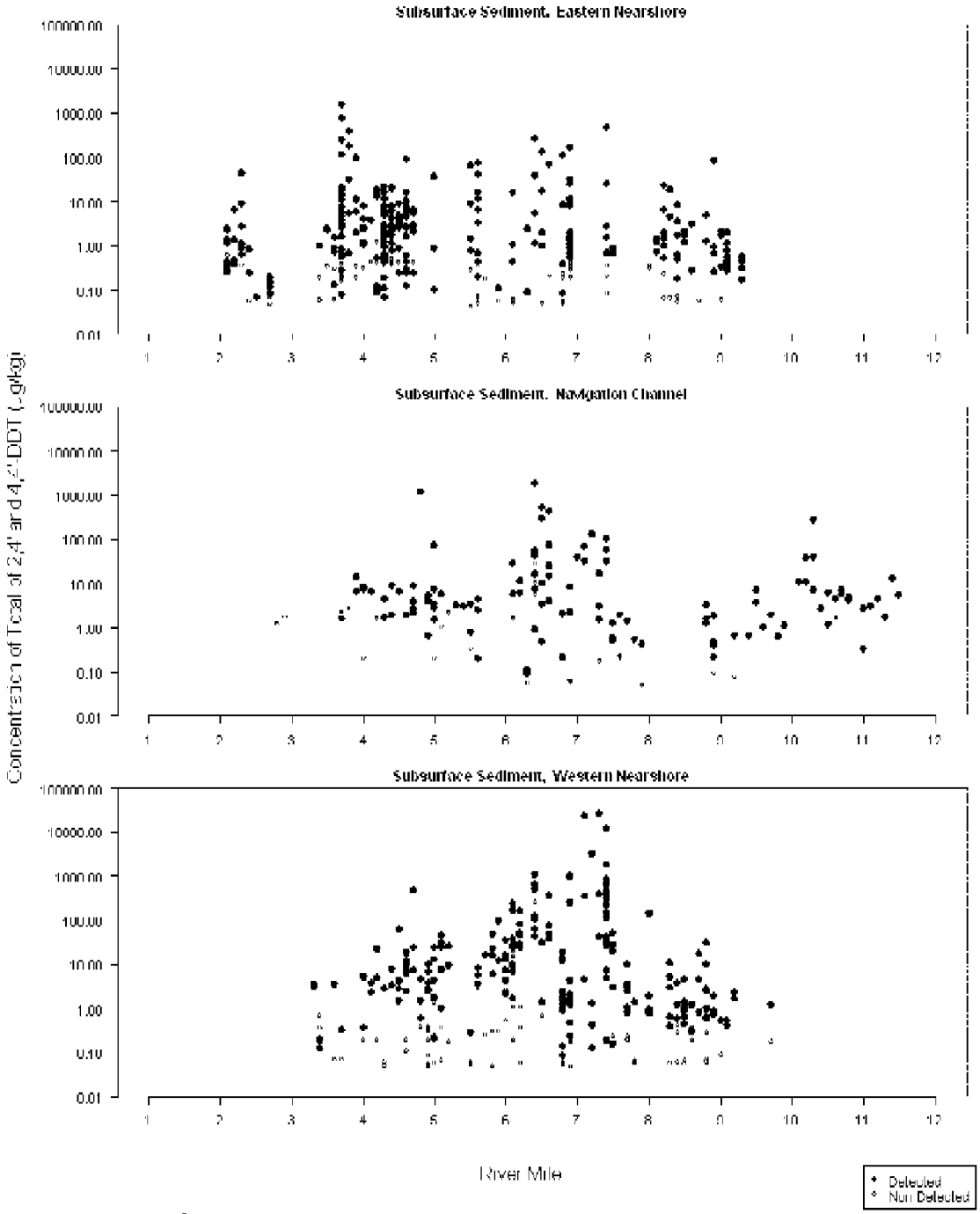
Figure 6.1-24
Portland Harbor RI/FS
Comprehensive Round 2 Report
Scatter Plot of Total of 2,4' and 4,4'-DDT Concentrations (ug/kg)
in Surface Sediment, RM 2-11, Eastern Nearshore (top plot),
Navigation Channel (center plot), and Western Nearshore (bottom plot)

BZTO104(e)031499



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LWG
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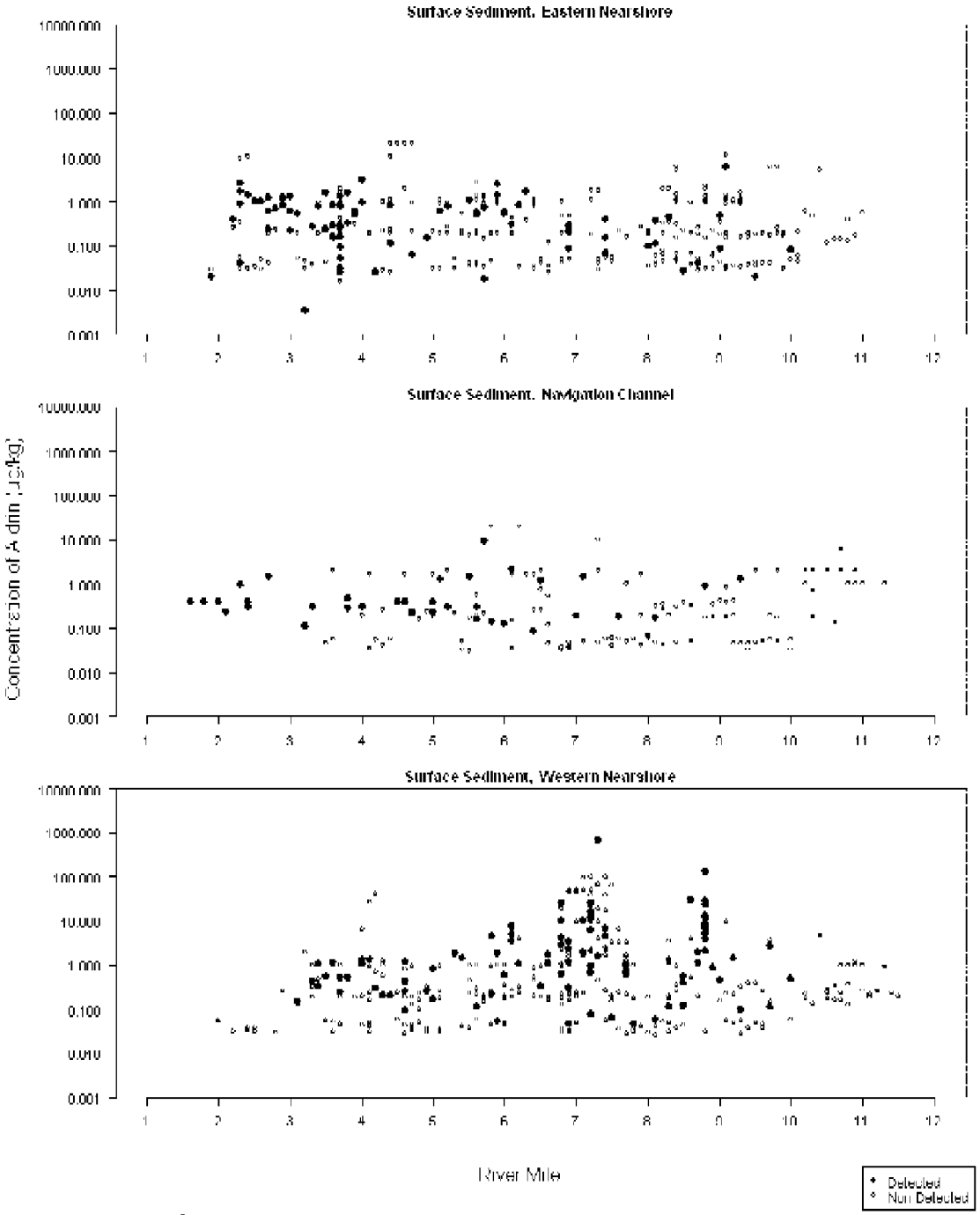
Figure 6.1-25
Portland Harbor RI/FS
Comprehensive Round 2 Report
Scatter Plot of Total of 2,4' and 4,4'-DDT Concentrations (ug/kg)
in Subsurface Sediment, RM 2-11, Eastern Nearshore (top plot),
Navigation Channel (center plot), and Western Nearshore (bottom plot)

BZTO104(e)031500



integral

LWG
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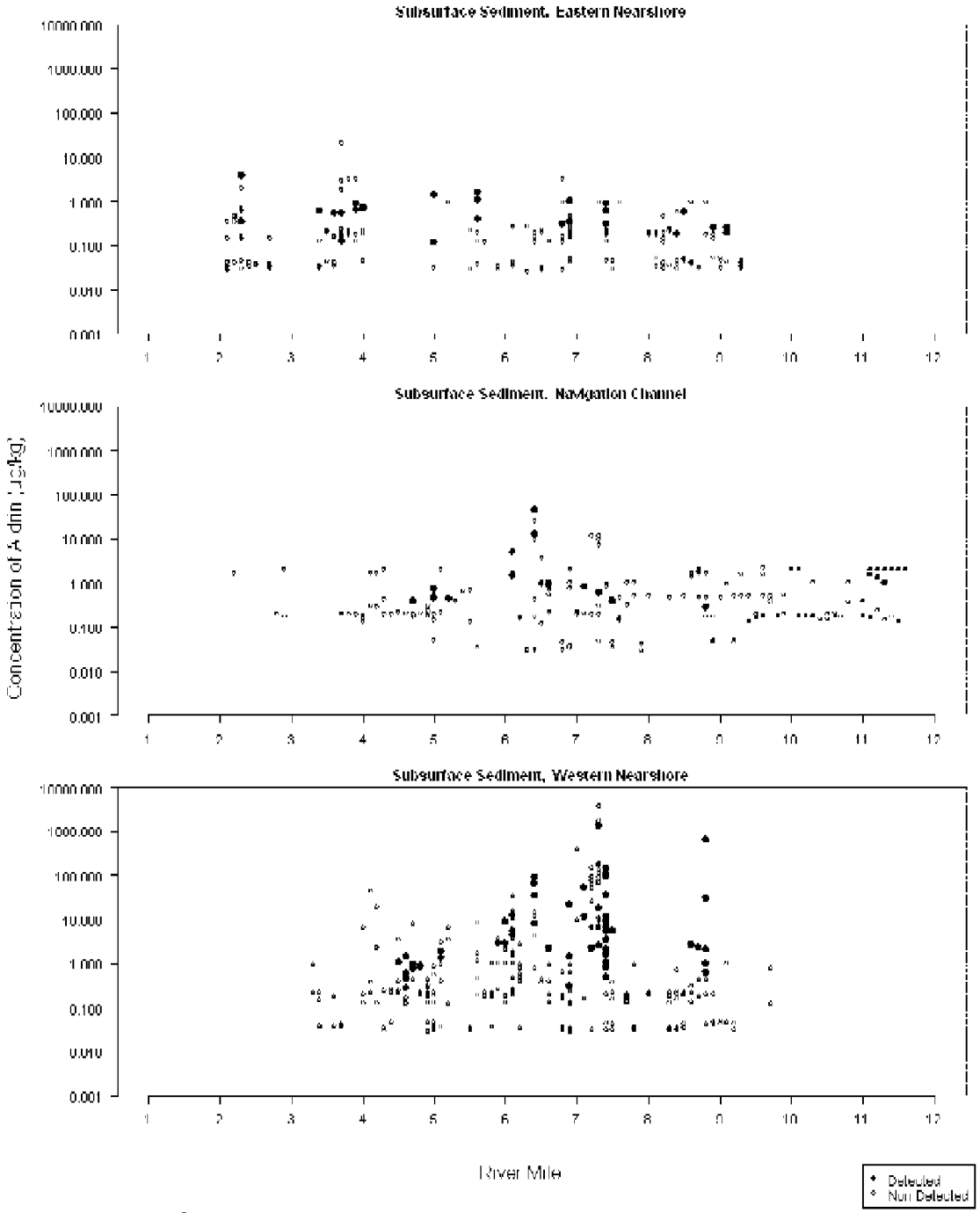
Figure 6.1-26
Portland Harbor RI/FS
Comprehensive Round 2 Report
Scatter Plot of Aldrin Concentrations (ug/kg)
in Surface Sediment, RM 2-11, Eastern Nearshore (top plot),
Navigation Channel (center plot), and Western Nearshore (bottom plot)

BZTO104(e)031501



integral

LWG
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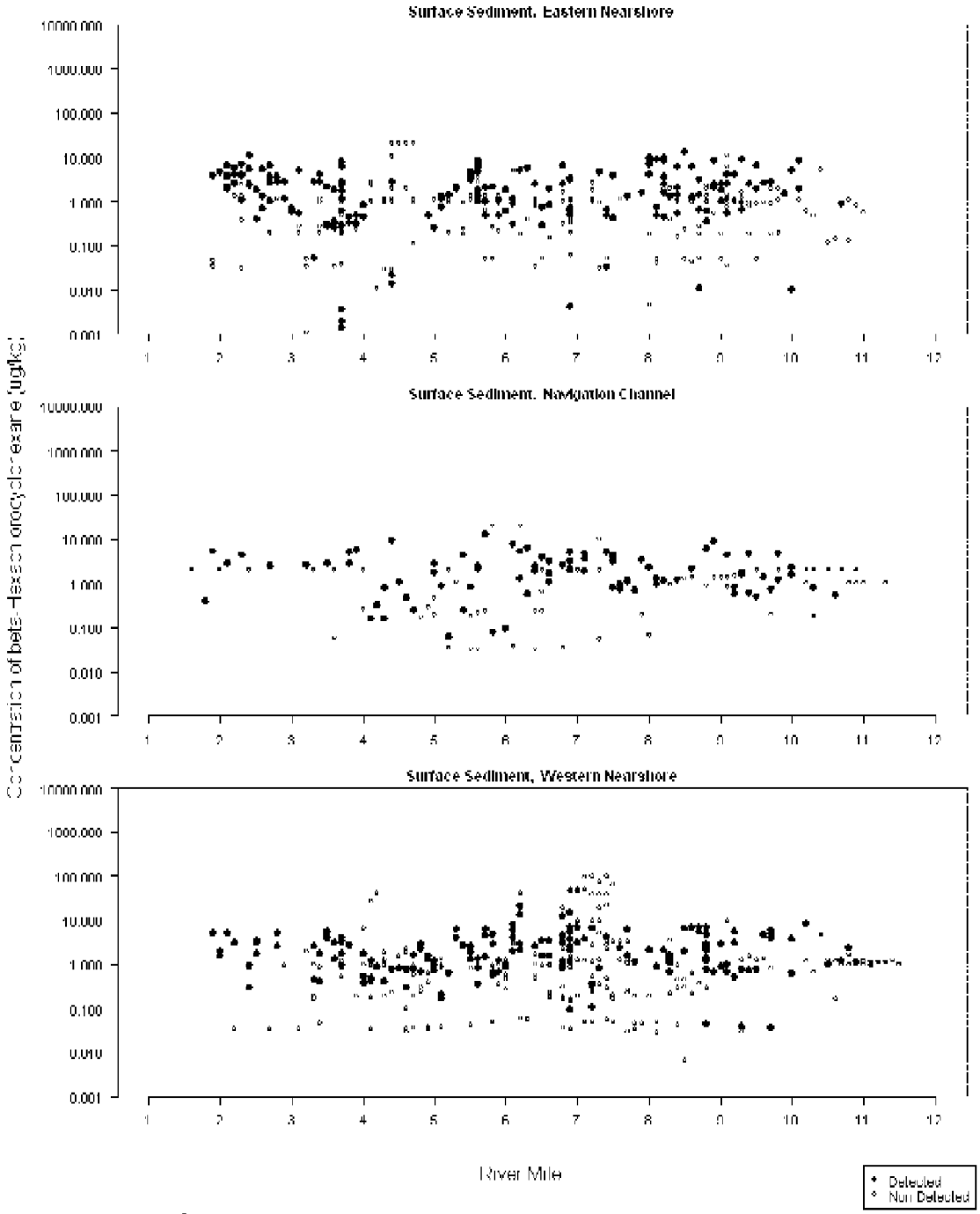
Figure 6.1-27
Portland Harbor RI/FS
Comprehensive Round 2 Report
Scatter Plot of Aldrin Concentrations (ug/kg)
in Subsurface Sediment, RM 2-11, Eastern Nearshore (top plot),
Navigation Channel (center plot), and Western Nearshore (bottom plot)

BZTO104(e)031502



integral

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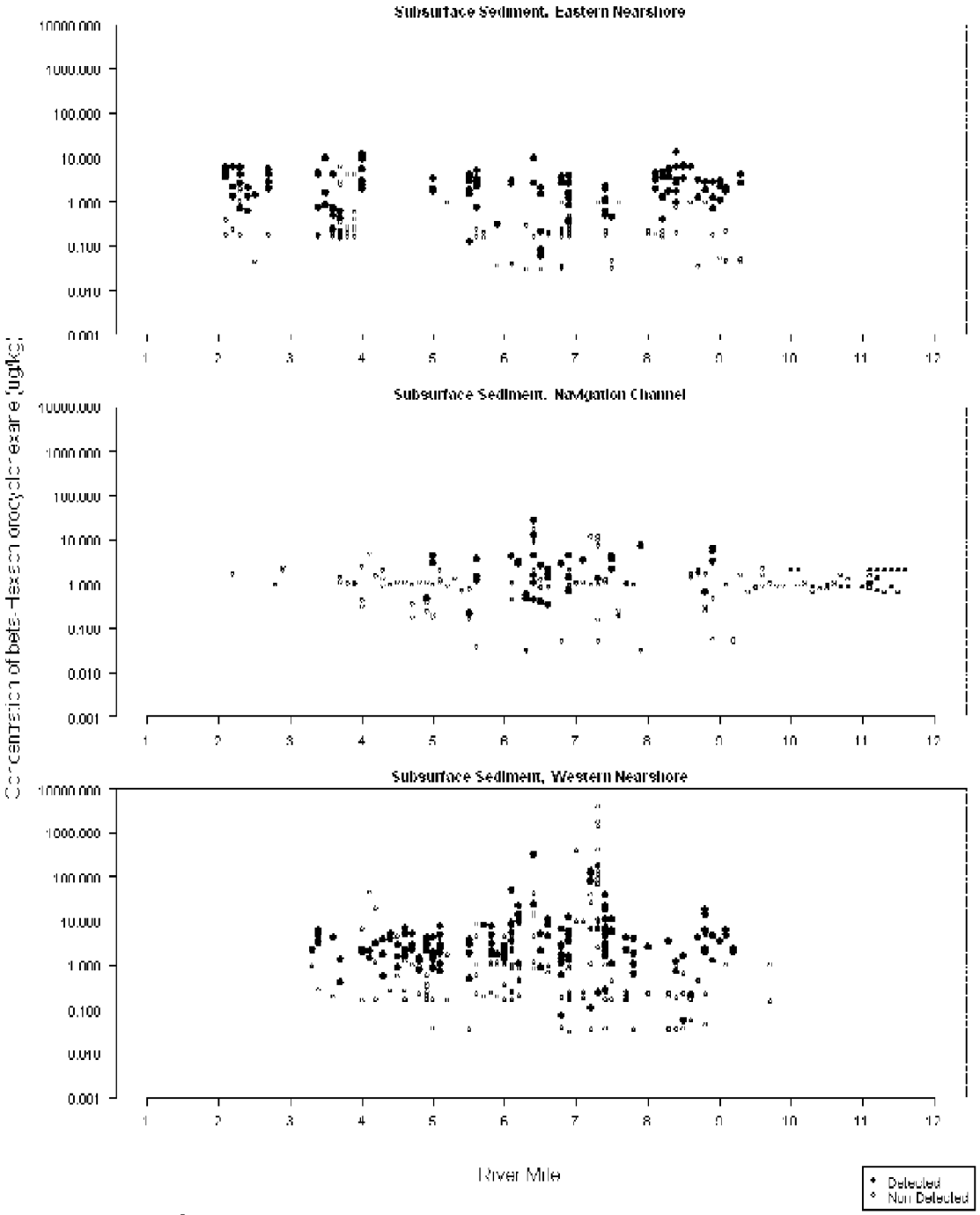
Figure 6.1-28
Portland Harbor RI/FS
Comprehensive Round 2 Report
Scatter Plot of beta-Hexachlorocyclohexane Concentrations (ug/kg)
in Surface Sediment, RM 2-11, Eastern Nearshore (top plot),
Navigation Channel (center plot), and Western Nearshore (bottom plot)

BZTO104(e)031503



integral

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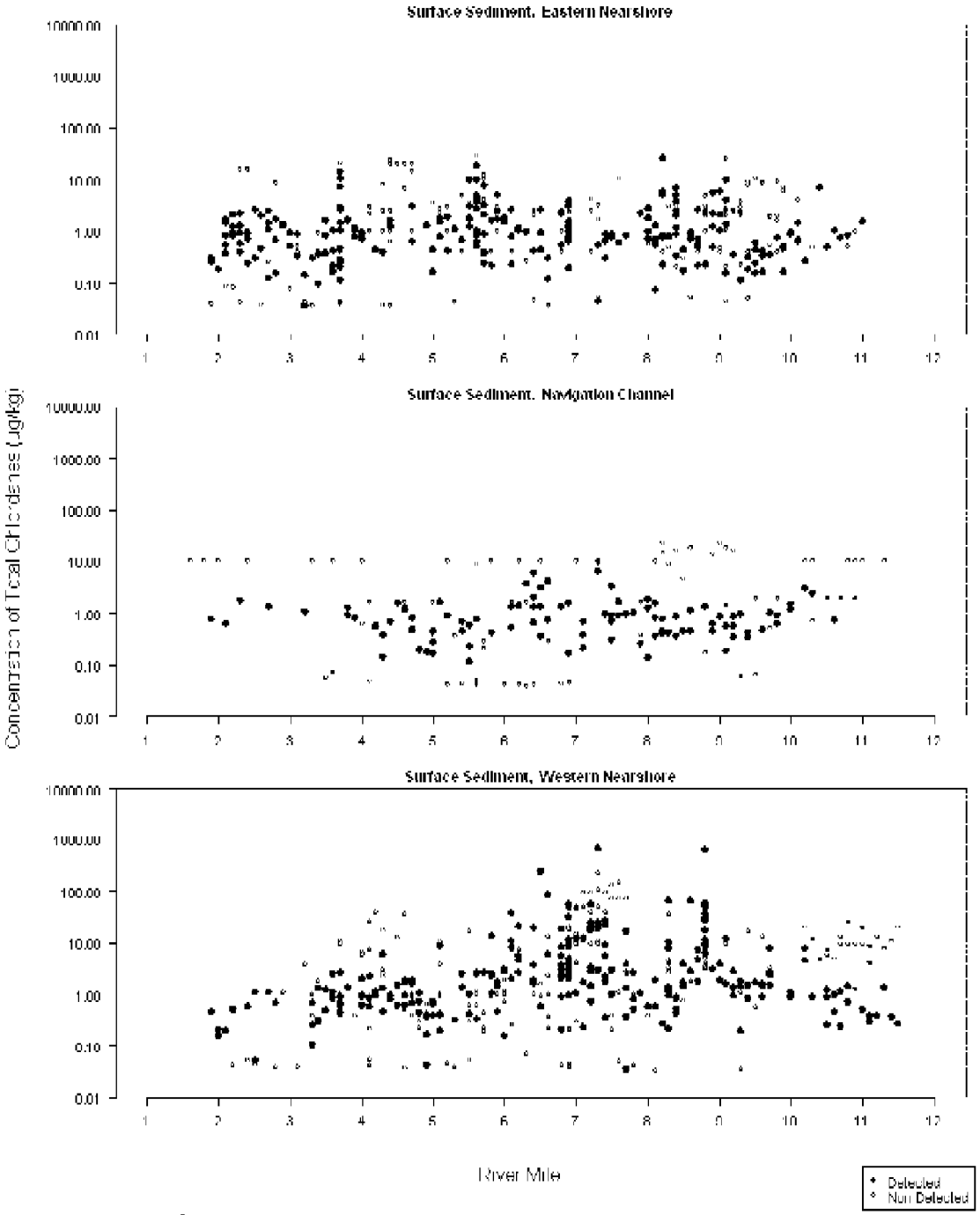
Figure 6.1-29
Portland Harbor RI/FS
Comprehensive Round 2 Report
Scatter Plot of beta-Hexachlorocyclohexane Concentrations (ug/kg)
in Subsurface Sediment, RM 2-11, Eastern Nearshore (top plot),
Navigation Channel (center plot), and Western Nearshore (bottom plot)

BZTO104(e)031504



integral

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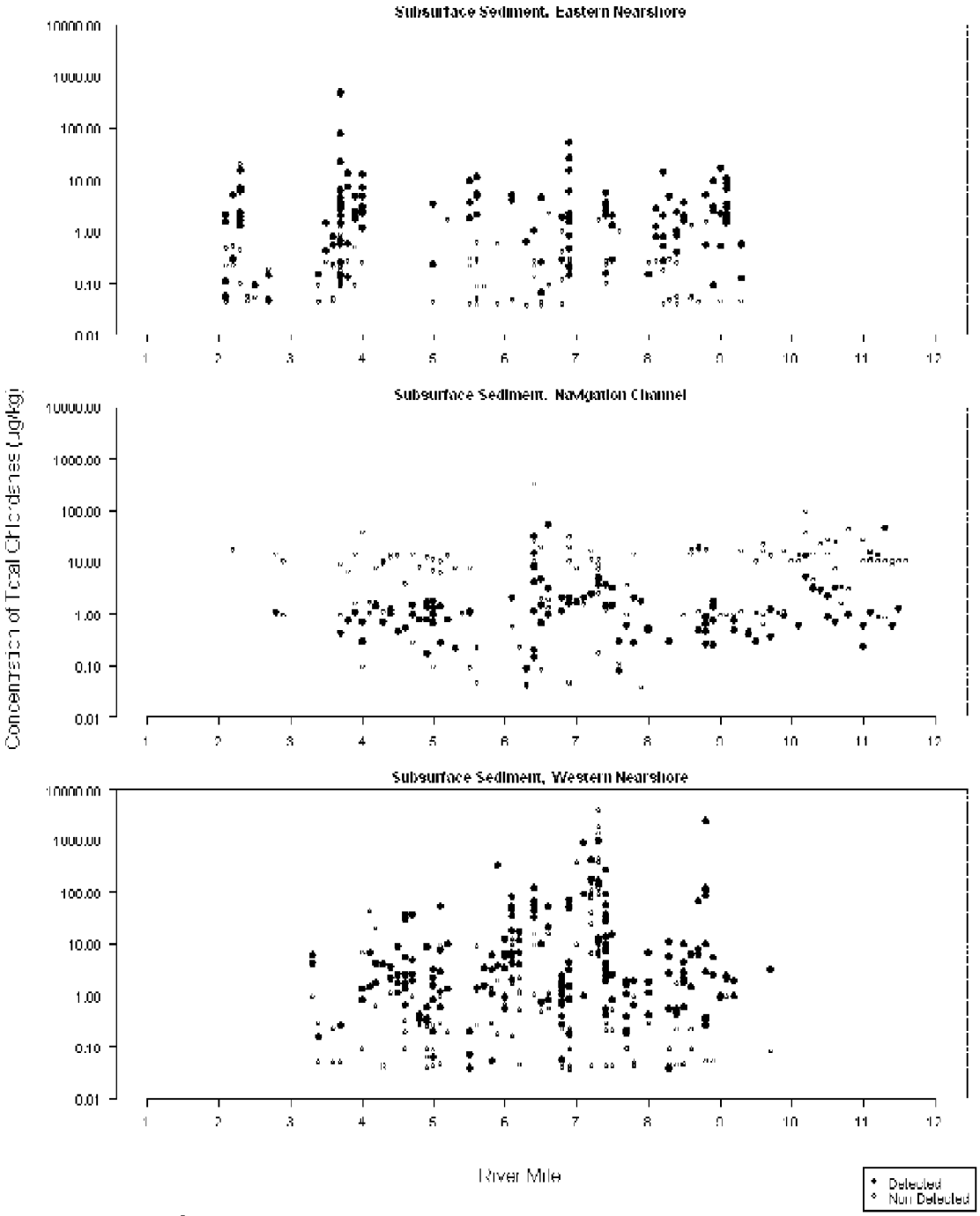
Figure 6.1-30
Portland Harbor RI/FS
Comprehensive Round 2 Report
Scatter Plot of Total Chlordanes Concentrations (ug/kg)
in Surface Sediment, RM 2-11, Eastern Nearshore (top plot),
Navigation Channel (center plot), and Western Nearshore (bottom plot)

BZTO104(e)031505



integral

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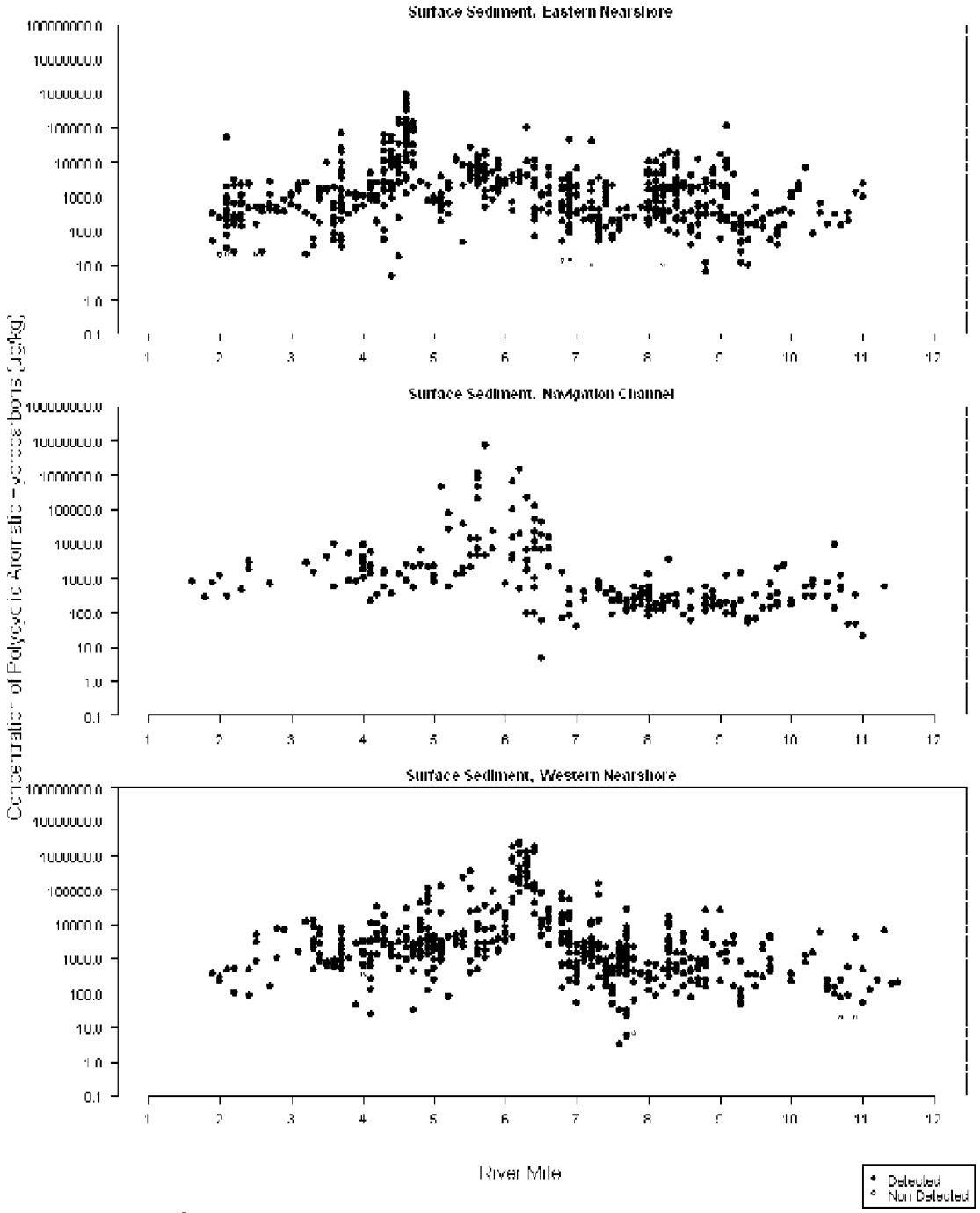
Figure 6.1-31
Portland Harbor RI/FS
Comprehensive Round 2 Report
Scatter Plot of Total Chlordanes Concentrations (ug/kg)
in Subsurface Sediment, RM 2-11, Eastern Nearshore (top plot),
Navigation Channel (center plot), and Western Nearshore (bottom plot)

BZTO104(e)031506



integral

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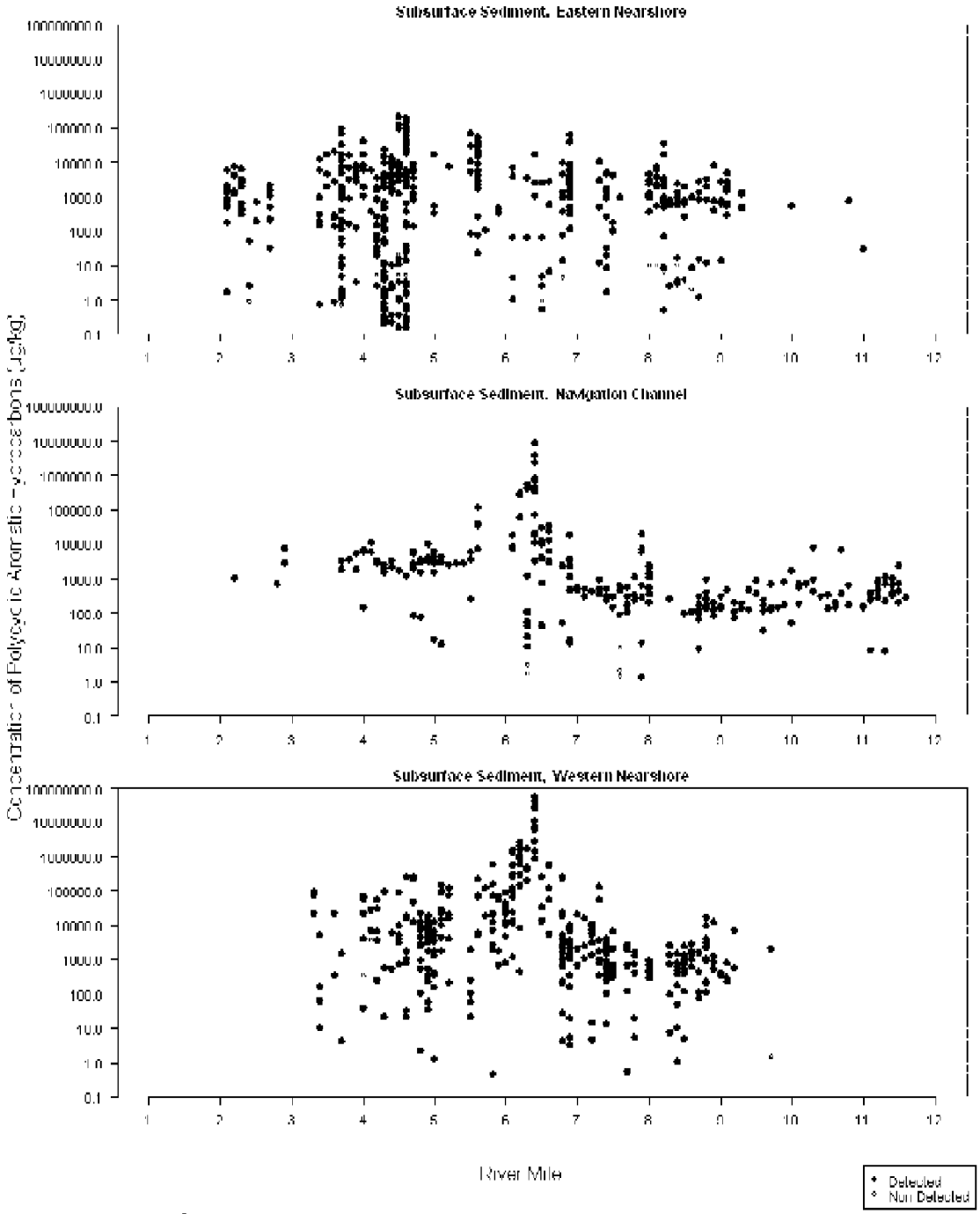
Figure 6.1-32
Portland Harbor RI/FS
Comprehensive Round 2 Report
Scatter Plot of Polycyclic Aromatic Hydrocarbons Concentrations (ug/kg)
in Surface Sediment, RM 2-11, Eastern Nearshore (top plot),
Navigation Channel (center plot), and Western Nearshore (bottom plot)

BZTO104(e)031507



integral

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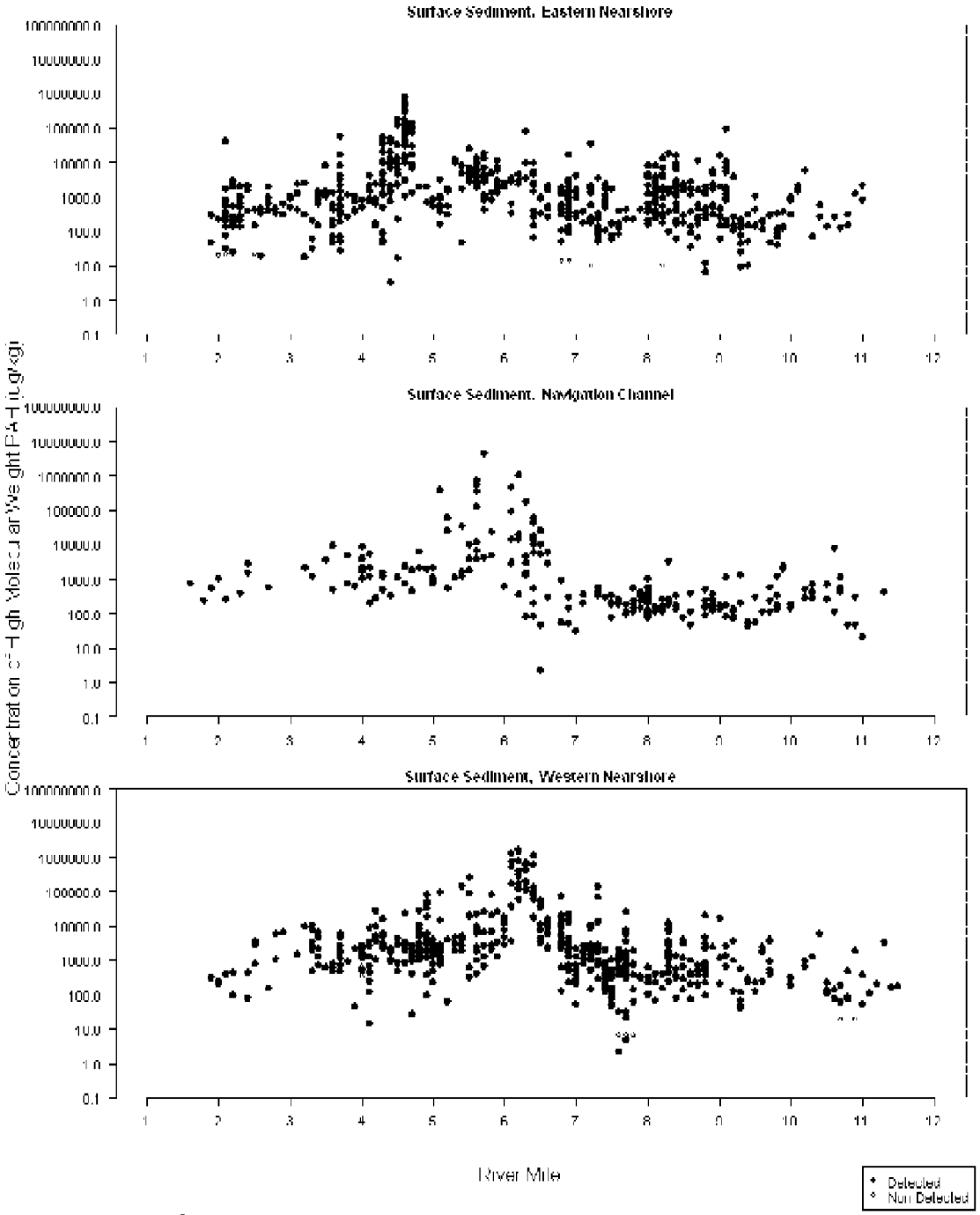
Figure 6.1-33
Portland Harbor RI/FS
Comprehensive Round 2 Report
Scatter Plot of Polycyclic Aromatic Hydrocarbons Concentrations (ug/kg)
in Subsurface Sediment, RM 2-11, Eastern Nearshore (top plot),
Navigation Channel (center plot), and Western Nearshore (bottom plot)

BZTO104(e)031508



integral

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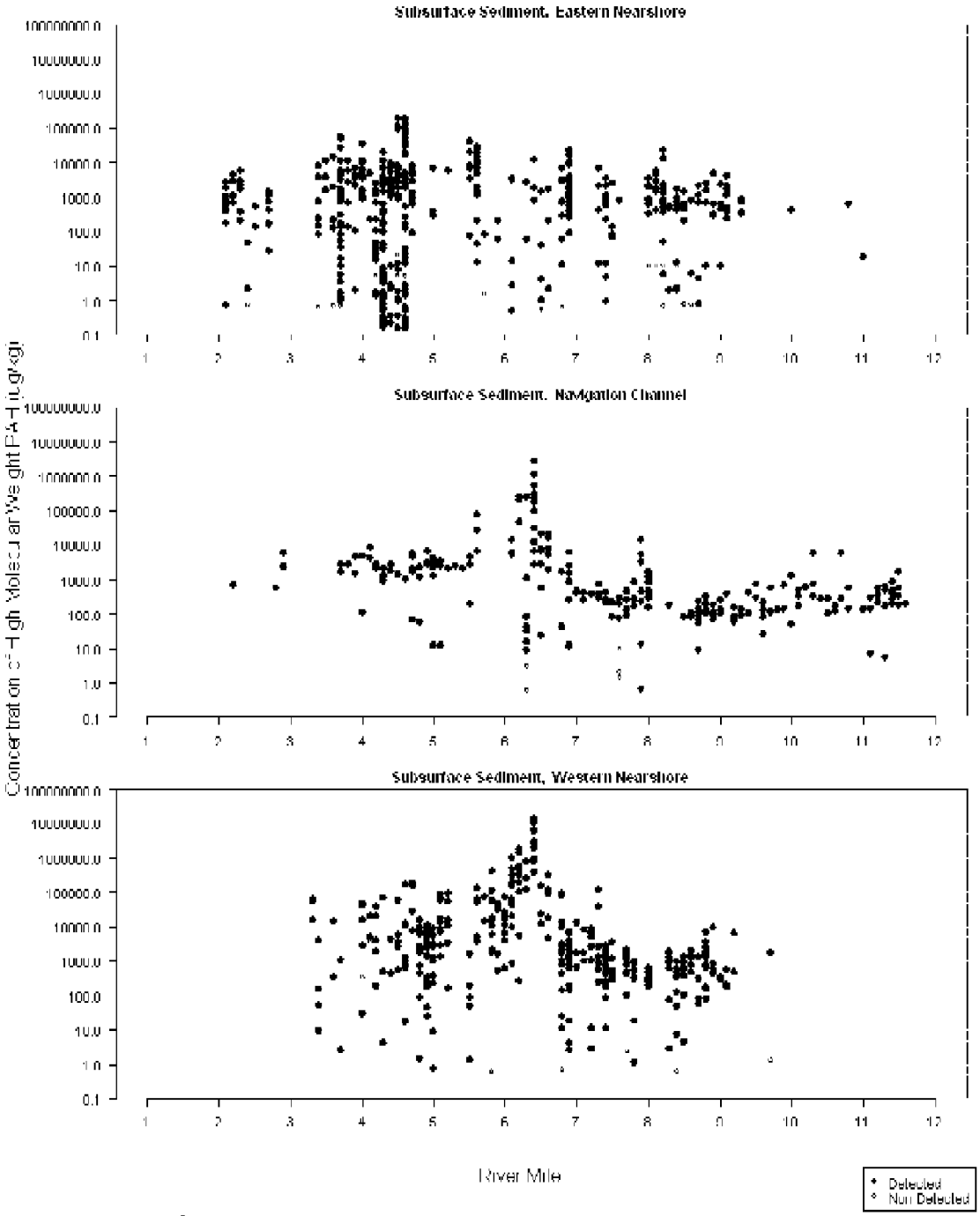
Figure 6.1-34
Portland Harbor RI/FS
Comprehensive Round 2 Report
Scatter Plot of High Molecular Weight PAH Concentrations (ug/kg)
in Surface Sediment, RM 2-11, Eastern Nearshore (top plot),
Navigation Channel (center plot), and Western Nearshore (bottom plot)

BZTO104(e)031509



integral

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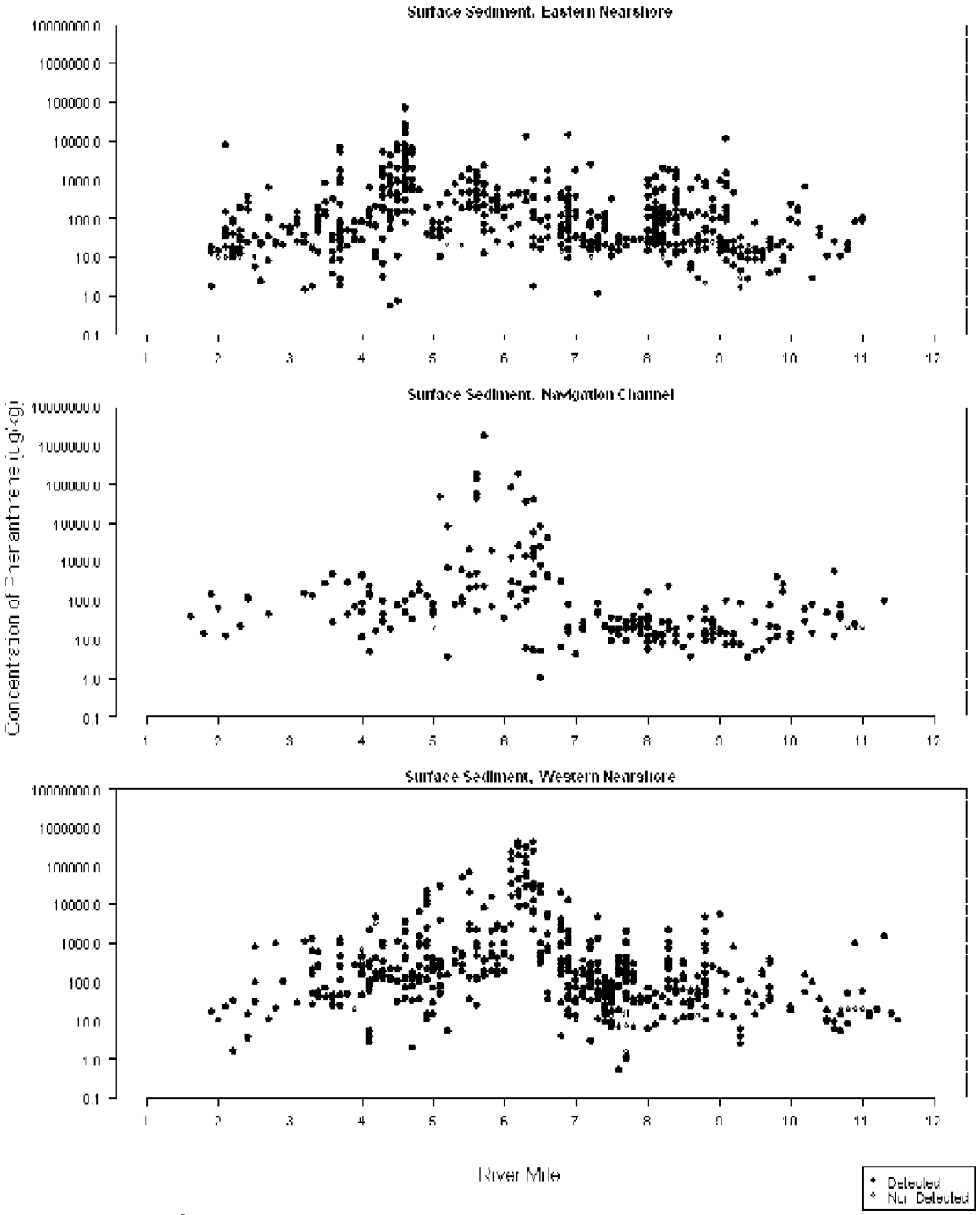
Figure 6.1-35
Portland Harbor RI/FS
Comprehensive Round 2 Report
Scatter Plot of High Molecular Weight PAH Concentrations (ug/kg)
in Subsurface Sediment, RM 2-11, Eastern Nearshore (top plot),
Navigation Channel (center plot), and Western Nearshore (bottom plot)

BZTO104(e)031510



integral

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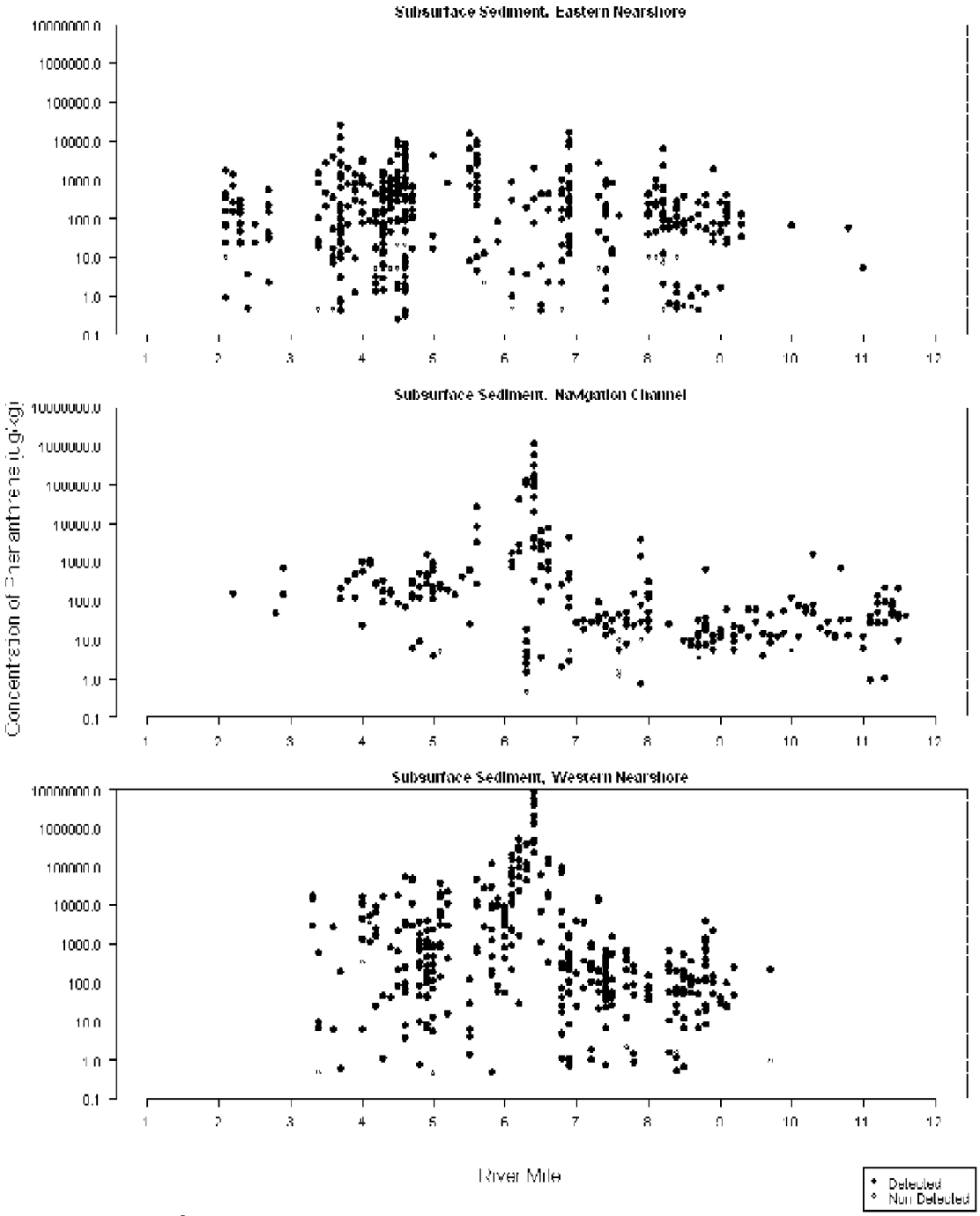
Figure 6.1-36
Portland Harbor RI/FS
Comprehensive Round 2 Report
Scatter Plot of Phenanthrene Concentrations (ug/kg)
in Surface Sediment, RM 2-11, Eastern Nearshore (top plot),
Navigation Channel (center plot), and Western Nearshore (bottom plot)

BZTO104(e)031511



integral

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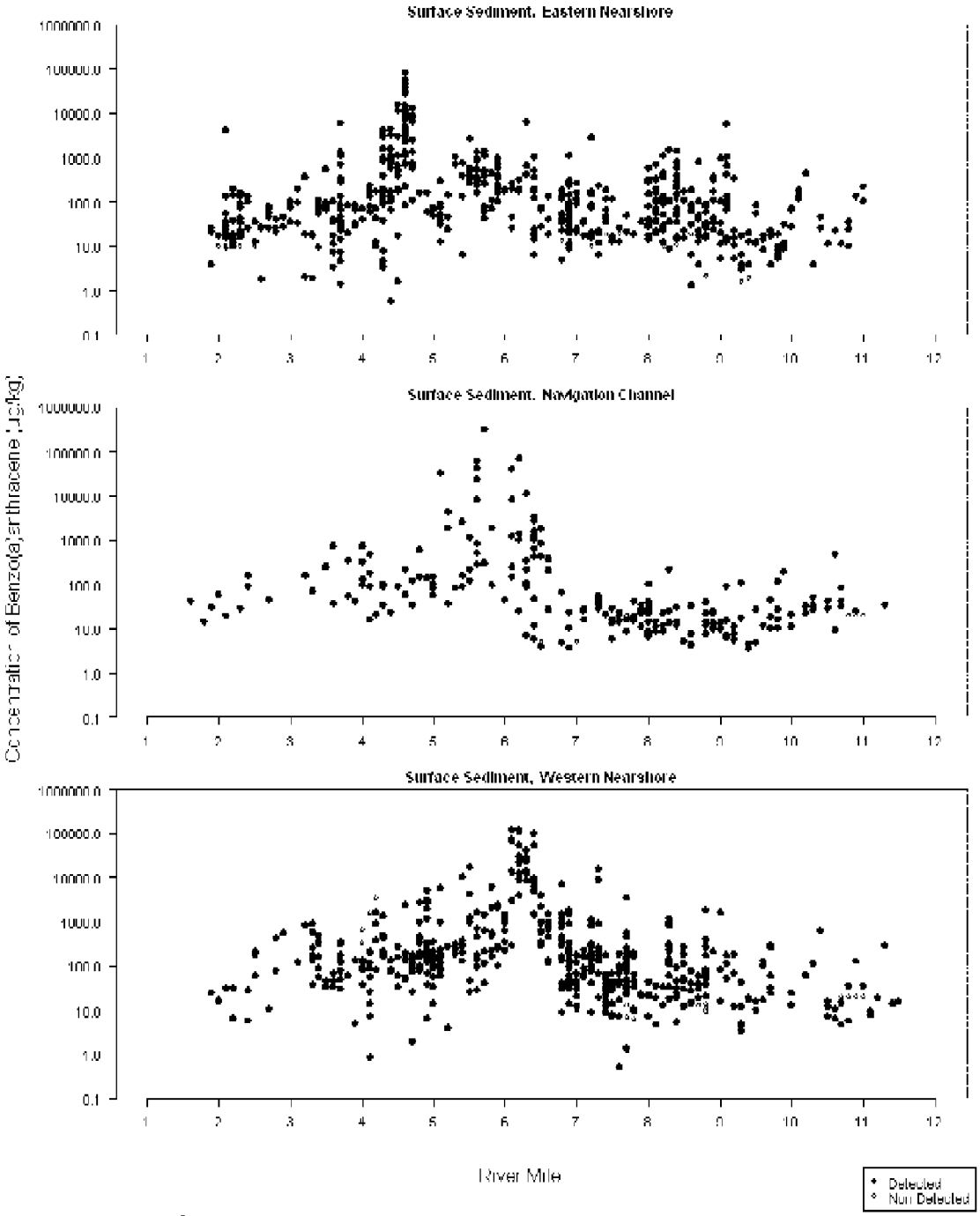
Figure 6.1-37
Portland Harbor RI/FS
Comprehensive Round 2 Report
Scatter Plot of Phenanthrene Concentrations (ug/kg)
in Subsurface Sediment, RM 2-11, Eastern Nearshore (top plot),
Navigation Channel (center plot), and Western Nearshore (bottom plot)

BZTO104(e)031512



integral

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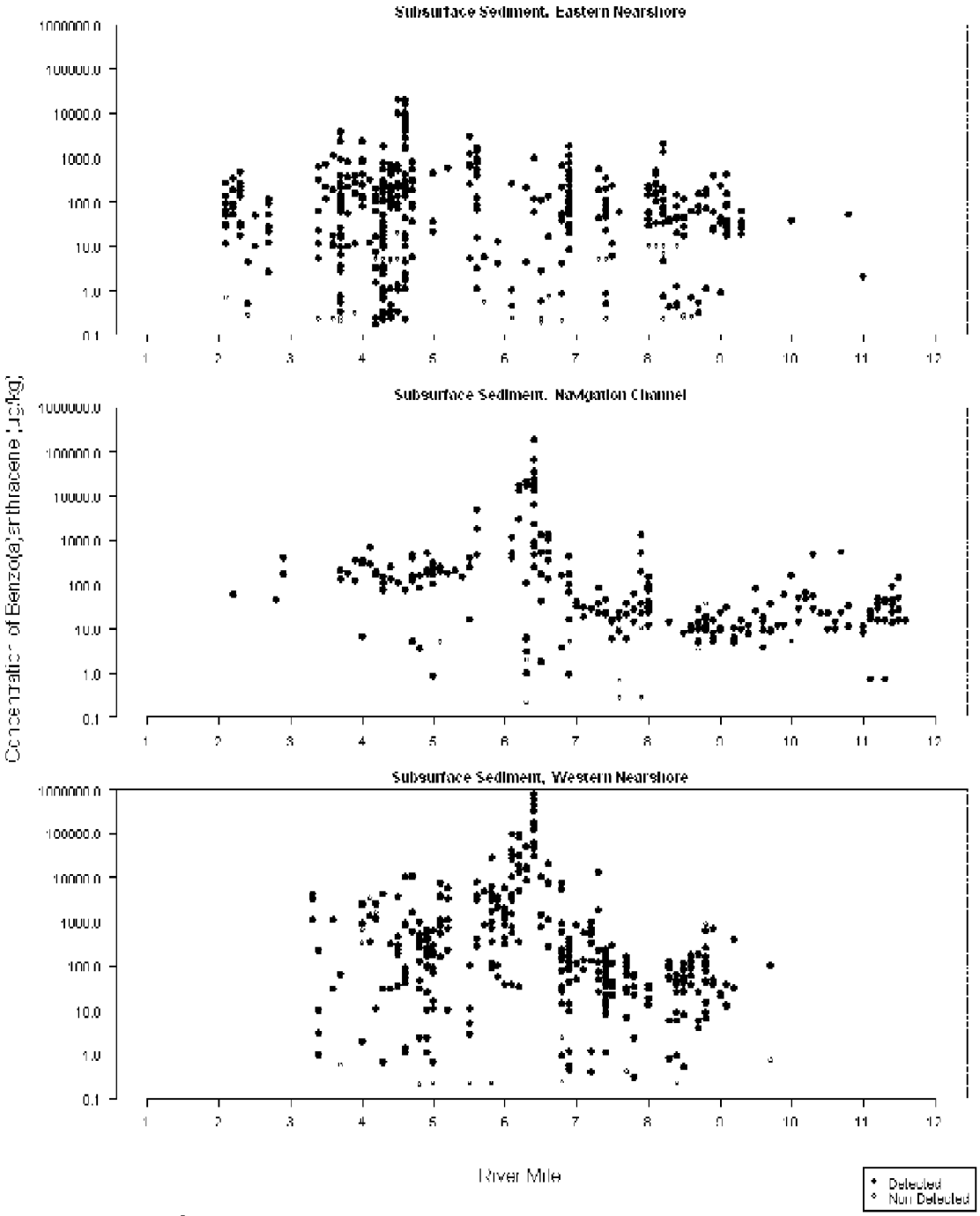
Figure 6.1-38
Portland Harbor RI/FS
Comprehensive Round 2 Report
Scatter Plot of Benzo(a)anthracene Concentrations (ug/kg)
in Surface Sediment, RM 2-11, Eastern Nearshore (top plot),
Navigation Channel (center plot), and Western Nearshore (bottom plot)

BZTO104(e)031513



integral

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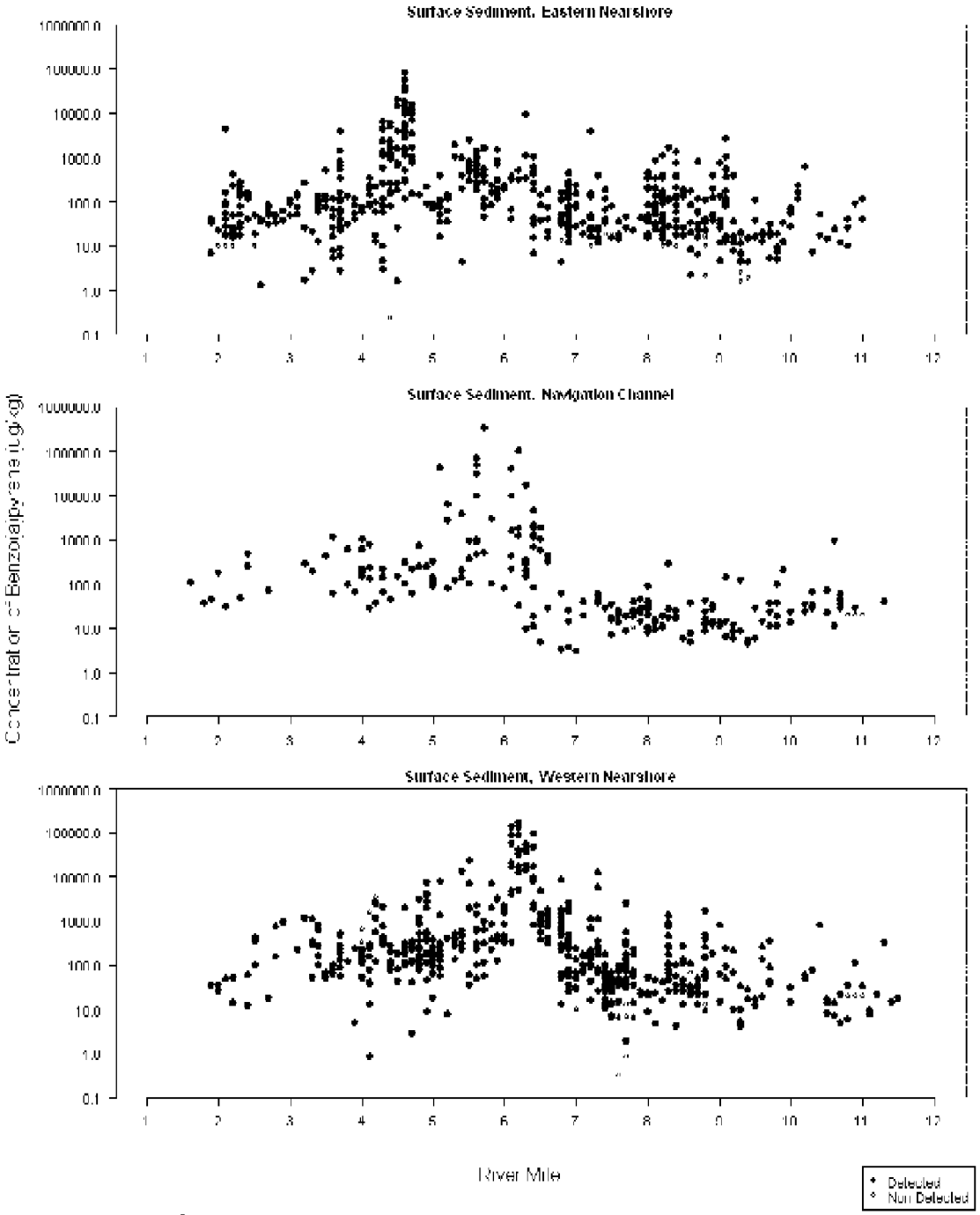
Figure 6.1-39
Portland Harbor RI/FS
Comprehensive Round 2 Report
Scatter Plot of Benzo(a)anthracene Concentrations (ug/kg)
in Subsurface Sediment, RM 2-11, Eastern Nearshore (top plot),
Navigation Channel (center plot), and Western Nearshore (bottom plot)

BZTO104(e)031514



integral

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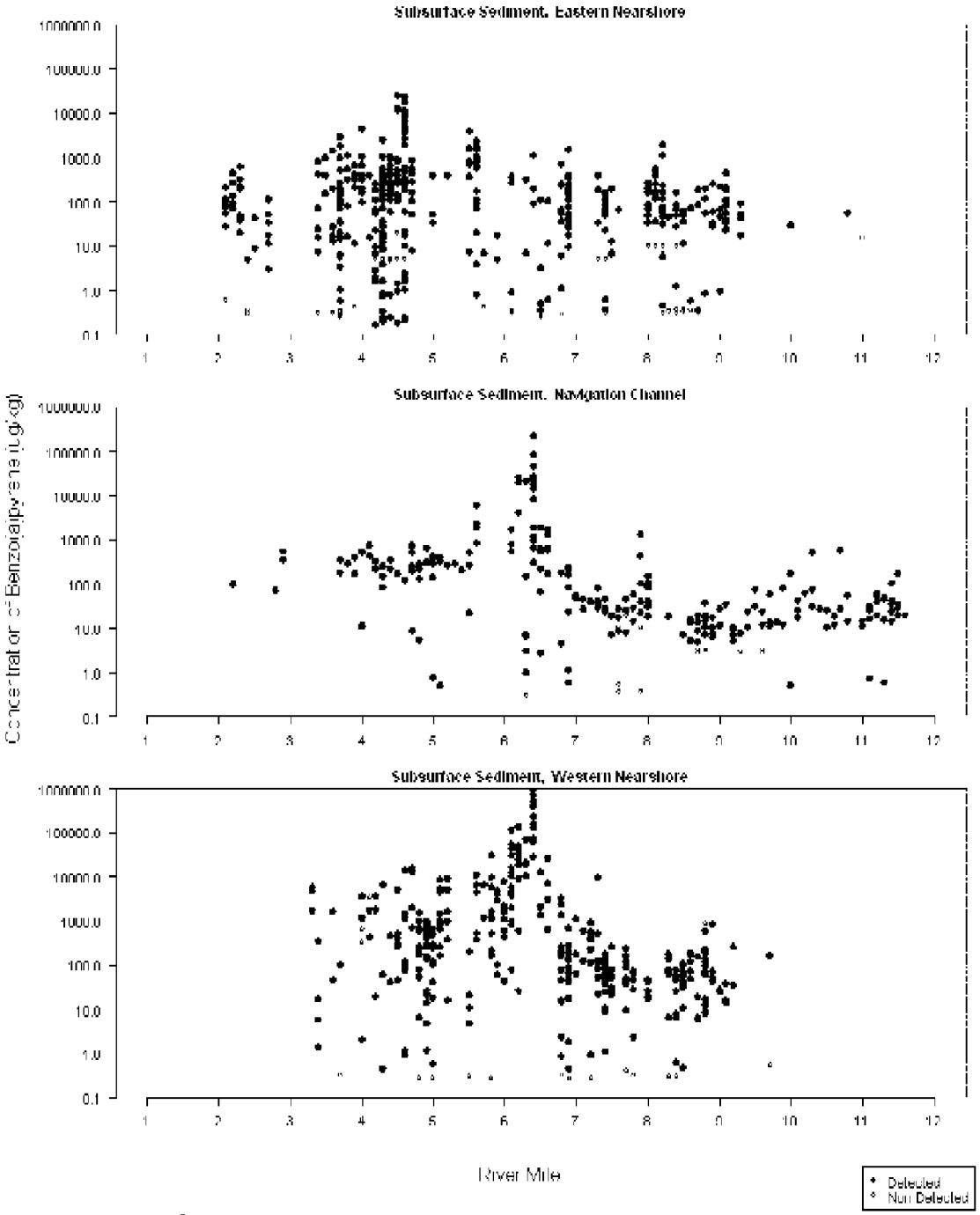
Figure 6.1-40
Portland Harbor RI/FS
Comprehensive Round 2 Report
Scatter Plot of Benzo(a)pyrene Concentrations (ug/kg)
in Surface Sediment, RM 2-11, Eastern Nearshore (top plot),
Navigation Channel (center plot), and Western Nearshore (bottom plot)

BZTO104(e)031515



integral

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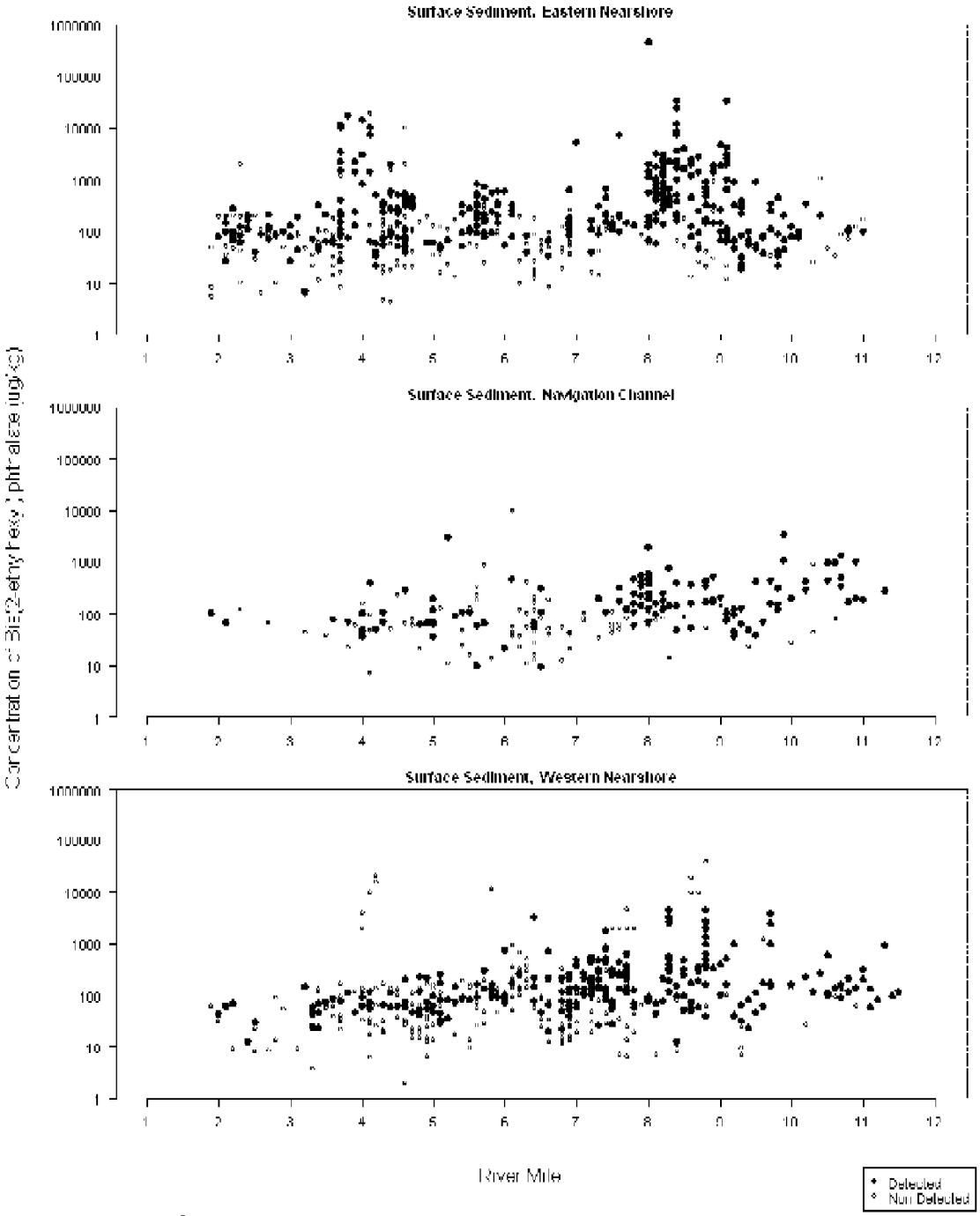
Figure 6.1-41
Portland Harbor RI/FS
Comprehensive Round 2 Report
Scatter Plot of Benzo(a)pyrene Concentrations (ug/kg)
in Subsurface Sediment, RM 2-11, Eastern Nearshore (top plot),
Navigation Channel (center plot), and Western Nearshore (bottom plot)

BZTO104(e)031516



integral

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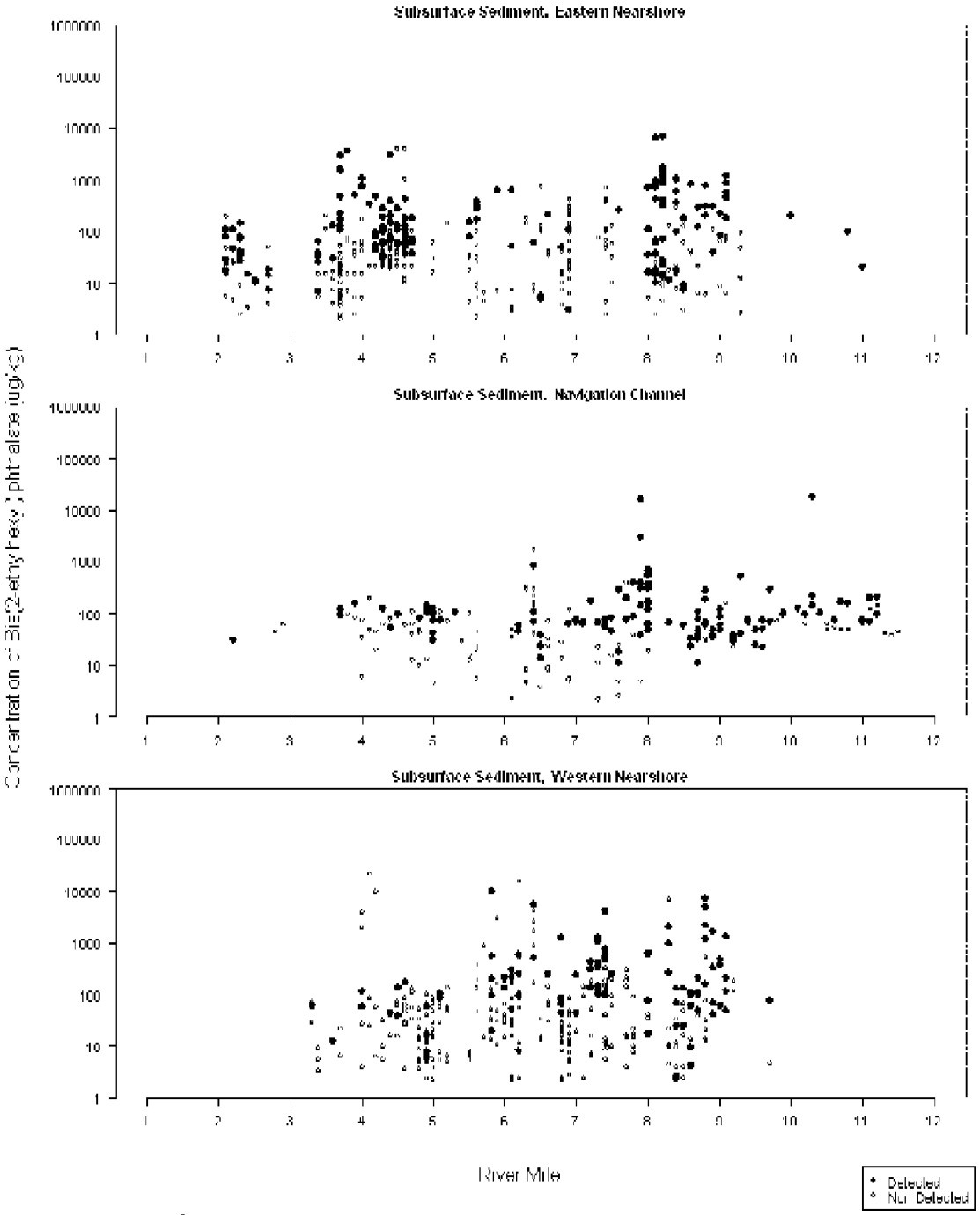
Figure 6.1-42
Portland Harbor RI/FS
Comprehensive Round 2 Report
Scatter Plot of Bis(2-ethylhexyl) phthalate Concentrations (ug/kg)
in Surface Sediment, RM 2-11, Eastern Nearshore (top plot),
Navigation Channel (center plot), and Western Nearshore (bottom plot)

BZTO104(e)031517



integral

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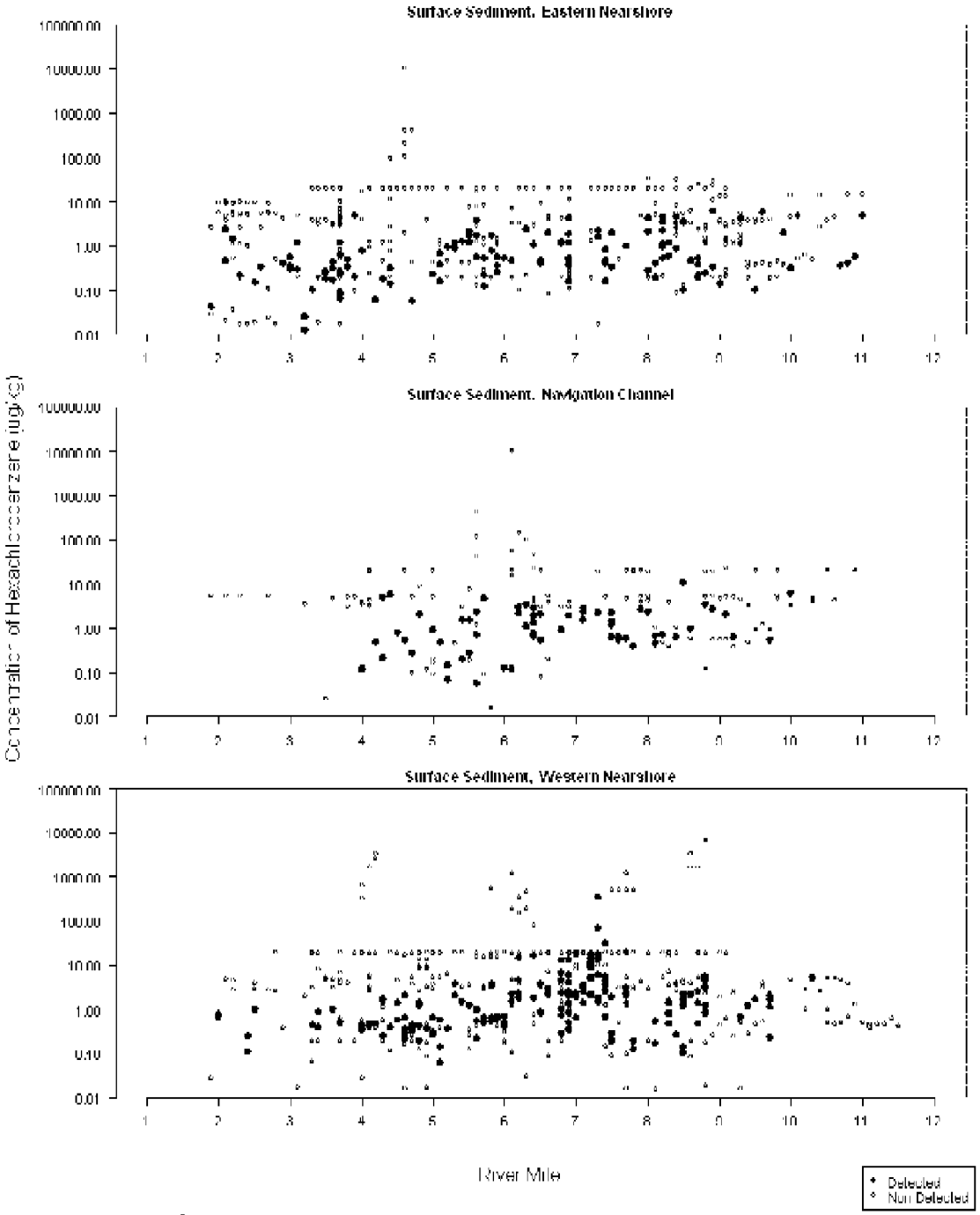
Figure 6.1-43
Portland Harbor RI/FS
Comprehensive Round 2 Report
Scatter Plot of Bis(2-ethylhexyl) phthalate Concentrations (ug/kg)
in Subsurface Sediment, RM 2-11, Eastern Nearshore (top plot),
Navigation Channel (center plot), and Western Nearshore (bottom plot)

BZTO104(e)031518



integral

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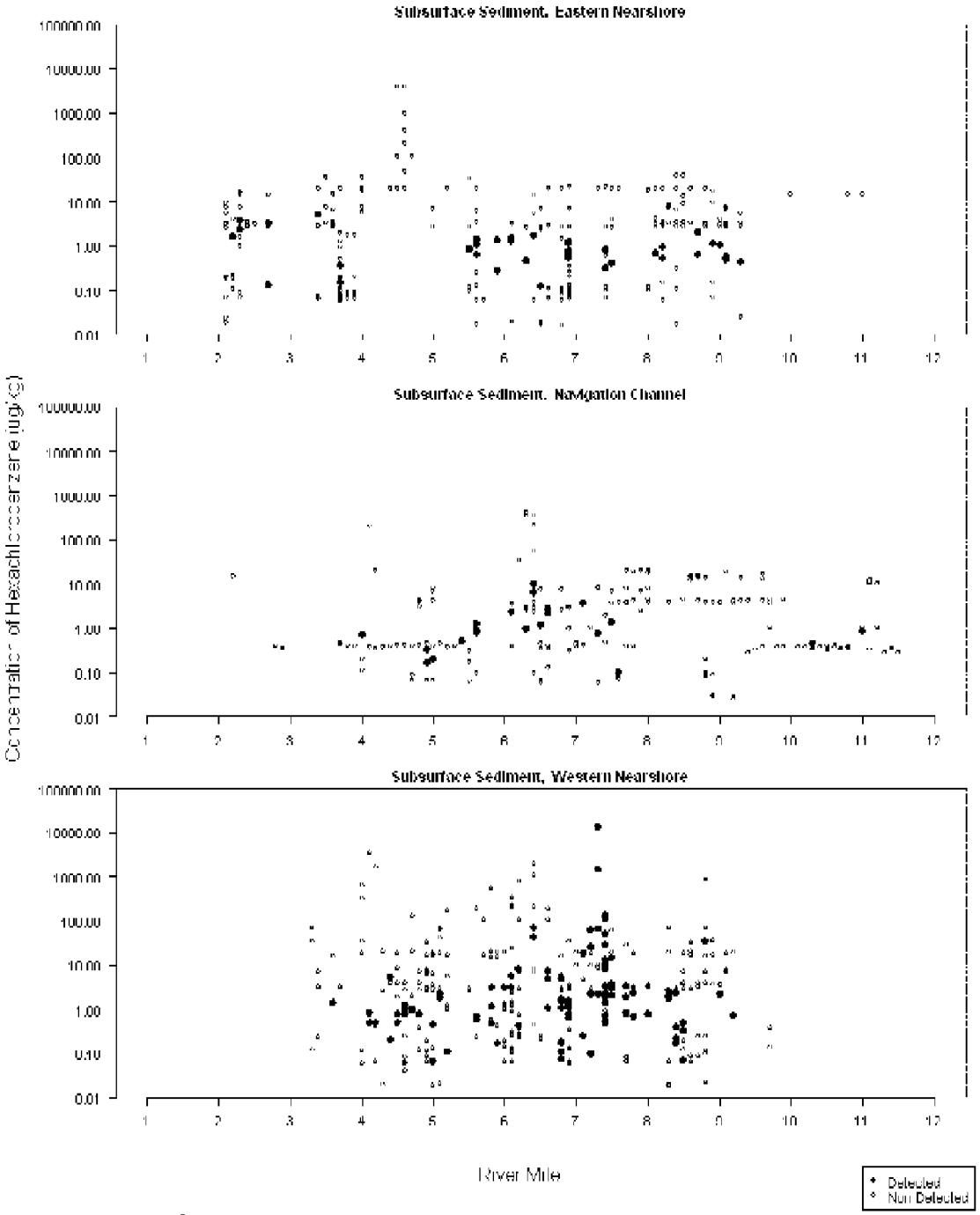
Figure 6.1-44
Portland Harbor RI/FS
Comprehensive Round 2 Report
Scatter Plot of Hexachlorobenzene Concentrations (ug/kg)
in Surface Sediment, RM 2-11, Eastern Nearshore (top plot),
Navigation Channel (center plot), and Western Nearshore (bottom plot)

BZTO104(e)031519



integral

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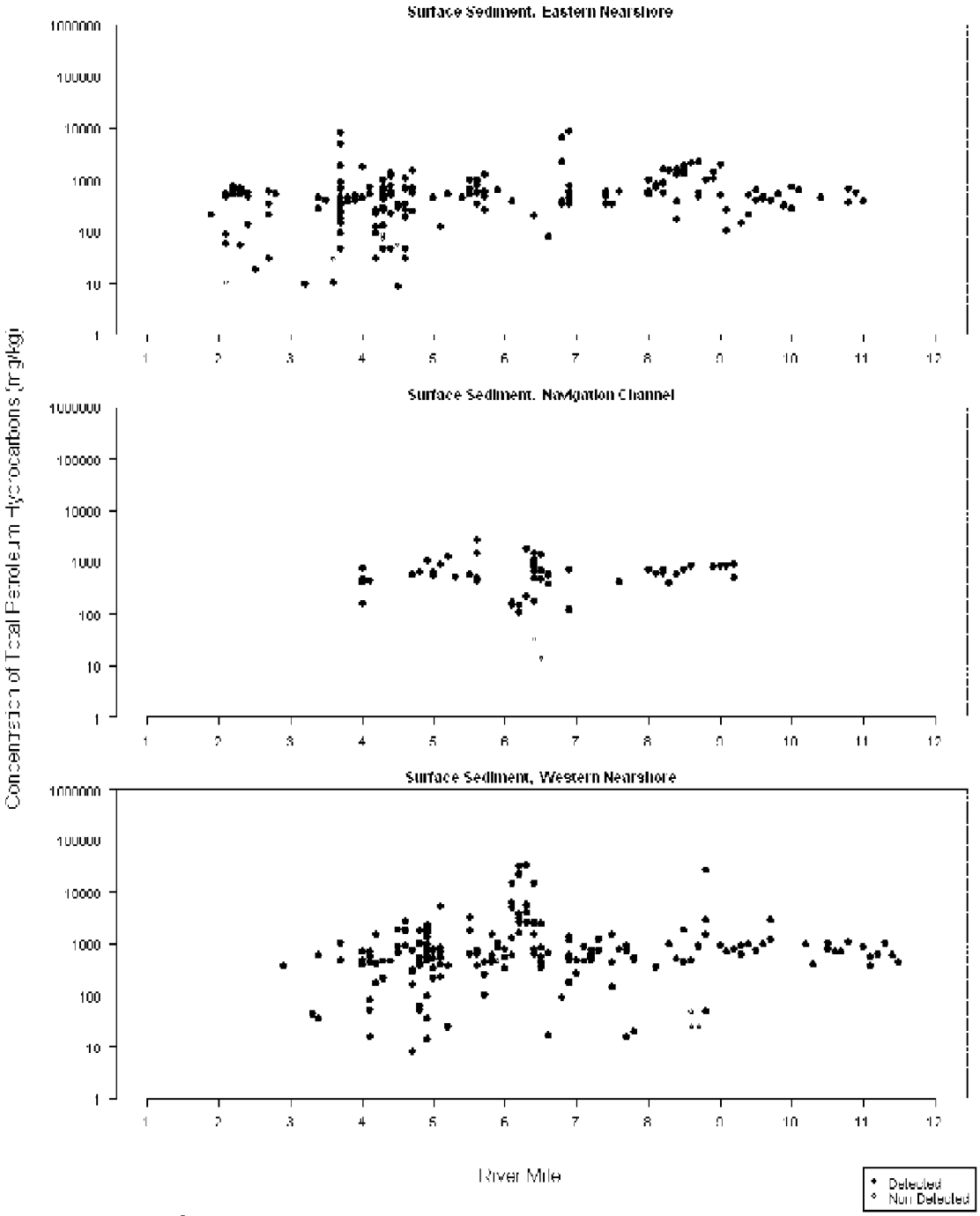
Figure 6.1-45
Portland Harbor RI/FS
Comprehensive Round 2 Report
Scatter Plot of Hexachlorobenzene Concentrations (ug/kg)
in Subsurface Sediment, RM 2-11, Eastern Nearshore (top plot),
Navigation Channel (center plot), and Western Nearshore (bottom plot)

BZTO104(e)031520



integral

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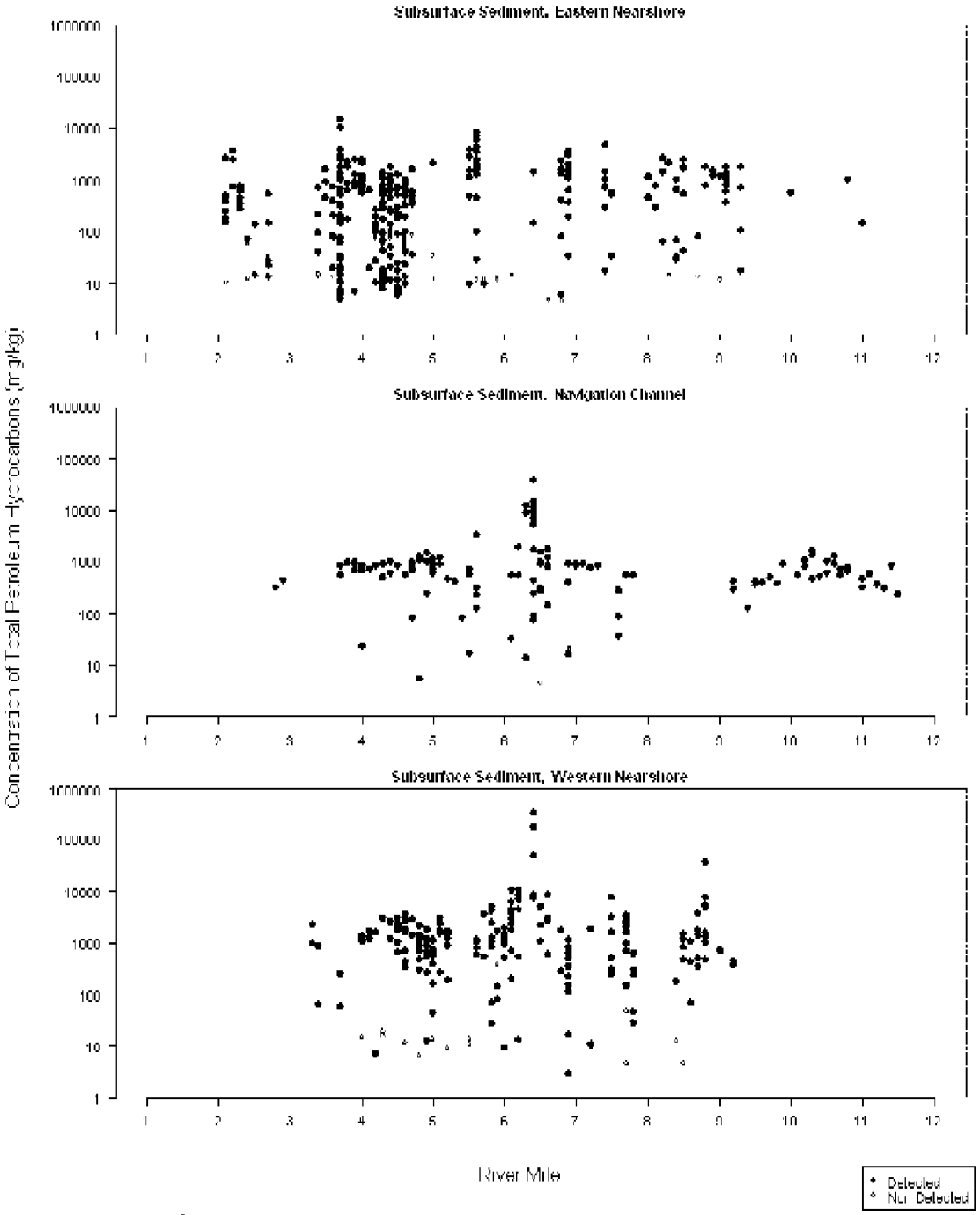
Figure 6.1-46
Portland Harbor RI/FS
Comprehensive Round 2 Report
Scatter Plot of Total Petroleum Hydrocarbons Concentrations (mg/kg)
in Surface Sediment, RM 2-11, Eastern Nearshore (top plot),
Navigation Channel (center plot), and Western Nearshore (bottom plot)

BZTO104(e)031521



integral

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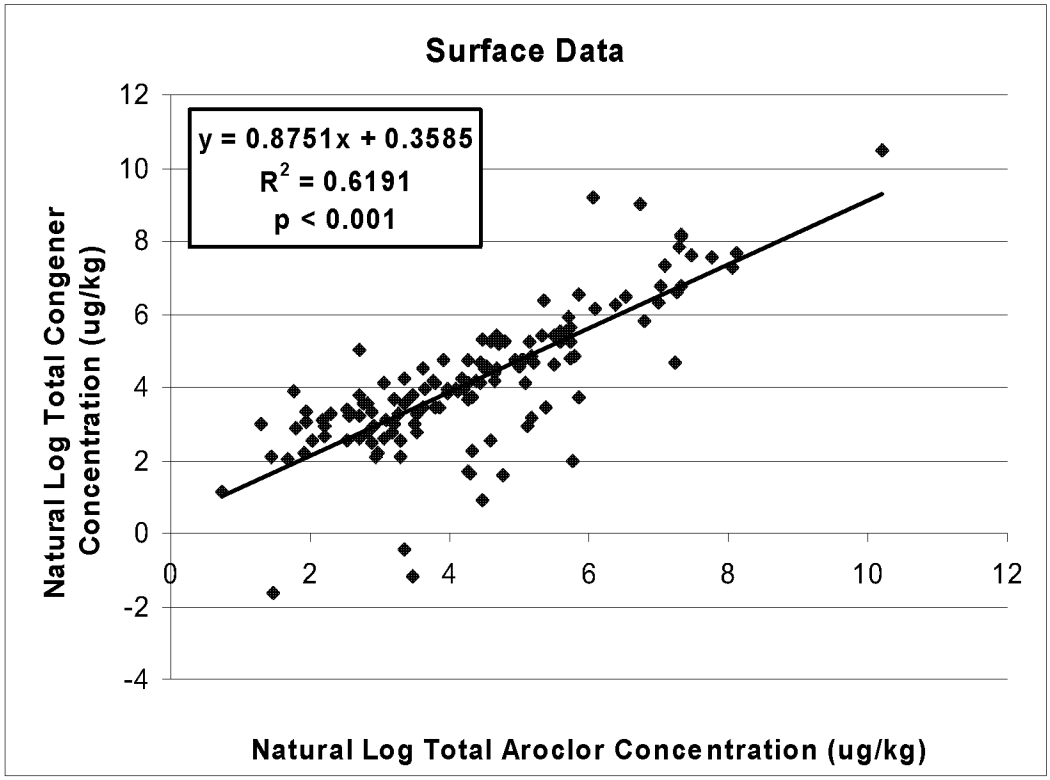
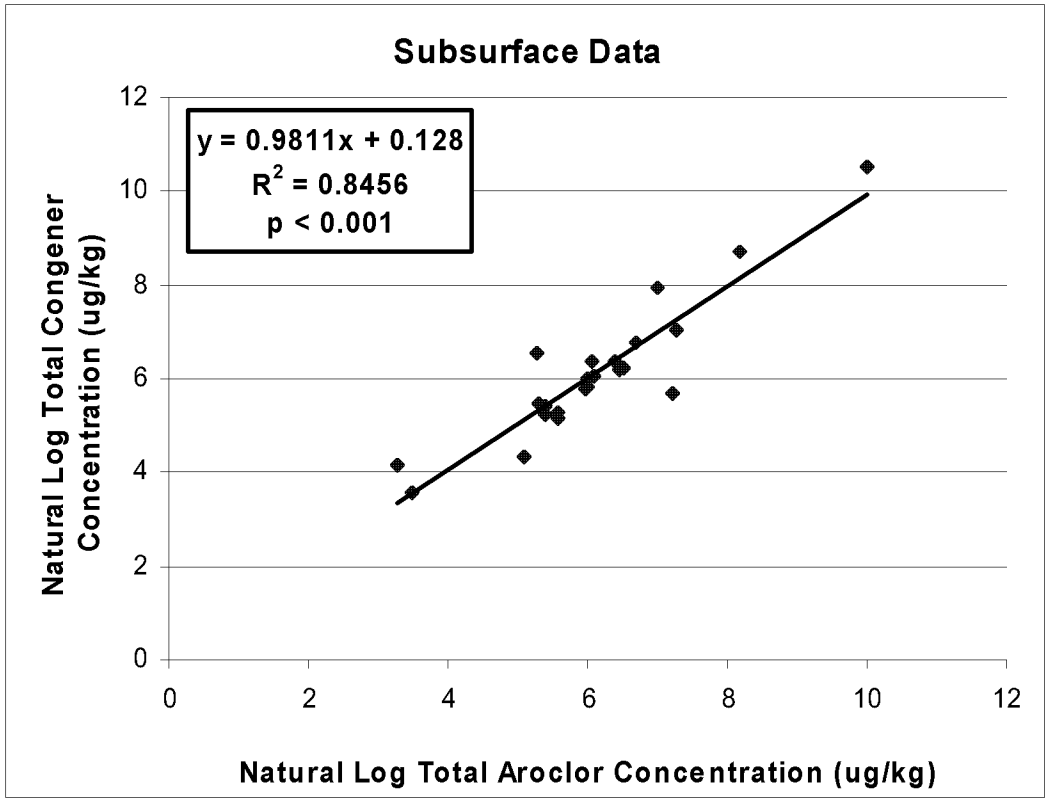
Figure 6.1-47
Portland Harbor RI/FS
Comprehensive Round 2 Report
Scatter Plot of Total Petroleum Hydrocarbons Concentrations (mg/kg)
in Subsurface Sediment, RM 2-11, Eastern Nearshore (top plot),
Navigation Channel (center plot), and Western Nearshore (bottom plot)

BZTO104(e)031522





integral

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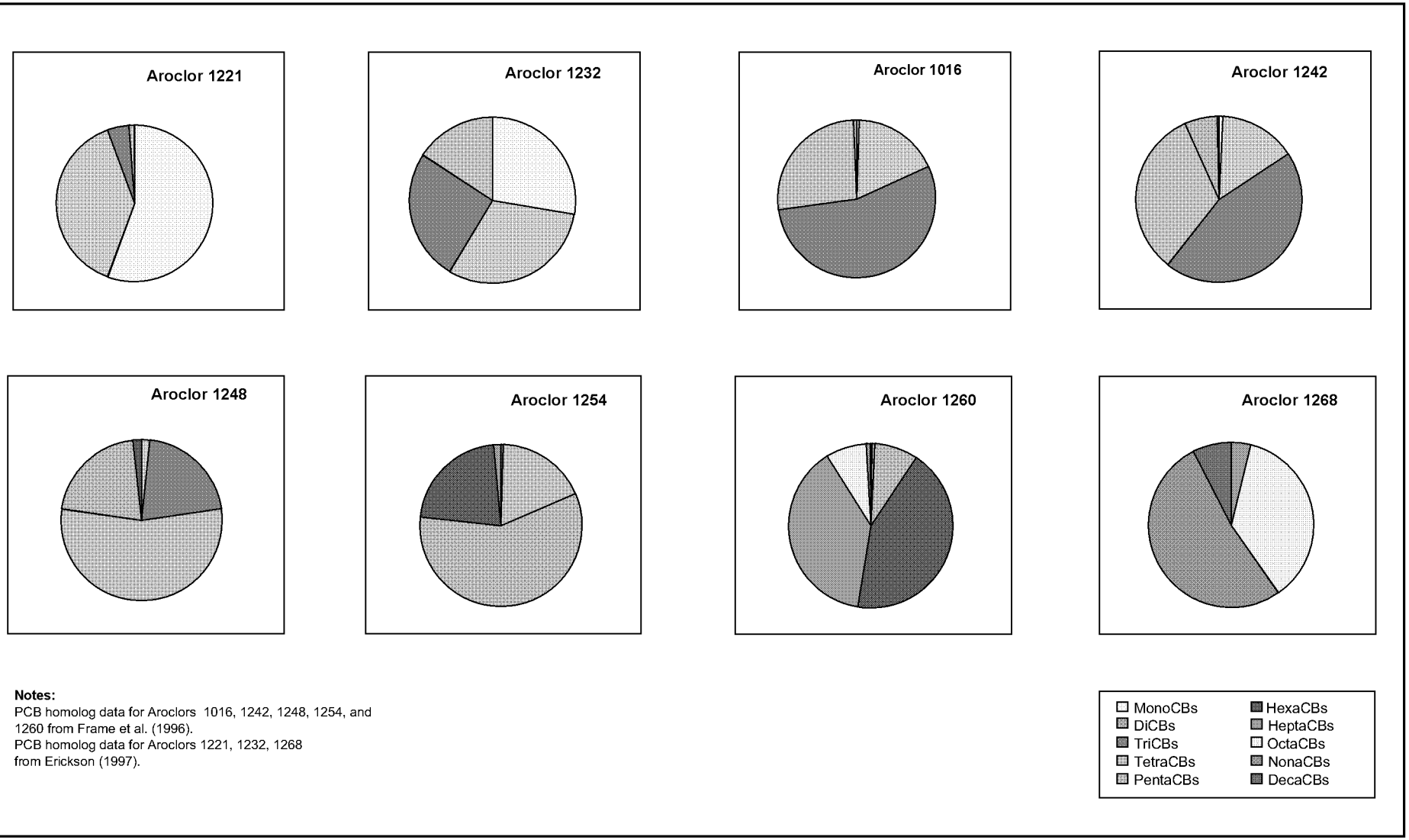
Figure 6.1-48
Portland Harbor RI/FS
Comprehensive Round 2 Report
Plots of Detected Total PCB Aroclor and Congener Concentrations in Surface and Subsurface Sediments

BZTO104(e)031523



Notes:
PCB homolog data for Aroclors 1016, 1242, 1248, 1254, and 1260 from Frame et al. (1996).
PCB homolog data for Aroclors 1221, 1232, 1268 from Erickson (1997).

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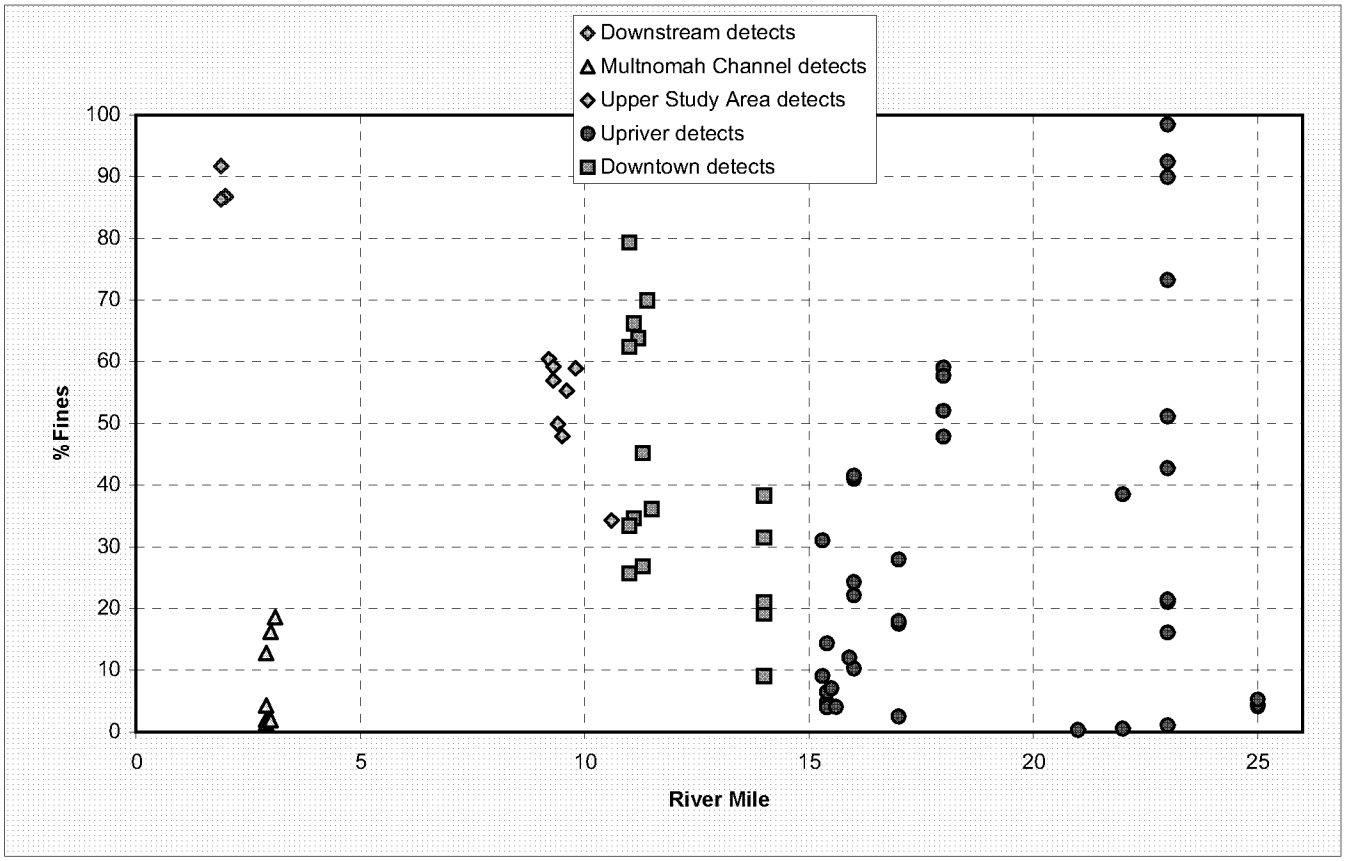
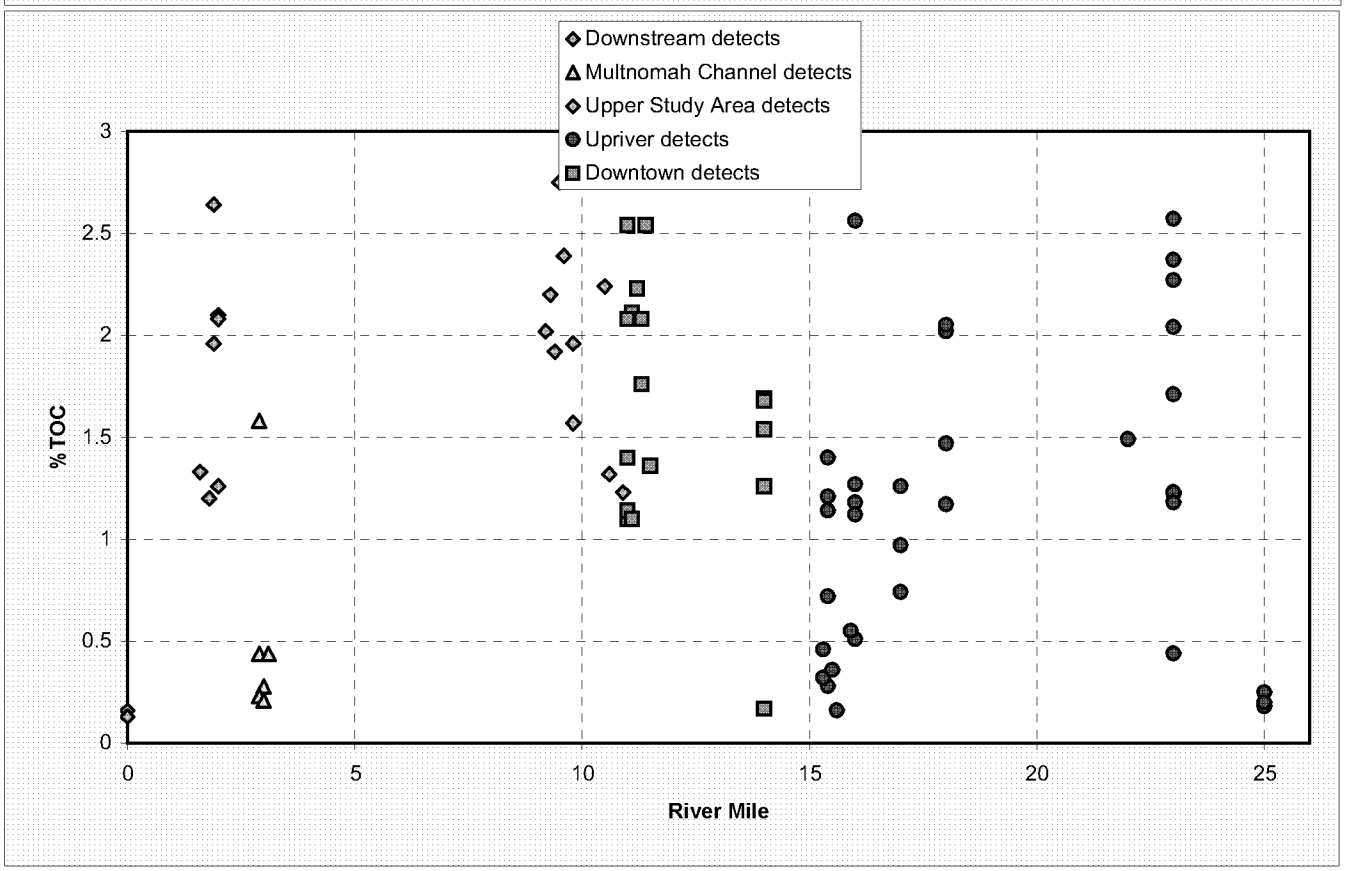
Privileged and Confidential:
Work Product Prepared in Anticipation of Litigaiton

Figure 6.1-49
Portland Harbor RI/FS
Comprehensive Round 2 Report
Homolog Composition of Aroclors Reported in Sediment





integral

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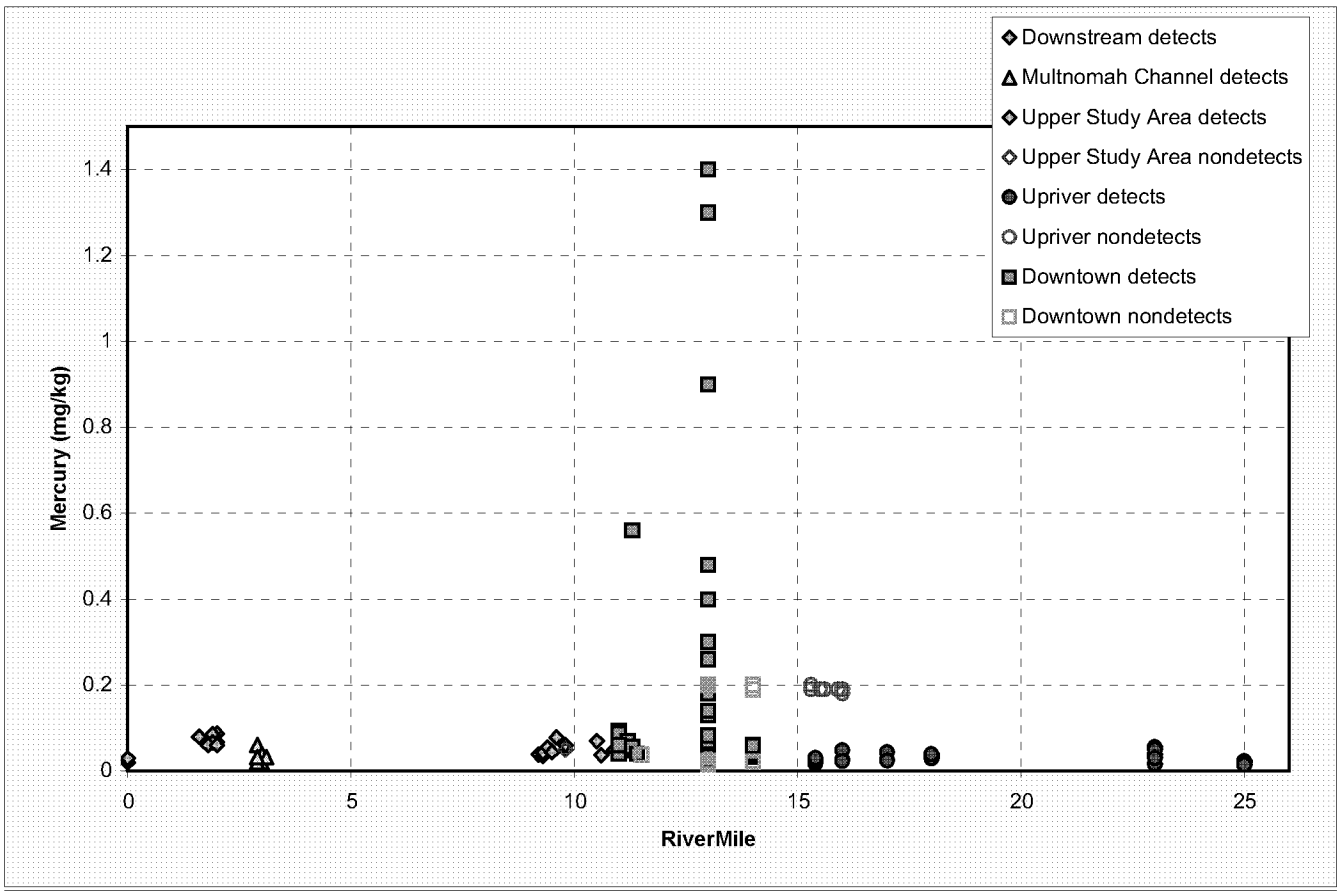
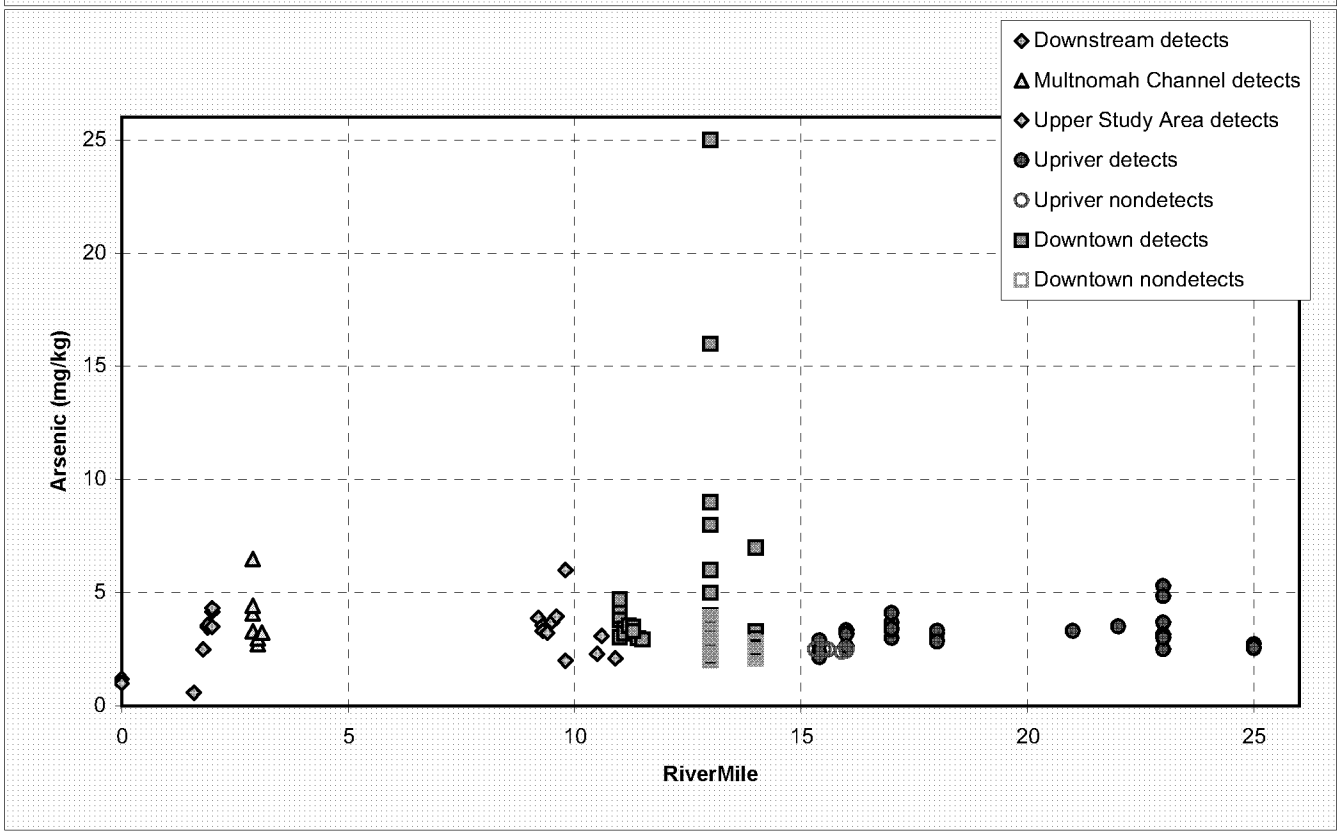
Figure 6.1-50
Portland Harbor RI/FS
Comprehensive Round 2 Report
Analyte Concentrations by River Mile for
Upstream/Downstream Subareas





integral

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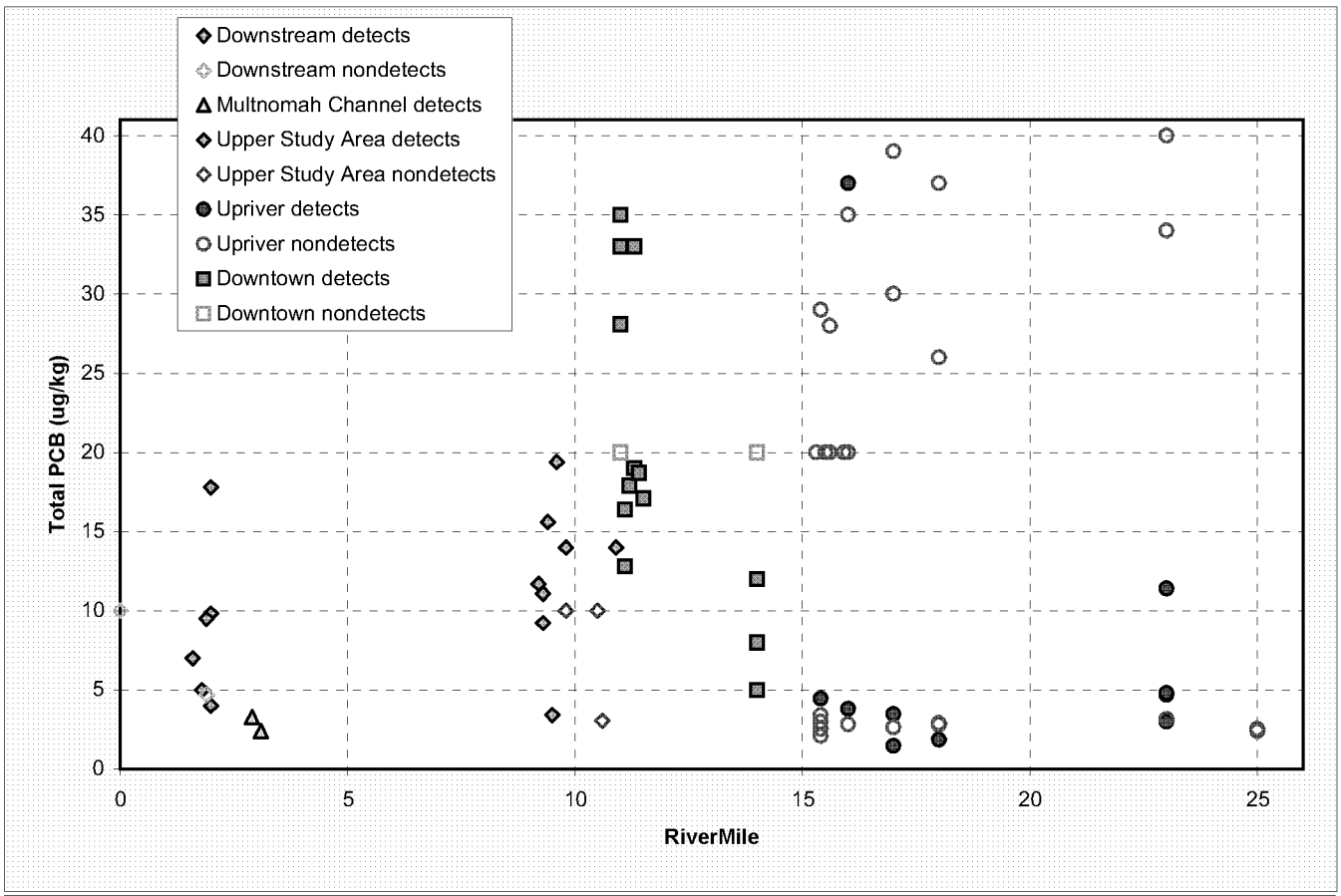
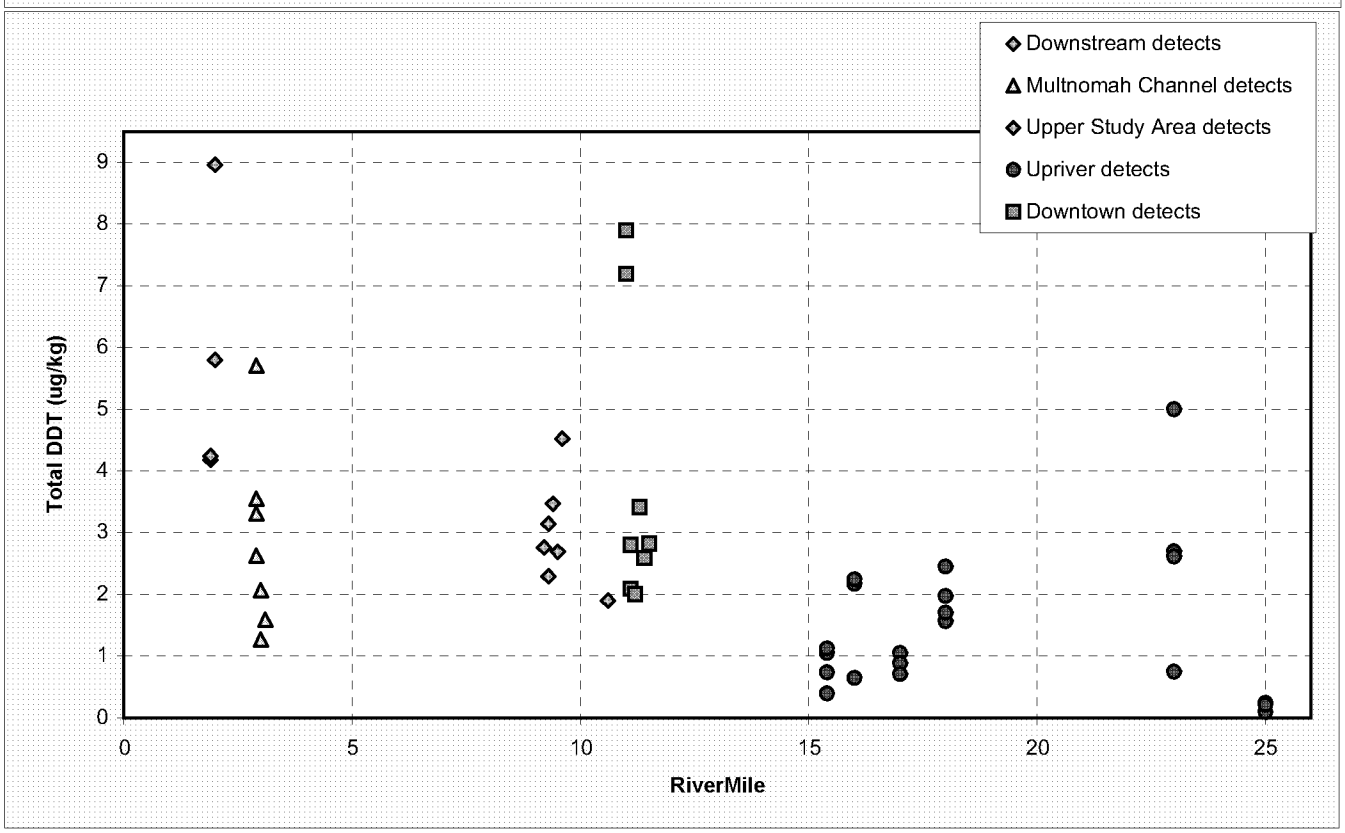
Figure 6.1-50
Portland Harbor RI/FS
Comprehensive Round 2 Report
Analyte Concentrations by River Mile for
Upstream/Downstream Subareas





integral

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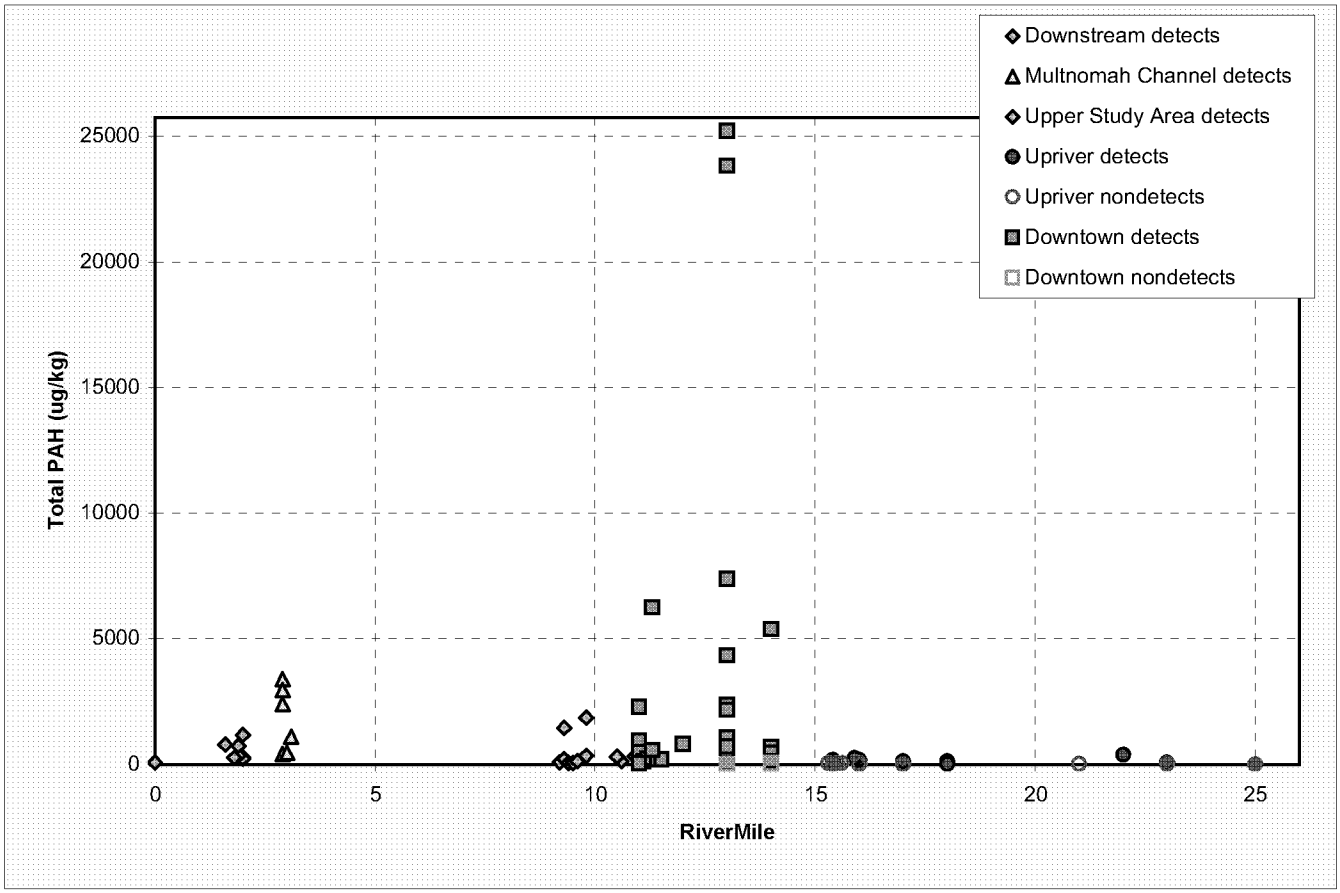
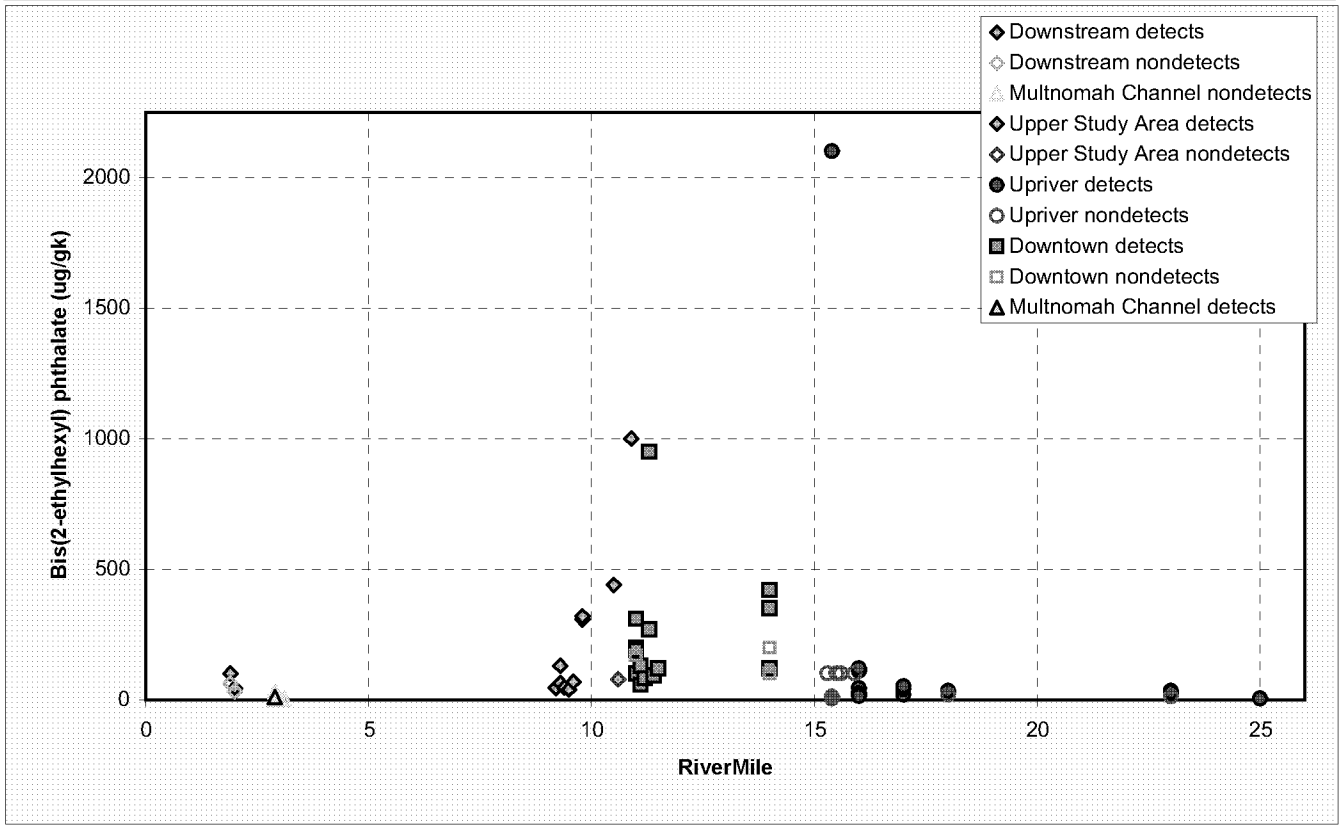
Figure 6.1-50
Portland Harbor RI/FS
Comprehensive Round 2 Report
Analyte Concentrations by River Mile for
Upstream/Downstream Subareas

BZTO104(e)031527





integral

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Figure 6.1-50
Portland Harbor RI/FS
Comprehensive Round 2 Report
Analyte Concentrations by River Mile for
Upstream/Downstream Subareas

BZTO104(e)031528

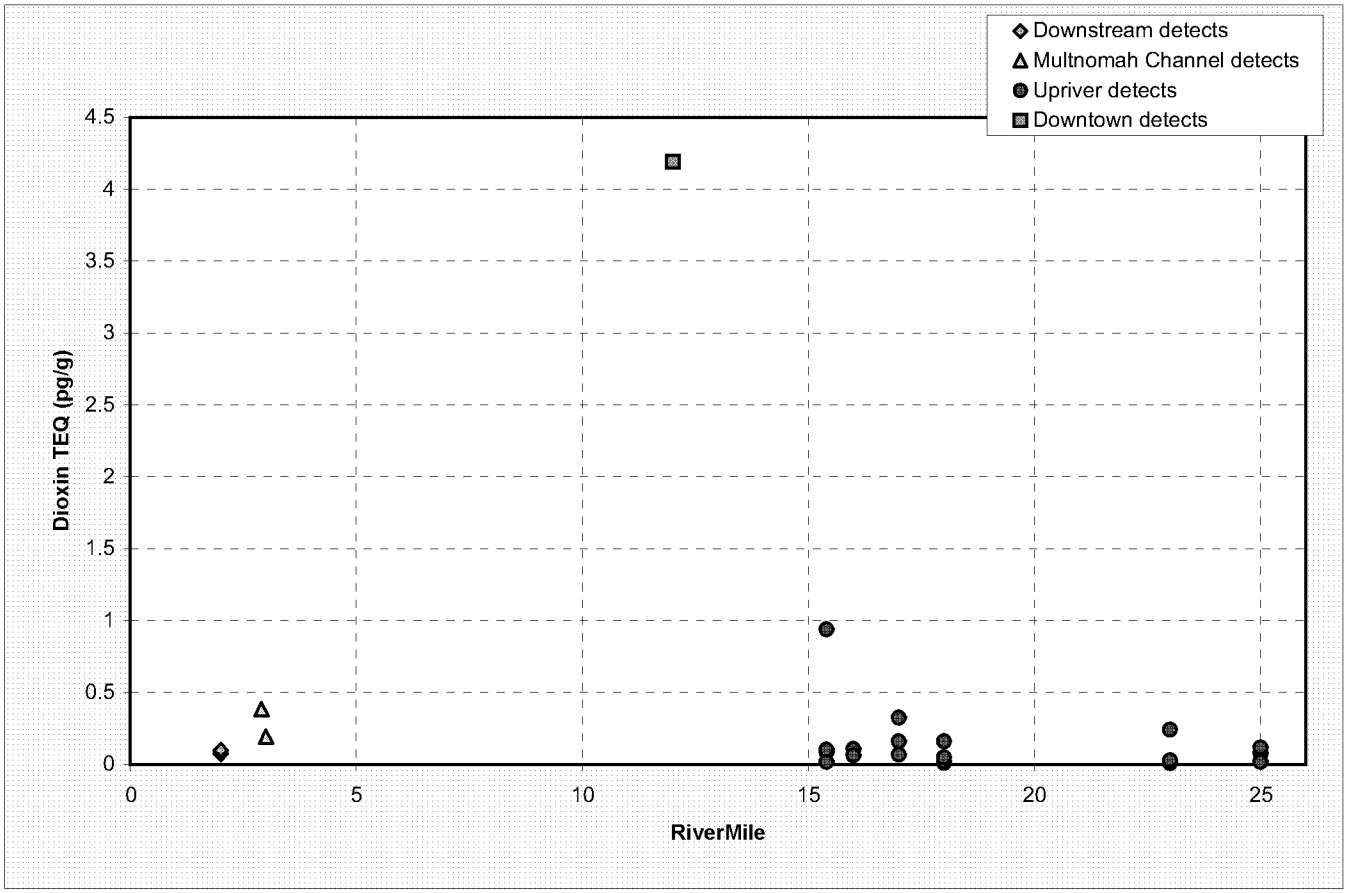

Figure 6.1-50
Portland Harbor RI/FS
Comprehensive Round 2 Report
Analyte Concentrations by River Mile for
Upstream/Downstream Subareas

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BZTO104(e)031529

	Average Concentration	Units	UR	DT	USA	DS	MC
Fines							
UR	24	%		<	<	<	>
DT	41	%			=	<	>
USA	53	%				<	>
DS	88	%					>
MC	7	%					
TOC							
UR	1.06	%		<	<	=	>
DT	1.63	%			=	=	>
USA	1.98	%				=	>
DS	1.43	%					=
MC	0.34	%					
Hg							
UR	0.03	mg/kg		<	<	<	=
DT	0.09	mg/kg			=	=	>
USA	0.05	mg/kg				=	>
DS	0.06	mg/kg					>
MC	0.03	mg/kg					
As							
UR	2.97	mg/kg		=	=	=	=
DT	3.31	mg/kg			=	=	=
USA	3.37	mg/kg				=	=
DS	2.71	mg/kg					=
MC	3.81	mg/kg					
PCB							
UR	3.37	ug/kg		<	<	<	na
DT	18.26	ug/kg			>	>	na
USA	10.21	ug/kg				=	na
DS	7.72	ug/kg					na
MC	2.4	ug/kg					
DDT							
UR	1.44	ug/kg		<	<	<	<
DT	3.85	ug/kg			=	=	=
USA	2.97	ug/kg				<	=
DS	5.8	ug/kg					>
MC	2.4	ug/kg					
PAH							
UR	57	ug/kg		<	<	<	<
DT	698	ug/kg			=	=	<
USA	452	ug/kg				=	<
DS	446	ug/kg					<
MC	1374	ug/kg					
BEHP							
UR	95	ug/kg		<	<	=	na
DT	215	ug/kg			=	>	na
USA	229	ug/kg				>*	na
DS	48	ug/kg					na
MC	16	ug/kg					
TEQ							
UR	0.13	pg/g		na	na	=	na
DT	na	pg/g			na	na	na
USA	na	pg/g				na	na
DS	0.09	pg/g					na
MC	0.19	pg/g					

Notes:

< or > subarea means are significantly less than or greater than each other

= subarea means values are not significantly different

na = not enough data to compare statistically

* p = 0.05

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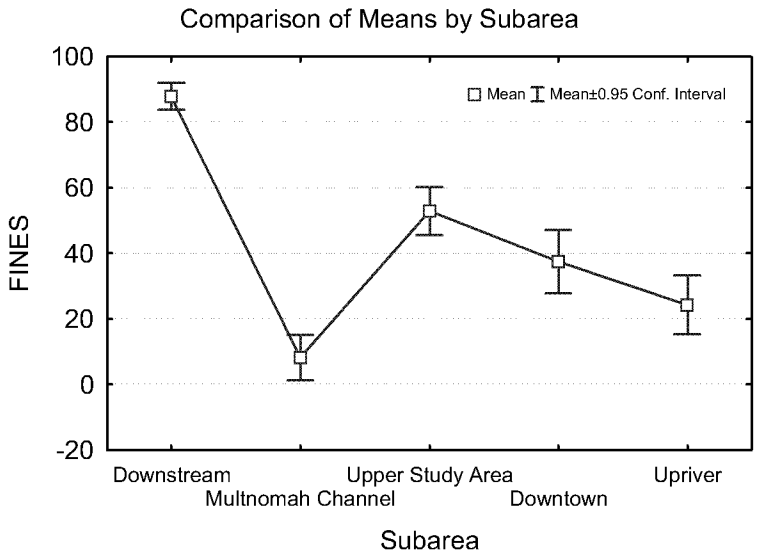
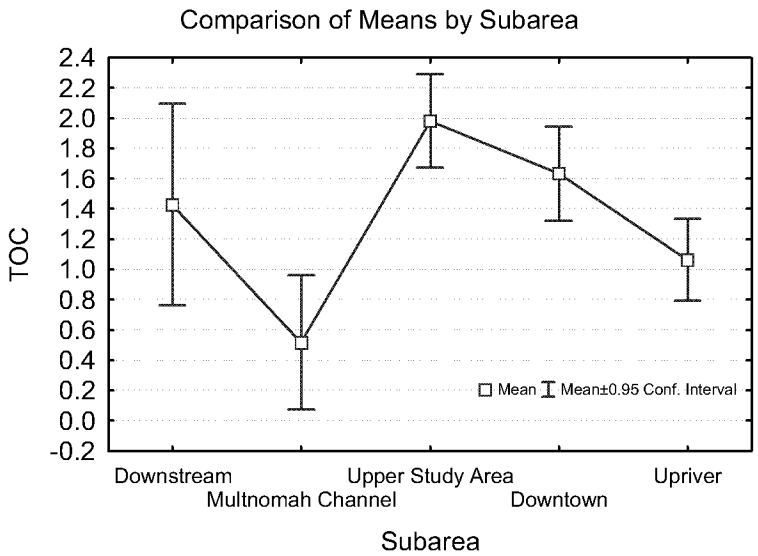
Figure 6.1-51
Portland Harbor RI/FS
Comprehensive Round 2 Report
Summary Matrix of Statistical Test Results Reported in Table 6.1-14

BZTO104(e)031530



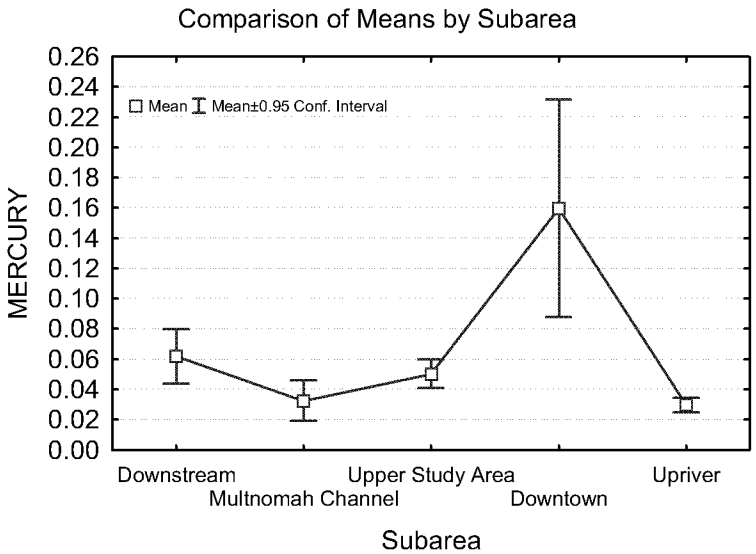


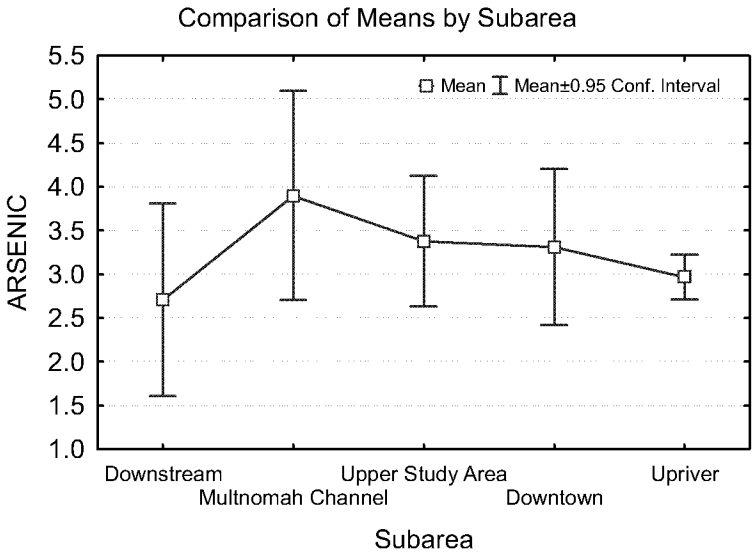
BZTO104(e)031531

integral

LWG
LOWER WILLAMETTE GROUP

Figure 6.1-52
Portland Harbor RI/FS
Comprehensive Round 2 Report
Comparison of Means +/- 95% Confidence
Limits by Subareas



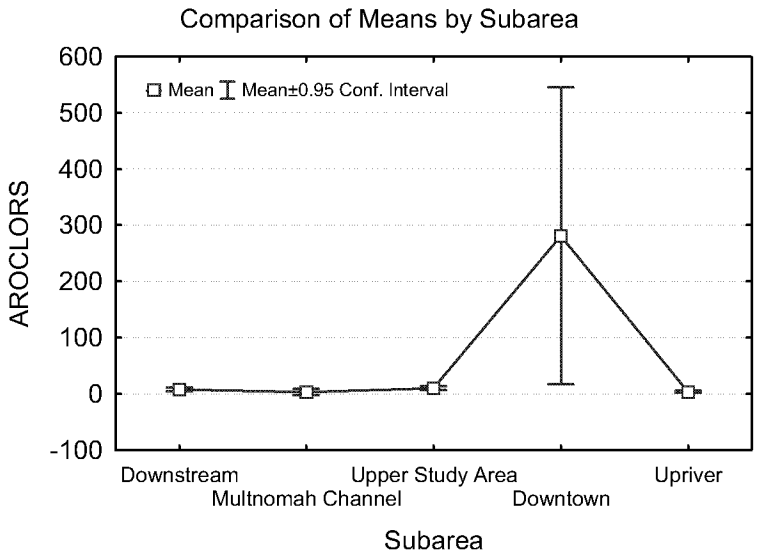


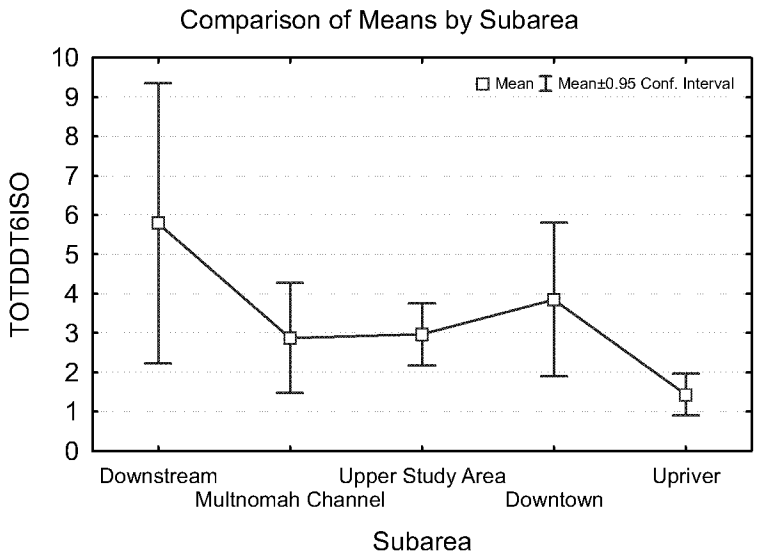
BZTO104(e)031532

integral

LWG
LOWER WILLAMETTE GROUP

Figure 6.1-52 cont.
Portland Harbor RI/FS
Comprehensive Round 2 Report
Comparison of Means +/- 95% Confidence
Limits by Subareas



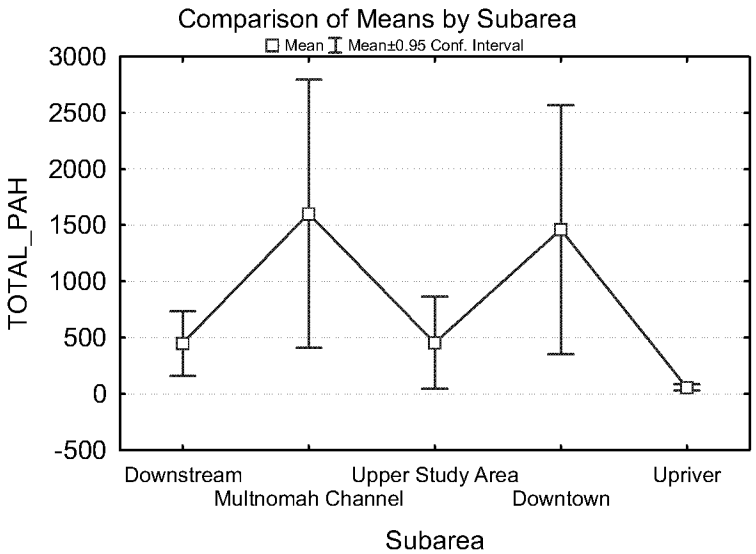


BZTO104(e)031533

integral

LWG
LOWER WILLAMETTE GROUP

Figure 6.1-52 cont.
Portland Harbor RI/FS
Comprehensive Round 2 Report
Comparison of Means +/- 95% Confidence
Limits by Subareas



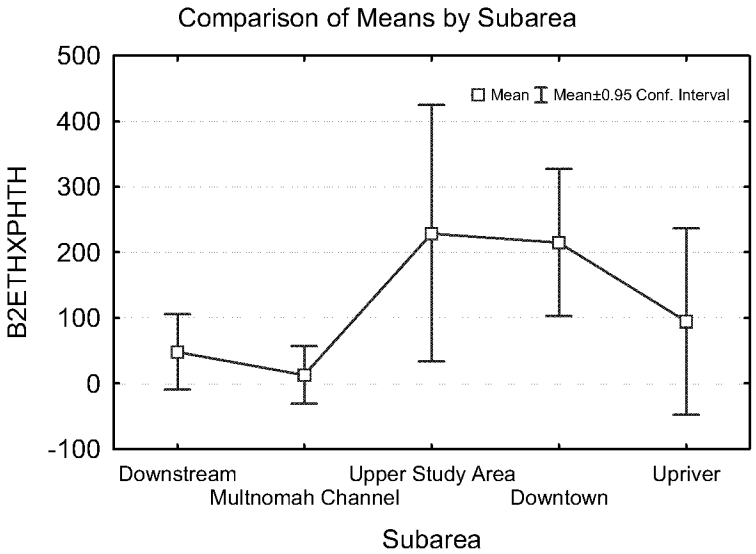


Figure 6.1-52 cont.
Portland Harbor RI/FS
Comprehensive Round 2 Report
Comparison of Means +/- 95% Confidence
Limits by Subareas

BZTO104(e)031534

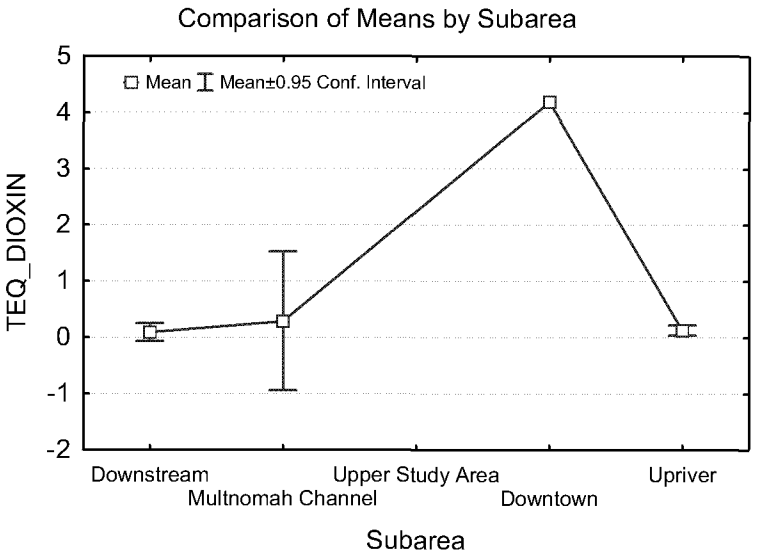


Figure 6.1-52 cont.
Portland Harbor RI/FS
Comprehensive Round 2 Report
Comparison of Means +/- 95% Confidence
Limits by Subareas

BZTO104(e)031535

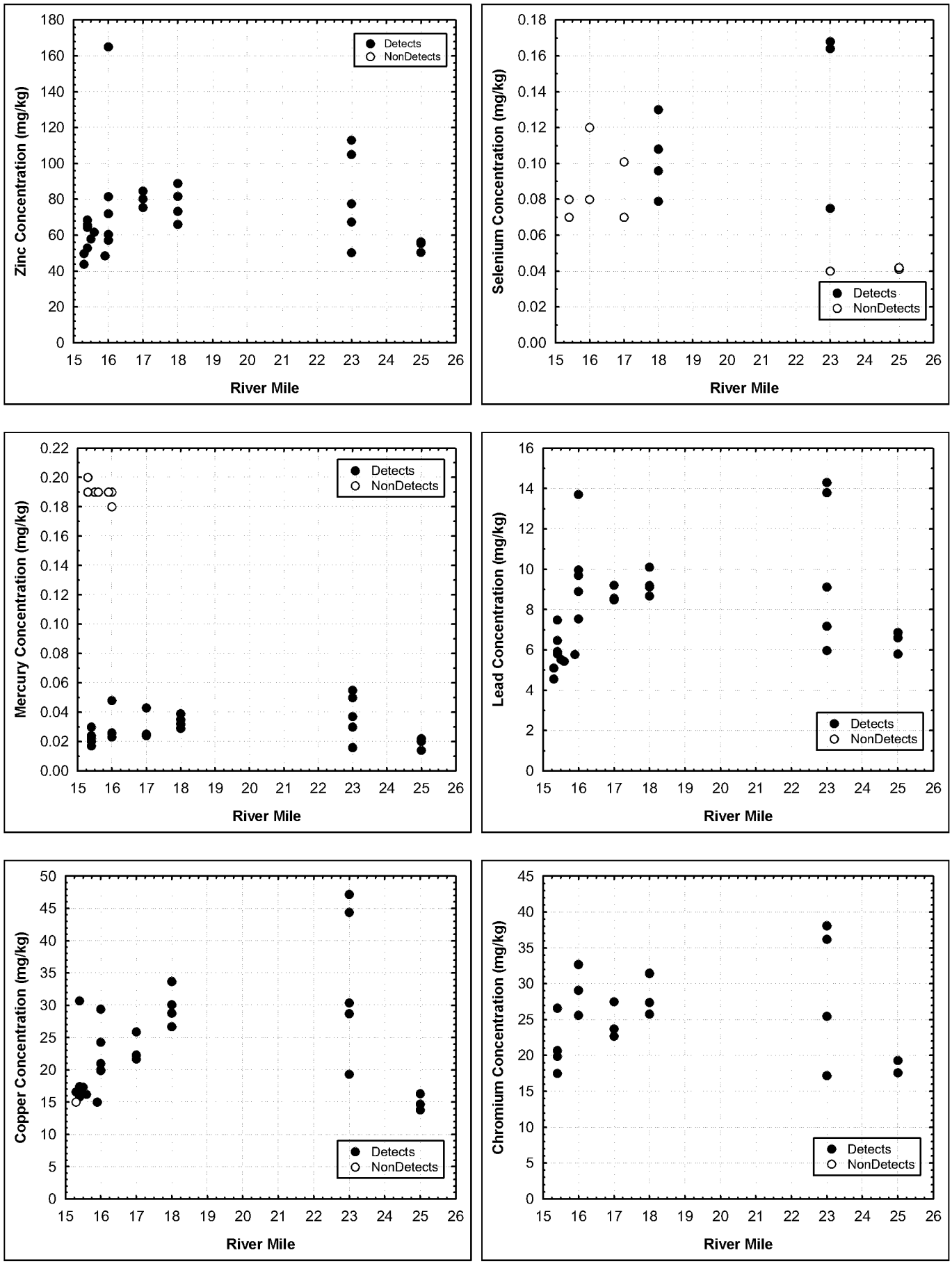


Figure 6.1-53
Portland Harbor RI/FS
Comprehensive Round 2 Report
Scatterplots of Surface Sediment Data for
Selected Chemicals in the Upriver Reach

integral

LWG
Lower Willamette Group

BZTO104(e)031536

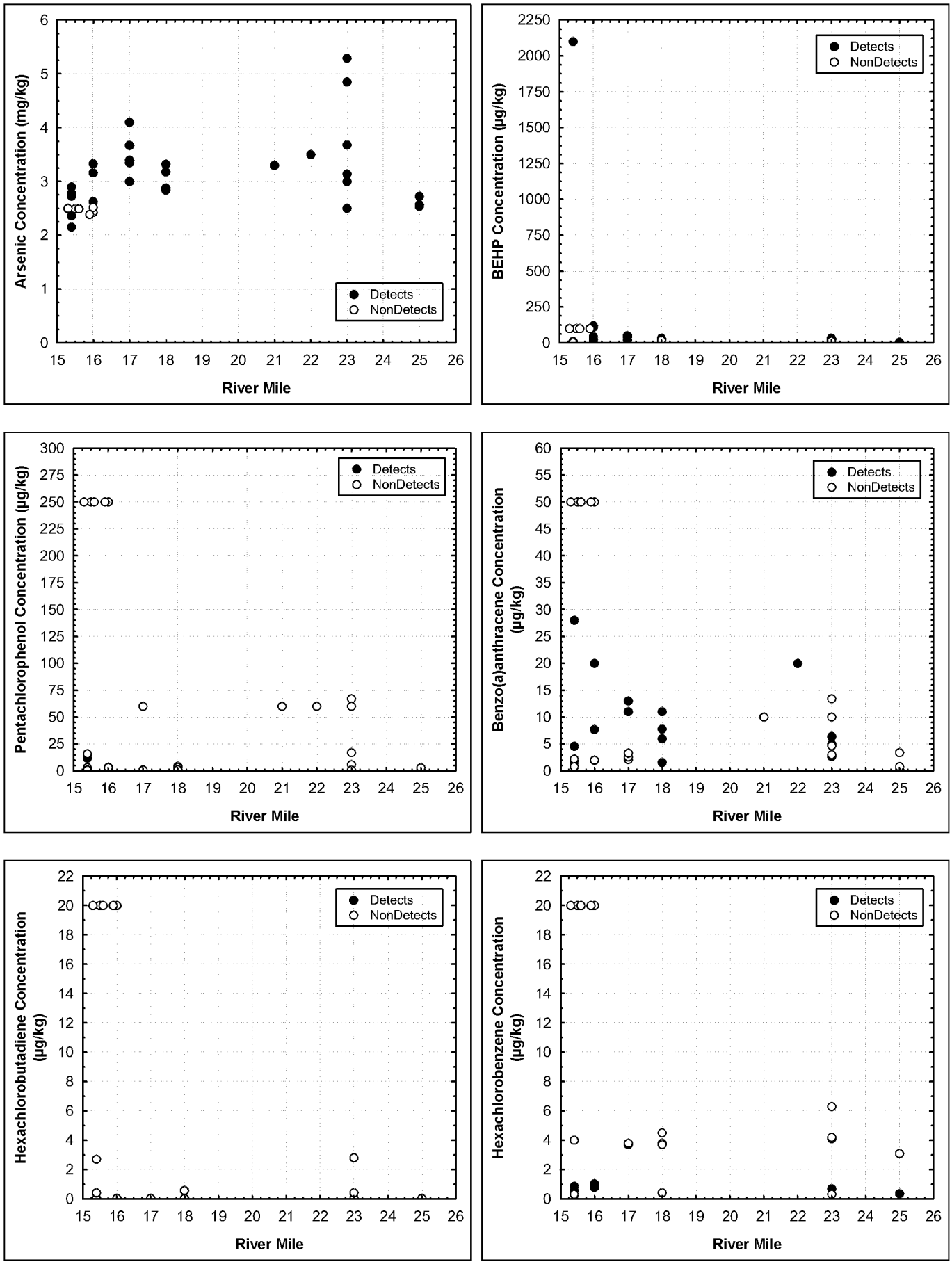
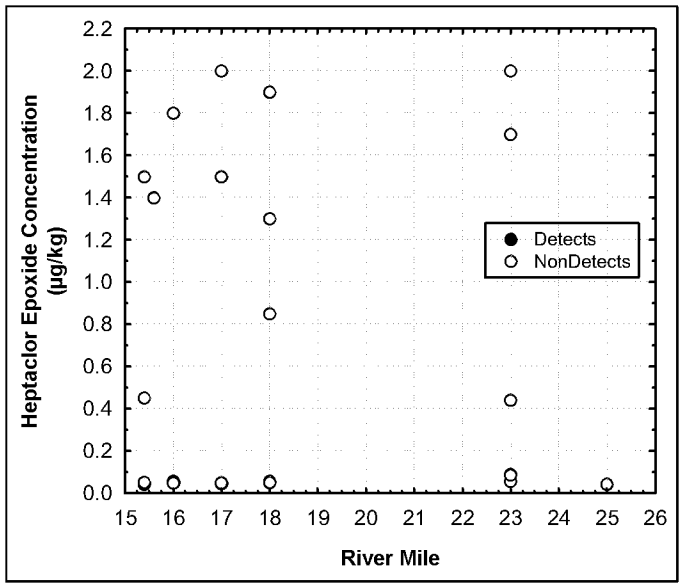


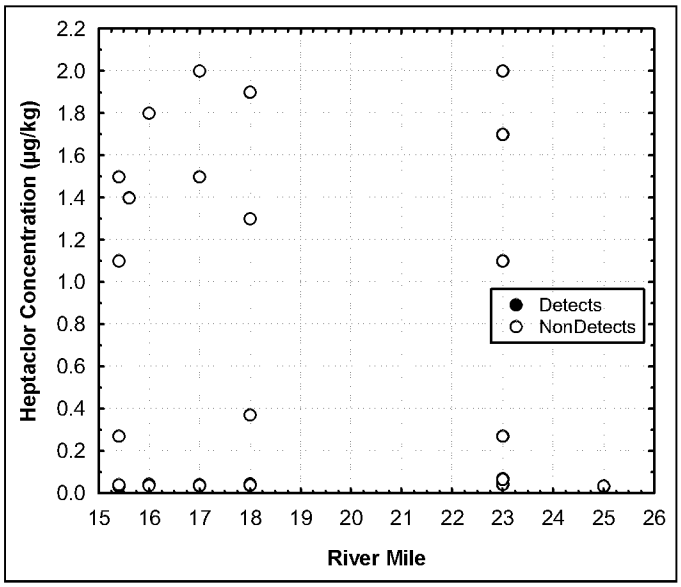
Figure 6.1-53 cont.
Portland Harbor RI/FS
Comprehensive Round 2 Report
Scatterplots of Surface Sediment Data for
Selected Chemicals in the Upriver Reach

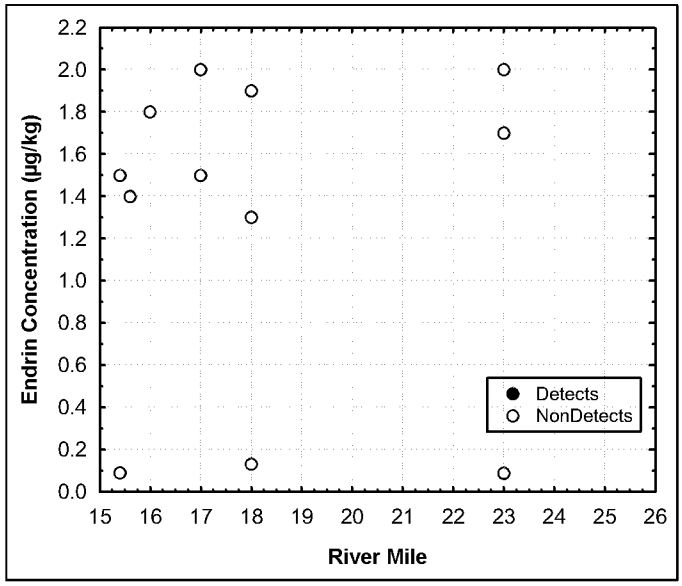
integral

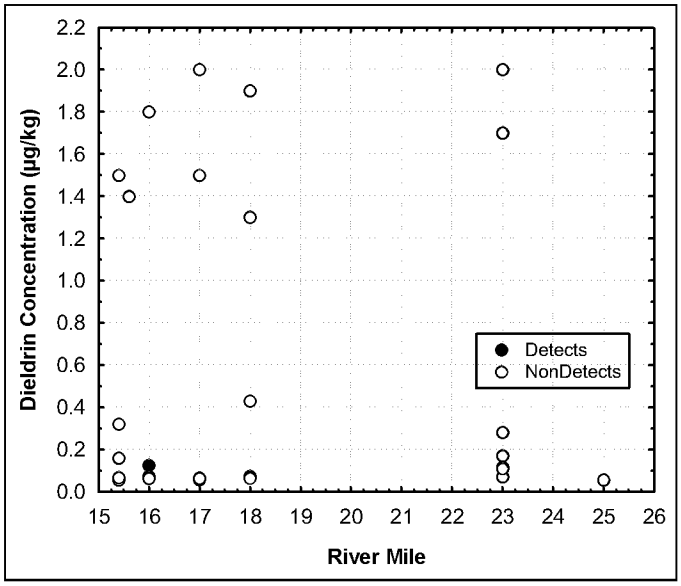
LWG
Lower Willamette Group

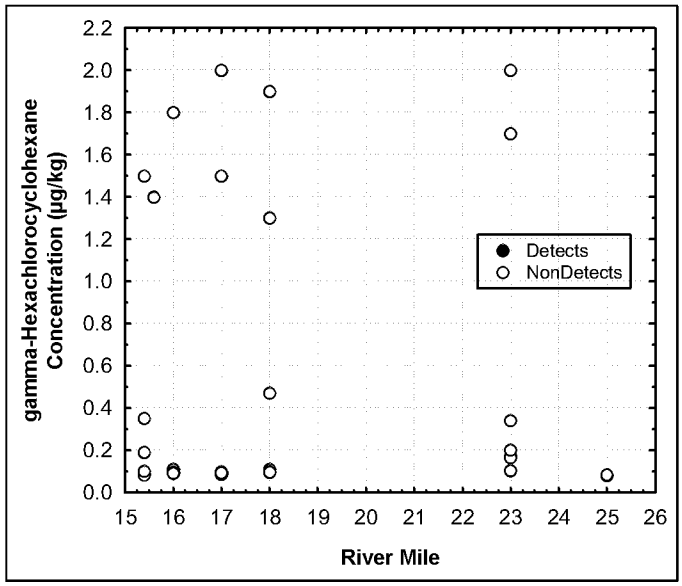
BZTO104(e)031537

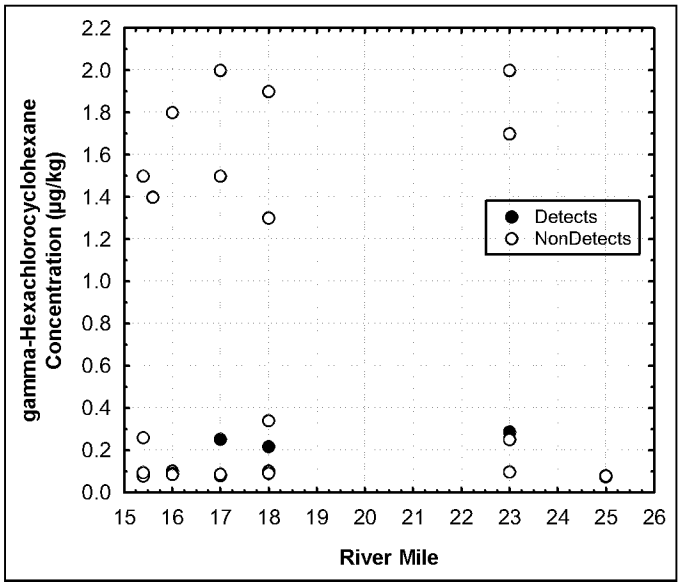












integral

LWG Lower Willamette Group

Figure 6.1-53 cont.
Portland Harbor RI/FS
Comprehensive Round 2 Report
Scatterplots of Surface Sediment Data for
Selected Chemicals in the Upriver Reach

BZTO104(e)031538

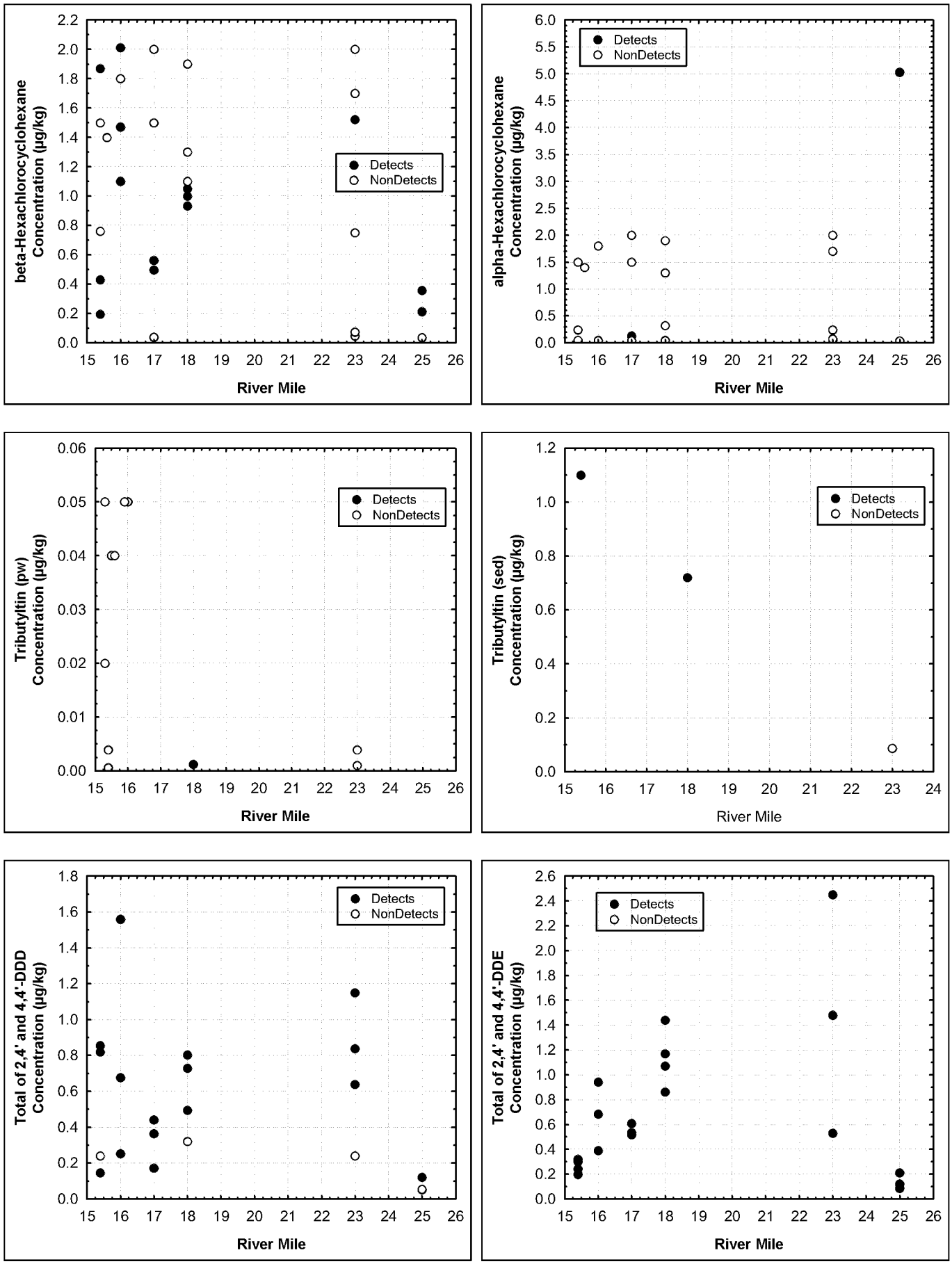
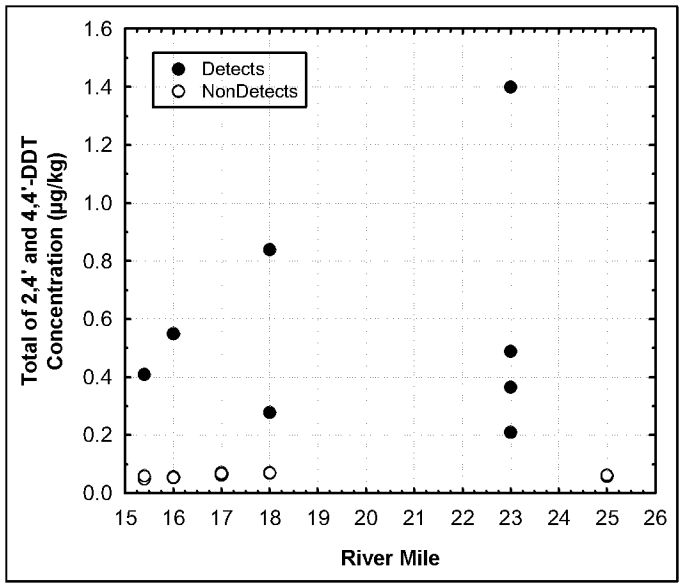


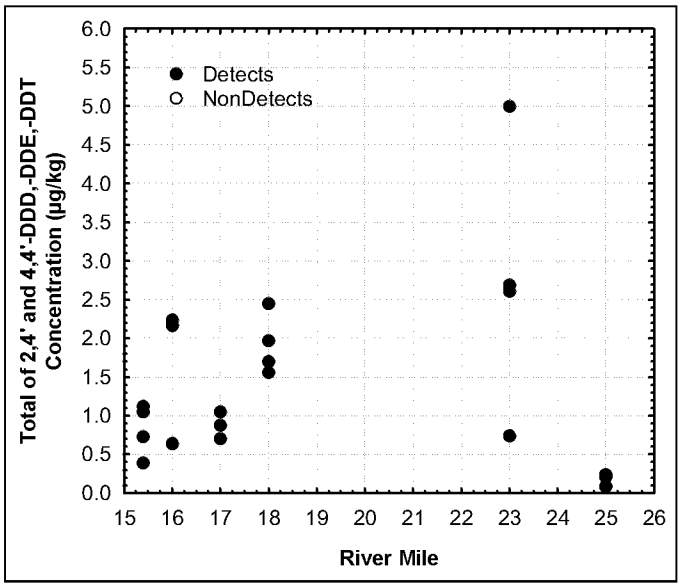
Figure 6.1-53 cont.
Portland Harbor RI/FS
Comprehensive Round 2 Report
Scatterplots of Surface Sediment Data for
Selected Chemicals in the Upriver Reach

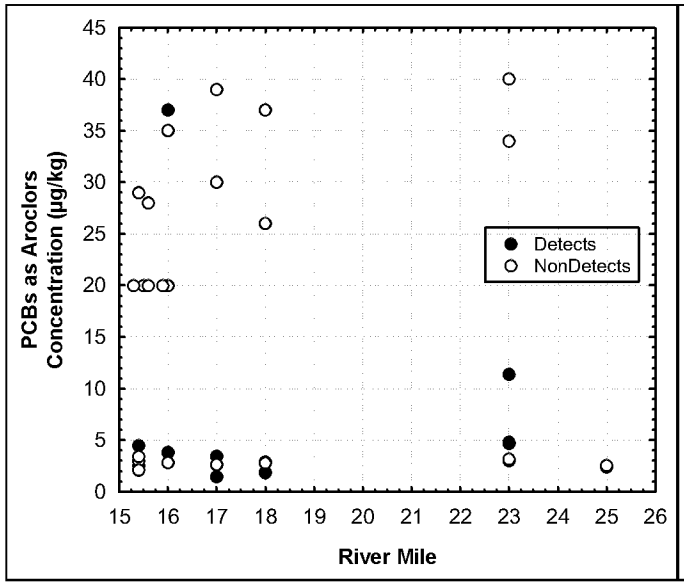
integral

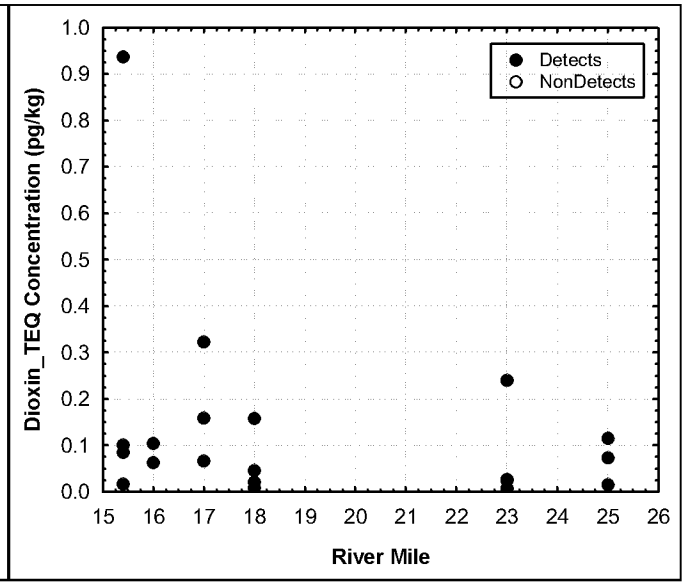
LWG Lower Willamette Group

BZTO104(e)031539









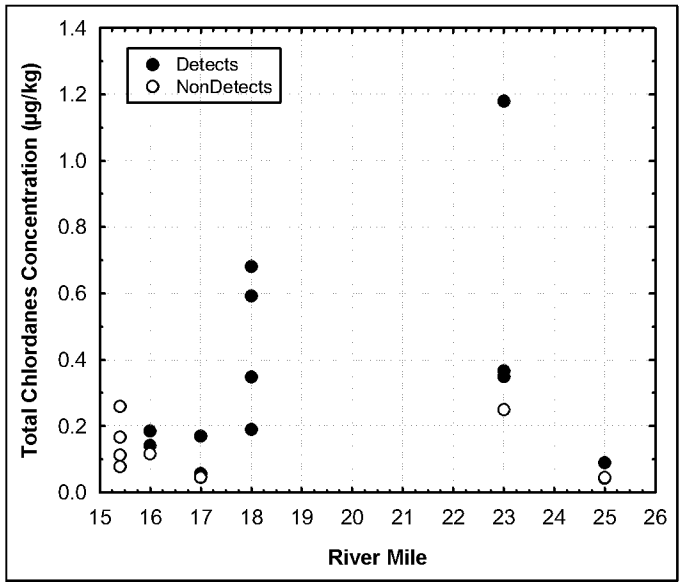
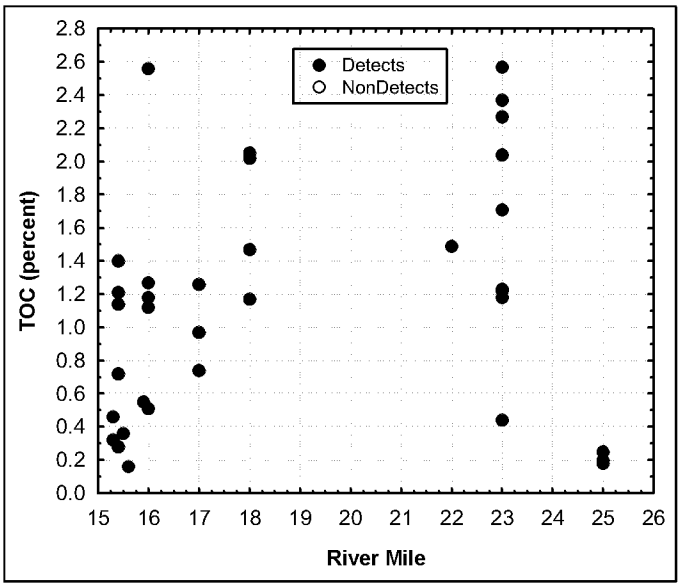


Figure 6.1-53 cont.
Portland Harbor RI/FS
Comprehensive Round 2 Report
Scatterplots of Surface Sediment Data for
Selected Chemicals in the Upriver Reach

integral LWG Lower Willamette Group

BZTO104(e)031540



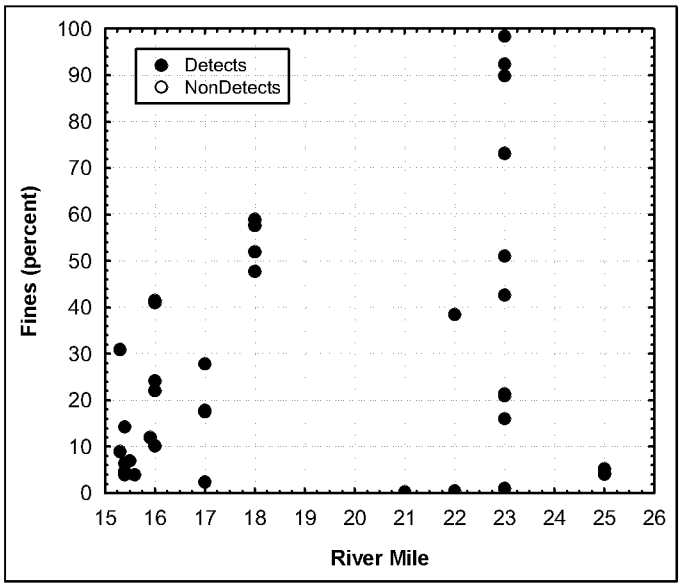
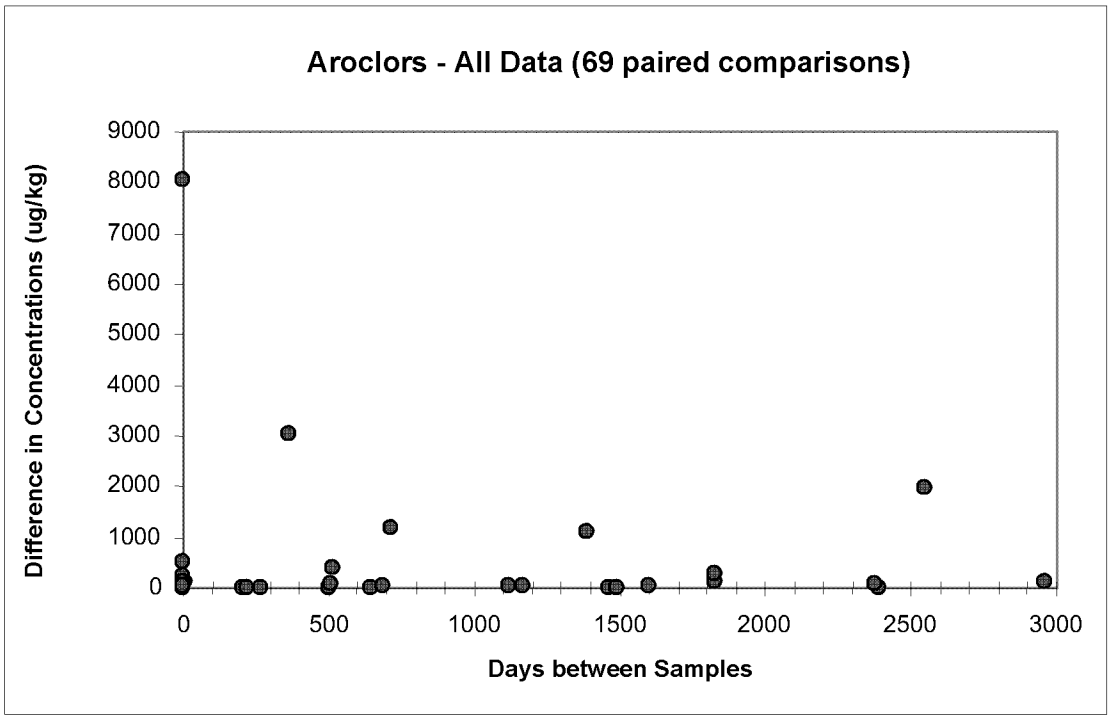


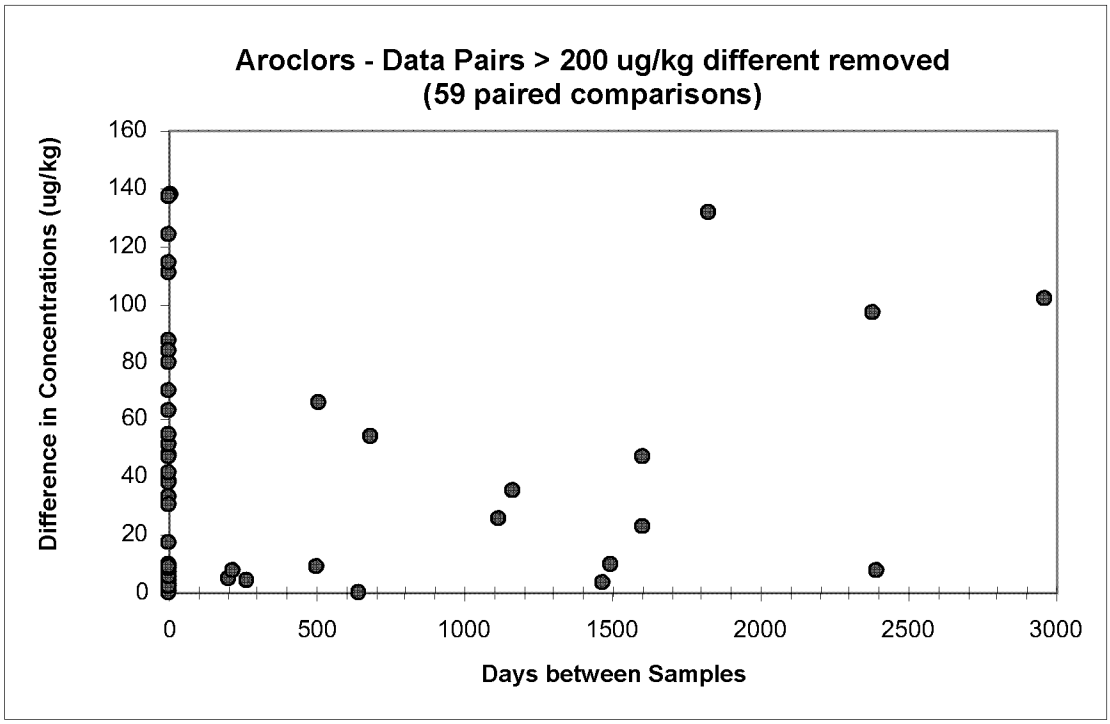
Figure 6.1-53 cont.
Portland Harbor RI/FS
Comprehensive Round 2 Report
Scatterplots of Surface Sediment Data for
Selected Chemicals in the Upriver Reach

integral

LWG
LOWER WILLAMETTE GROUP

BZTO104(e)031541



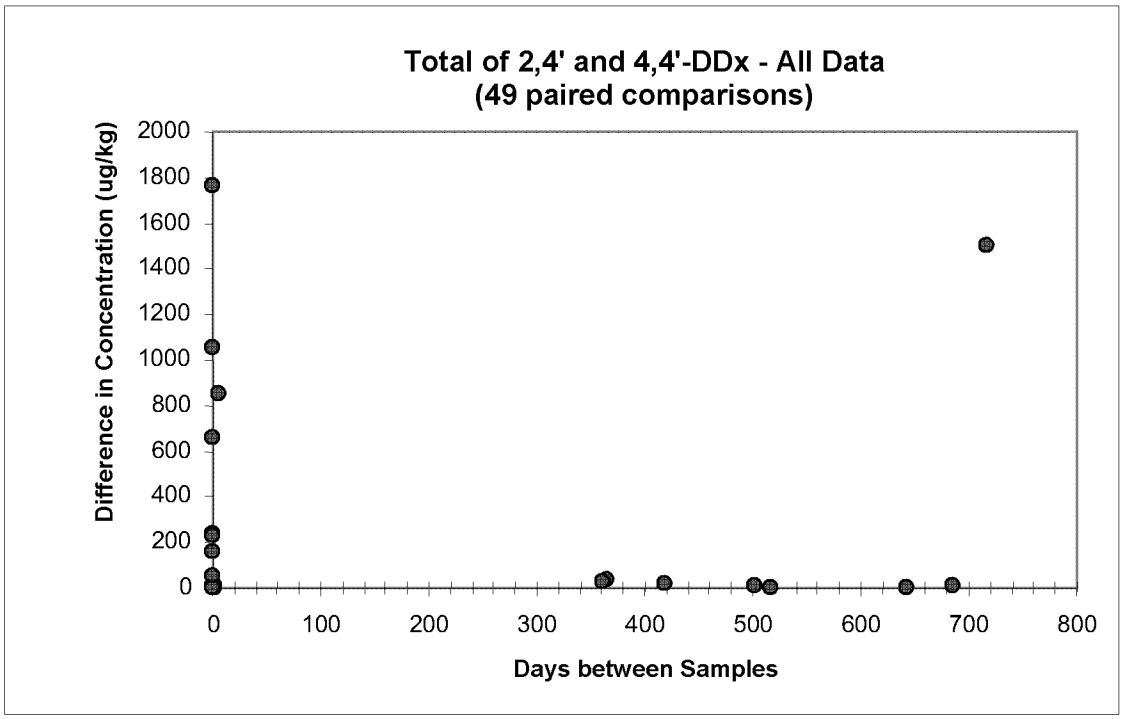


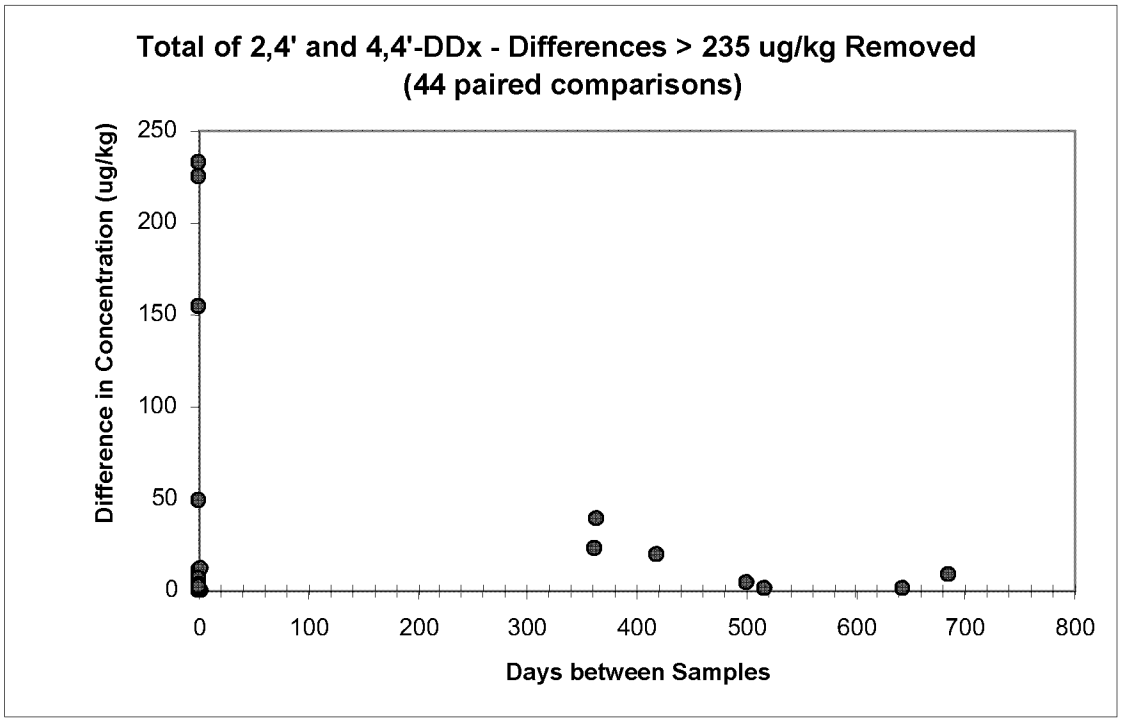
integral

LWG
LOWER WILLAMETTE GROUP

Figure 6.1-54
Portland Harbor RI/FS
Comprehensive Round 2 Report
Concentration Differences in Collocated Samples
Versus Time between Samples

BZTO104(e)031542



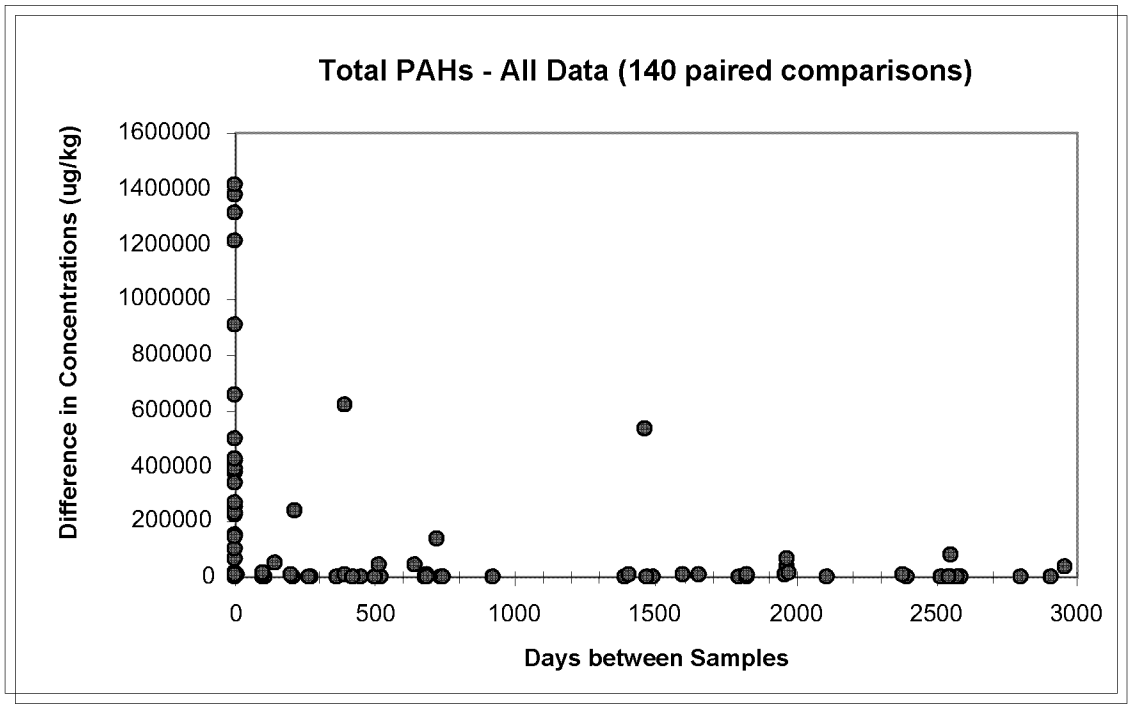


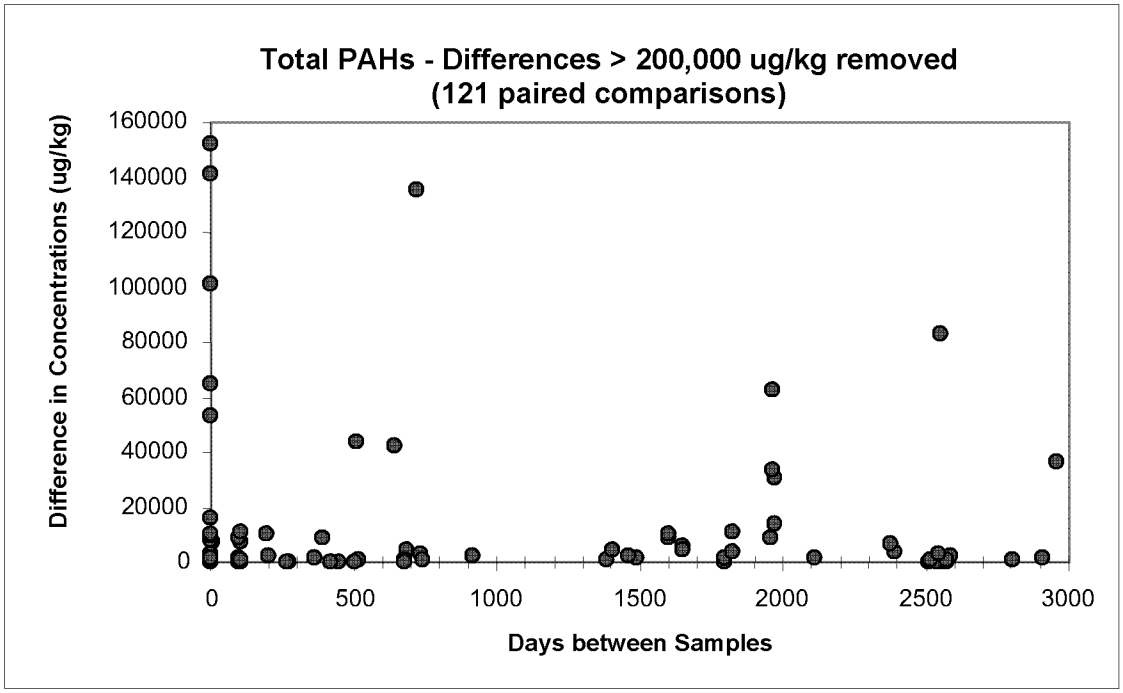
integral

LWG
LOWER WILLAMETTE GROUP

Figure 6.1-54 cont.
Portland Harbor RI/FS
Comprehensive Round 2 Report
Concentration Differences in Collocated Samples
Versus Time between Samples

BZTO104(e)031543



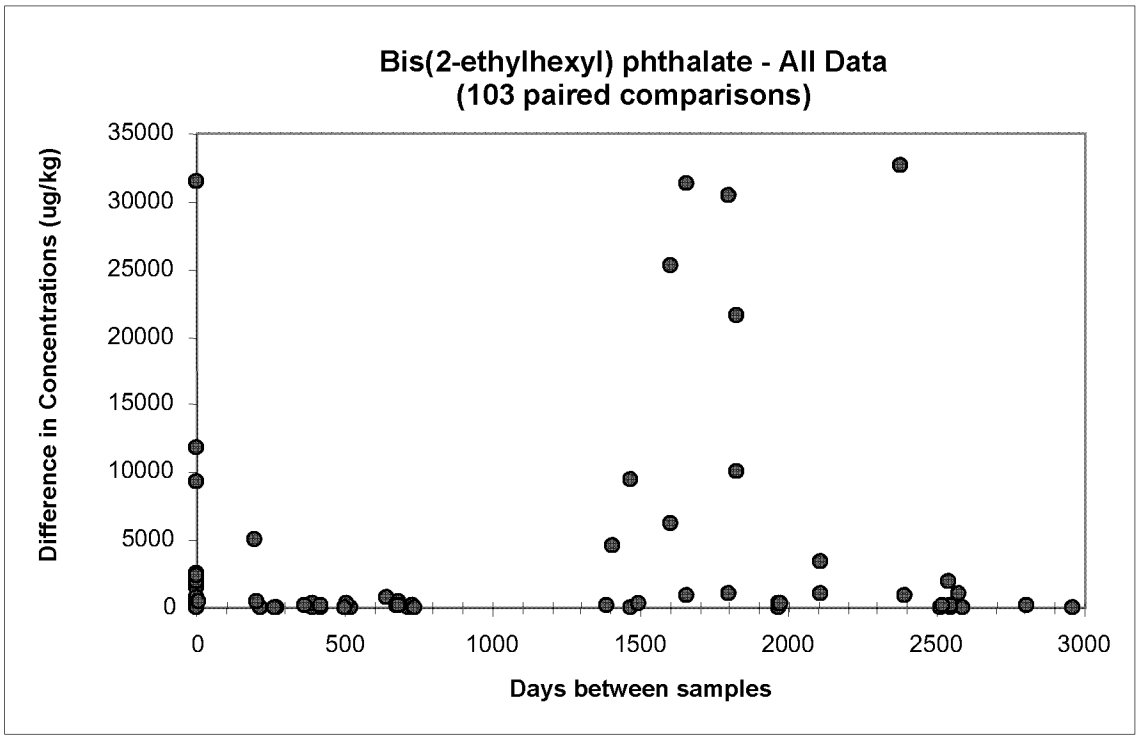


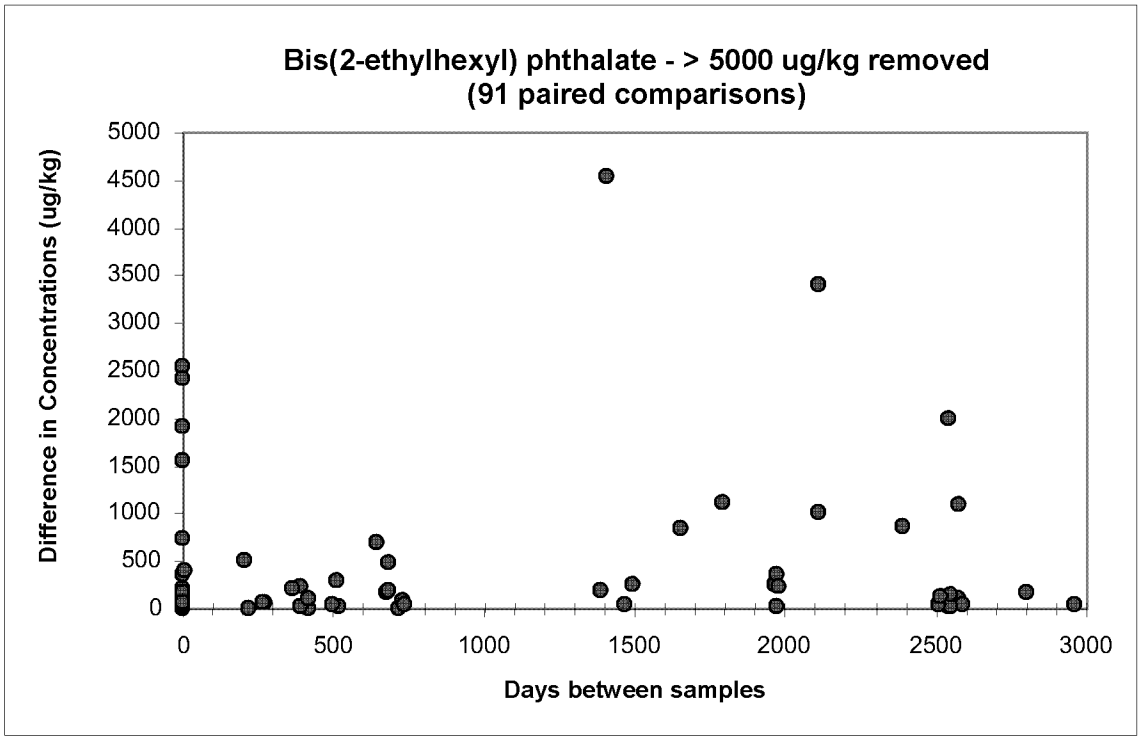
integral

LWG
LOWER WILLAMETTE GROUP

Figure 6.1-54 cont.
Portland Harbor RI/FS
Comprehensive Round 2 Report
Concentration Differences in Collocated Samples
Versus Time between Samples

BZTO104(e)031544



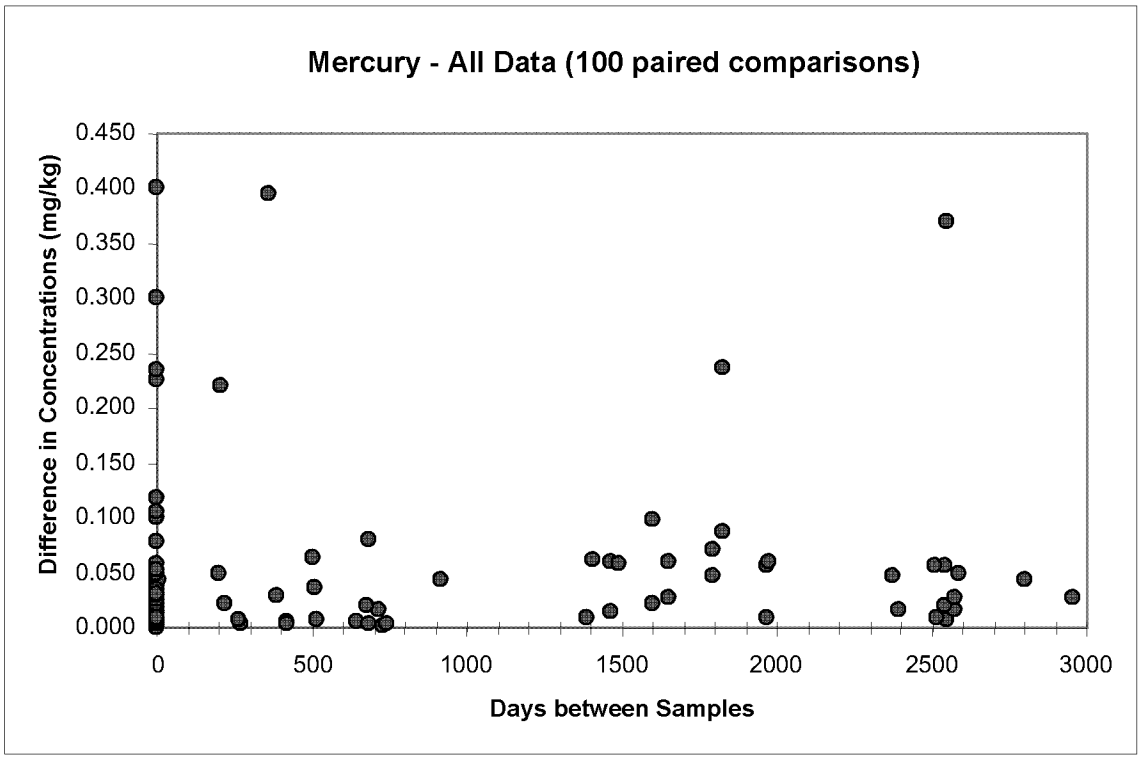


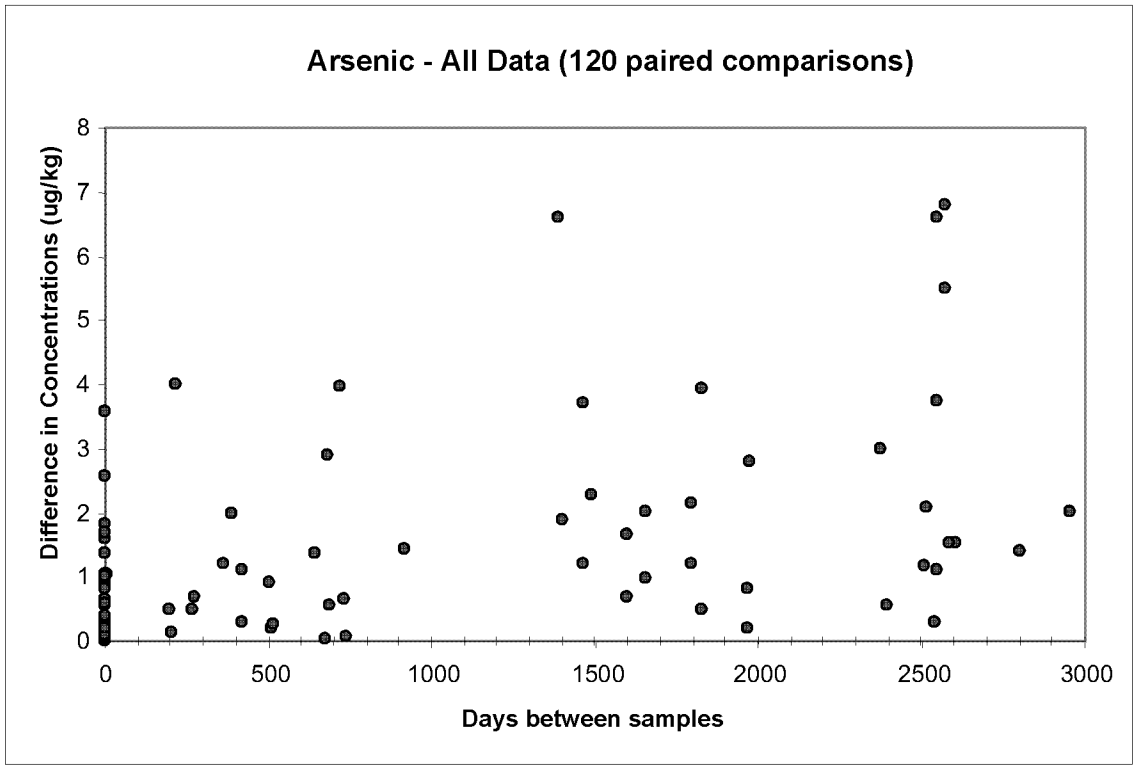
integral

LWG
LOWER WILLAMETTE GROUP

Figure 6.1-54 cont.

Portland Harbor RI/FS
Comprehensive Round 2 Report
Concentration Differences in Collocated Samples
Versus Time between Samples





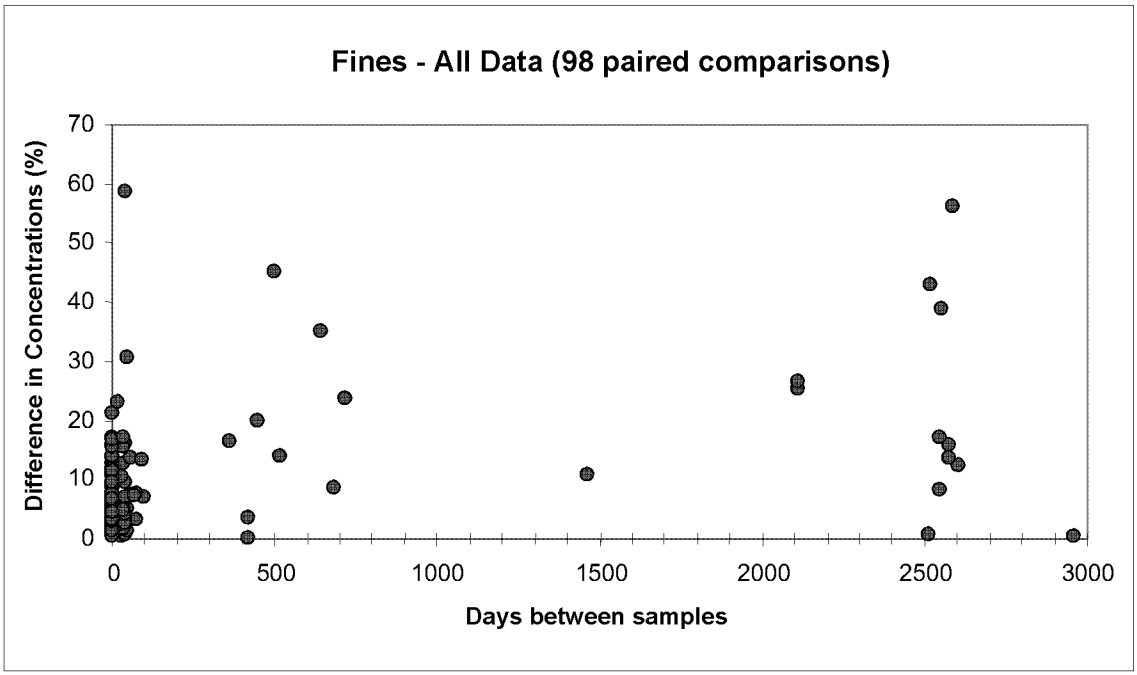
integral

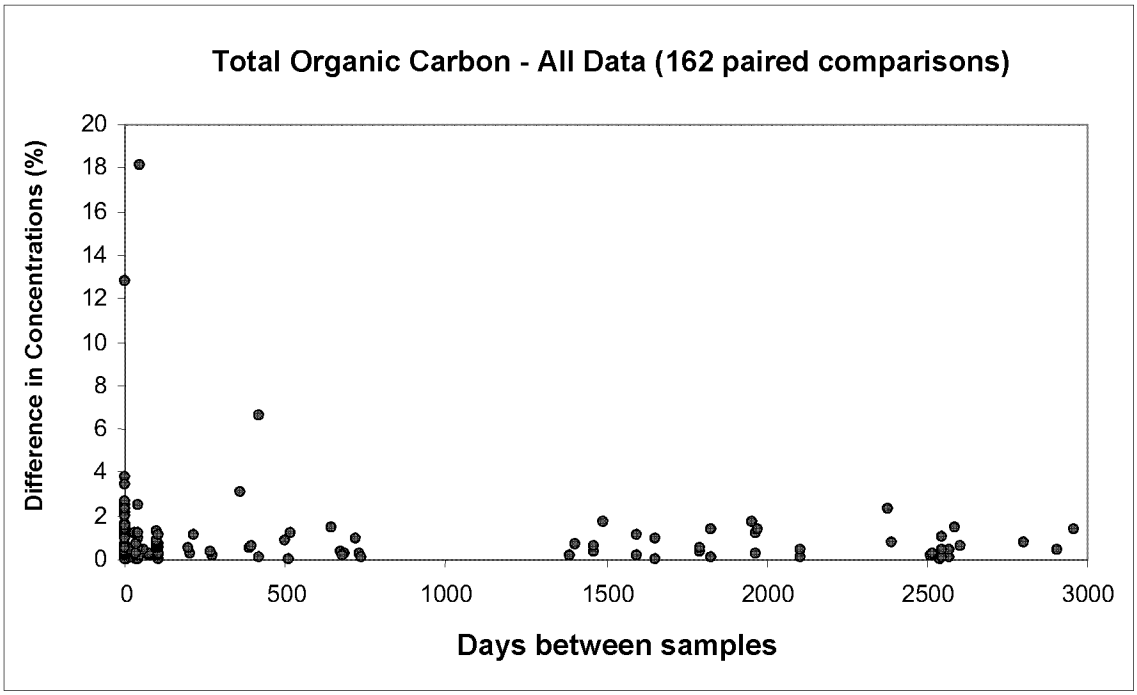
LWG
LOWER WILLAMETTE GROUP

Figure 6.1-54 cont.

Portland Harbor RI/FS
Comprehensive Round 2 Report
Concentration Differences in Collocated Samples
Versus Time between Samples

BZTO104(e)031546



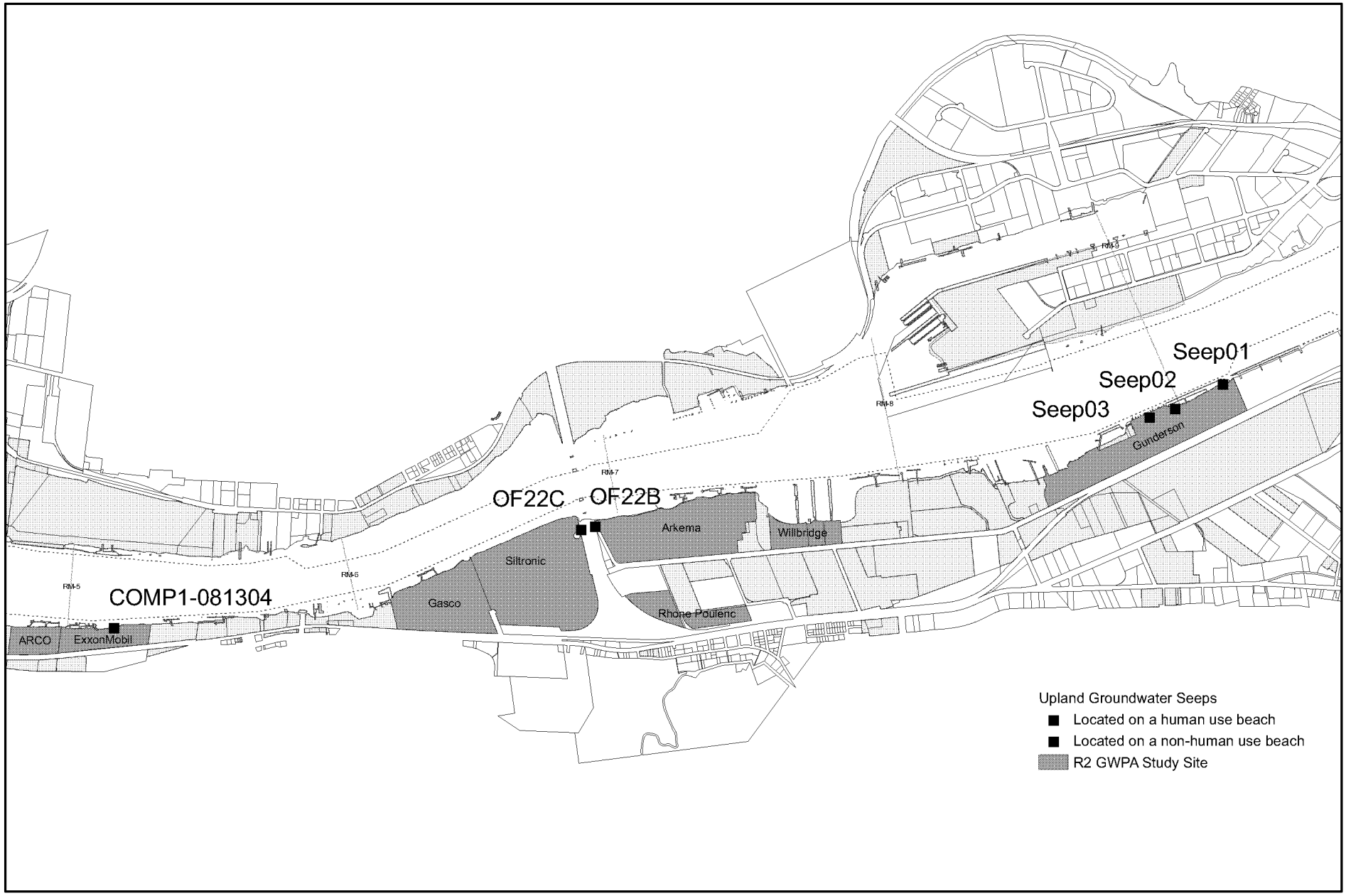


integral

LWG
LOWER WILLAMETTE GROUP

Figure 6.1-54 cont.
Portland Harbor RI/FS
Comprehensive Round 2 Report
Concentration Differences in Collocated Samples
Versus Time between Samples

BZTO104(e)031547



\\192.168.3.11\gis\dm\Projects\B0101 - Portland_Harbor\LWG-Map-Projects\TZW\Analyte Maps\TZW_Seep_Location_Map_20060103.mxd - 1/3/2007 @ 2:45:57 PM

integral consulting inc.

LWG Lower Willamette Group

Map Features:
- Docks and Structures
- River miles
- Navigation Channel
- Upland Sites (2006)
- Waterfront Taxlots
- R2 GWPA Study Site

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

FEATURE SOURCES:
Transportation, Property, or Boundaries: Metro RLIS.
Channel & River miles: US Army Corps of Engineers.
Bathymetric Information: David Evans and Associates, Inc.

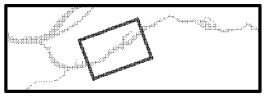
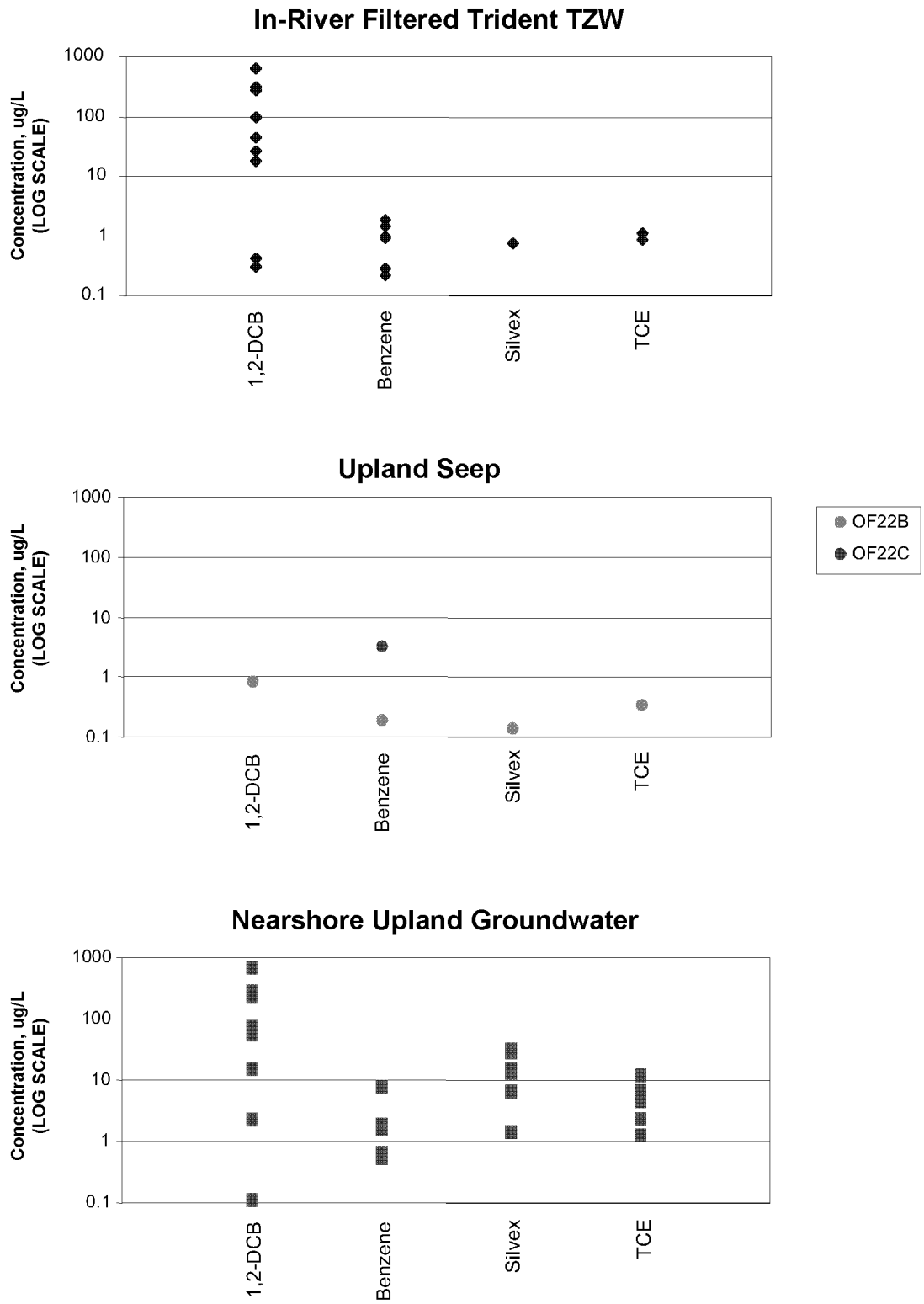


Figure 6.2-1
Portland Harbor RI/FS
Comprehensive Round 2 Report
Upland Seep Locations



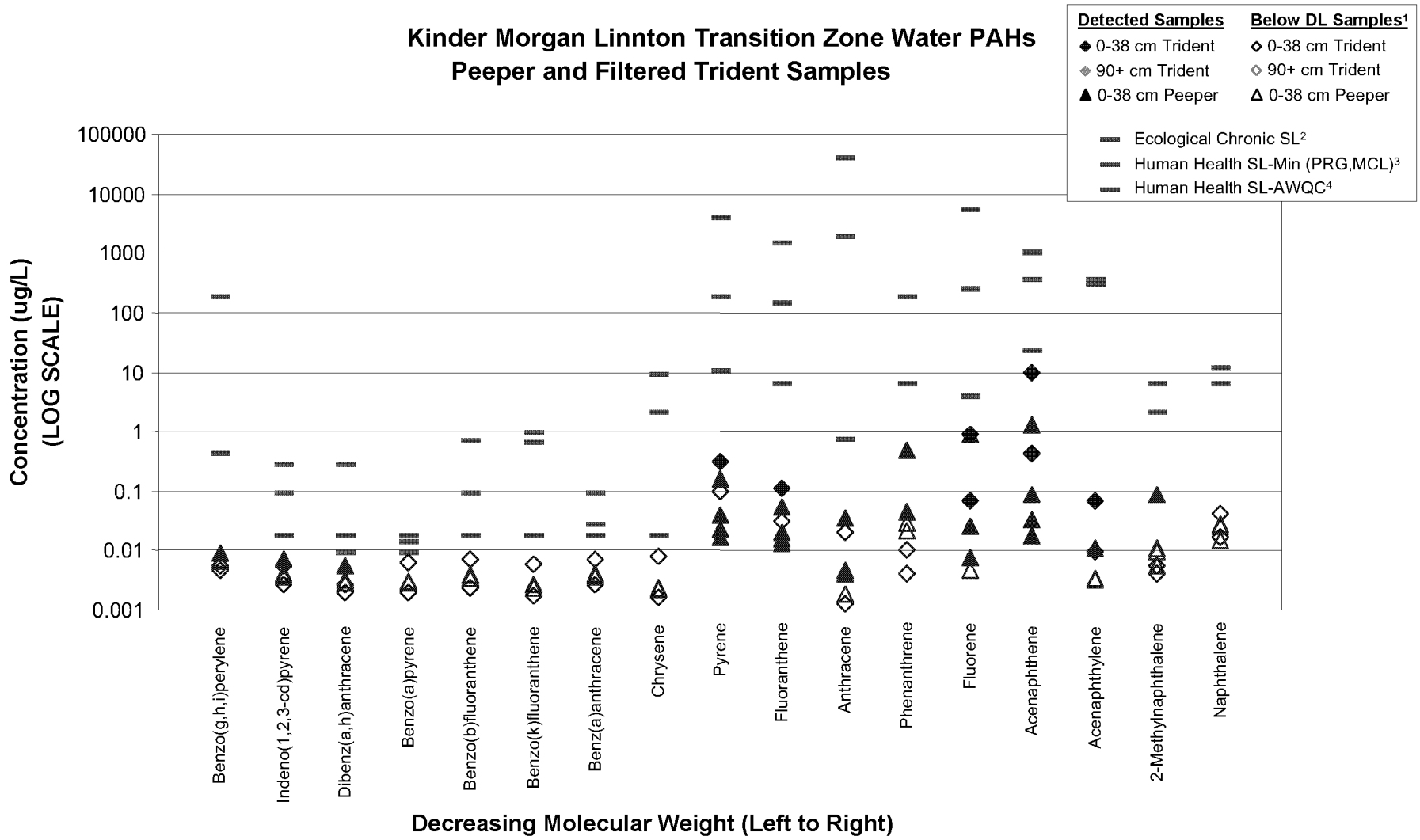
[1] Filtered results are presented for all analytes except 1,2-DCB, Benzene, and TCE.

integral

LWG LOWER WILLAMETTE GROUP

Figure 6.2-2
Portland Harbor RI/FS
Comprehensive Round 2 Report
Rhone Poulenc Nearshore Upland Groundwater,
Upland Seep, and TZW – Select Analytes

BZTO104(e)031549



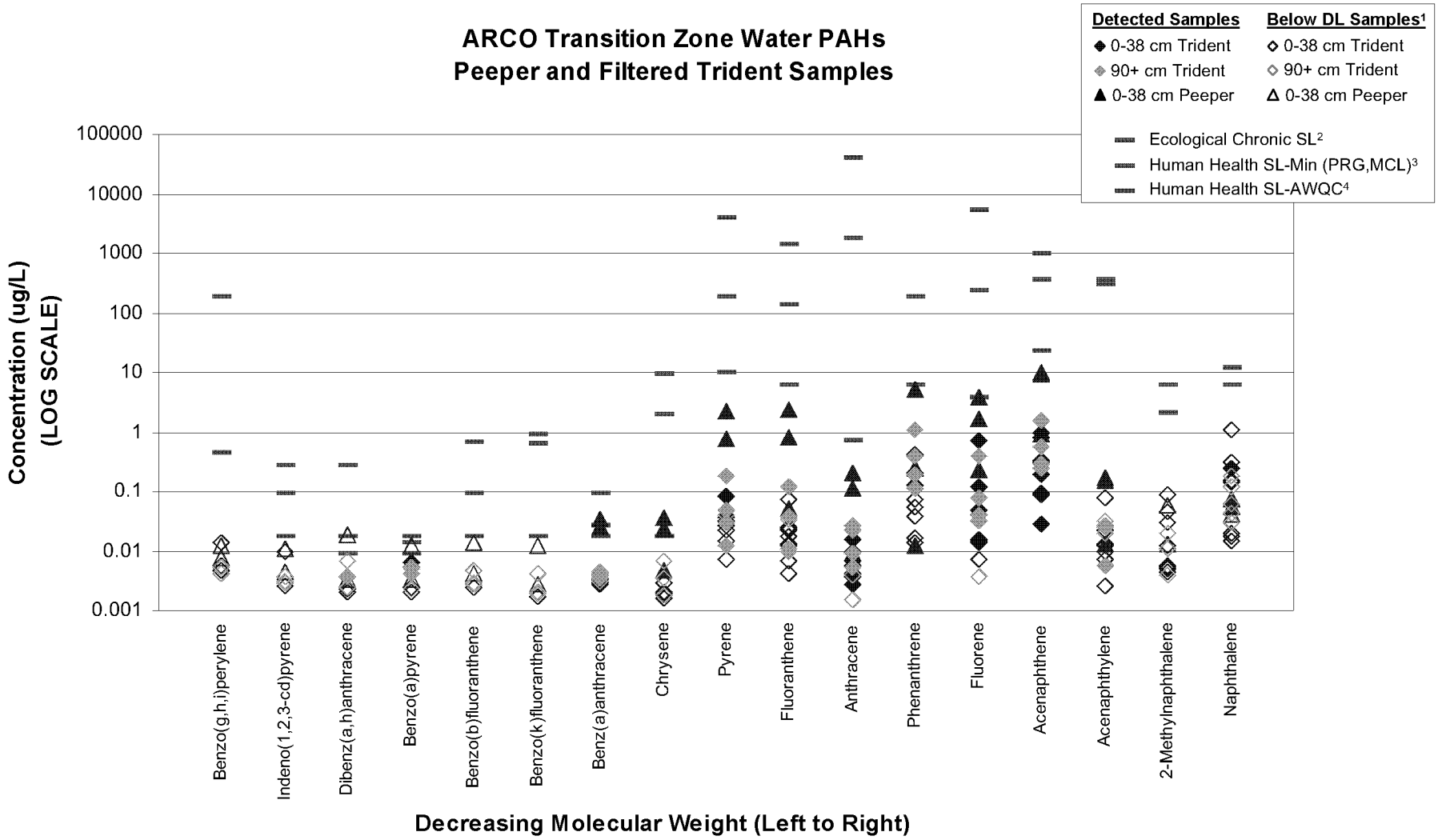
Note: Presentation of the ecological and human health screening values on these figures is for data comparison purposes only and does not constitute a formal risk-based screening.

[1]Shown at full detection limit.
[2] 2October 13, 2006 Portland Harbor RI/FS Chronic Ecological screening levels for chemicals in water.
[3] The minimum value of the Region 9 Tap Water PRG and MCL, where available.
[4] Human Health AWQC screening values (for fish consumption at 17.5 g/day).

integral

LWG

Figure 6.2-3a
Portland Harbor RI/FS
Comprehensive Round 2 Report
Transition Zone Water
Kinder Morgan Linnton PAH Concentration Graph



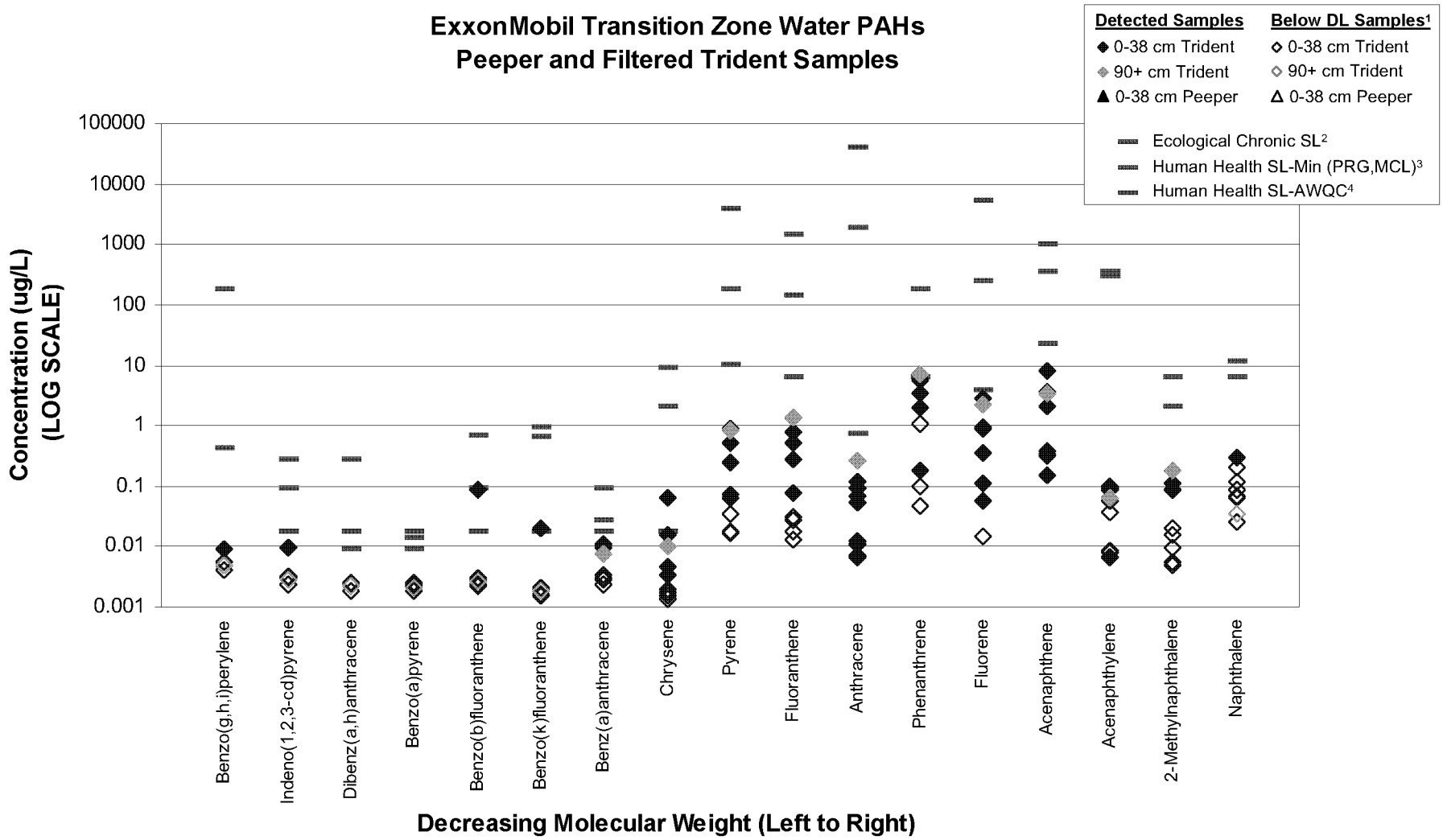
Note: Presentation of the ecological and human health screening values on these figures is for data comparison purposes only and does not constitute a formal risk-based screening.

[1]Shown at full detection limit.
[2] 2October 13, 2006 Portland Harbor RI/FS Chronic Ecological screening levels for chemicals in water.
[3] The minimum value of the Region 9 Tap Water PRG and MCL, where available.
[4] Human Health AWQC screening values (for fish consumption at 17.5 g/day).

integral

LWG

Figure 6.2-3b
Portland Harbor RI/FS
Comprehensive Round 2 Report
Transition Zone Water
ARCO PAH Concentration Graph



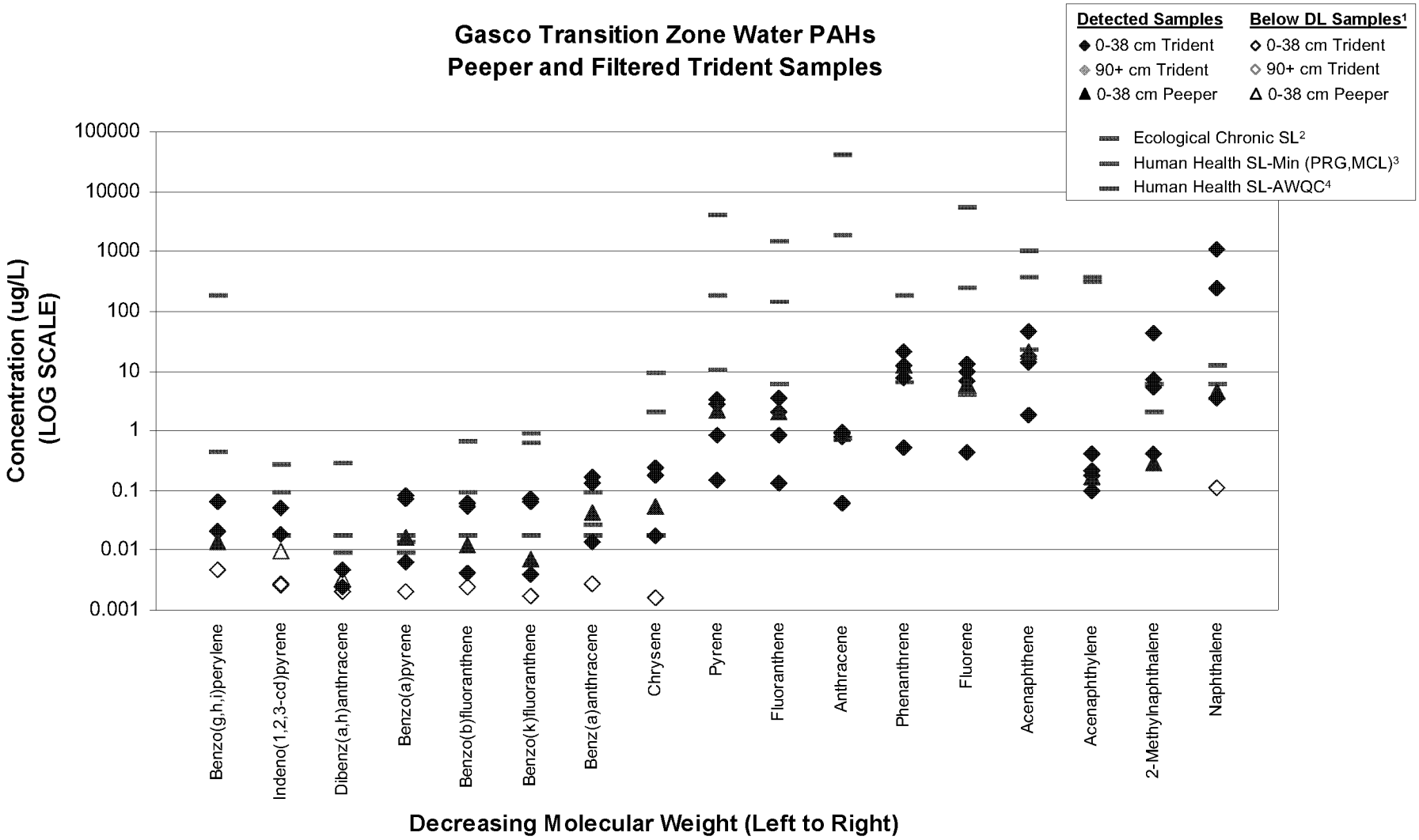
Note: Presentation of the ecological and human health screening values on these figures is for data comparison purposes only and does not constitute a formal risk-based screening.

[1]Shown at full detection limit.
[2] 2October 13, 2006 Portland Harbor RI/FS Chronic Ecological screening levels for chemicals in water.
[3] The minimum value of the Region 9 Tap Water PRG and MCL, where available.
[4] Human Health AWQC screening values (for fish consumption at 17.5 g/day).

integral

LWG

Figure 6.2-3c
Portland Harbor RI/FS
Comprehensive Round 2 Report
Transition Zone Water
ExxonMobil PAH Concentration Graph



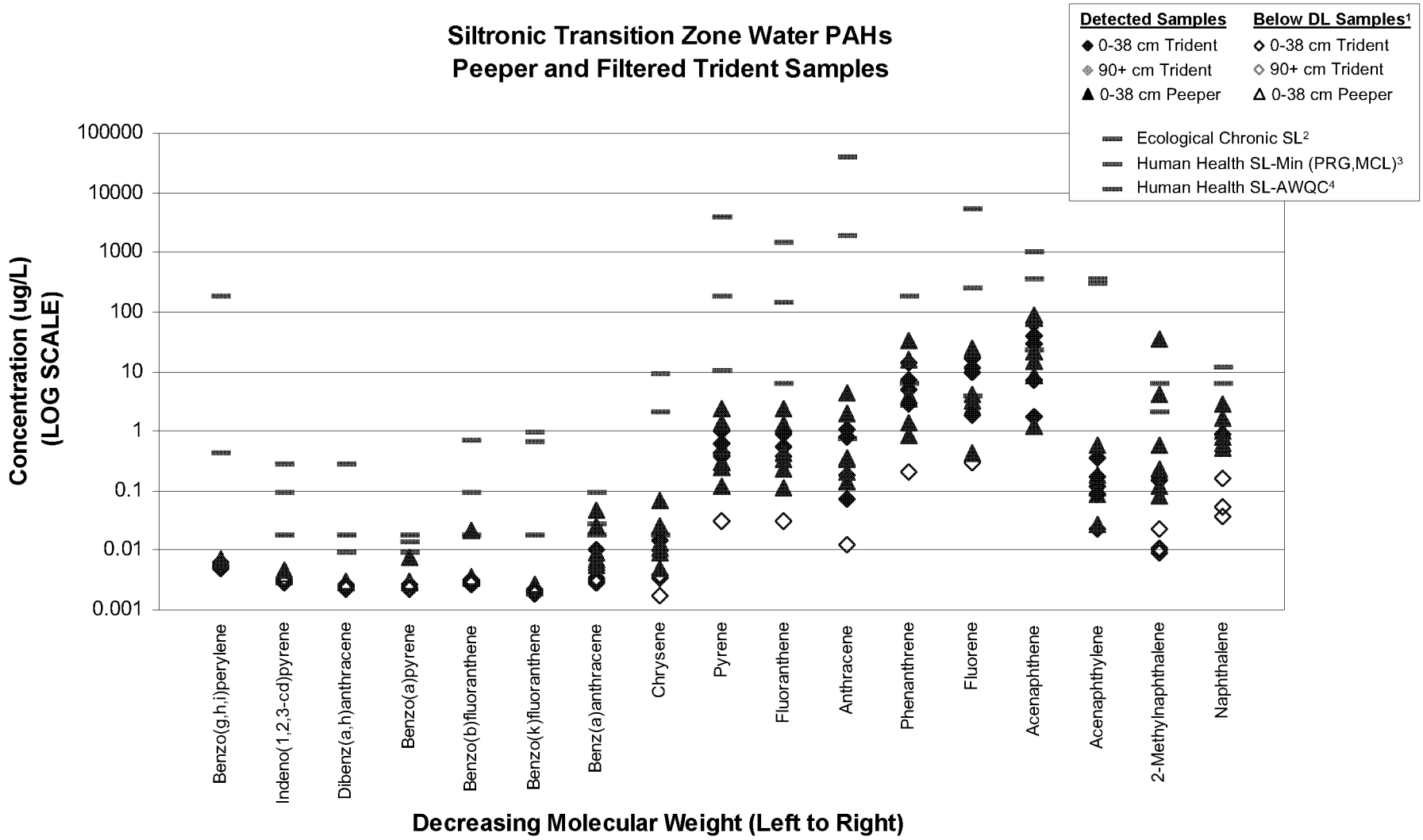
Note: Presentation of the ecological and human health screening values on these figures is for data comparison purposes only and does not constitute a formal risk-based screening.

[1]Shown at full detection limit.
[2] 2October 13, 2006 Portland Harbor RI/FS Chronic Ecological screening levels for chemicals in water.
[3] The minimum value of the Region 9 Tap Water PRG and MCL, where available.
[4] Human Health AWQC screening values (for fish consumption at 17.5 g/day).

integral

LWG

Figure 6.2-3d
Portland Harbor RI/FS
Comprehensive Round 2 Report
Transition Zone Water
Gasco PAH Concentration Graph



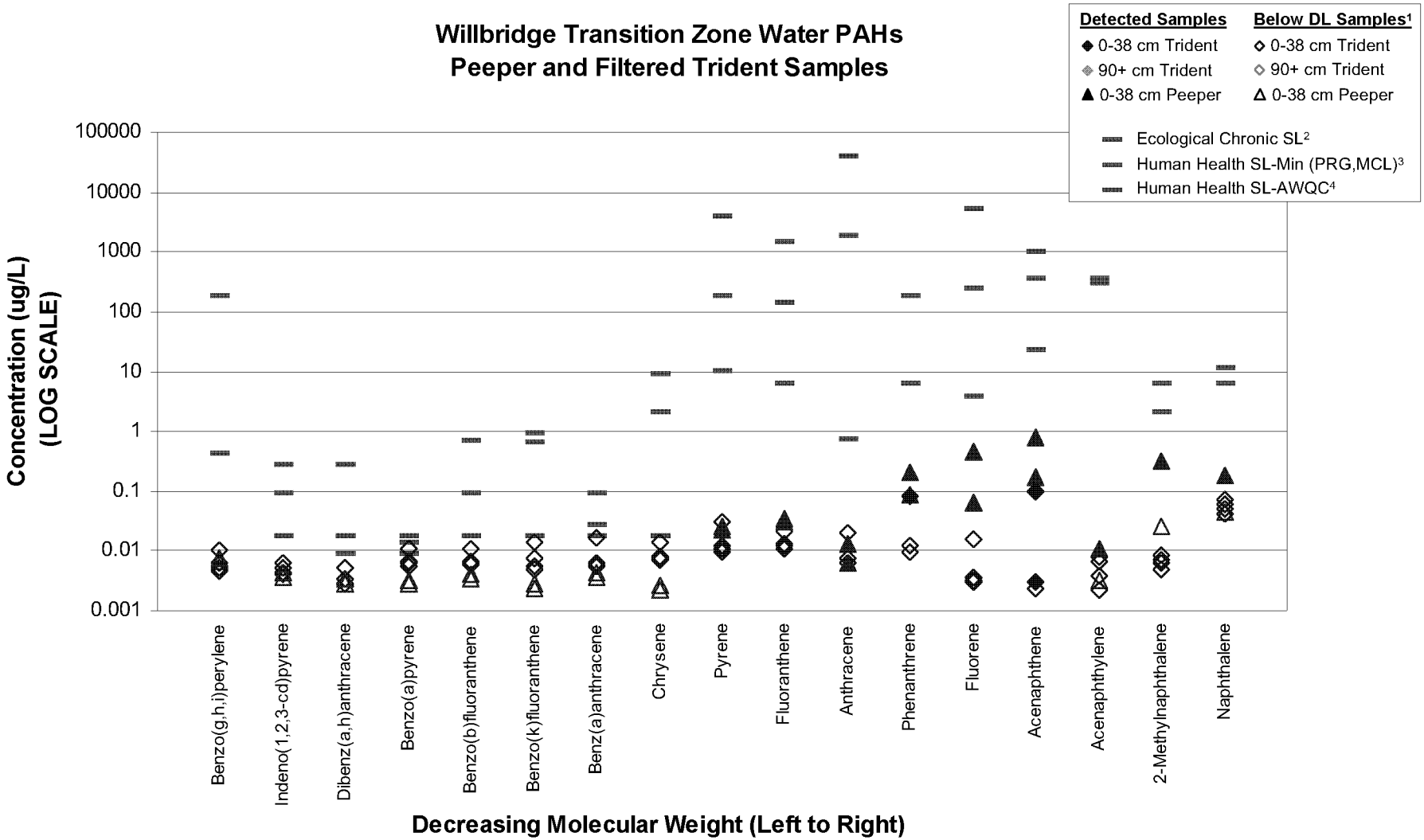
Note: Presentation of the ecological and human health screening values on these figures is for data comparison purposes only and does not constitute a formal risk-based screening.

[1]Shown at full detection limit.
[2] 2October 13, 2006 Portland Harbor RI/FS Chronic Ecological screening levels for chemicals in water.
[3] The minimum value of the Region 9 Tap Water PRG and MCL, where available.
[4] Human Health AWQC screening values (for fish consumption at 17.5 g/day).

integral

LWG

Figure 6.2-3e
Portland Harbor RI/FS
Comprehensive Round 2 Report
Transition Zone Water
Siltronic PAH Concentration Graph



Note: Presentation of the ecological and human health screening values on these figures is for data comparison purposes only and does not constitute a formal risk-based screening.

[1]Shown at full detection limit.
[2] 2October 13, 2006 Portland Harbor RI/FS Chronic Ecological screening levels for chemicals in water.
[3] The minimum value of the Region 9 Tap Water PRG and MCL, where available.
[4] Human Health AWQC screening values (for fish consumption at 17.5 g/day).

integral

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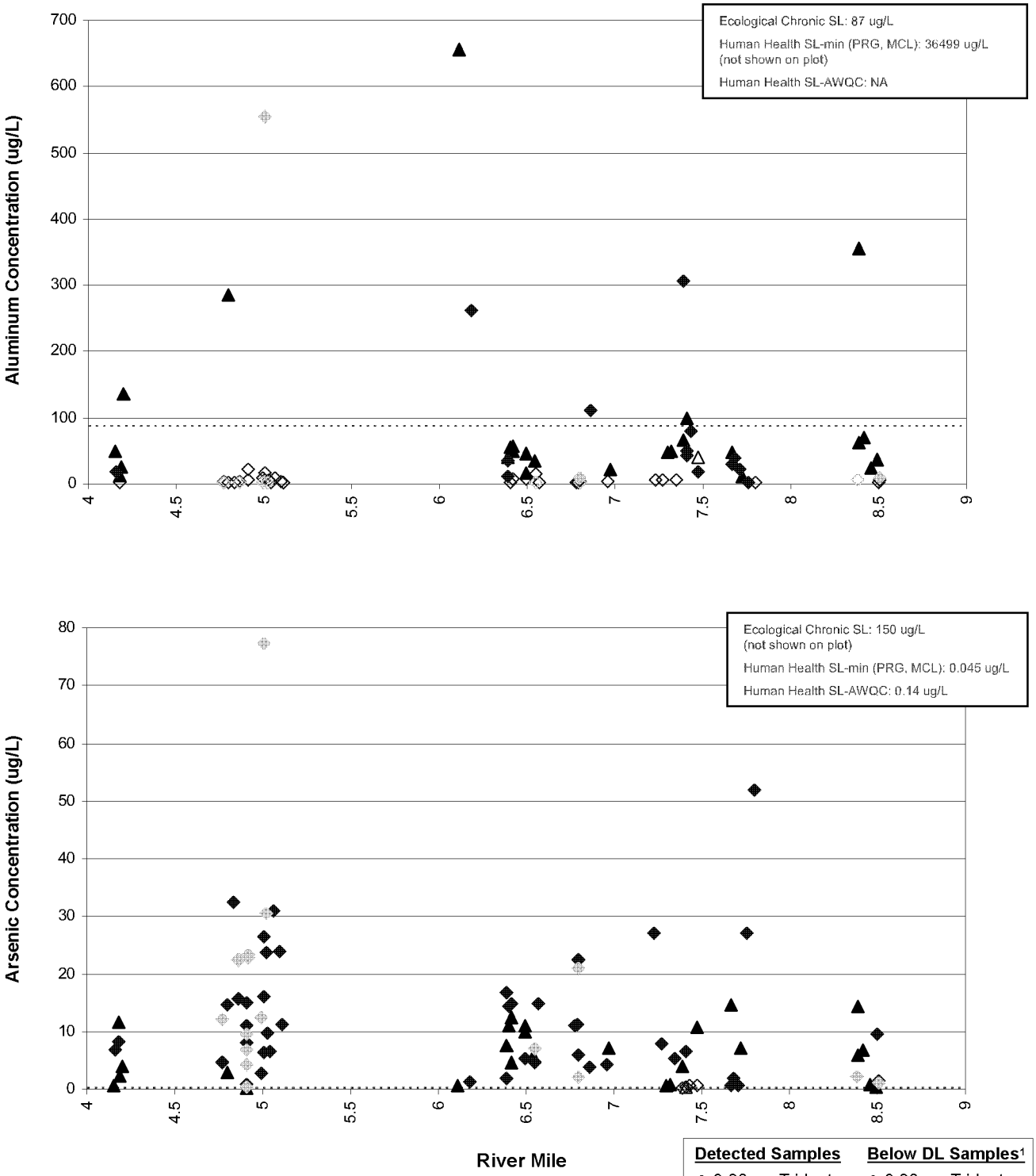
Figure 6.2-3f
Portland Harbor RI/FS
Comprehensive Round 2 Report
Transition Zone Water
Willbridge PAH Concentration Graph



Note: Presentation of the ecological and human health screening values on these figures is for data comparison purposes only and does not constitute a formal risk-based screening.

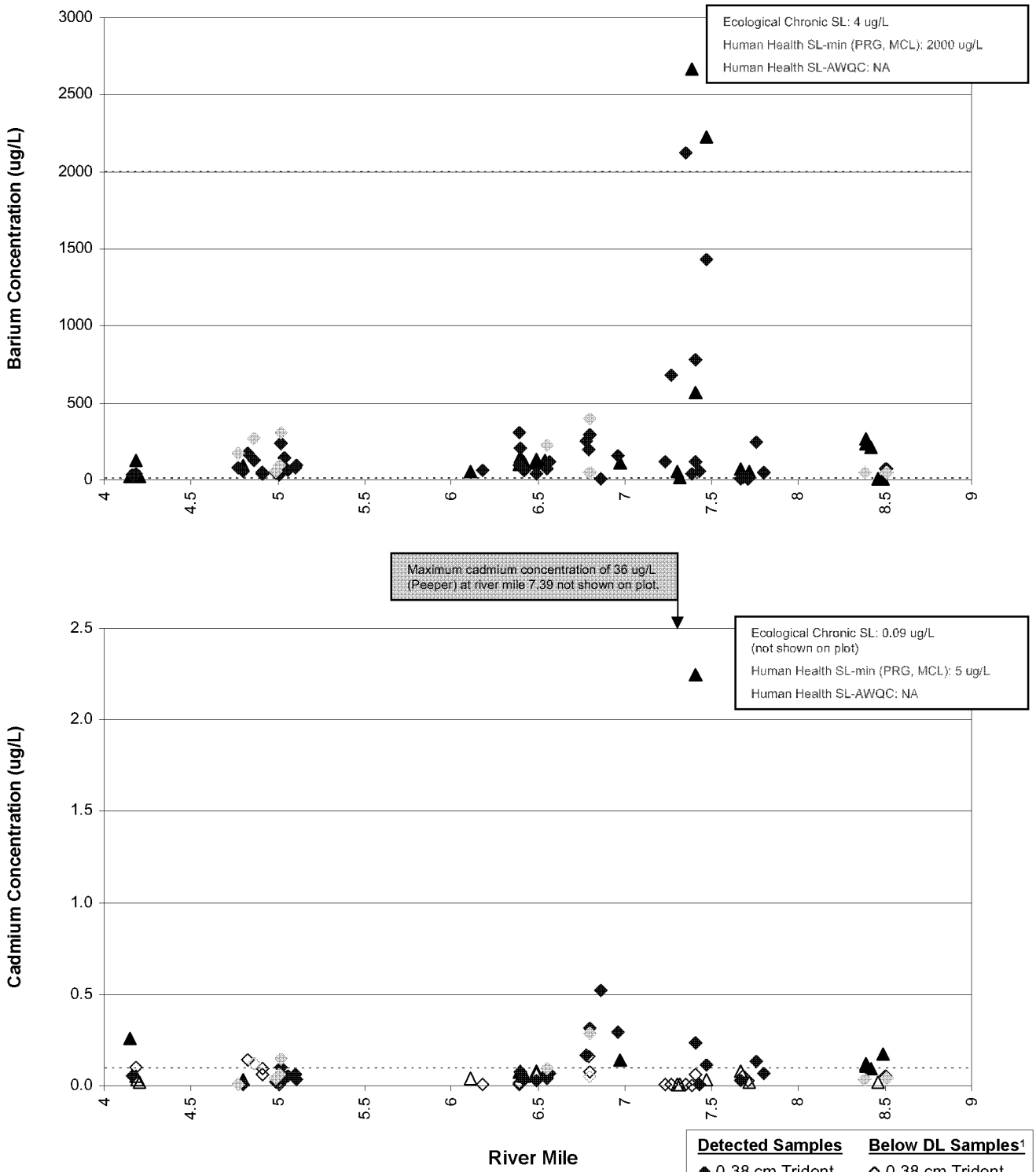
[1]Shown at full detection limit.
[2] 2October 13, 2006 Portland Harbor RI/FS Chronic Ecological screening levels for chemicals in water.
[3] The minimum value of the Region 9 Tap Water PRG and MCL, where available.
[4] Human Health AWQC screening values (for fish consumption at 17.5 g/day).

integral

LWG LOWER WILLAMETTE GROUP

Figure 6.2-4a
Portland Harbor RI/FS
Comprehensive Round 2 Report
Transition Zone Water
Filtered Trident and Peeper Al and As Concentration Graphs

BZTO104(e)031556



Note: Presentation of the ecological and human health screening values on these figures is for data comparison purposes only and does not constitute a formal risk-based screening.

[1]Shown at full detection limit.
[2] 2October 13, 2006 Portland Harbor RI/FS Chronic Ecological screening levels for chemicals in water.
[3] The minimum value of the Region 9 Tap Water PRG and MCL, where available.
[4] Human Health AWQC screening values (for fish consumption at 17.5 g/day).

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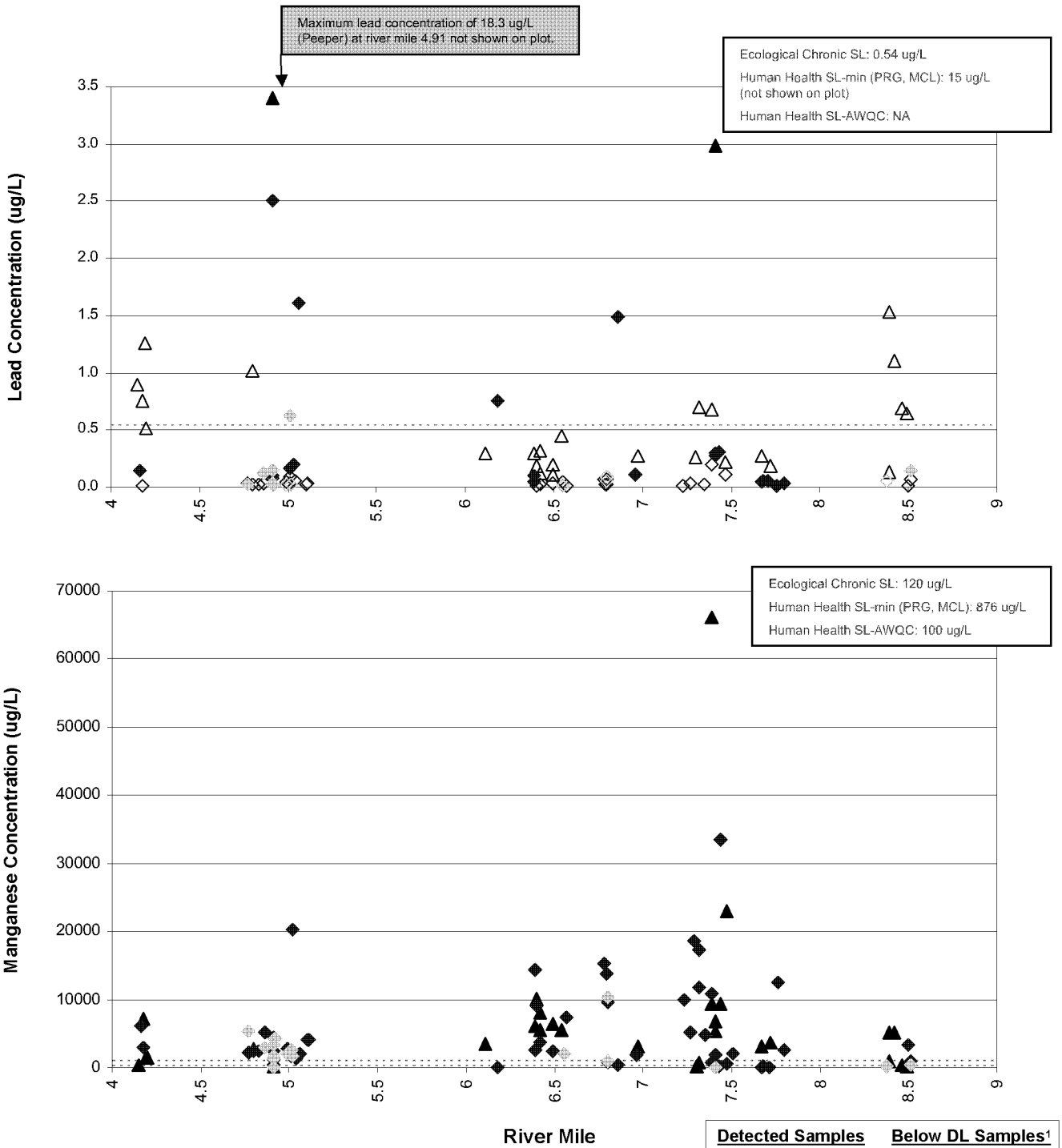
LWG LOWER WILLAMETTE GROUP

Figure 6.2-4b
Portland Harbor RI/FS
Comprehensive Round 2 Report
Transition Zone Water
Filtered Trident and Peeper Ba and Cd Concentration Graphs

BZTO104(e)031557



Note: Presentation of the ecological and human health screening values on these figures is for data comparison purposes only and does not constitute a formal risk-based screening.

[1]Shown at full detection limit.
[2] 2October 13, 2006 Portland Harbor RI/FS Chronic Ecological screening levels for chemicals in water.
[3] The minimum value of the Region 9 Tap Water PRG and MCL, where available.
[4] Human Health AWQC screening values (for fish consumption at 17.5 g/day).

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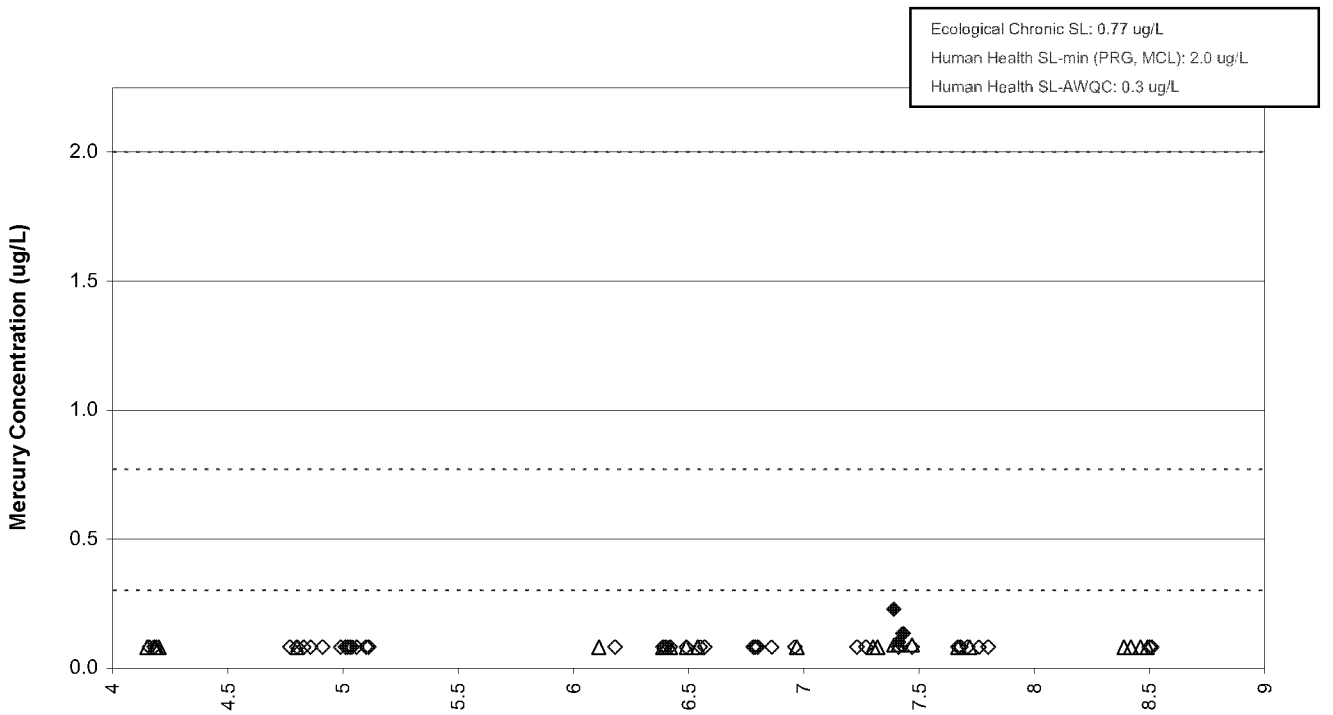
LWG LOWER WILLAMETTE GROUP

Figure 6.2-4c
Portland Harbor RI/FS
Comprehensive Round 2 Report
Transition Zone Water
Filtered Trident and Peeper Pb and Mn Concentration Graphs

BZTO104(e)031558



Detected Samples	Below DL Samples[1]
◆ 0-38 cm Trident	◇ 0-38 cm Trident
◈ 90+ cm Trident	◇ 90+ cm Trident
▲ 0-38 cm Peeper	△ 0-38 cm Peeper

····· Ecological Chronic SL[2]
····· Human Health SL-Min (PRG,MCL)[3]
····· Human Health SL-AWQC[3]

Note: Presentation of the ecological and human health screening values on these figures is for data comparison purposes only and does not constitute a formal risk-based screening.

[1]Shown at full detection limit.
[2] 2October 13, 2006 Portland Harbor RI/FS Chronic Ecological screening levels for chemicals in water.
[3] The minimum value of the Region 9 Tap Water PRG and MCL, where available.
[4] Human Health AWQC screening values (for fish consumption at 17.5 g/day).

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LWG LOWER WILLAMETTE GROUP

Figure 6.2-4d
Portland Harbor RI/FS
Comprehensive Round 2 Report
Transition Zone Water
Filtered Trident and Peeper Hg Concentration Graphs

BZTO104(e)031559

\\192.168.3.11\gis\dm\Projects\B0101 - Portland_Harbor\LWG-Map-Projects\TZW\Analyte Maps\TZW_BTEX_Extent_Mile_6_to_7_DETAIL_20070103.mxd - 1/3/2007 @ 4:13:30 PM

PSt Indicates sample collected during the GWPA Pilot Study by Trident sampler
PSp Indicates sample collected during the GWPA Pilot Study by small volume peeper

Qualifiers:
T Mathematically derived value.
J The associated numerical value was approximated by the analytical laboratory.
U The analyte was not detected above the reported sample quantitation limit.
UJ The analyte was not detected above the reported sample quantitation limit; however, the reported quantitation limit was approximated by the analytical laboratory.

GP72 0.8 *T*
GP74 28.22 *T*
GP38 20.81 *T*
GP66 2.31 *T*
GP39 12.89 *T*
GP63 3.09 *T*
GP70 305.25 *T*
GP71 66.38 *T*
GP50 1.3 *T*
GP65 41.33 *T*
GP40 4.34 *T*
GP53 0.36 *T*
GP61 6.1 *T*
GP58 0.93 *T*
GP48 8.84 *T*
GP41 3.71 *T*
GP56 3.26 *T*
GP73 741.2 *T*
GP69 511.6 *T*
SL03F 23.3 *T*
GP57 3.71 *T*
GP52 1.66 *T*
GP43 1.945 *T*
SL02E 9.05 *T*
GP64 1240 *T*
GP54 1180 *T*
GP68 4740 *T*
GP62 5.65 *T*
SL04F 69.3 *T*
SL03C 0.44 *JT*
GS07D 0.74 *JT*
GS08D 17.8 *T*
SL01E 13.8 *JT*
GP44 43.72 *T*
SL05A 0.11 *JT*
GP75 5.37 *T*
GP45 11.38 *T*
GP55 3.16 *T*
GP81 1240 *T*
GP82 170.92 *T*
SL02C 1.52 *JT*
SL04A 0.42 *JT*
GS07B 733 *T*
GP80 4.08 *T*
GP46 13.51 *T*
GS08A 0.33 *JT*
GP76 11.39 *T*
SL01A 3.58 *JT*
GP67 175 *T*
GP84 2.73 *T*
SL03A 0.12 *JT*

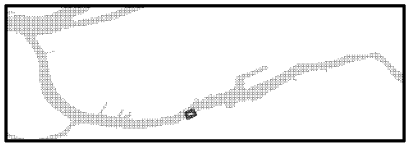
Gasco

Siltronic

Map Features

- Docks and Structures
- River miles
- Navigation Channel
- Upland Sites (2006)
- Waterfront Taxlots
- R2 GWPA Study Site

0 50 100 150 200 Feet



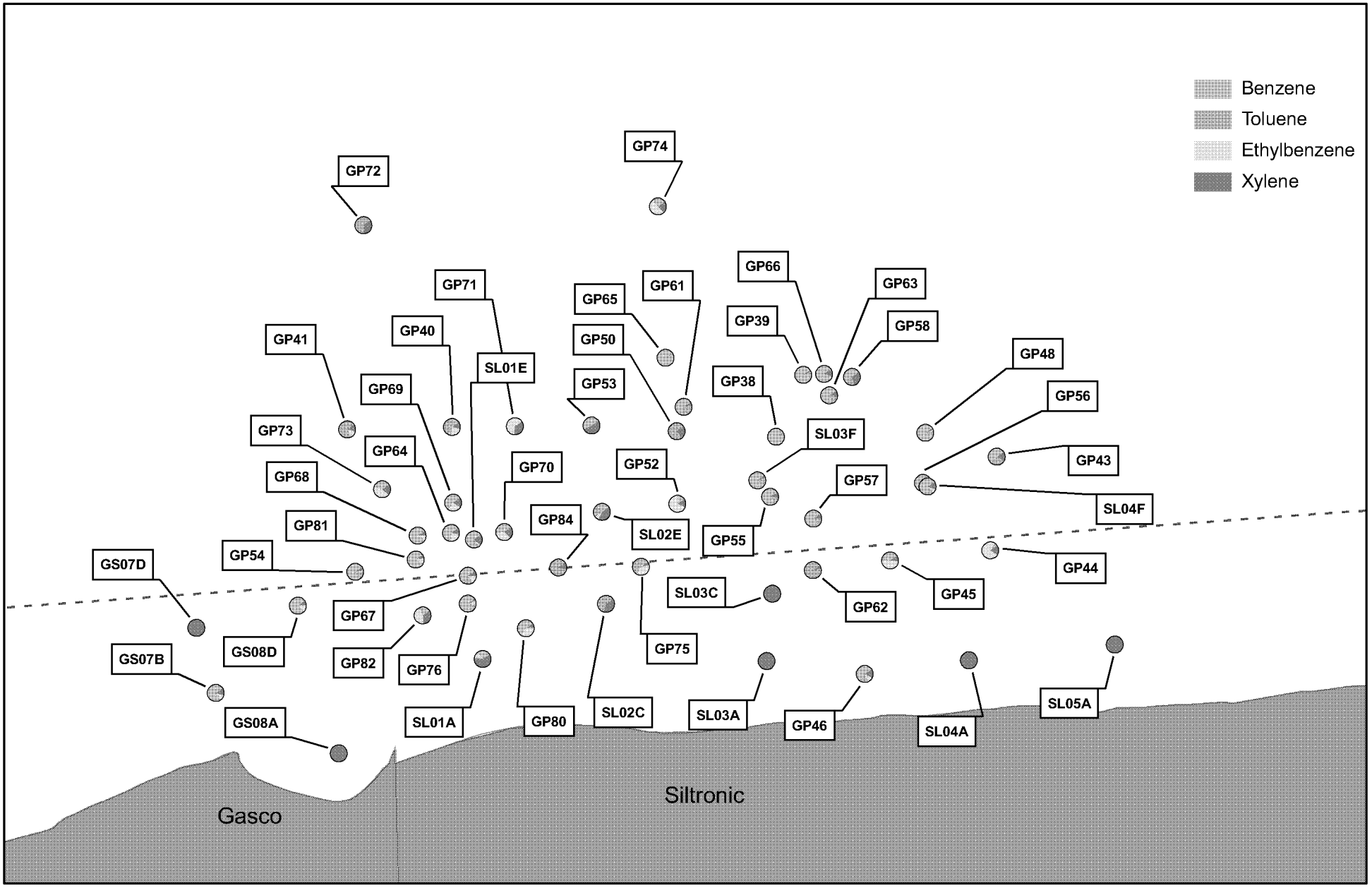
FEATURE SOURCES:
Property and Taxlot Boundaries: Metro RLIS
Channel & River miles: US Army Corps of Engineers.
Docks & In-water Structures: digitized from October 2001 0.33 ft. resolution color orthophotos

integral consulting inc.

LWG Lower Willamette Group

Figure 6.2-5a
Portland Harbor RI/FS
Comprehensive Round 2 Report
Transition Zone Water Sample Results
River Mile 6 to 7 - Total BTEX Concentrations (ug/L)
(Detail to Map 6.2-8c)

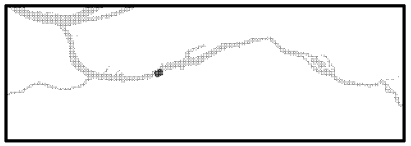
\\192.168.3.11\gisdm\Projects\B0101 - Portland_Harbor\LWG-Map-Projects\TZW\Analyte Maps\TZW_BTEX_Nature_Mile_6_to_7_DETAIL_20070103.mxd - 1/3/2007 @ 3:35:29 PM



Map Features:

- Docks and Structures
- River miles
- Navigation Channel
- Upland Sites (2006)
- Waterfront Taxlots
- R2 GWPA Study Site

0 50 100 150 200 Feet

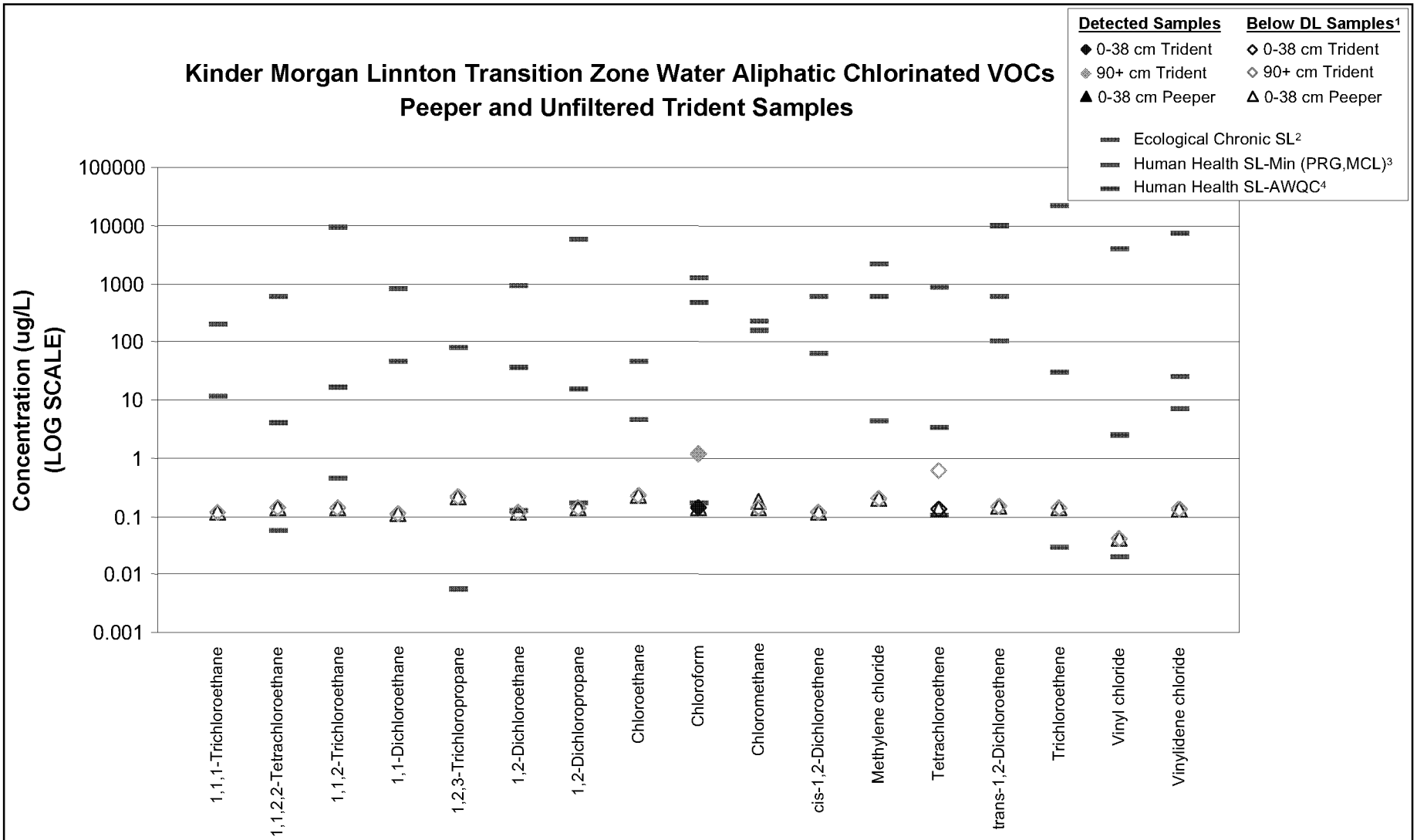


FEATURE SOURCES:
Property and Taxlot Boundaries: Metro RLIS
Channel & River miles: US Army Corps of Engineers.
Docks & In-water Structures: digitized from October 2001 0.33 ft. resolution color orthophotos

integral consulting inc.

LWG Lower Willamette Group

Figure 6.2-5b
Portland Harbor RI/FS
Comprehensive Round 2 Report
Transition Zone Water Sample Results
River Mile 6 to 7 - Total BTEX Pie Charts (ug/L)
(Detail to Map 6.2-8c)



Note: Presentation of the ecological and human health screening values on these figures is for data comparison purposes only and does not constitute a formal risk-based screening.

[1]Shown at full detection limit.
[2] 2October 13, 2006 Portland Harbor RI/FS Chronic Ecological screening levels for chemicals in water.
[3] The minimum value of the Region 9 Tap Water PRG and MCL, where available.
[4] Human Health AWQC screening values (for fish consumption at 17.5 g/day).

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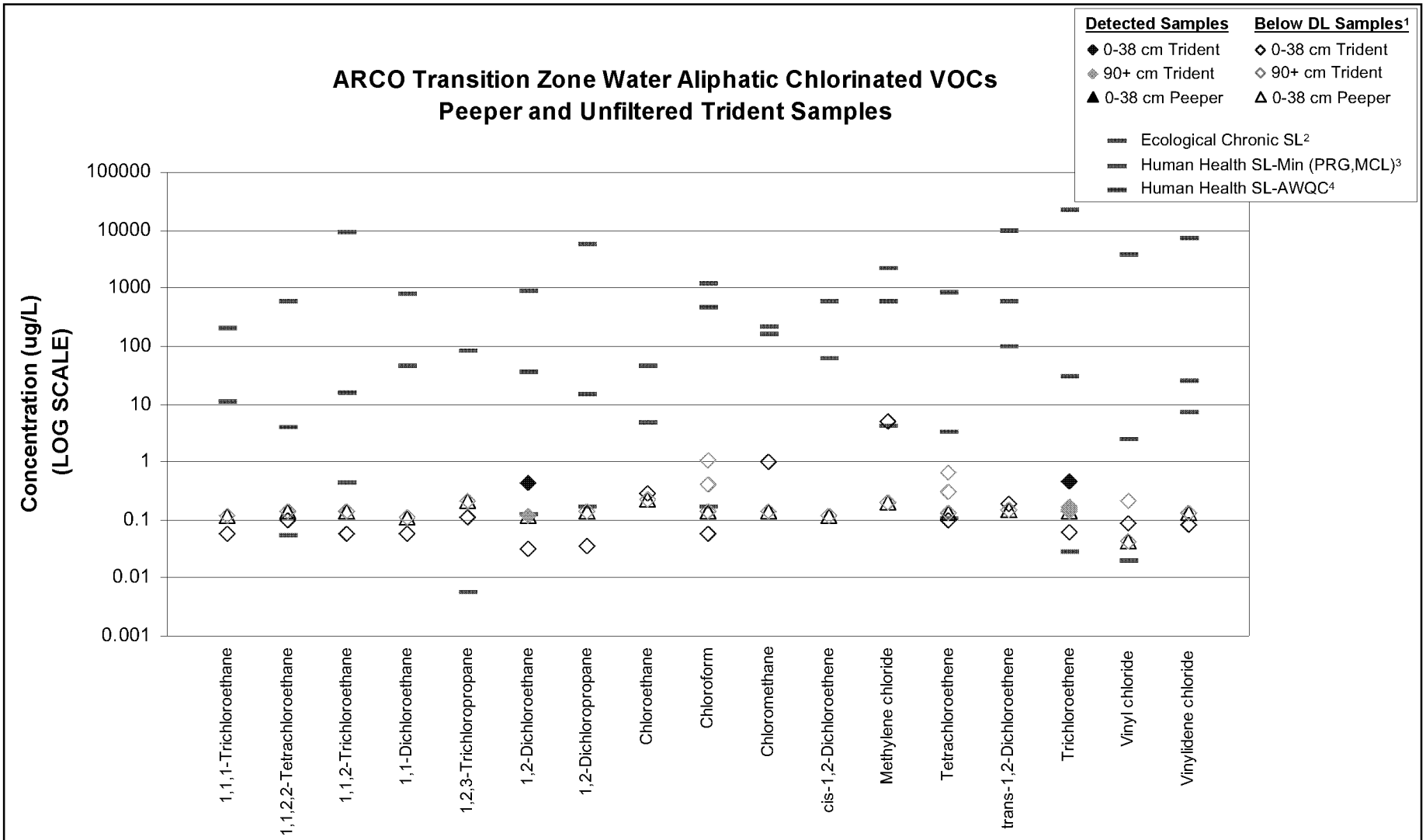
Figure 6.2-6a
Portland Harbor RI/FS
Comprehensive Round 2 Report
Transition Zone Water
Kinder Morgan Linnton Aliphatic CVOC Concentration Graph



Note: Presentation of the ecological and human health screening values on these figures is for data comparison purposes only and does not constitute a formal risk-based screening.

[1]Shown at full detection limit.
[2] 2October 13, 2006 Portland Harbor RI/FS Chronic Ecological screening levels for chemicals in water.
[3] The minimum value of the Region 9 Tap Water PRG and MCL, where available.
[4] Human Health AWQC screening values (for fish consumption at 17.5 g/day).

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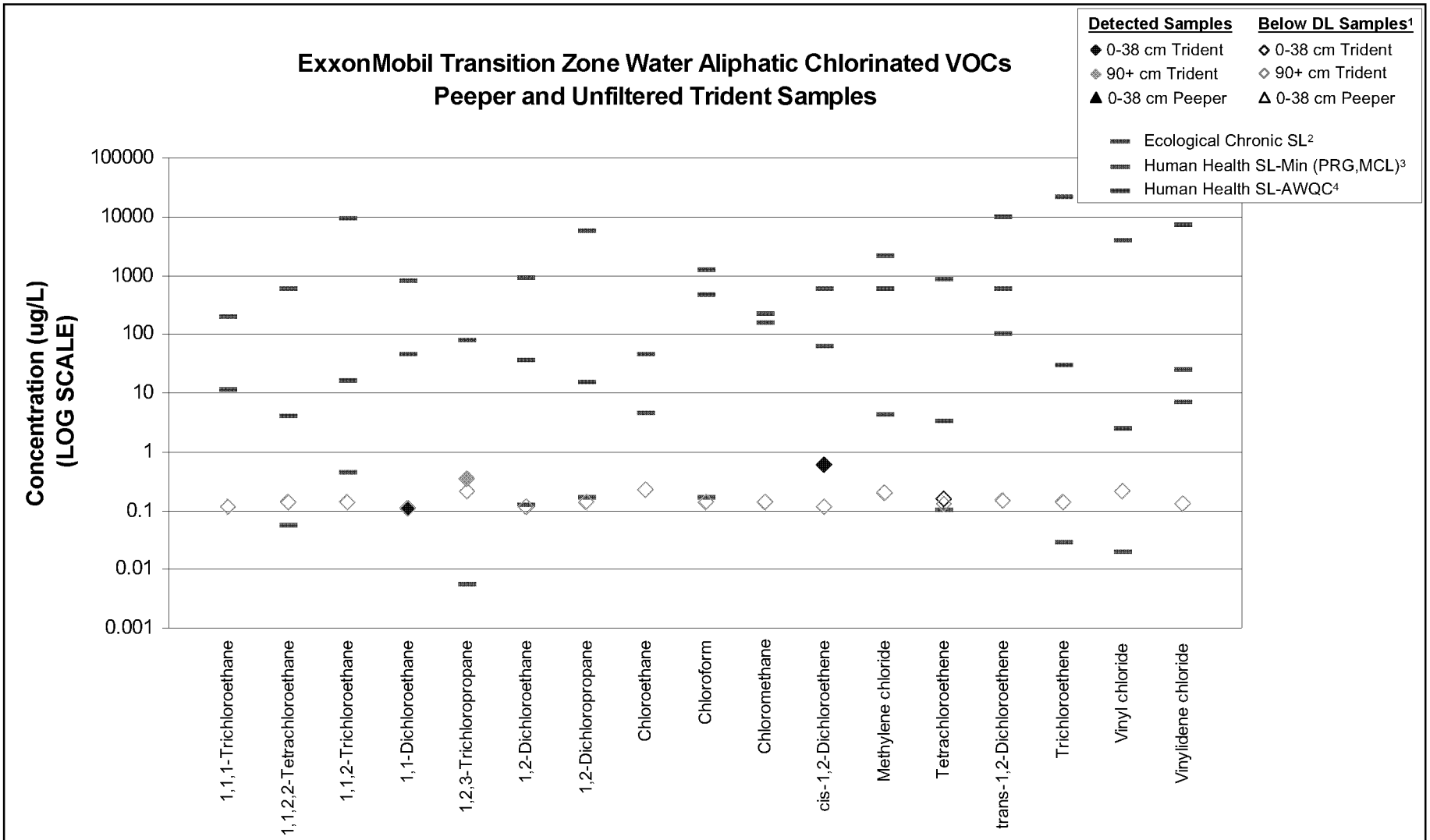
Figure 6.2-6b
Portland Harbor RI/FS
Comprehensive Round 2 Report
Transition Zone Water
ARCO Aliphatic CVOC Concentration Graph



Note: Presentation of the ecological and human health screening values on these figures is for data comparison purposes only and does not constitute a formal risk-based screening.

[1]Shown at full detection limit.
[2] 2October 13, 2006 Portland Harbor RI/FS Chronic Ecological screening levels for chemicals in water.
[3] The minimum value of the Region 9 Tap Water PRG and MCL, where available.
[4] Human Health AWQC screening values (for fish consumption at 17.5 g/day).

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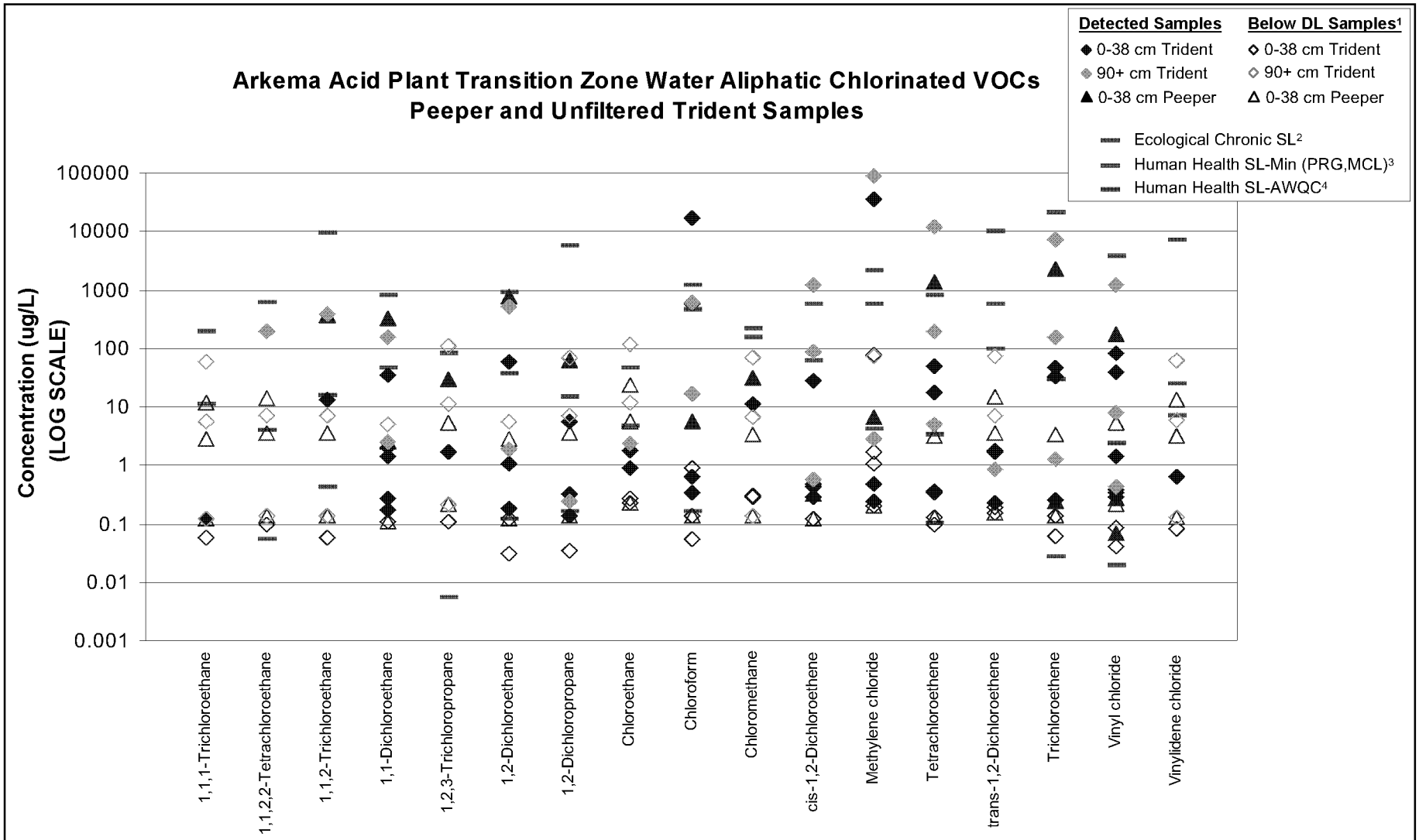
Figure 6.2-6c
Portland Harbor RI/FS
Comprehensive Round 2 Report
Transition Zone Water
ExxonMobil Aliphatic CVOC Concentration Graph



Note: Presentation of the ecological and human health screening values on these figures is for data comparison purposes only and does not constitute a formal risk-based screening.

[1]Shown at full detection limit.
[2] 2October 13, 2006 Portland Harbor RI/FS Chronic Ecological screening levels for chemicals in water.
[3] The minimum value of the Region 9 Tap Water PRG and MCL, where available.
[4] Human Health AWQC screening values (for fish consumption at 17.5 g/day).

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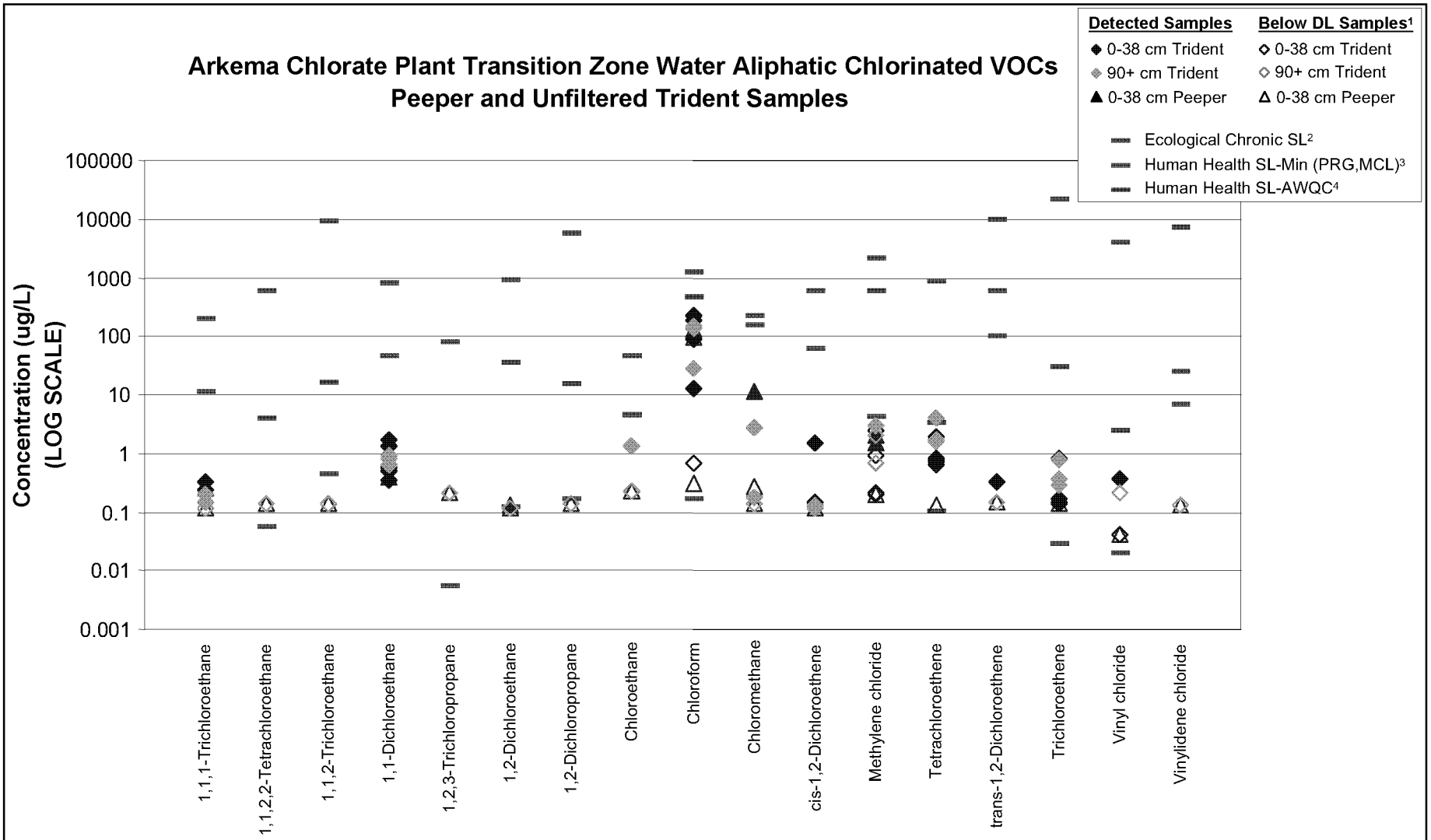
Figure 6.2-6d
Portland Harbor RI/FS
Comprehensive Round 2 Report
Transition Zone Water
Former Arkema Acid Plant Aliphatic CVOC Concentration Graph



Note: Presentation of the ecological and human health screening values on these figures is for data comparison purposes only and does not constitute a formal risk-based screening.

[1]Shown at full detection limit.
[2] 2October 13, 2006 Portland Harbor RI/FS Chronic Ecological screening levels for chemicals in water.
[3] The minimum value of the Region 9 Tap Water PRG and MCL, where available.
[4] Human Health AWQC screening values (for fish consumption at 17.5 g/day).

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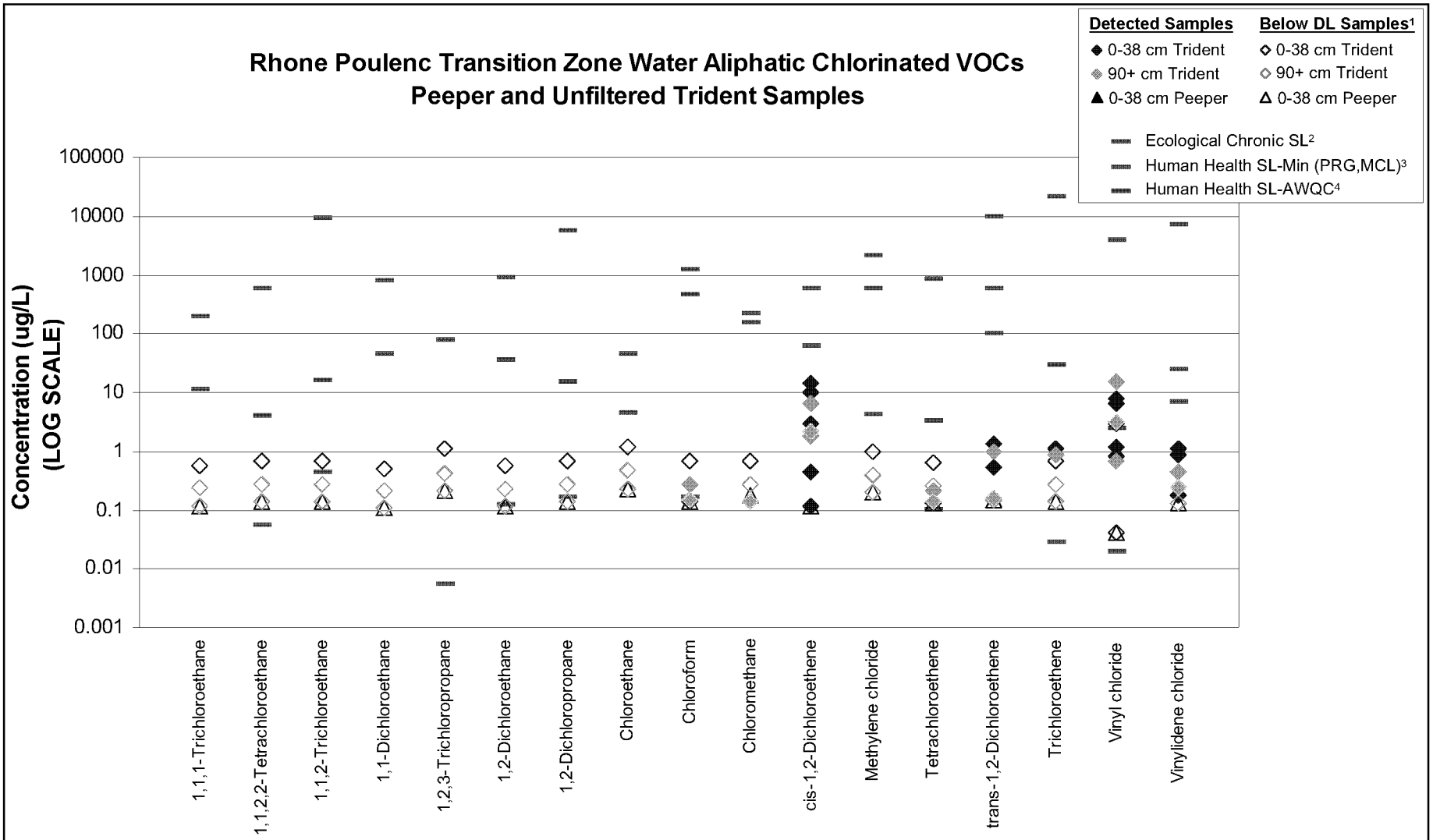
Figure 6.2-6e
Portland Harbor RI/FS
Comprehensive Round 2 Report
Transition Zone Water
Former Arkema Chlorate Plant Aliphatic CVOC Concentration Graph



Note: Presentation of the ecological and human health screening values on these figures is for data comparison purposes only and does not constitute a formal risk-based screening.

[1]Shown at full detection limit.
[2] 2October 13, 2006 Portland Harbor RI/FS Chronic Ecological screening levels for chemicals in water.
[3] The minimum value of the Region 9 Tap Water PRG and MCL, where available.
[4] Human Health AWQC screening values (for fish consumption at 17.5 g/day).

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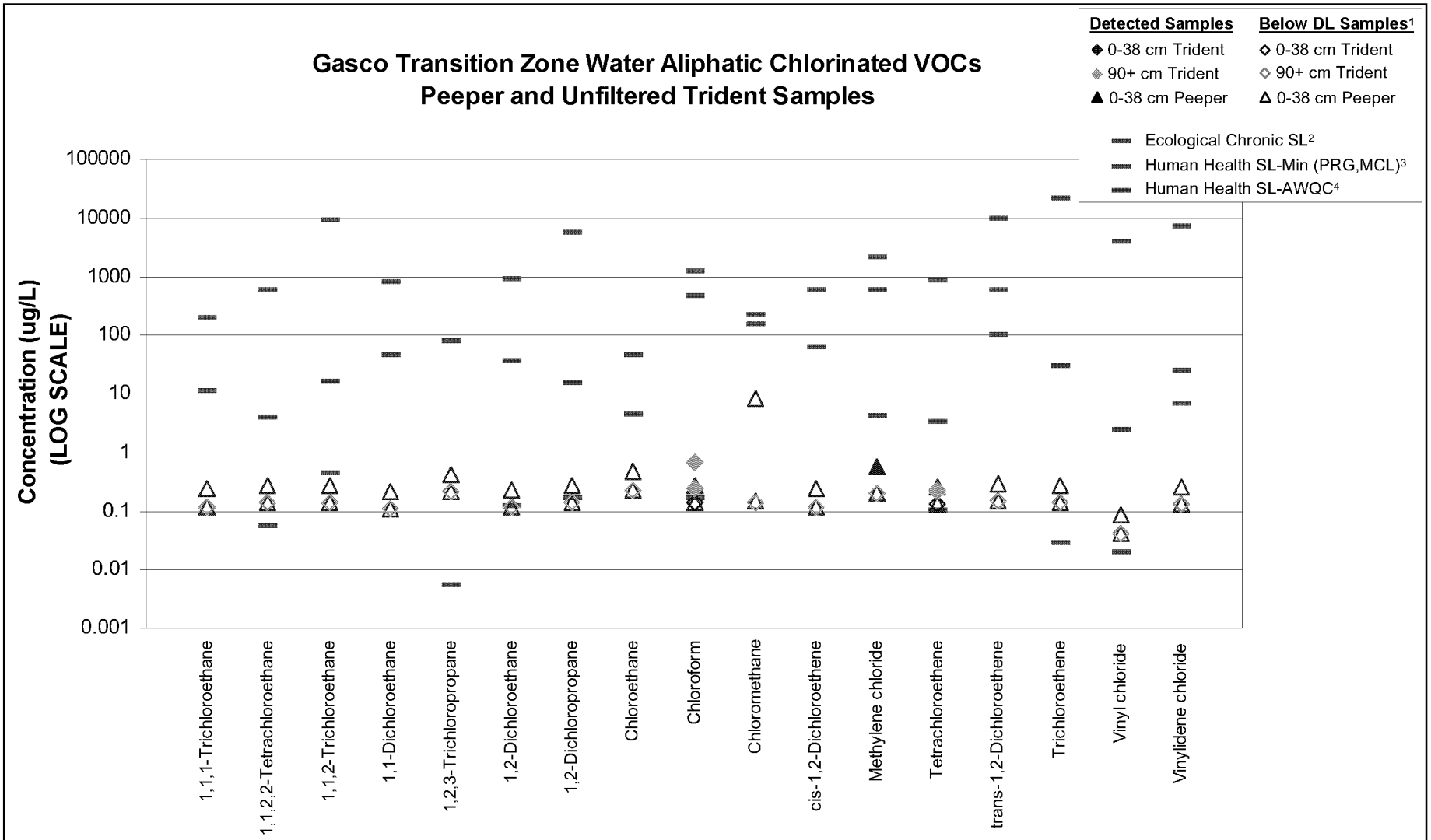
Figure 6.2-6f
Portland Harbor RI/FS
Comprehensive Round 2 Report
Transition Zone Water
Rhone Poulenc Aliphatic CVOC Concentration Graph



Note: Presentation of the ecological and human health screening values on these figures is for data comparison purposes only and does not constitute a formal risk-based screening.

[1]Shown at full detection limit.
[2] 2October 13, 2006 Portland Harbor RI/FS Chronic Ecological screening levels for chemicals in water.
[3] The minimum value of the Region 9 Tap Water PRG and MCL, where available.
[4] Human Health AWQC screening values (for fish consumption at 17.5 g/day).

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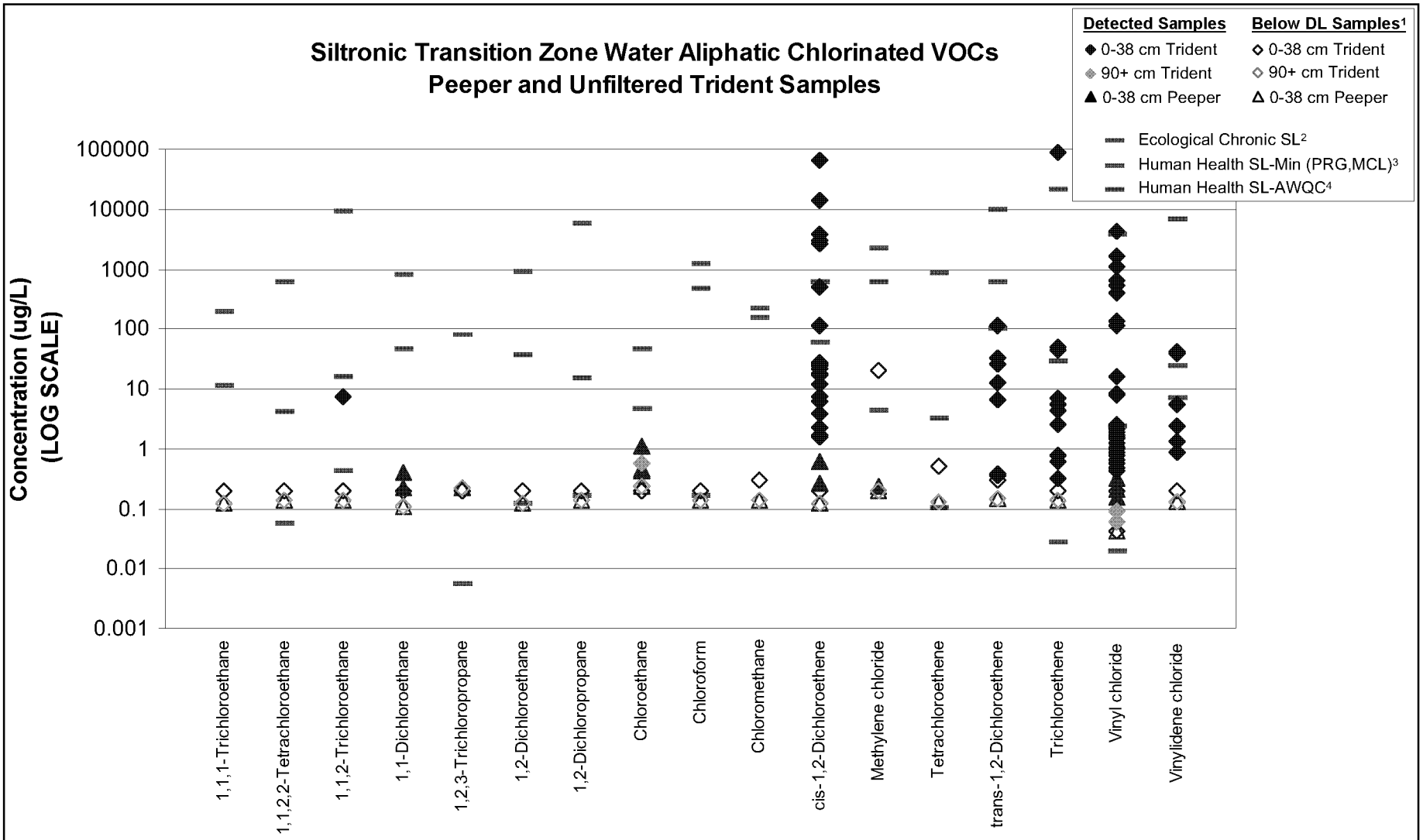
LWG

Figure 6.2-6g
Portland Harbor RI/FS
Comprehensive Round 2 Report
Transition Zone Water
Gasco Aliphatic CVOC Concentration Graph



Note: Presentation of the ecological and human health screening values on these figures is for data comparison purposes only and does not constitute a formal risk-based screening.

[1]Shown at full detection limit.
[2] 2October 13, 2006 Portland Harbor RI/FS Chronic Ecological screening levels for chemicals in water.
[3] The minimum value of the Region 9 Tap Water PRG and MCL, where available.
[4] Human Health AWQC screening values (for fish consumption at 17.5 g/day).

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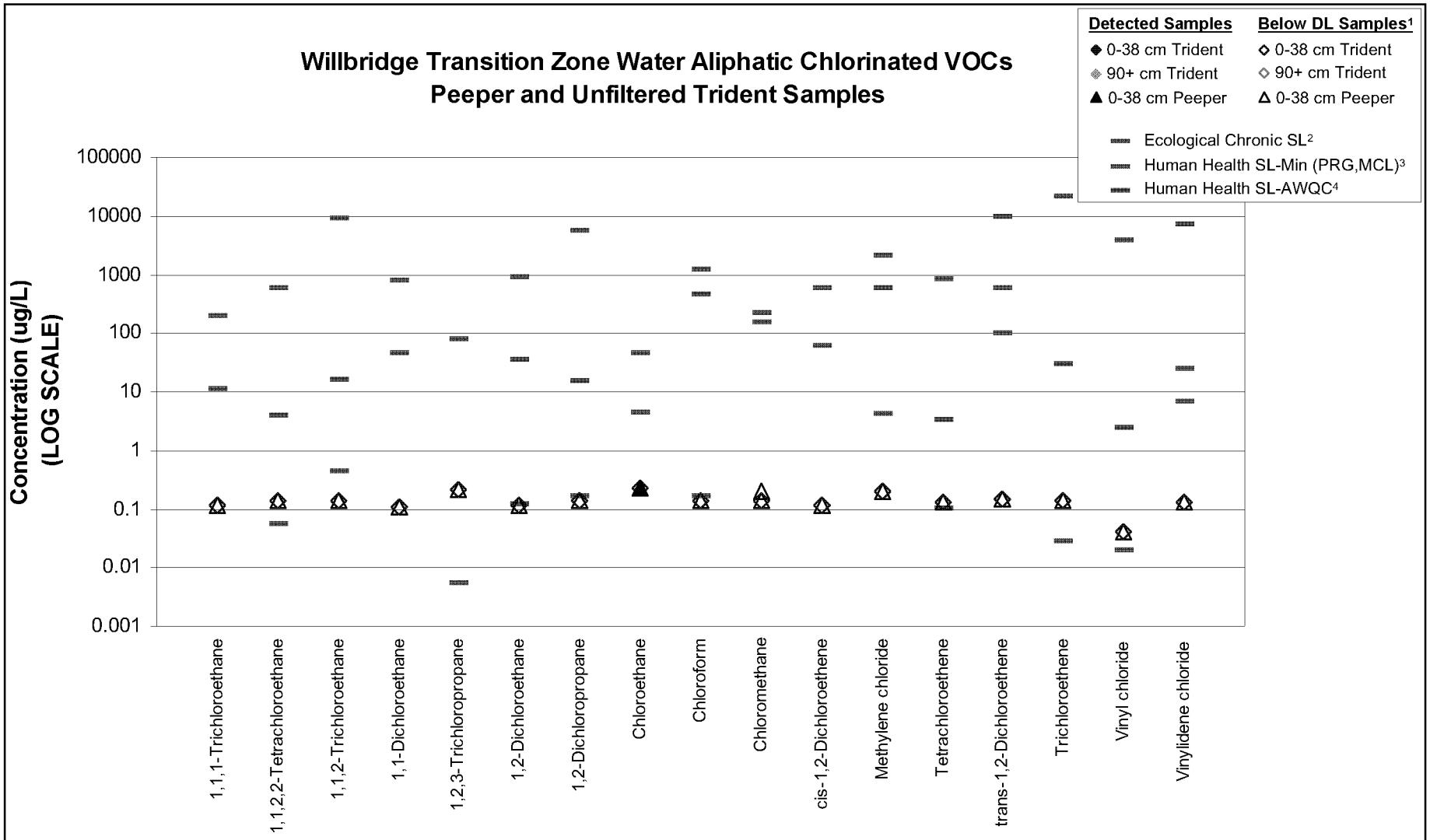
Figure 6.2-6h
Portland Harbor RI/FS
Comprehensive Round 2 Report
Transition Zone Water
Siltronic Aliphatic CVOC Concentration Graph



Note: Presentation of the ecological and human health screening values on these figures is for data comparison purposes only and does not constitute a formal risk-based screening.

[1]Shown at full detection limit.
[2] 2October 13, 2006 Portland Harbor RI/FS Chronic Ecological screening levels for chemicals in water.
[3] The minimum value of the Region 9 Tap Water PRG and MCL, where available.
[4] Human Health AWQC screening values (for fish consumption at 17.5 g/day).

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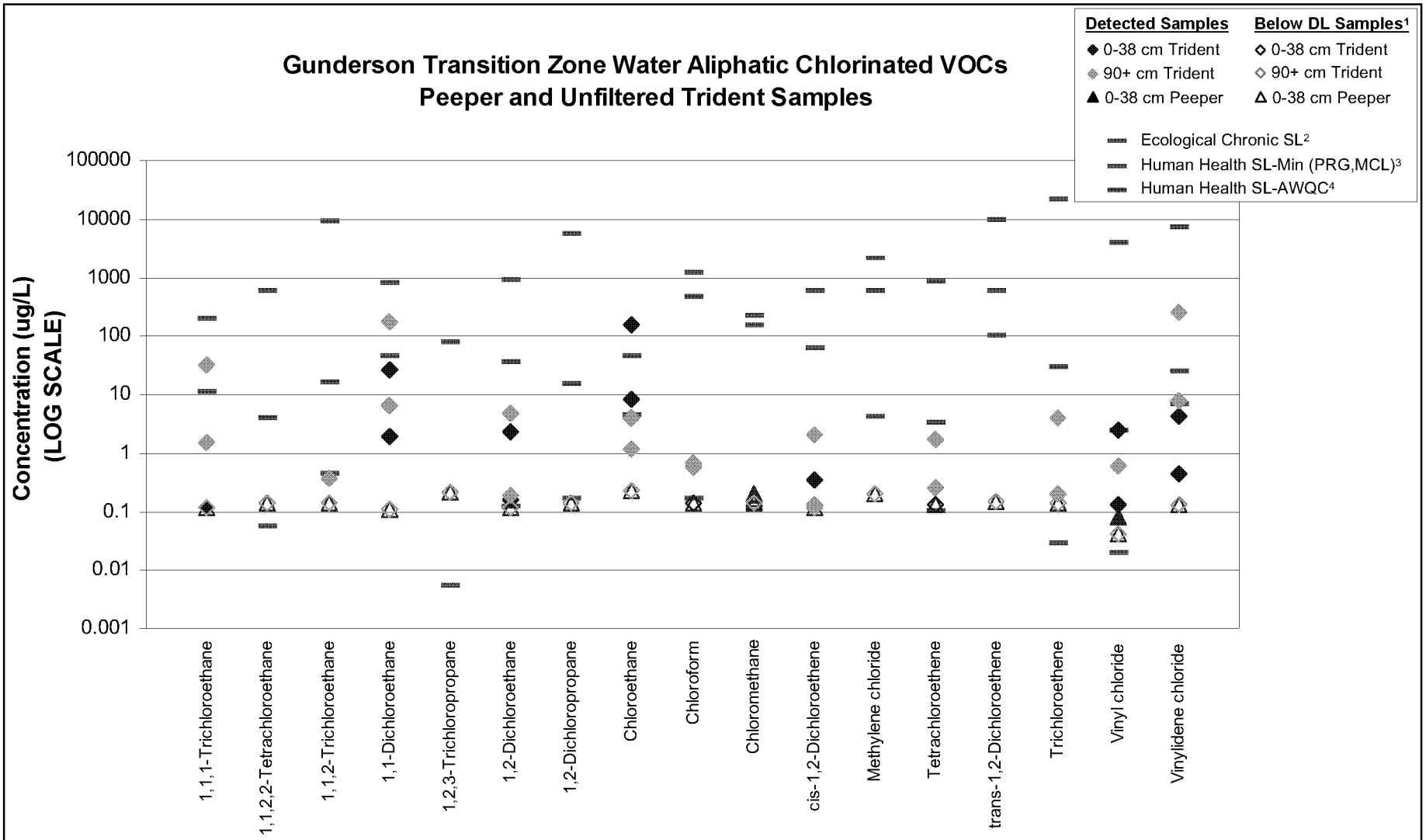
LWG

Figure 6.2-6i
Portland Harbor RI/FS
Comprehensive Round 2 Report
Transition Zone Water
Willbridge Aliphatic CVOC Concentration Graph



Note: Presentation of the ecological and human health screening values on these figures is for data comparison purposes only and does not constitute a formal risk-based screening.

[1]Shown at full detection limit.
[2] 2October 13, 2006 Portland Harbor RI/FS Chronic Ecological screening levels for chemicals in water.
[3] The minimum value of the Region 9 Tap Water PRG and MCL, where available.
[4] Human Health AWQC screening values (for fish consumption at 17.5 g/day).

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Figure 6.2-6j
Portland Harbor RI/FS
Comprehensive Round 2 Report
Transition Zone Water
Gunderson Aliphatic CVOC Concentration Graph

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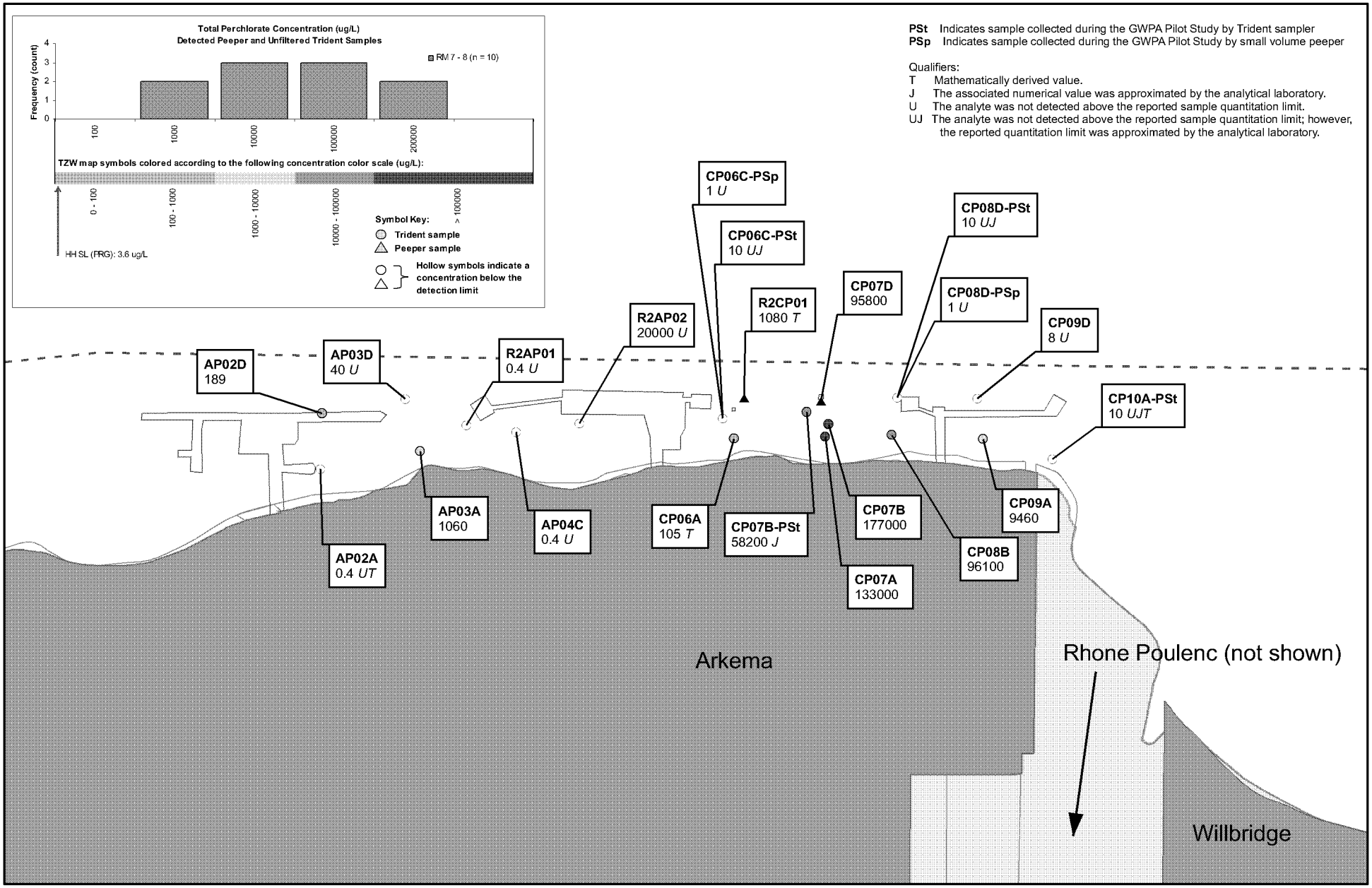
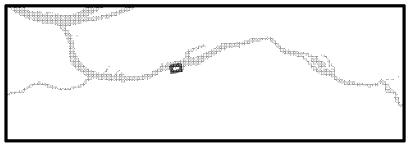


Map Features

- Docks and Structures
- River miles
- Navigation Channel
- Upland Sites (2006)
- Waterfront Taxlots
- R2 GWPA Study Site

0 100 200 300 400 Feet



FEATURE SOURCES:
Property and Taxlot Boundaries: Metro RLIS
Channel & River miles: US Army Corps of Engineers.
Docks & In-water Structures: digitized from October 2001 0.33 ft. resolution color orthophotos

integral consulting inc.

LWG Lower Willamette Group

Figure 6.2-7
Portland Harbor RI/FS
Comprehensive Round 2 Report
Transition Zone Water Sample Results
River Mile 7 to 8 - Perchlorate (ug/L)

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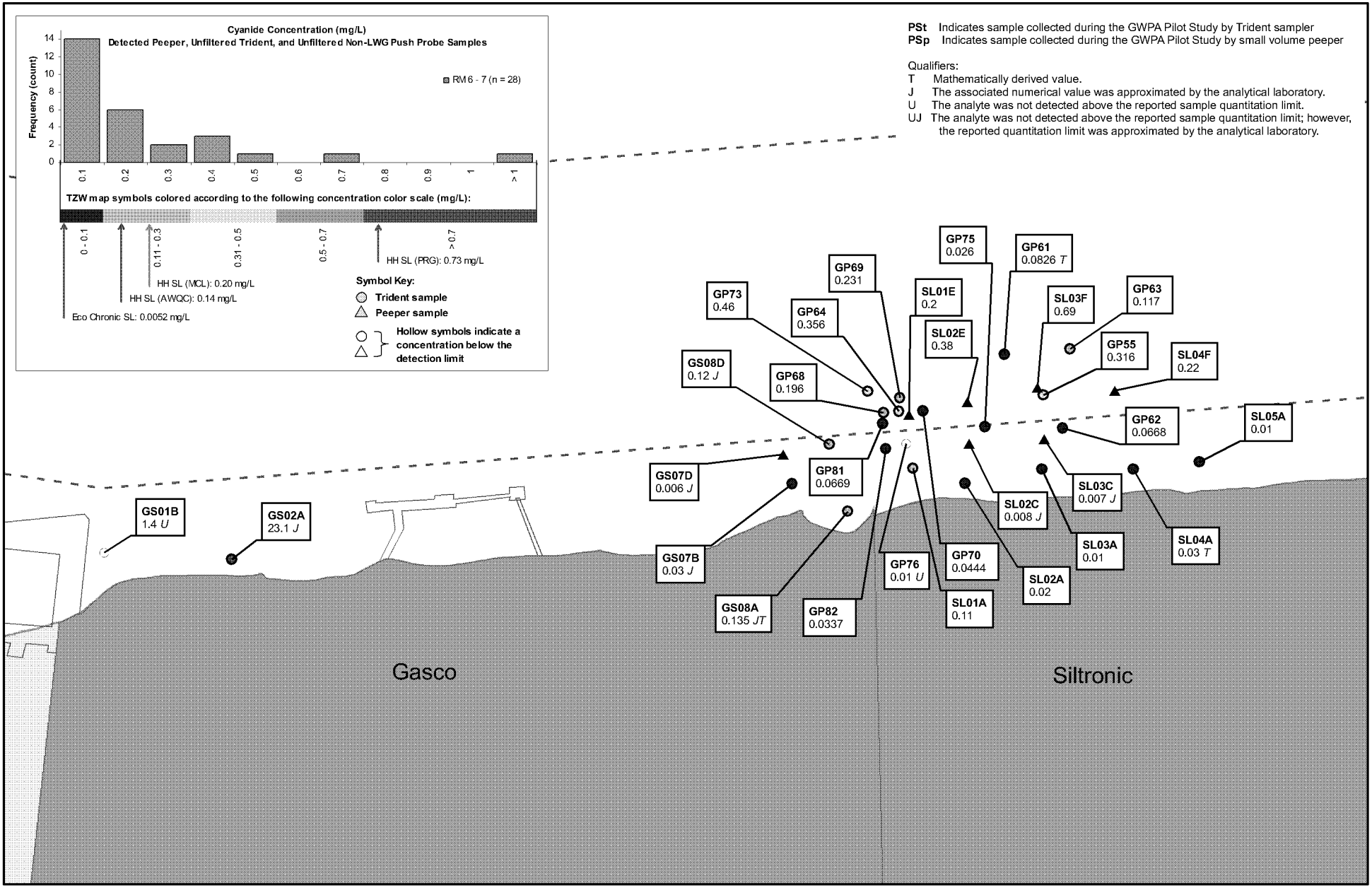
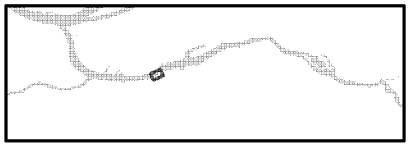


Map Features

- Docks and Structures
- River miles
- Navigation Channel
- Upland Sites (2006)
- Waterfront Taxlots
- R2 GWPA Study Site

0 100 200 300 400 Feet



FEATURE SOURCES:
Property and Taxlot Boundaries: Metro RLIS
Channel & River miles: US Army Corps of Engineers.
Docks & In-water Structures: digitized from October 2001 0.33 ft. resolution color orthophotos

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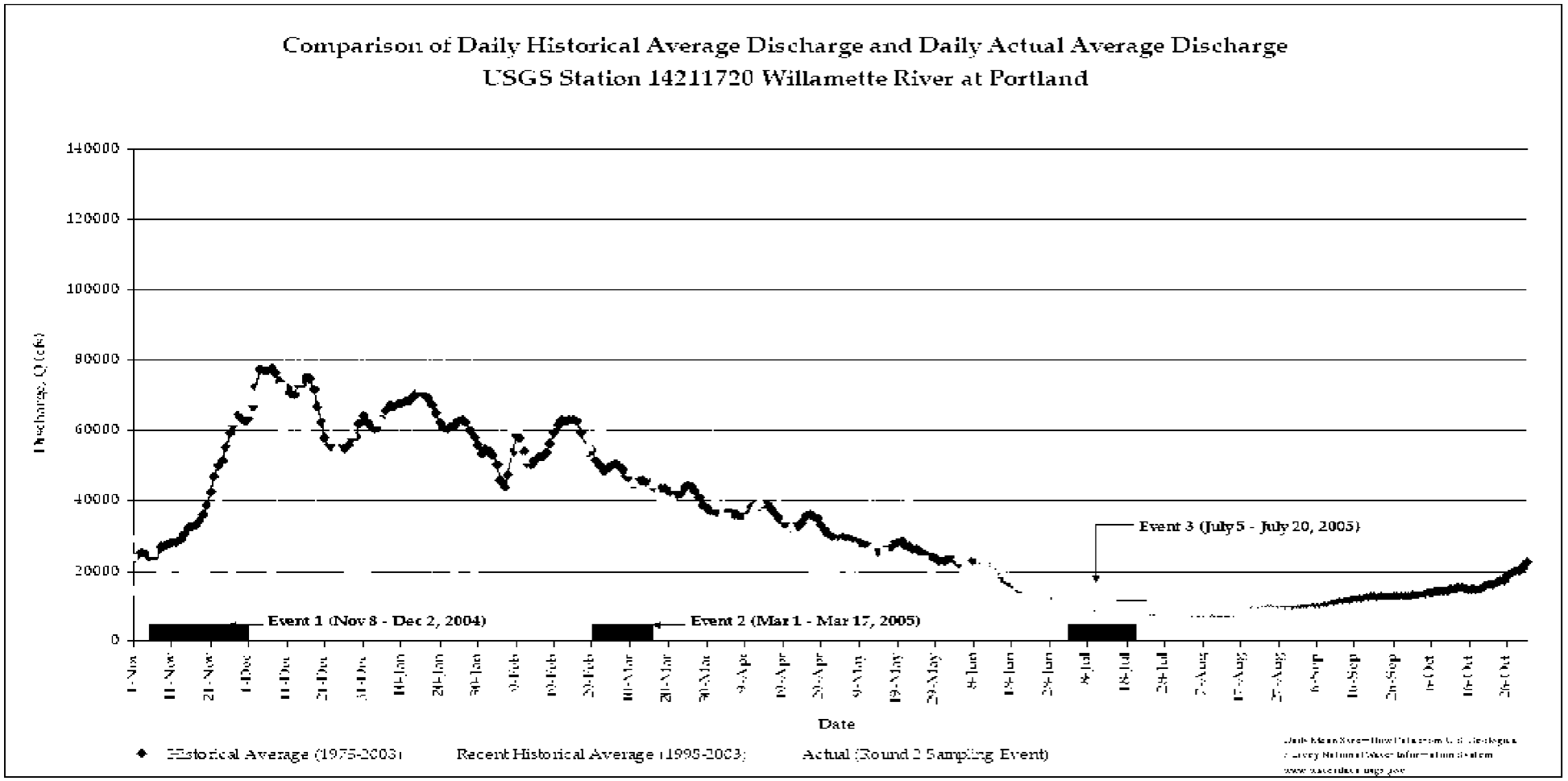
LWG Lower Willamette Group

Figure 6.2-8
Portland Harbor RI/FS
Comprehensive Round 2 Report
Transition Zone Water Sample Results
River Mile 6 to 7 - Cyanide (mg/L)



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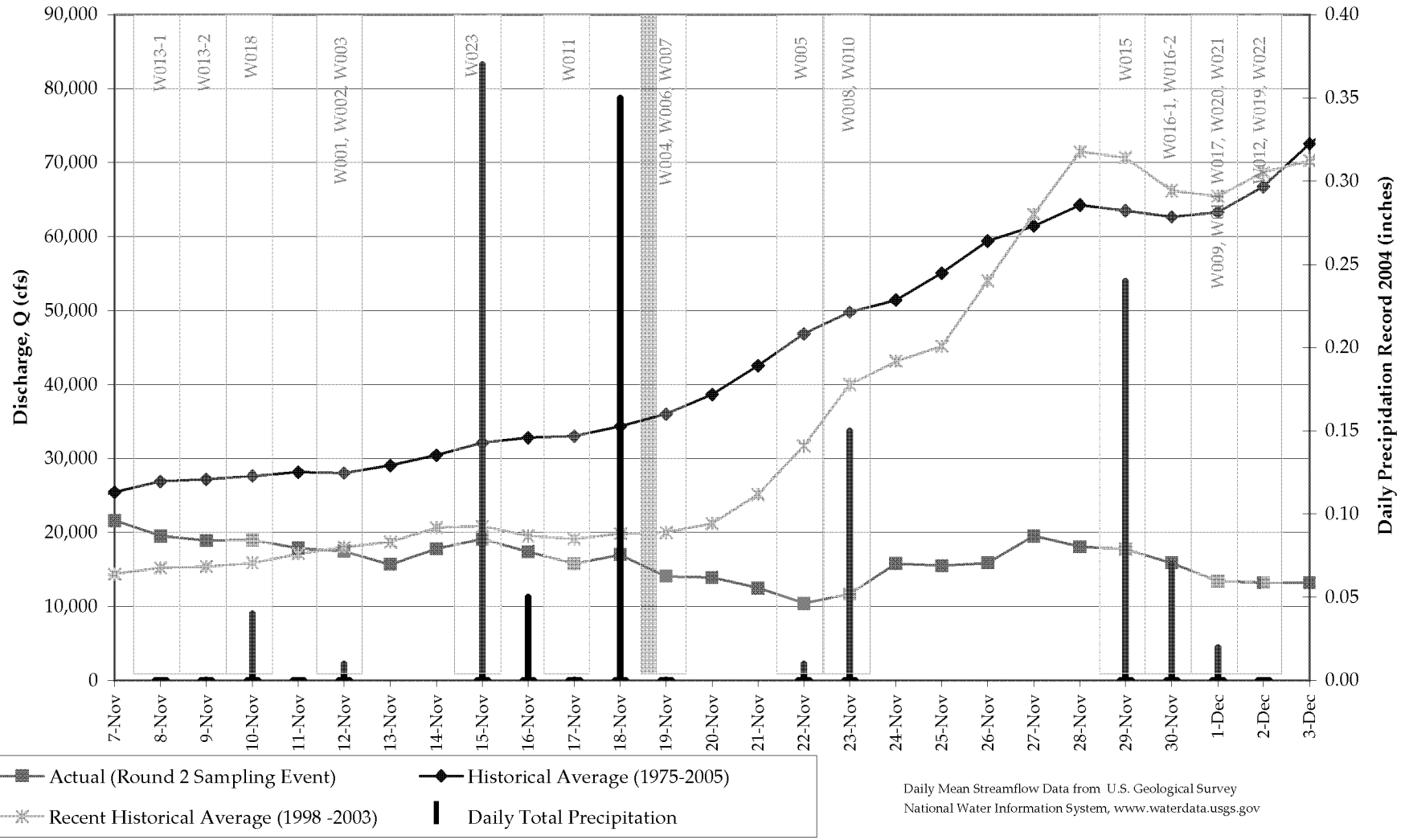
LWG LOWER WILLAMETTE GROUP

Figure 6.3-1
Portland Harbor RI/FS
Comprehensive Round 2 Report
Comparison of Historical Discharge

DRAFT
Privileged and Confidential:
Work Product Prepared in Anticipation of Litigation

November 2004 Surface Water Sampling Event Hydrograph and Hyetograph
(Including Historical Average Discharge Rates for Comparison)
USGS 14211720 Willamette River at Portland



Daily Mean Streamflow Data from U.S. Geological Survey
National Water Information System, www.waterdata.usgs.gov

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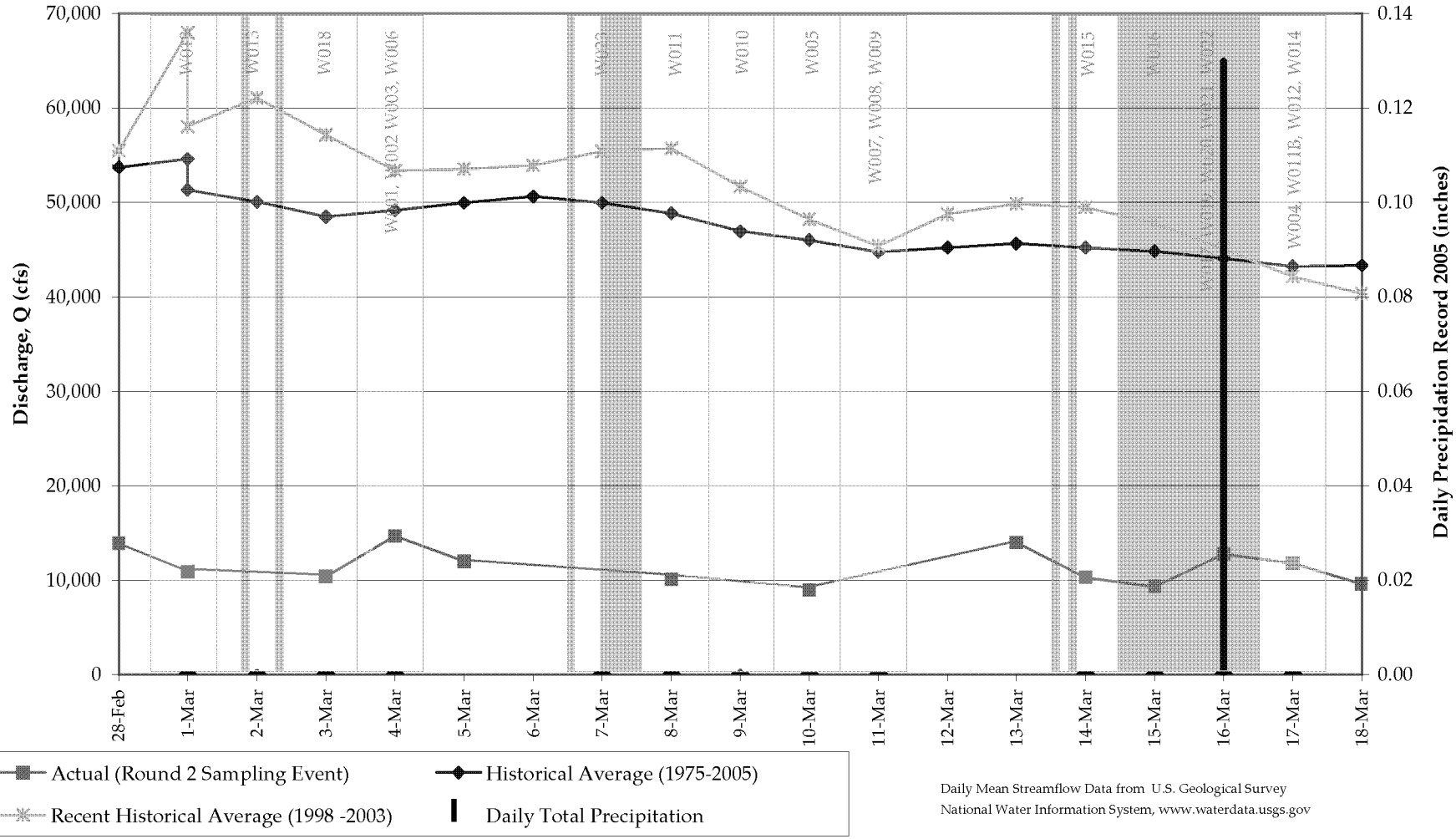
LOWER WILLAMETTE GROUP

Figure 6.3-2
Portland Harbor RI/FS
Comprehensive Round 2 Report

March 2005 Surface Water Sampling Event Hydrograph and Hyetograph
(Including Historical Average Discharge Rates for Comparison)
USGS 14211720 Willamette River at Portland



Daily Mean Streamflow Data from U.S. Geological Survey
National Water Information System, www.waterdata.usgs.gov

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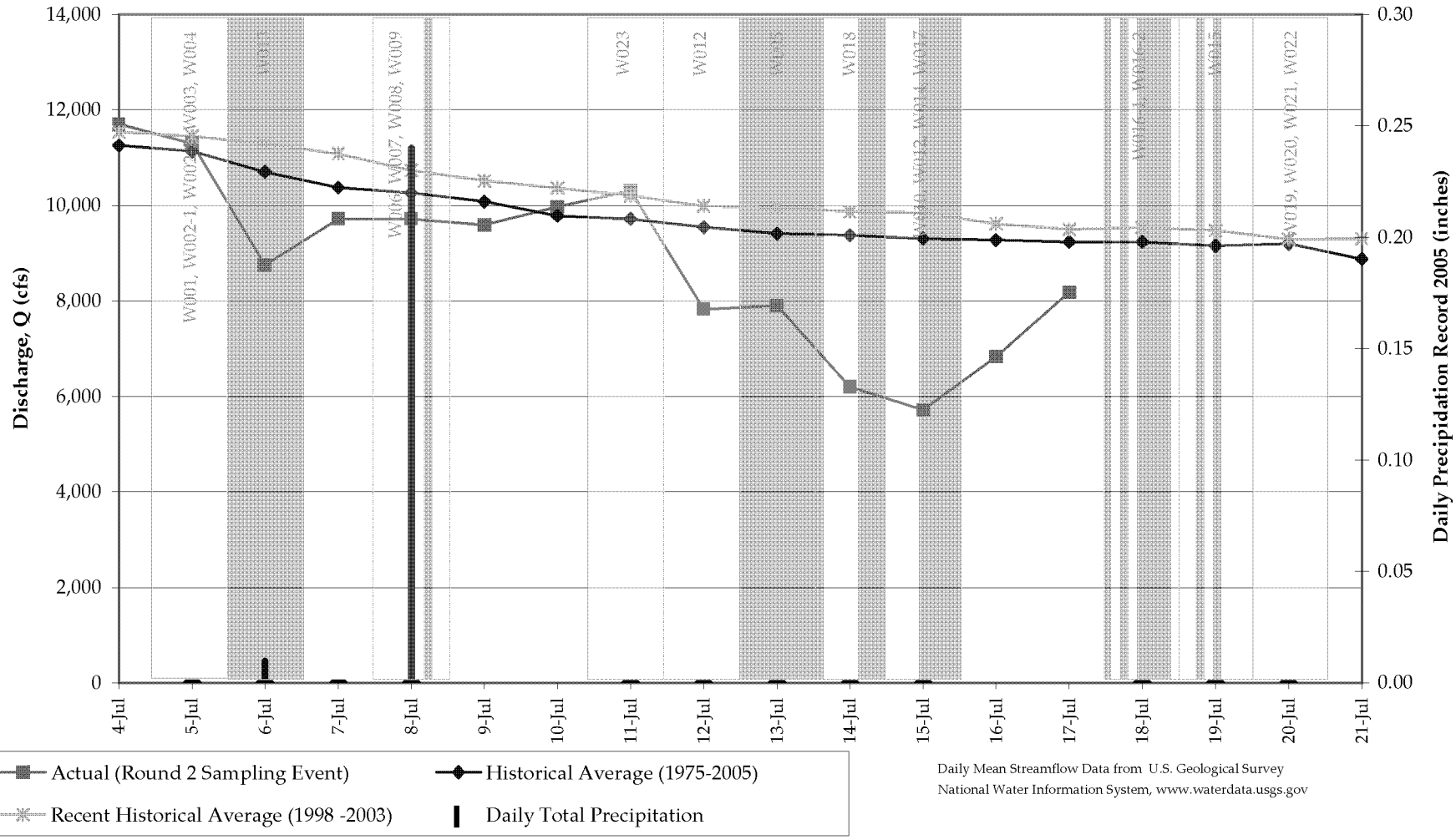
LWG
LOWER WILLAMETTE GROUP

Figure 6.3-3
Portland Harbor RI/FS
Comprehensive Round 2 Report

July 2005 Surface Water Sampling Event Hydrograph and Hyetograph
(Including Historical Average Discharge Rates for Comparison)
USGS 14211720 Willamette River at Portland



Daily Mean Streamflow Data from U.S. Geological Survey
National Water Information System, www.waterdata.usgs.gov

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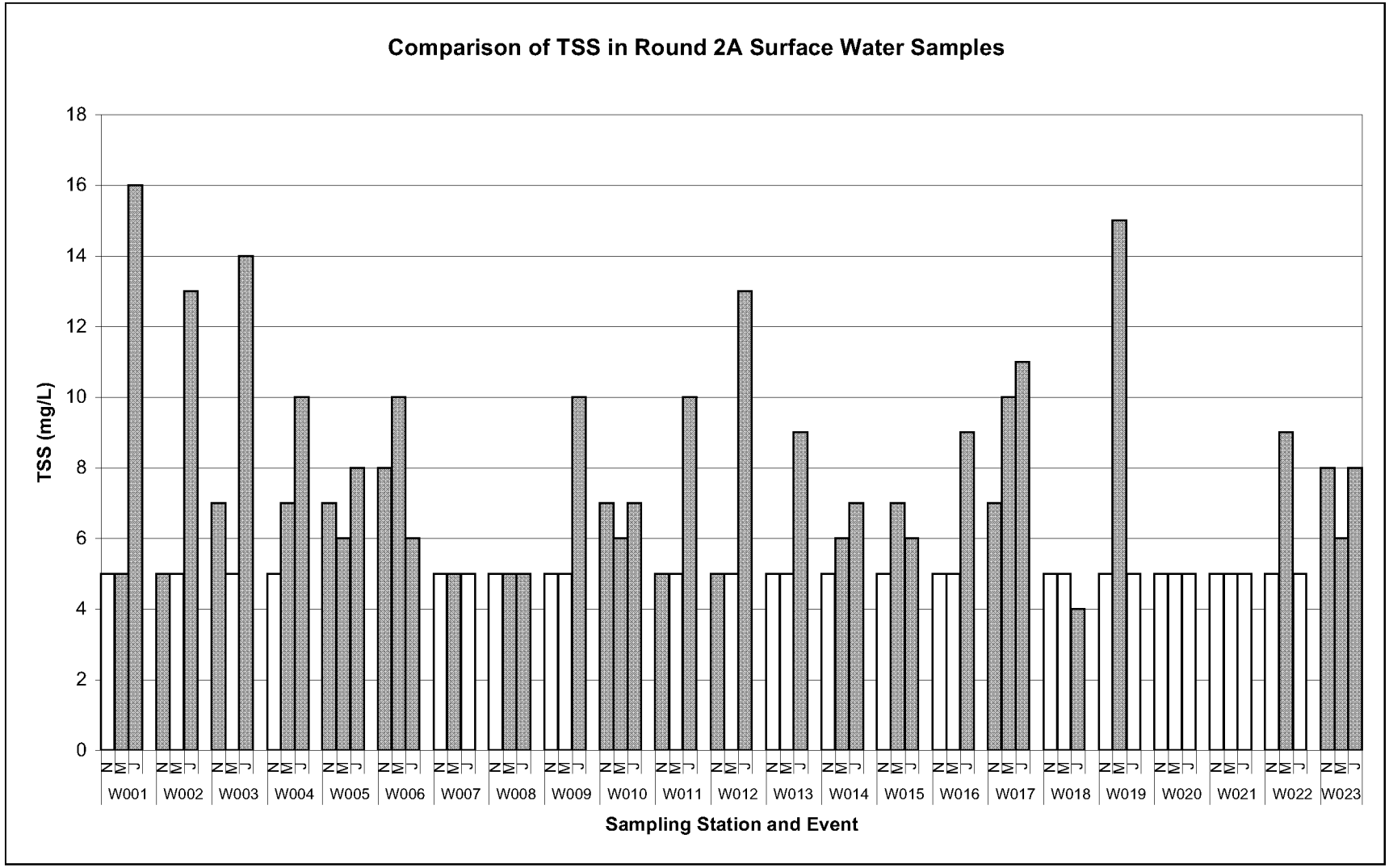
LOWER WILLAMETTE GROUP

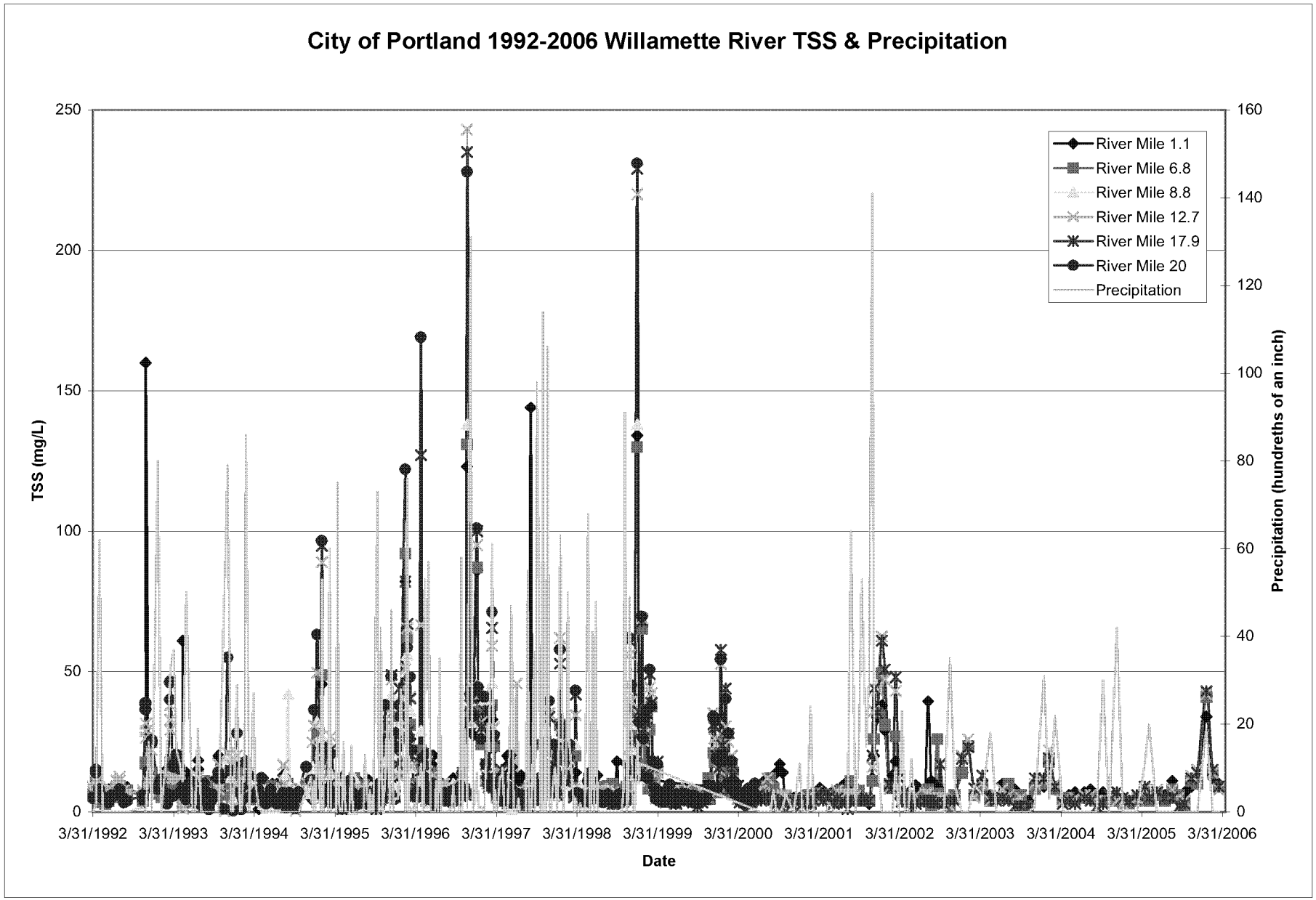
Figure 6.3-4
Portland Harbor RI/FS
Comprehensive Round 2 Report



Notes: Diagonally shaded bars represent undetected TSS concentrations with a reported detection limit of 5 mg/L.

integral LWG Lower Willamette Group

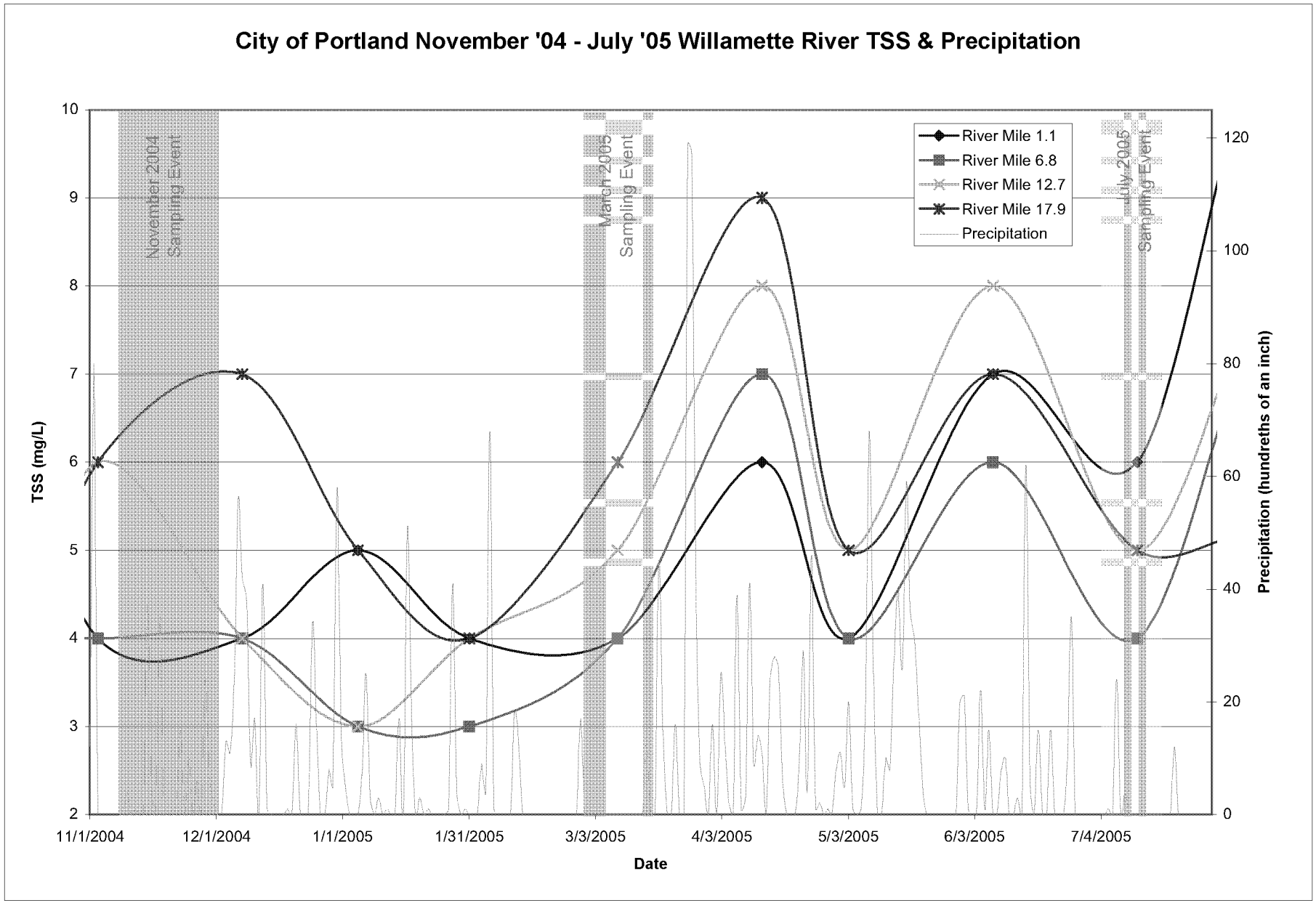
Figure 6.3-5
Portland Harbor RI/FS
Comprehensive Round 2 Report
Comparison of TSS in Round 2A Surface Water Samples



integral

LWG
LOWER WILLAMETTE GROUP

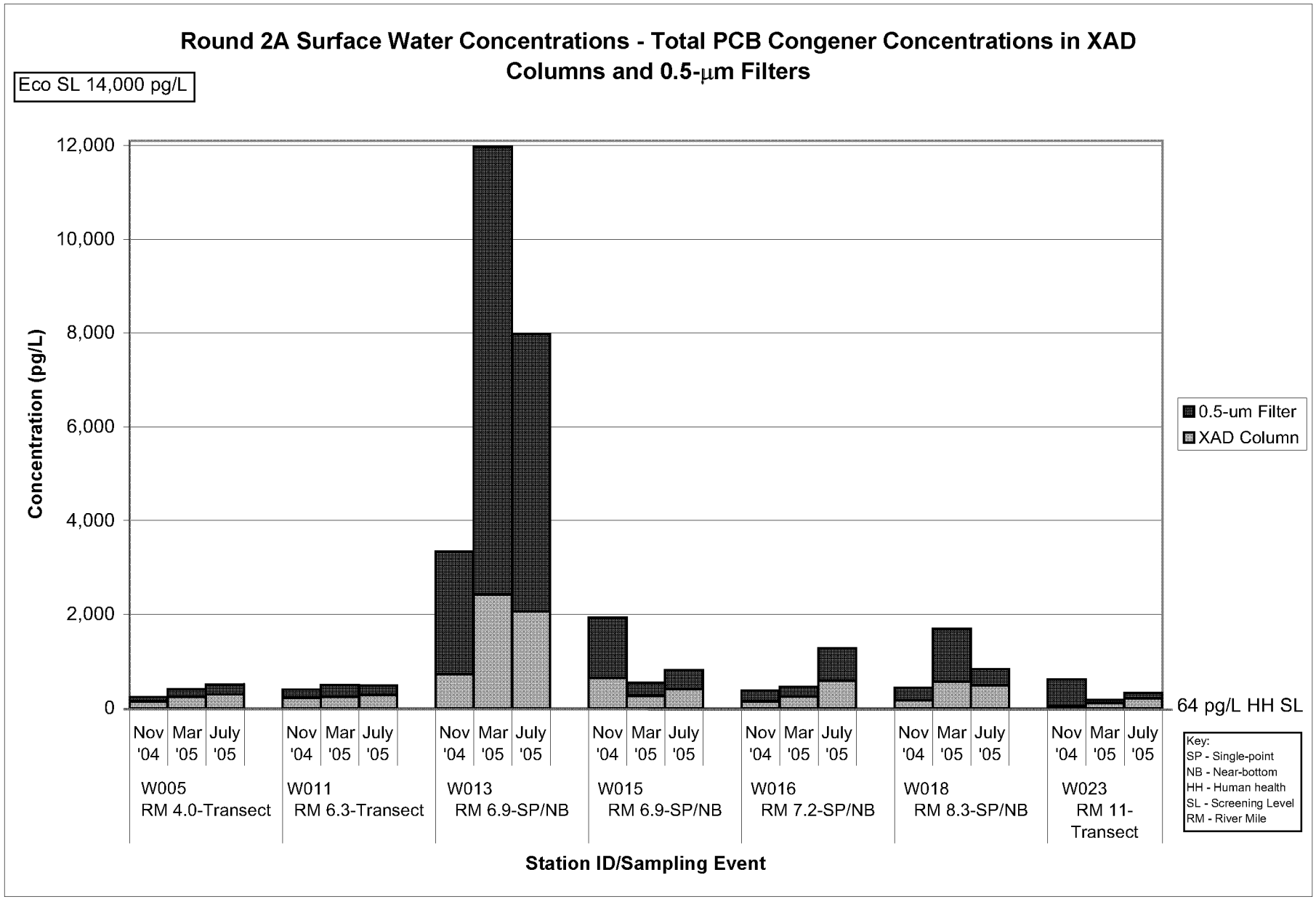
Figure 6.3-6
Portland Harbor RI/FS
Comprehensive Round 2 Report



integral

LWG
LOWER WILLAMETTE GROUP

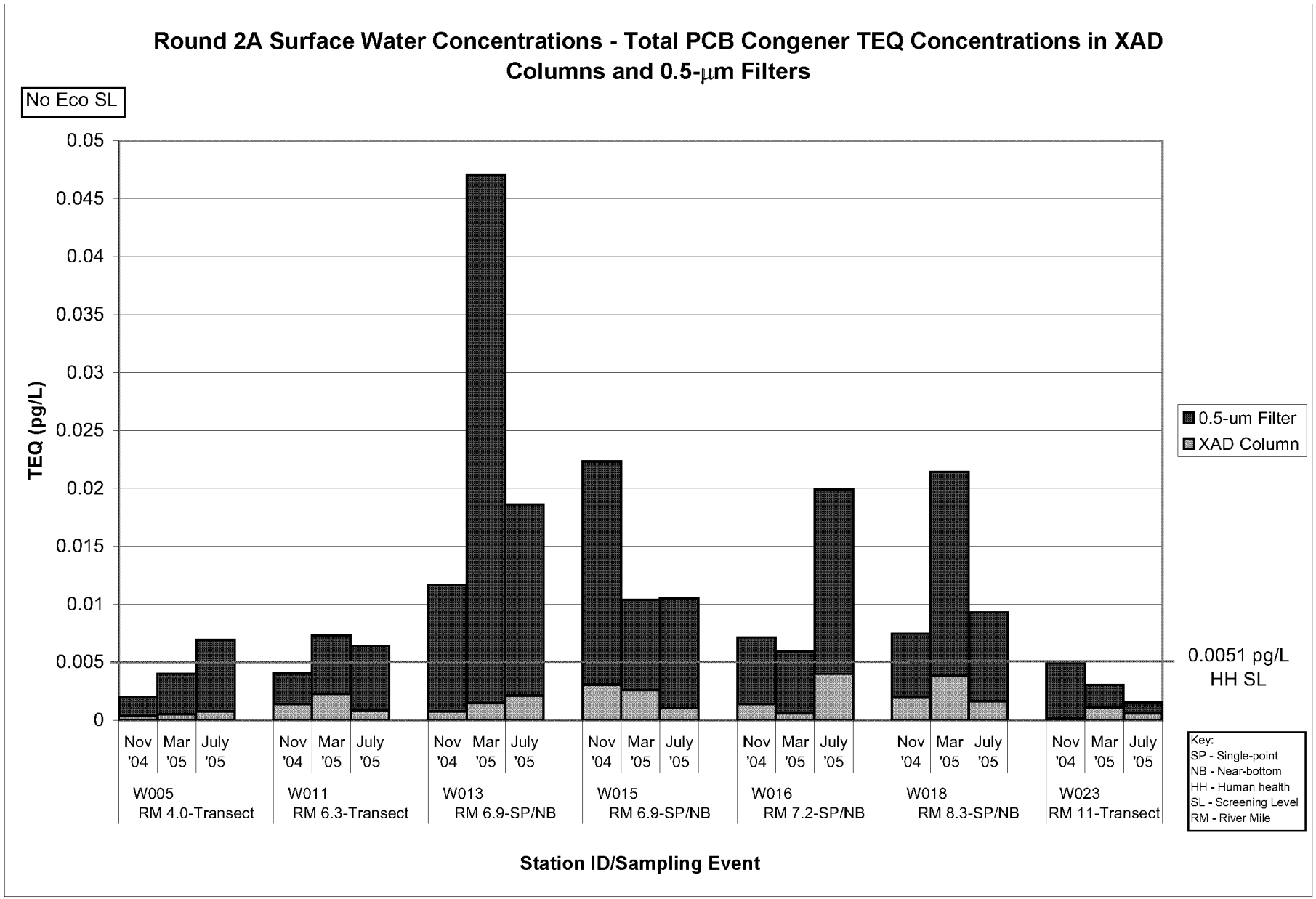
Figure 6.3-7
Portland Harbor RI/FS
Comprehensive Round 2 Report



integral

LWG Lower Willamette Group

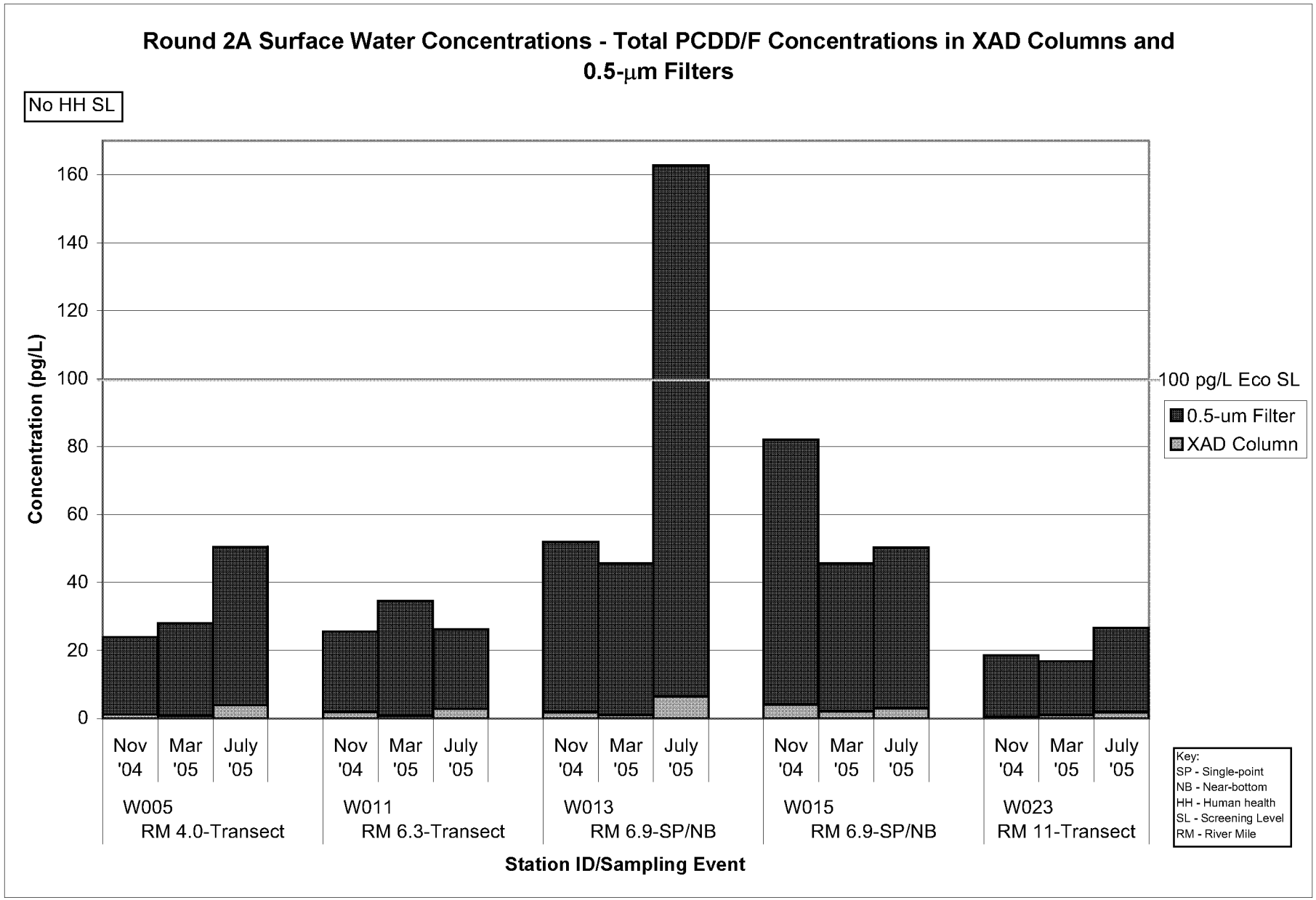
Figure 6.3-8
Portland Harbor RI/FS
Comprehensive Round 2 Report



integral

LWG
LOWER WILLAMETTE GROUP

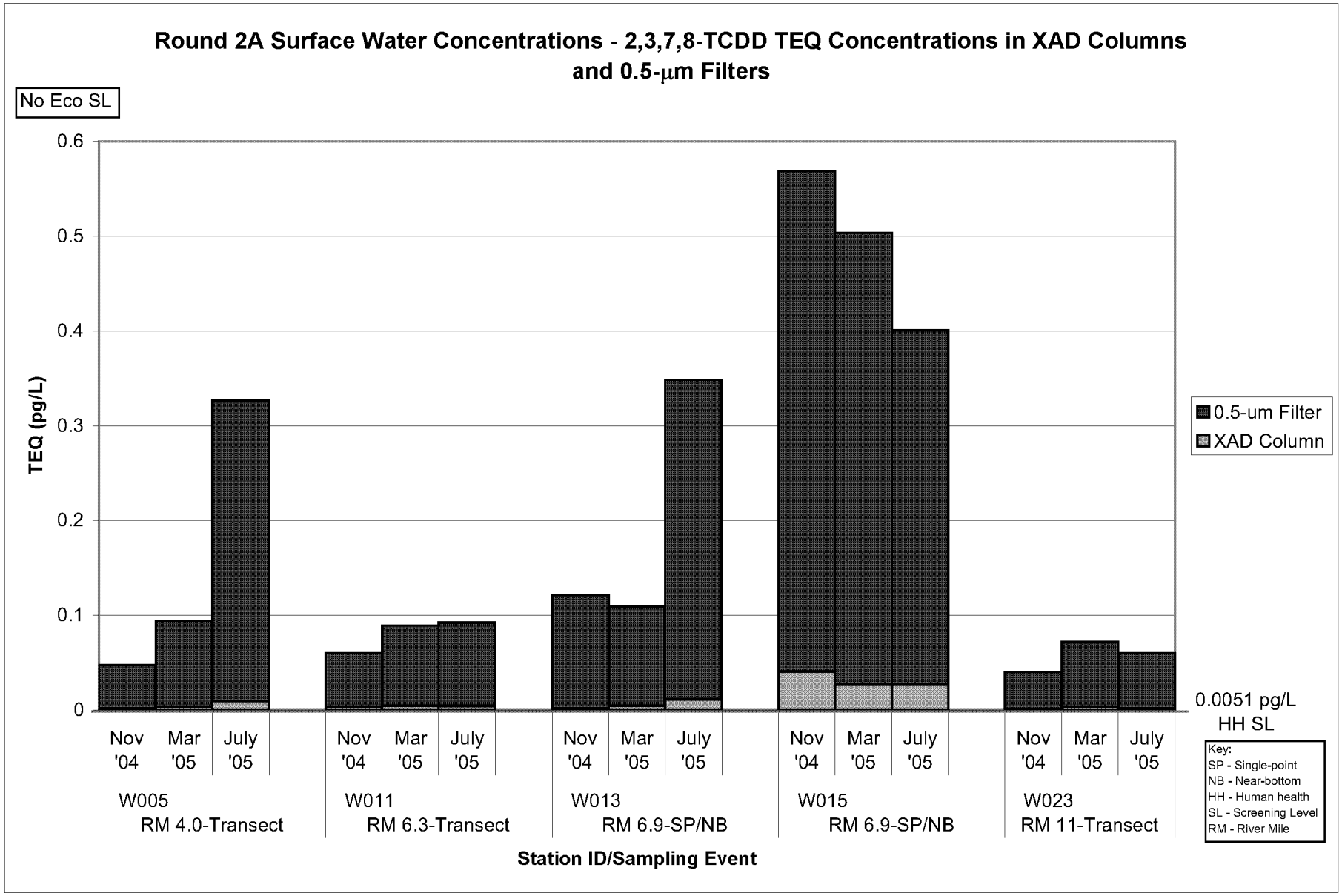
Figure 6.3-9
Portland Harbor RI/FS
Comprehensive Round 2 Report



integral

LWG Lower Willamette Group

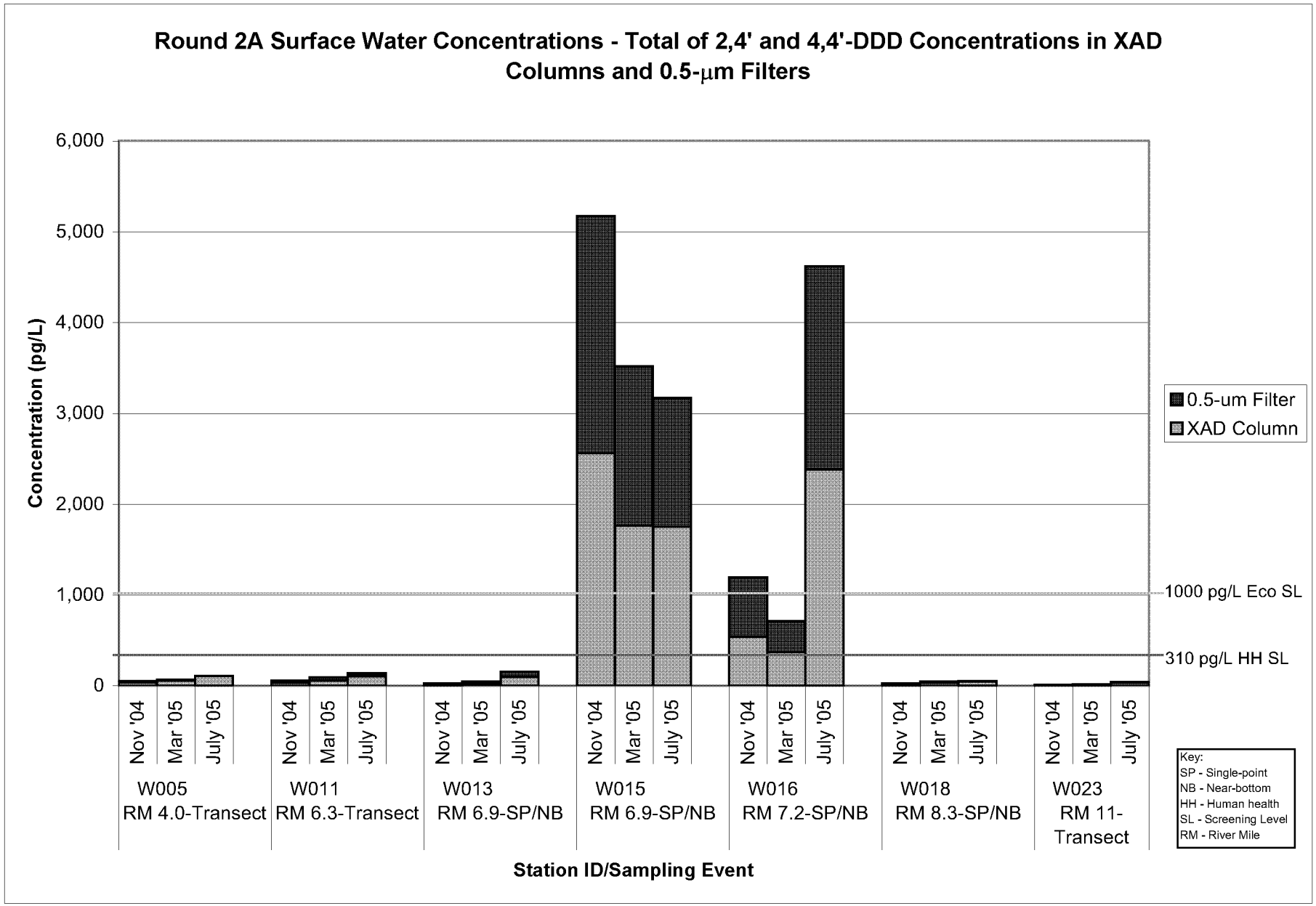
Figure 6.3-10
Portland Harbor RI/FS
Comprehensive Round 2 Report



integral

LWG
LOWER WILLAMETTE GROUP

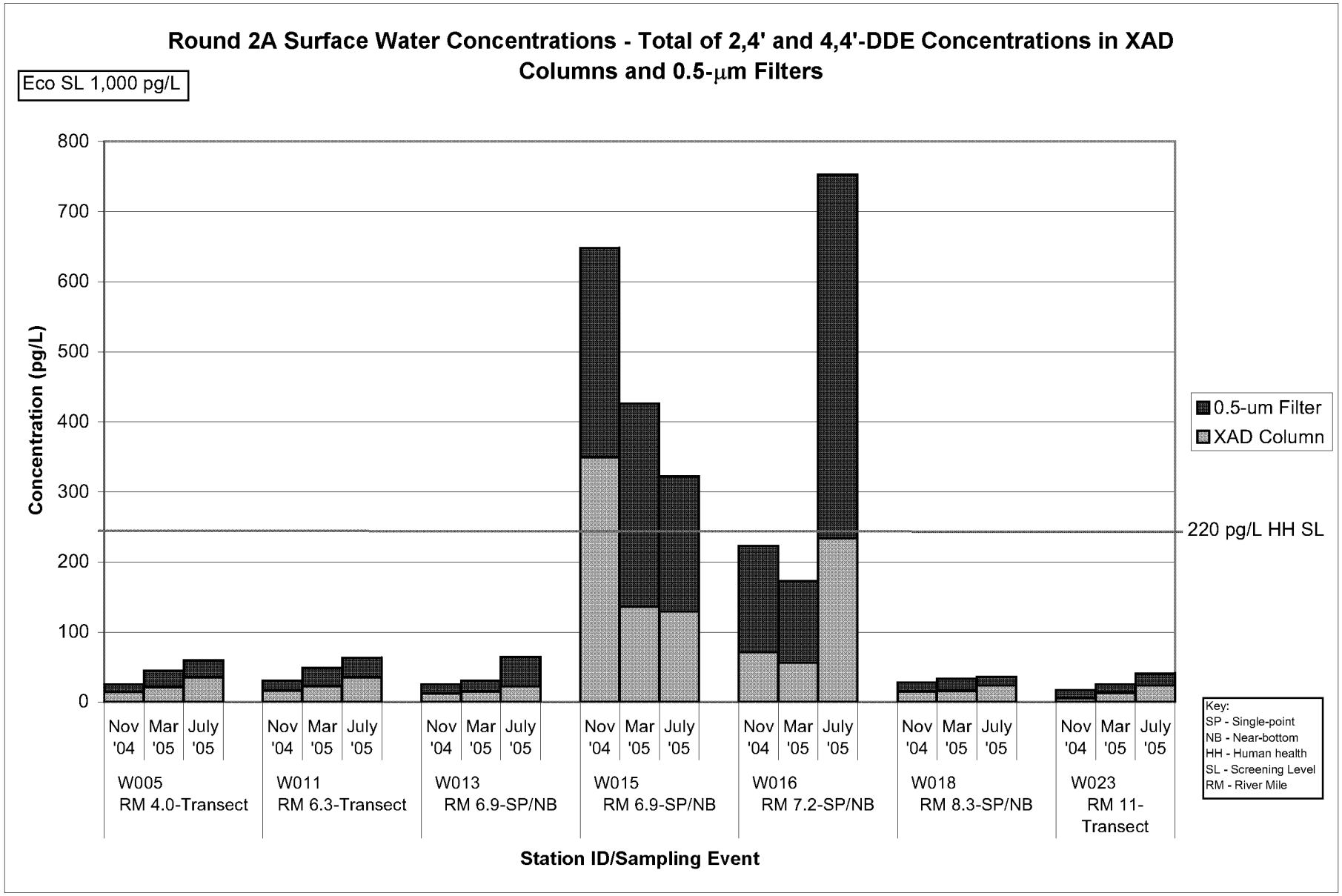
Figure 6.3-11
Portland Harbor RI/FS
Comprehensive Round 2 Report



integral

LWG LOWER WILLAMETTE GROUP

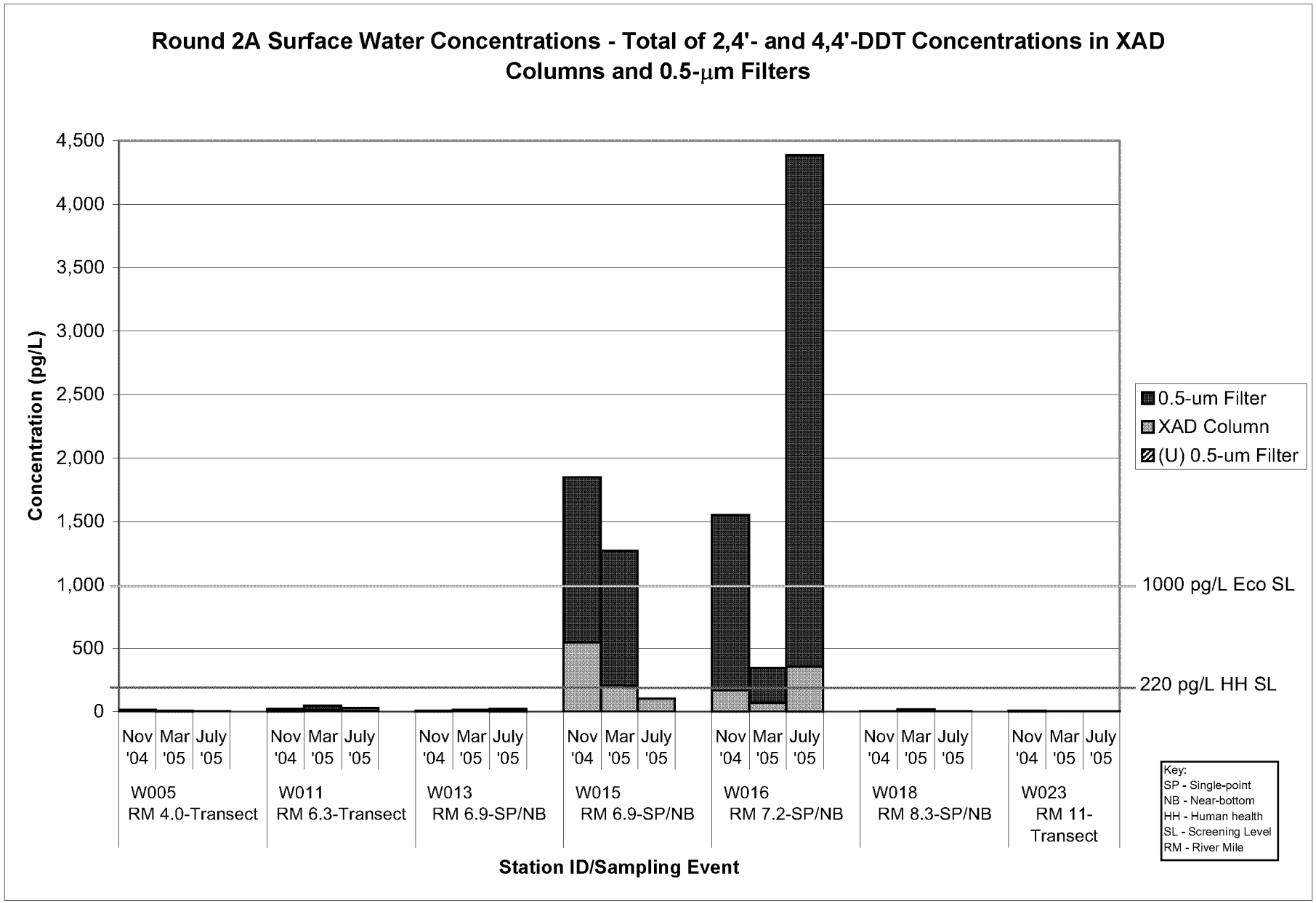
Figure 6.3-12
Portland Harbor RI/FS
Comprehensive Round 2 Report



integral

LWG LOWER WILLAMETTE GROUP

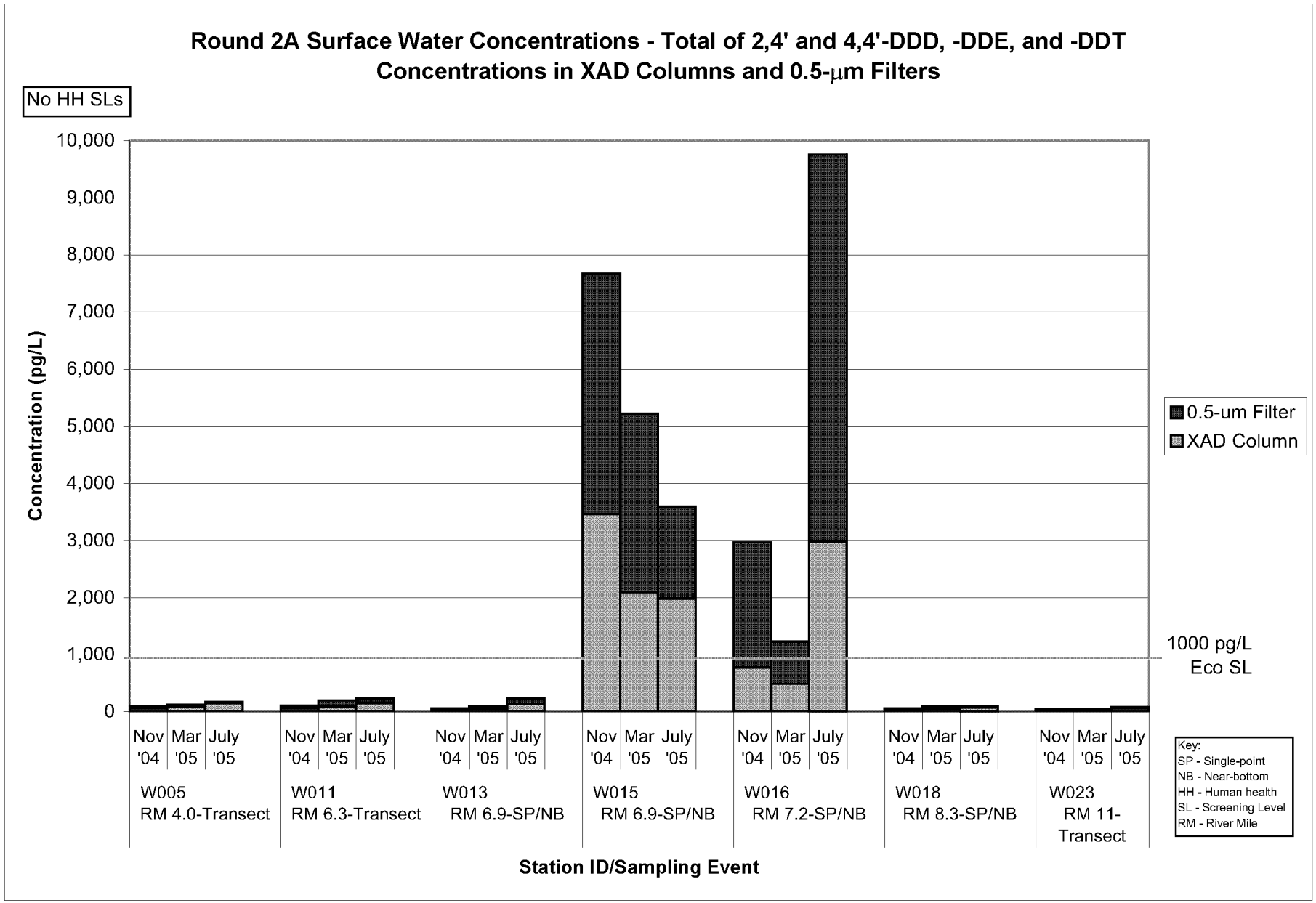
Figure 6.3-13
Portland Harbor RI/FS
Comprehensive Round 2 Report



integral

LWG LOWER WILLAMETTE GROUP

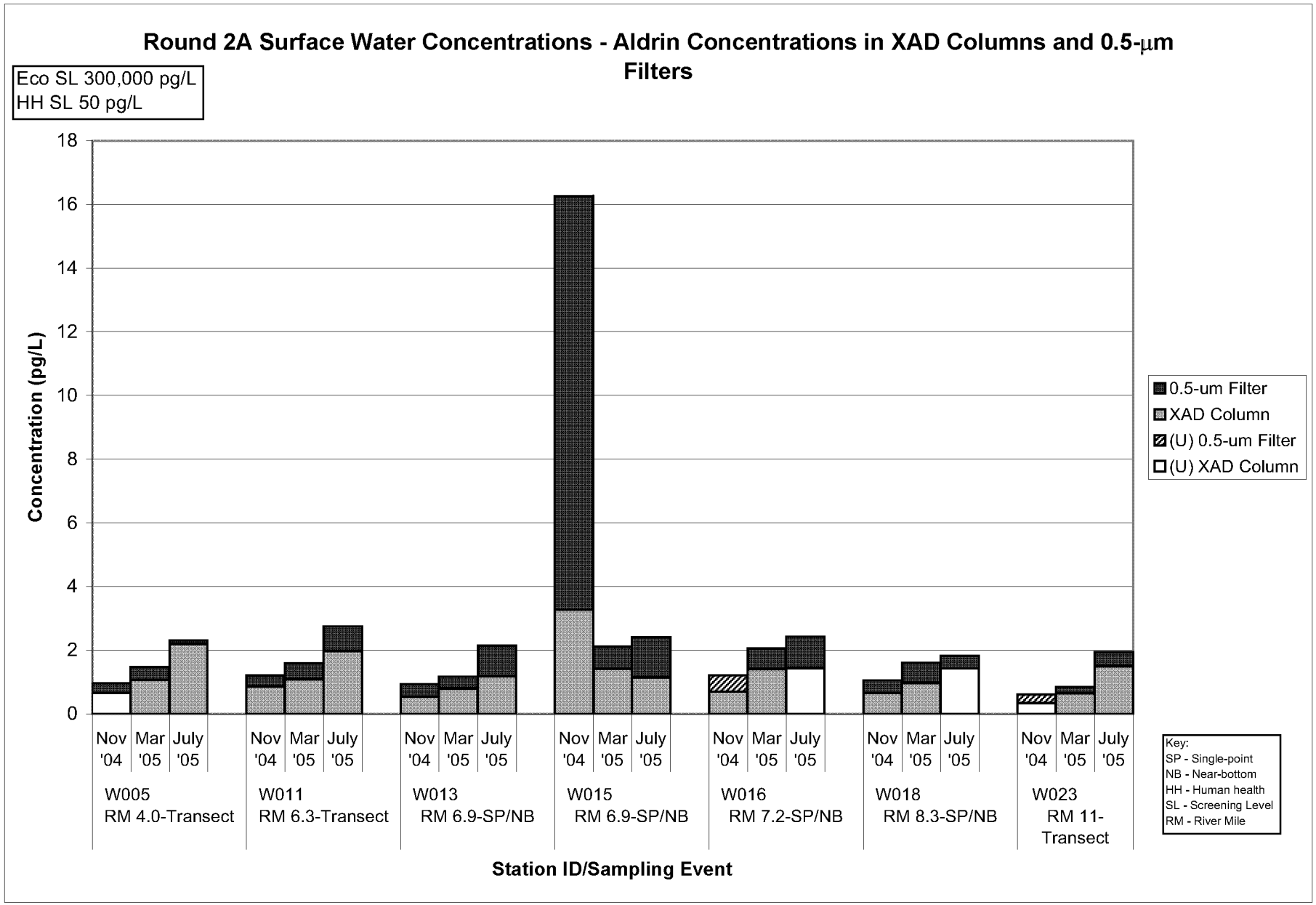
Figure 6.3-14
Portland Harbor RI/FS
Comprehensive Round 2 Report



integral

LWG LOWER WILLAMETTE GROUP

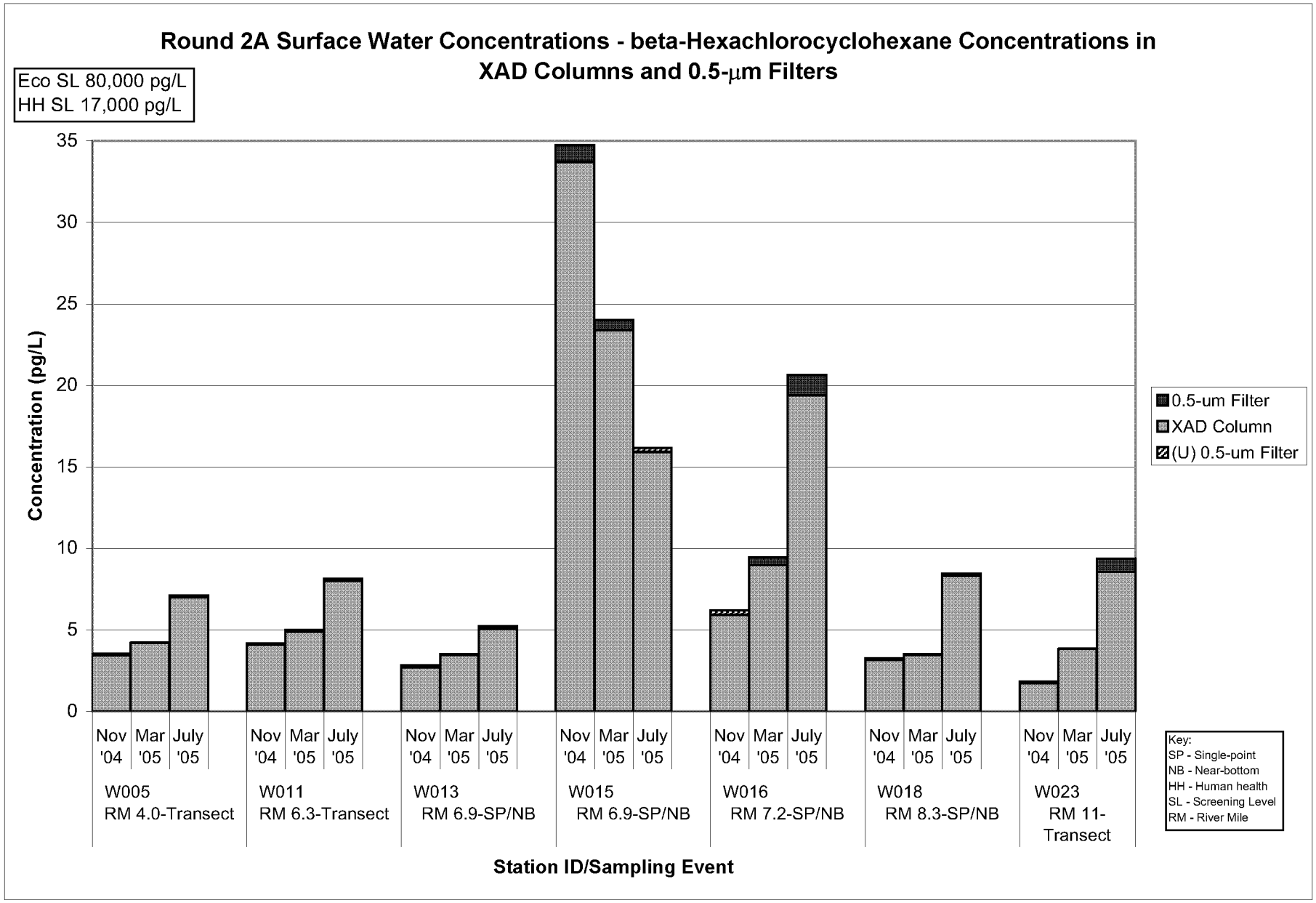
Figure 6.3-15
Portland Harbor RI/FS
Comprehensive Round 2 Report



integral

LWG Lower Willamette Group

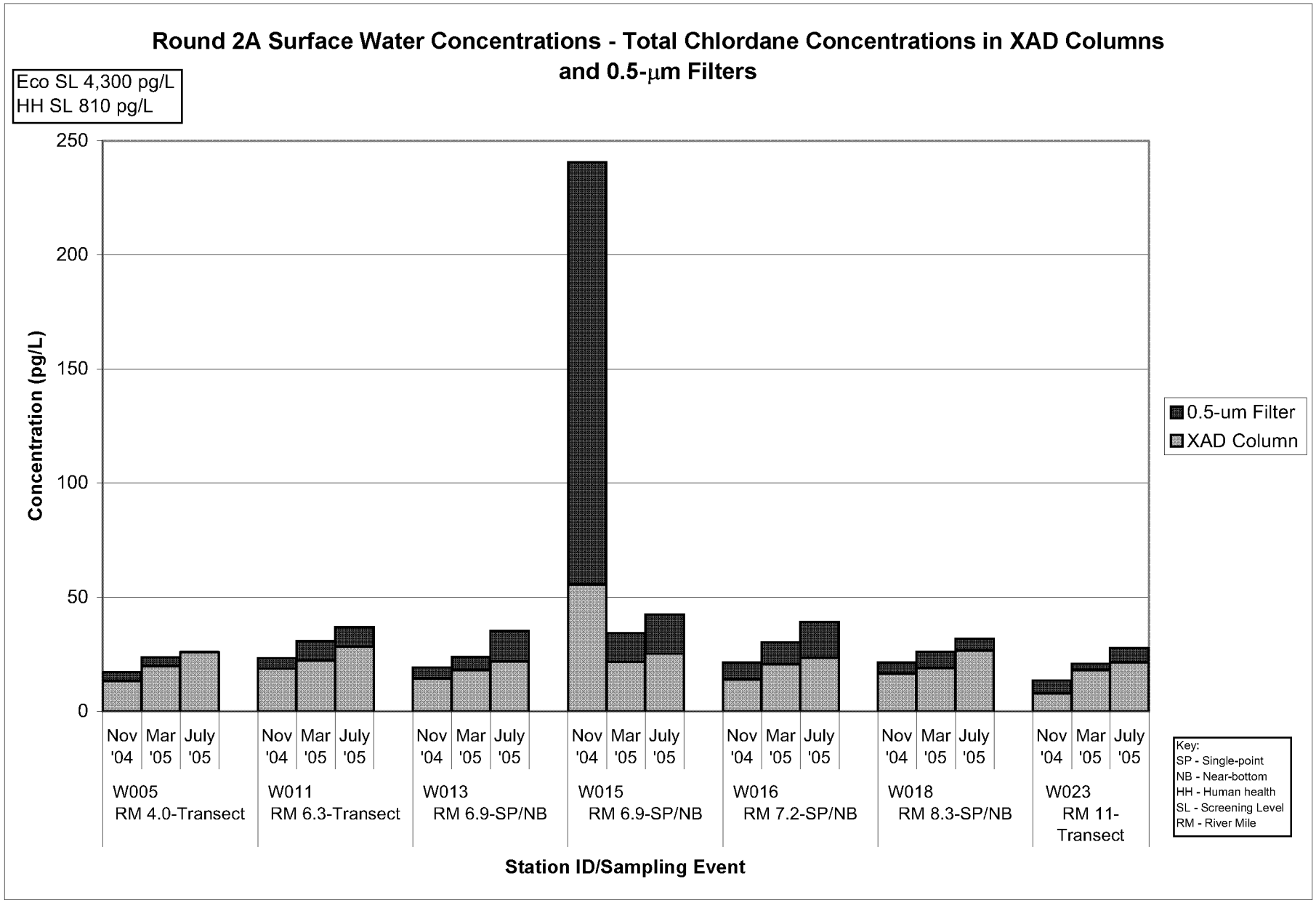
Figure 6.3-16
Portland Harbor RI/FS
Comprehensive Round 2 Report



integral

LWG LOWER WILLAMETTE GROUP

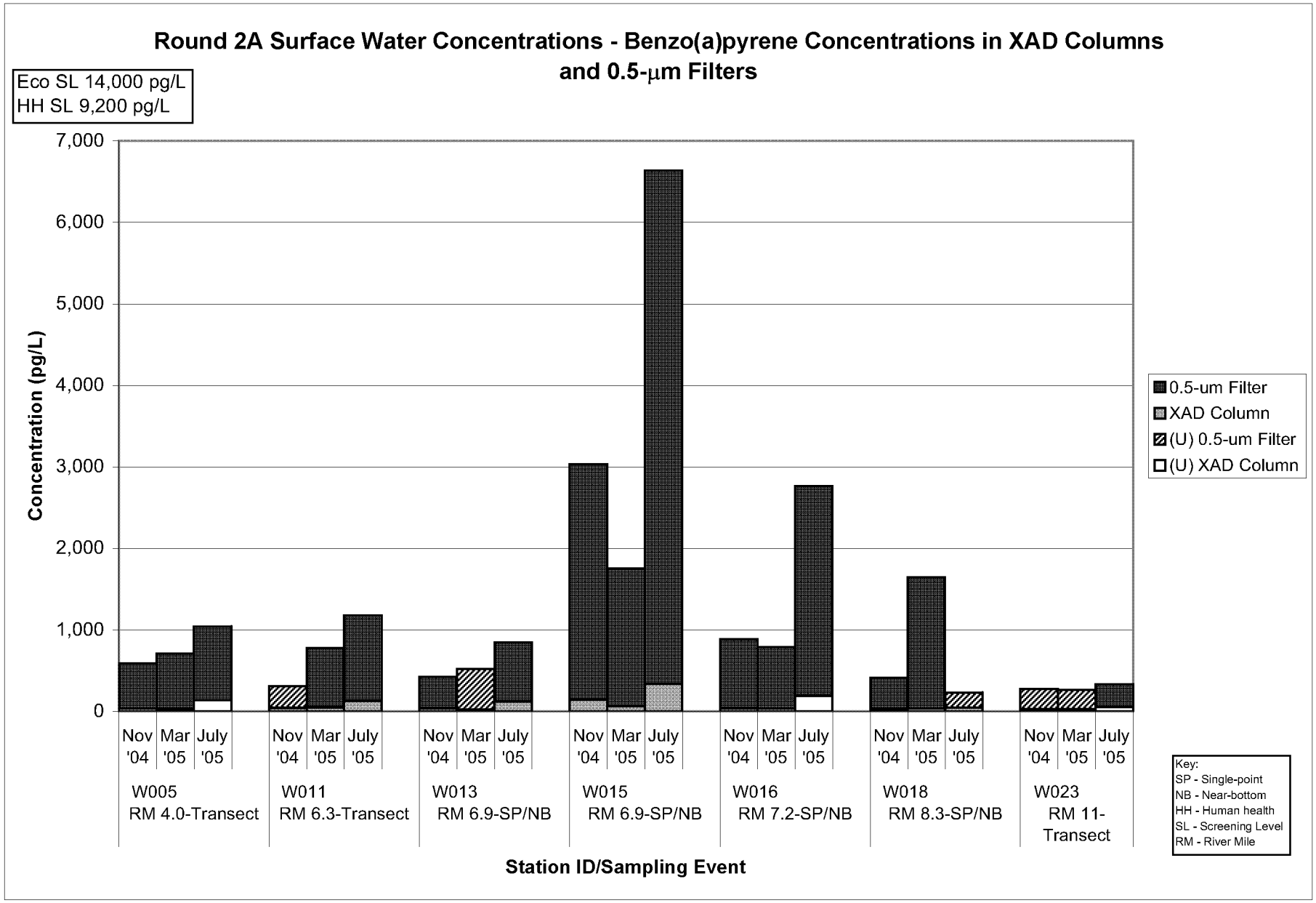
Figure 6.3-17
Portland Harbor RI/FS
Comprehensive Round 2 Report



integral

LWG LOWER WILLAMETTE GROUP

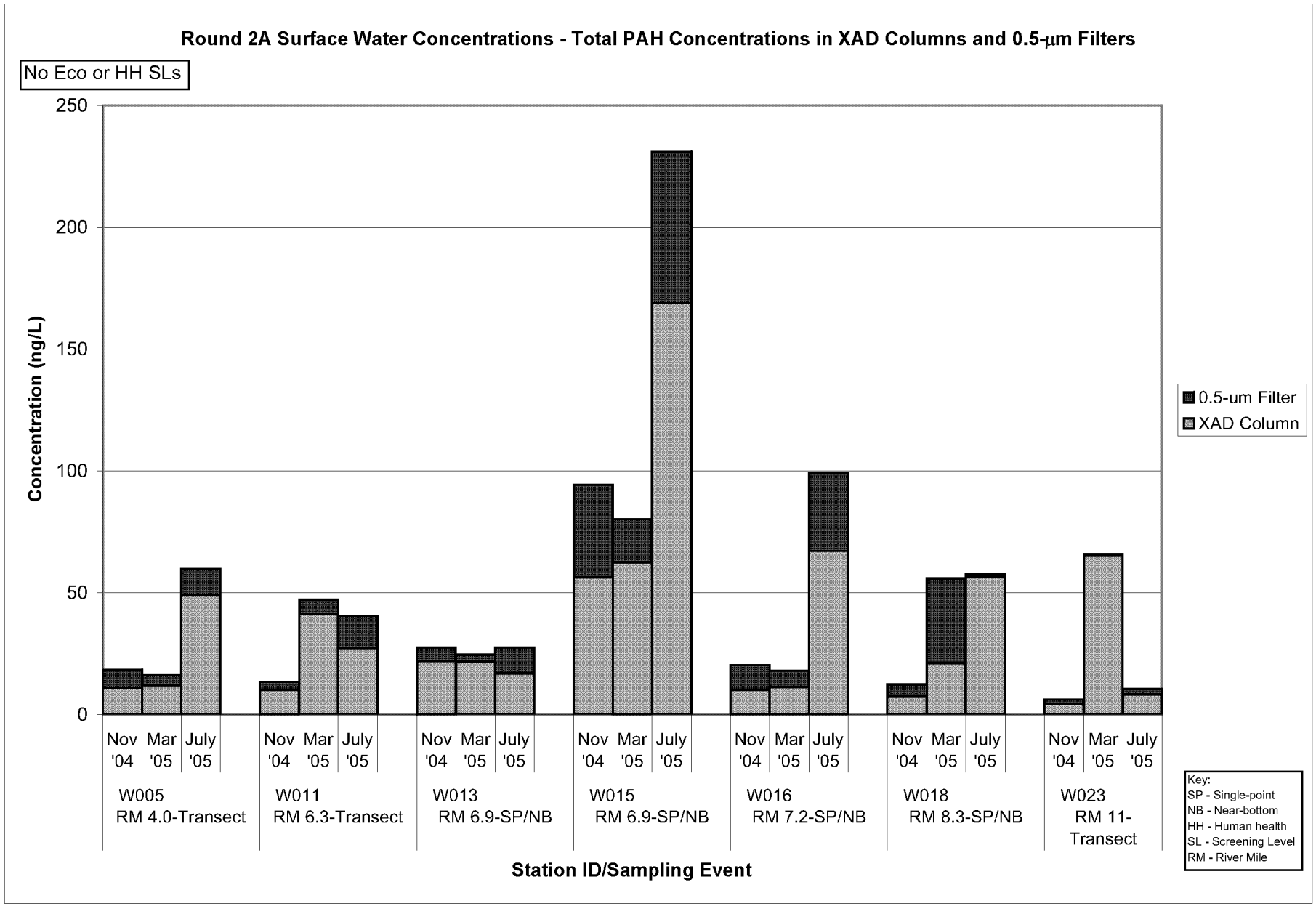
Figure 6.3-18
Portland Harbor RI/FS
Comprehensive Round 2 Report



integral

LWG LOWER WILLAMETTE GROUP

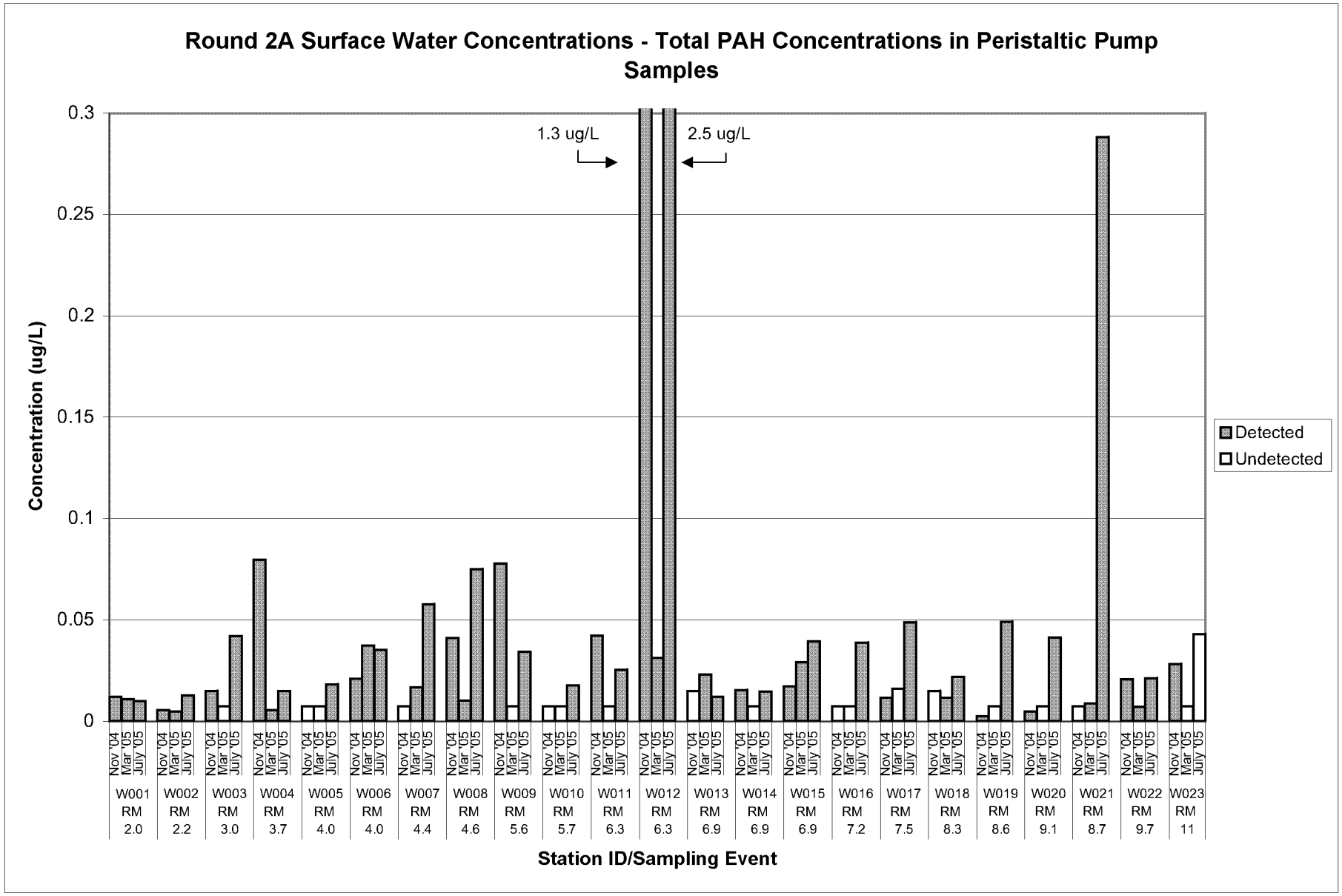
Figure 6.3-19
Portland Harbor RI/FS
Comprehensive Round 2 Report



integral

LWG LOWER WILLAMETTE GROUP

Figure 6.3-20
Portland Harbor RI/FS
Comprehensive Round 2 Report

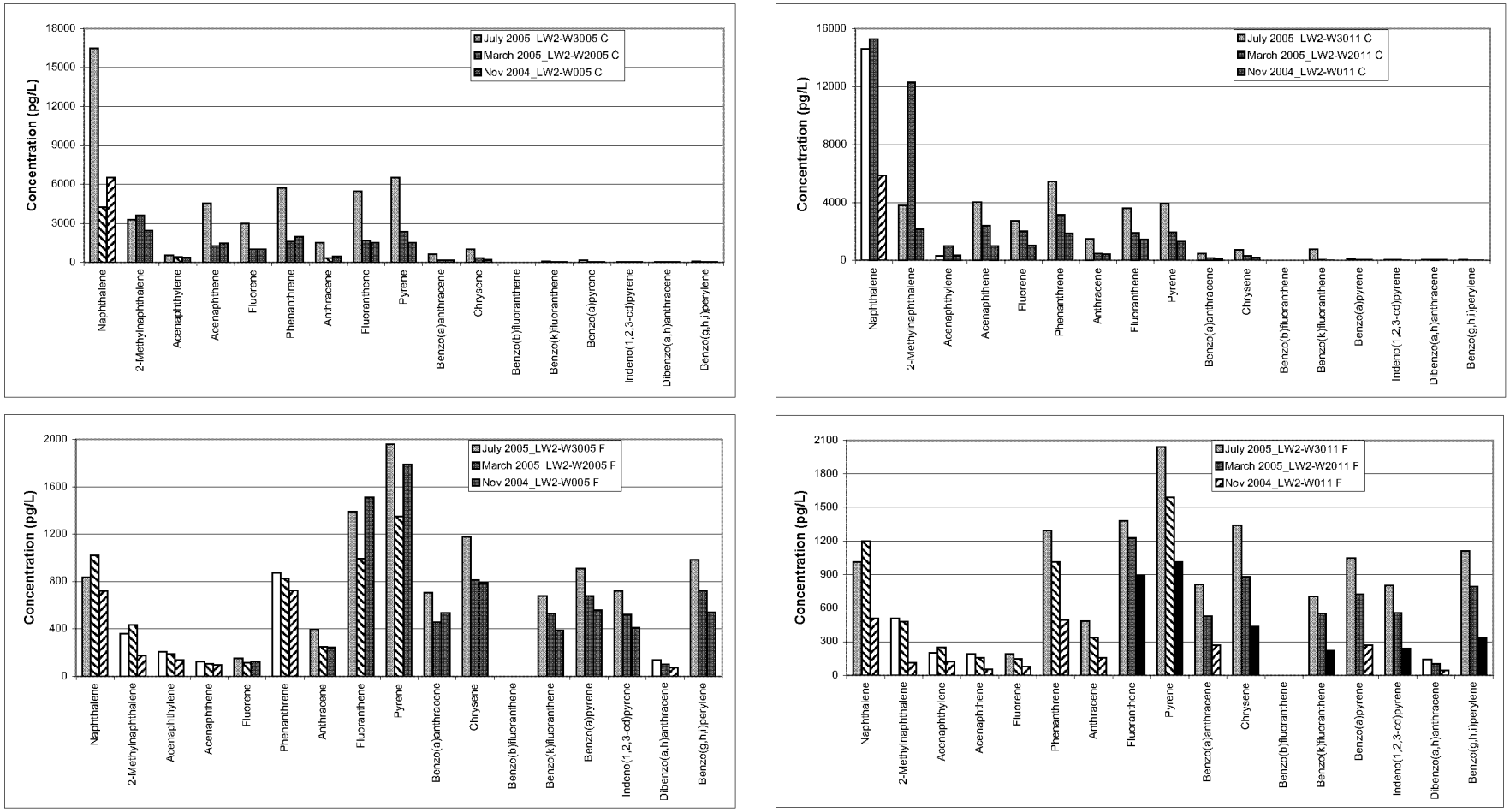


integral

LWG LOWER WILLAMETTE GROUP

Figure 6.3-21
Portland Harbor RI/FS
Comprehensive Round 2 Report

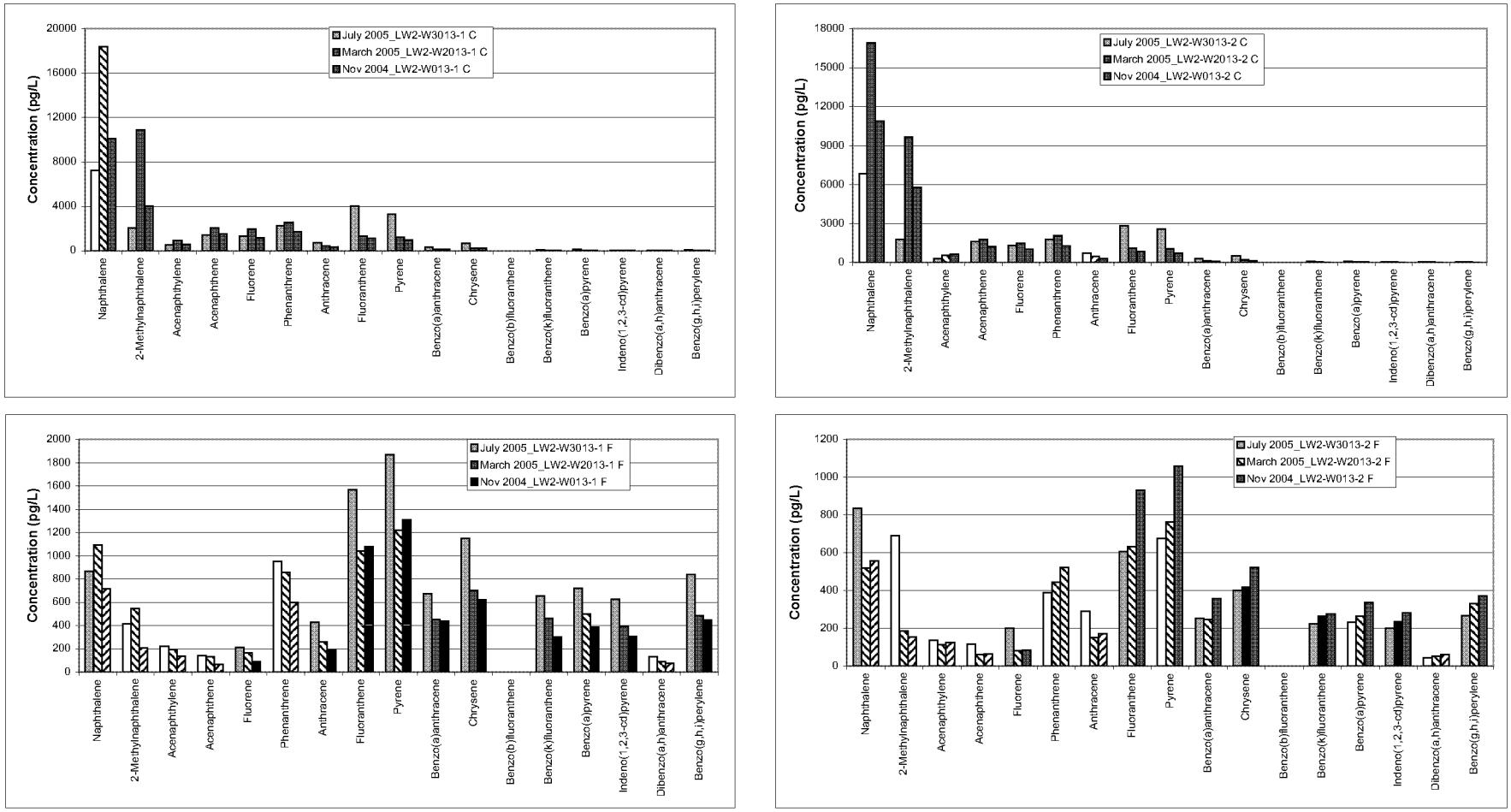
Figure 6.3-22. PAH Composition in High-Volume Surface Water Samples



Note: Cross-hatched bars indicate that the PAH was not detected. The bar height represents the detection limit.

Figure 6.3-22
Portland Harbor RI/FS
Comprehensive Round 2 Report

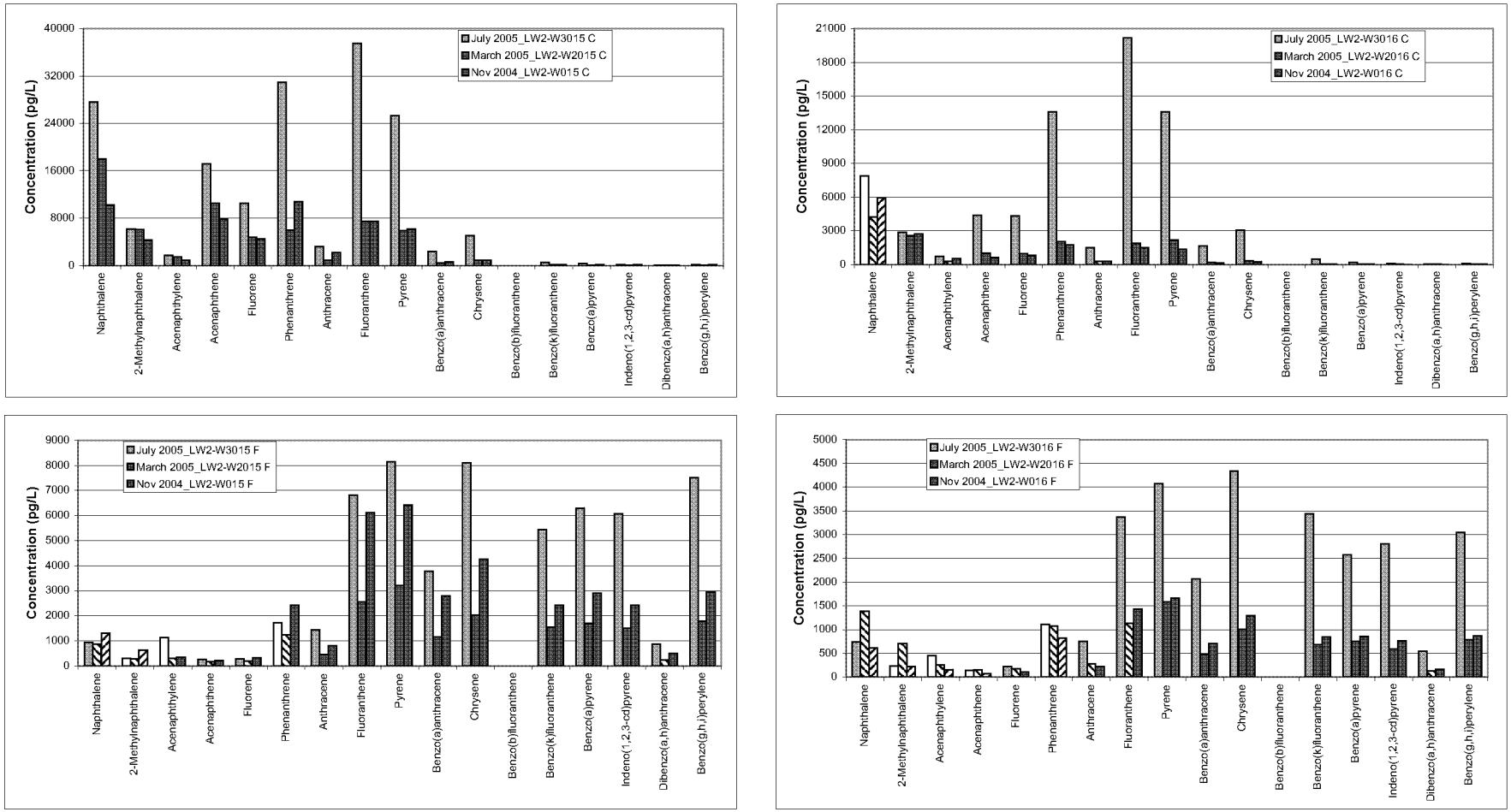
Figure 6.3-22. PAH Composition in High-Volume Surface Water Samples



Note: Cross-hatched bars indicate that the PAH was not detected. The bar height represents the detection limit.

Figure 6.3-22 cont.
Portland Harbor RI/FS
Comprehensive Round 2 Report

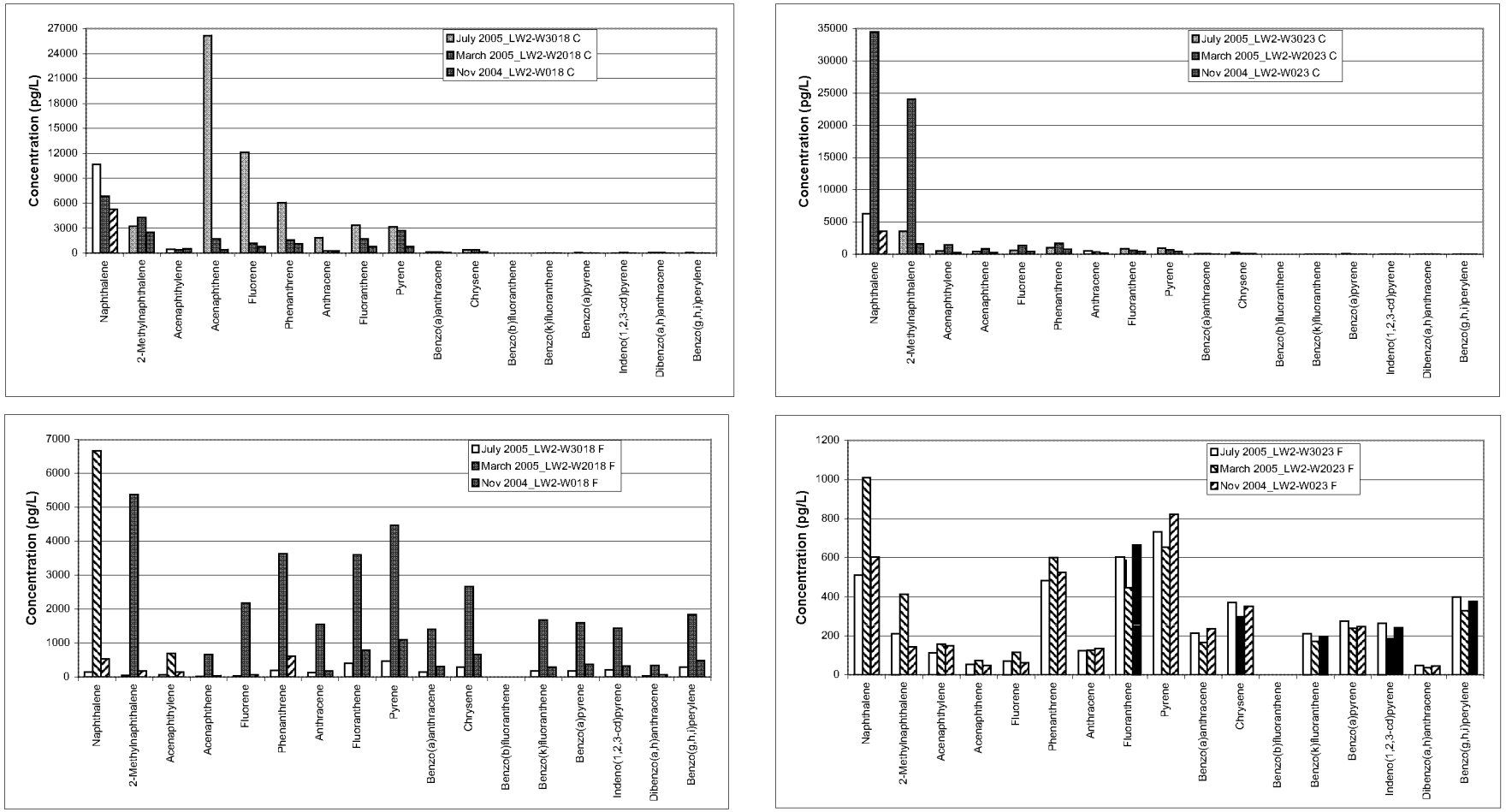
Figure 6.3-22. PAH Composition in High-Volume Surface Water Samples



Note: Cross-hatched bars indicate that the PAH was not detected. The bar height represents the detection limit.

Figure 6.3-22 cont.
Portland Harbor RI/FS
Comprehensive Round 2 Report

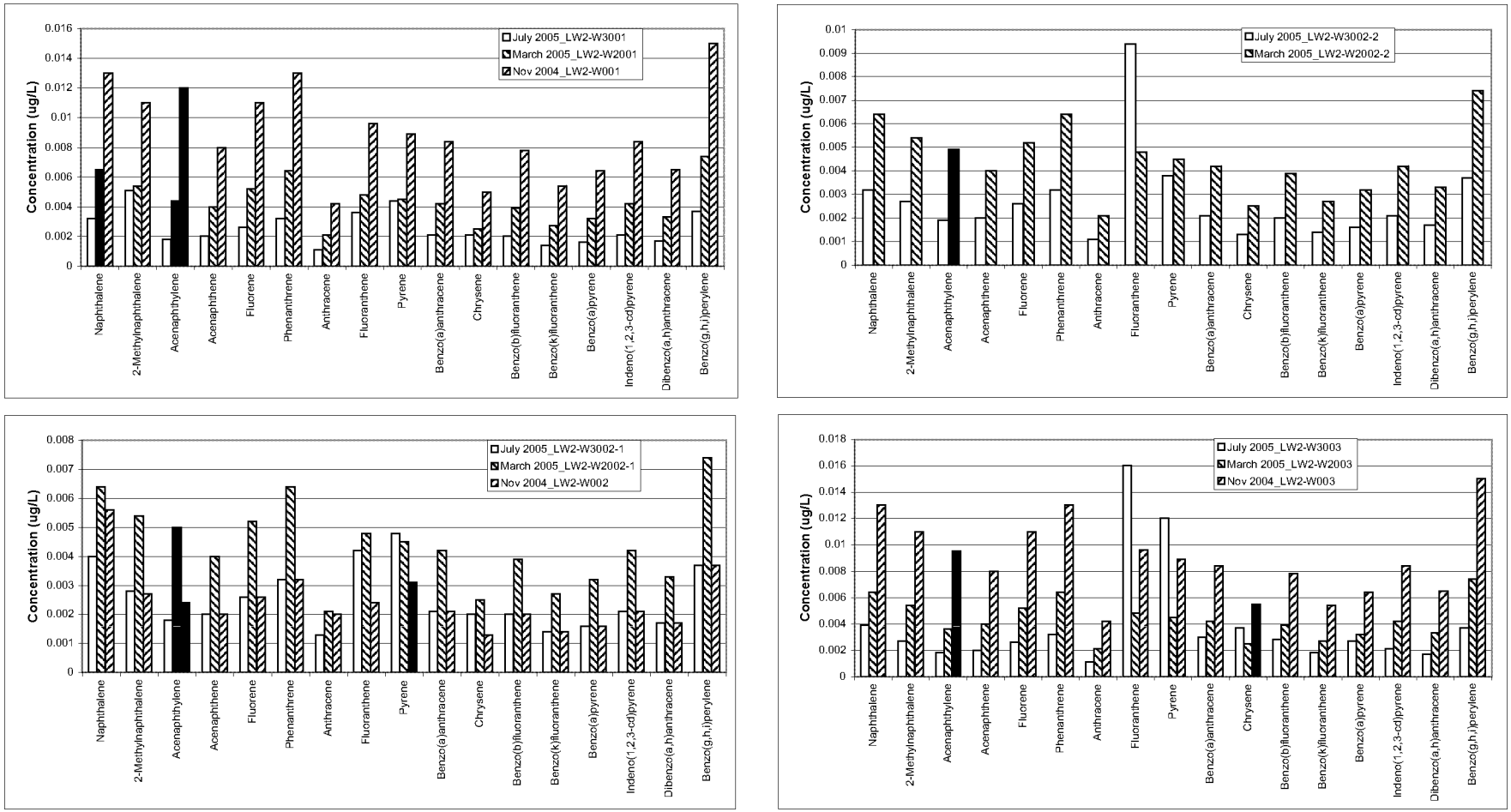
Figure 6.3-22. PAH Composition in High-Volume Surface Water Samples



Note: Cross-hatched bars indicate that the PAH was not detected. The bar height represents the detection limit.

Figure 6.3-22 cont.
Portland Harbor RI/FS
Comprehensive Round 2 Report

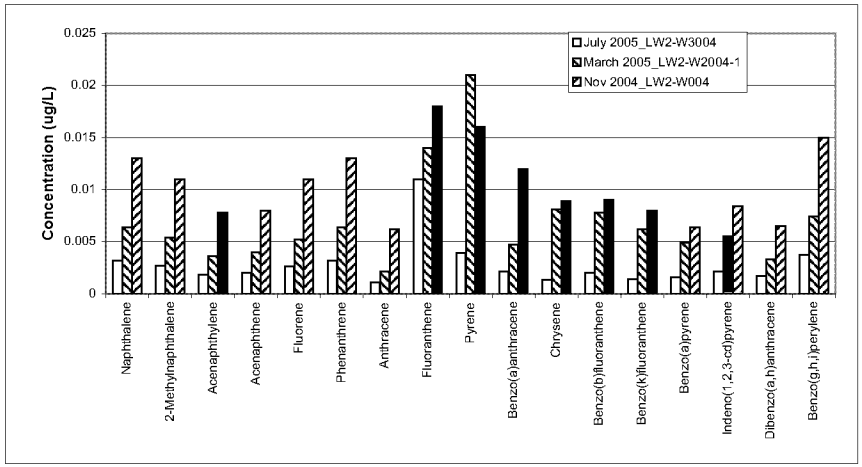
Figure 6.3-23. PAH Composition in Surface Water Samples Collected by Peristaltic Pump.

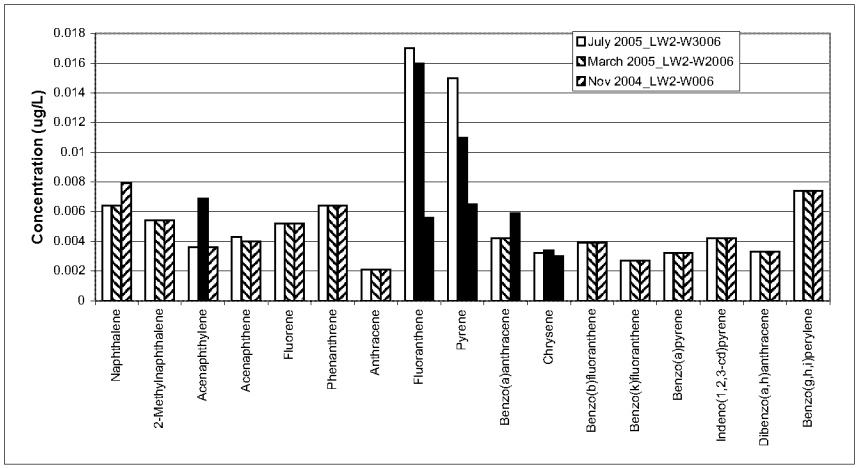


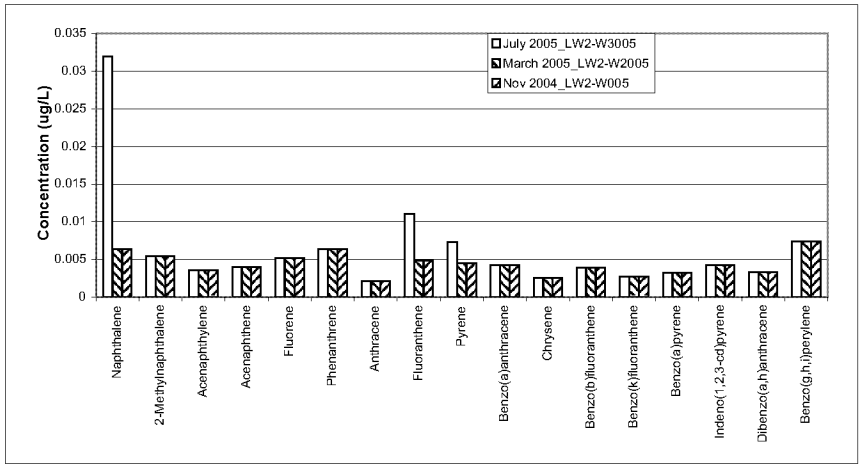
Note: Cross-hatched bars indicate that the PAH was not detected. The bar height represents the detection limit.

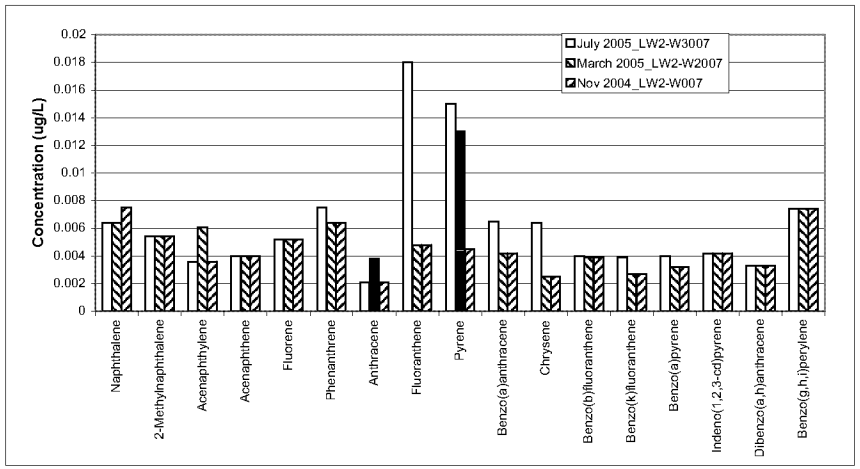
Figure 6.3-23
Portland Harbor RI/FS
Comprehensive Round 2 Report

Figure 6.3-23. PAH Composition in Surface Water Samples Collected by Peristaltic Pump.





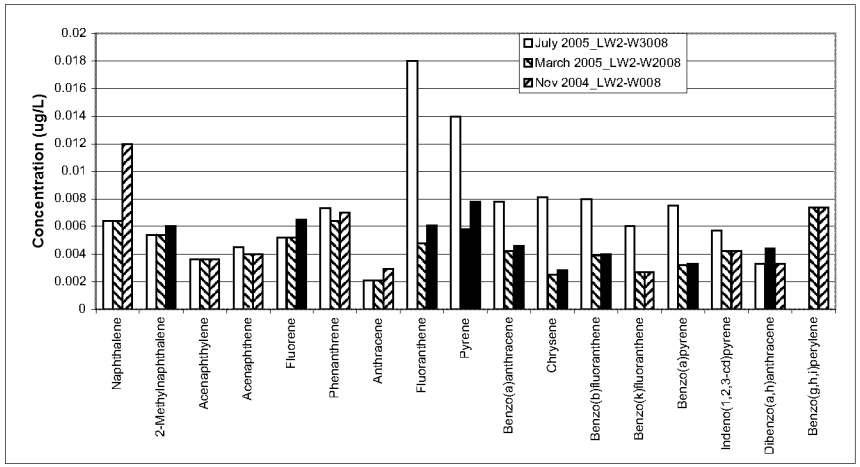


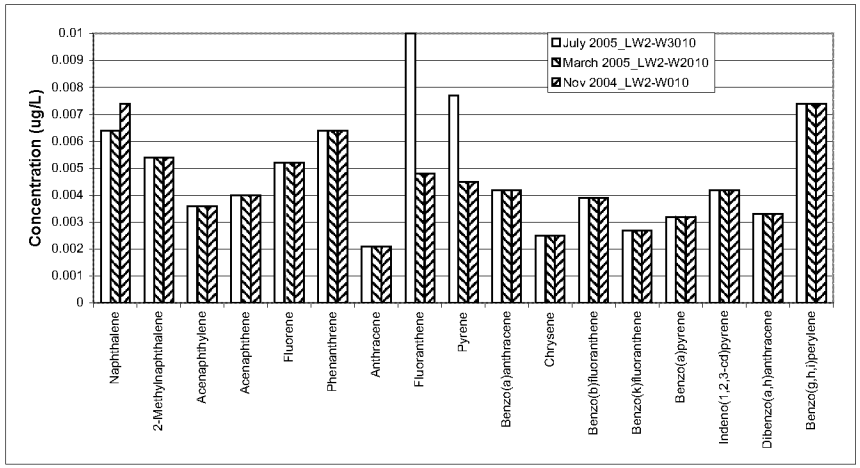


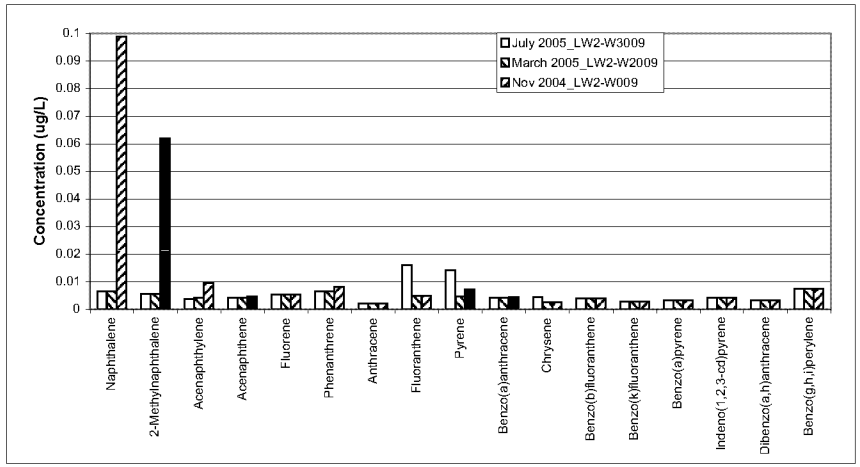
Note: Cross-hatched bars indicate that the PAH was not detected. The bar height represents the detection limit.

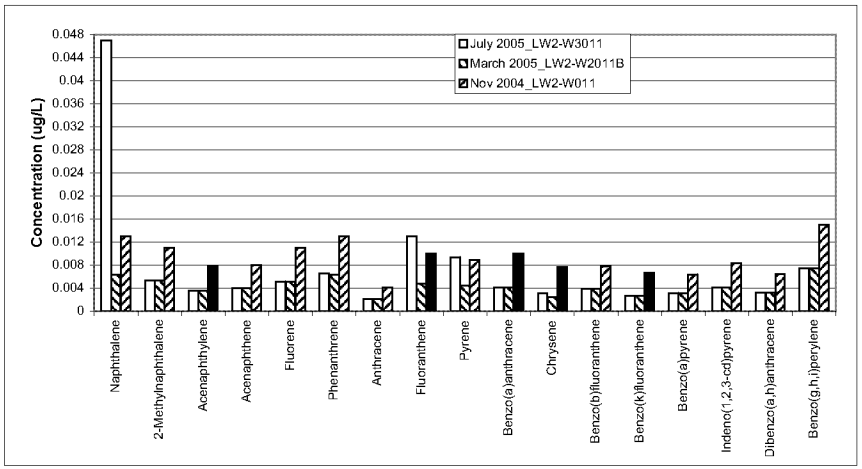
Figure 6.3-23 cont.
Portland Harbor RI/FS
Comprehensive Round 2 Report

Figure 6.3-23. PAH Composition in Surface Water Samples Collected by Peristaltic Pump.





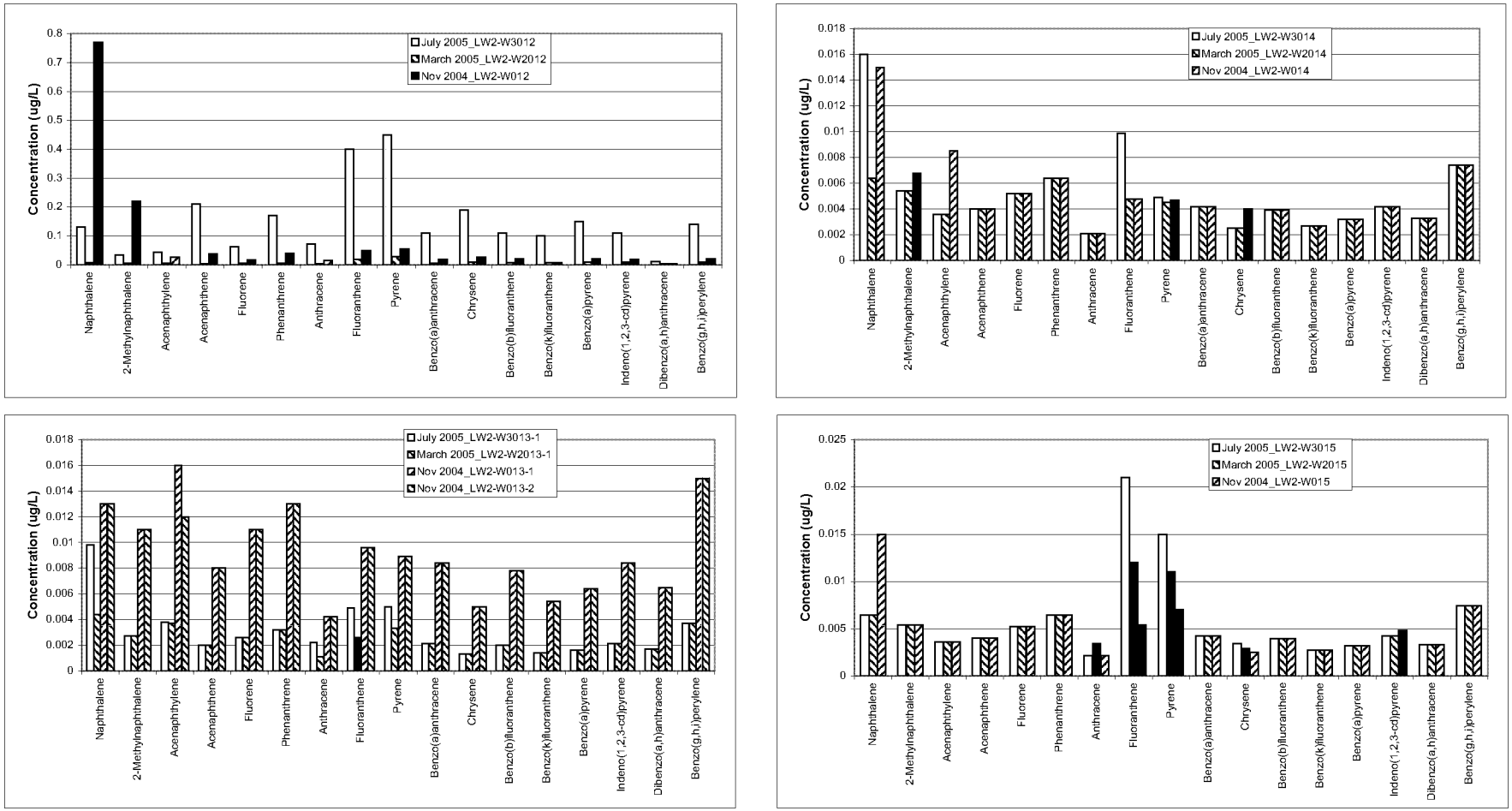




Note: Cross-hatched bars indicate that the PAH was not detected. The bar height represents the detection limit.

Figure 6.3-23 cont.
Portland Harbor RI/FS
Comprehensive Round 2 Report

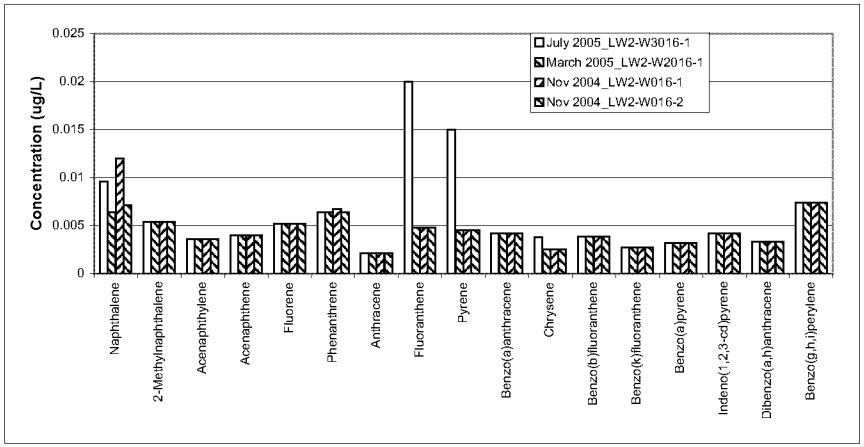
Figure 6.3-23. PAH Composition in Surface Water Samples Collected by Peristaltic Pump.

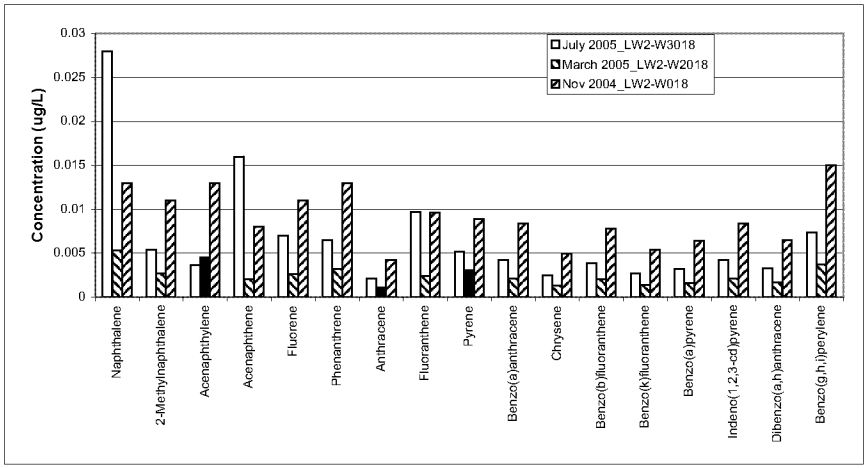


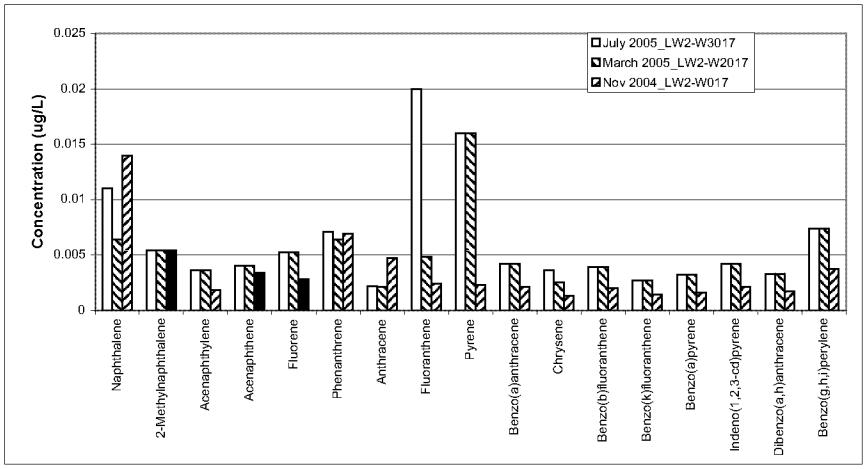
Note: Cross-hatched bars indicate that the PAH was not detected. The bar height represents the detection limit.

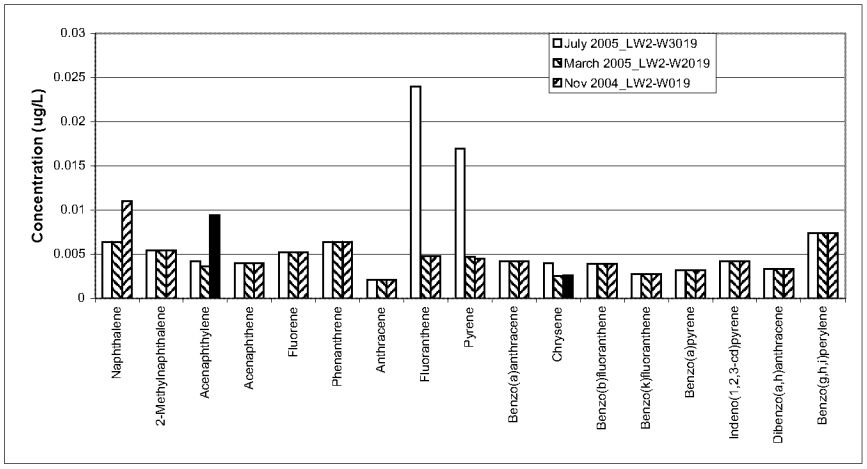
Figure 6.3-23 cont.
Portland Harbor RI/FS
Comprehensive Round 2 Report

Figure 6.3-23. PAH Composition in Surface Water Samples Collected by Peristaltic Pump.





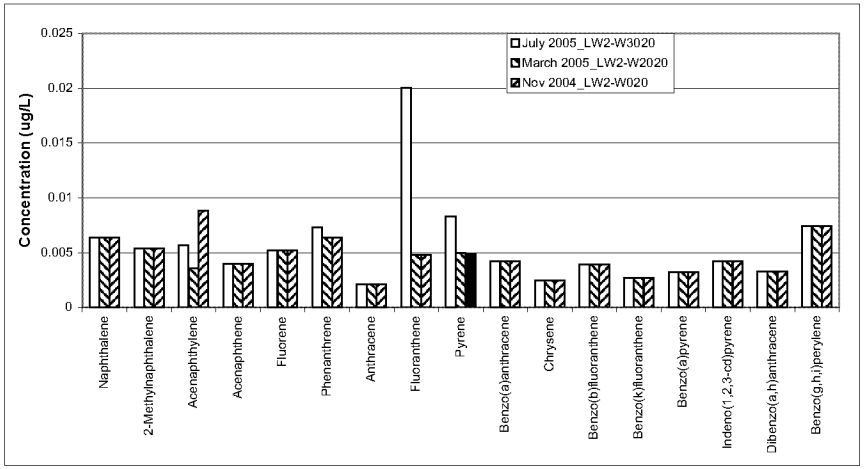


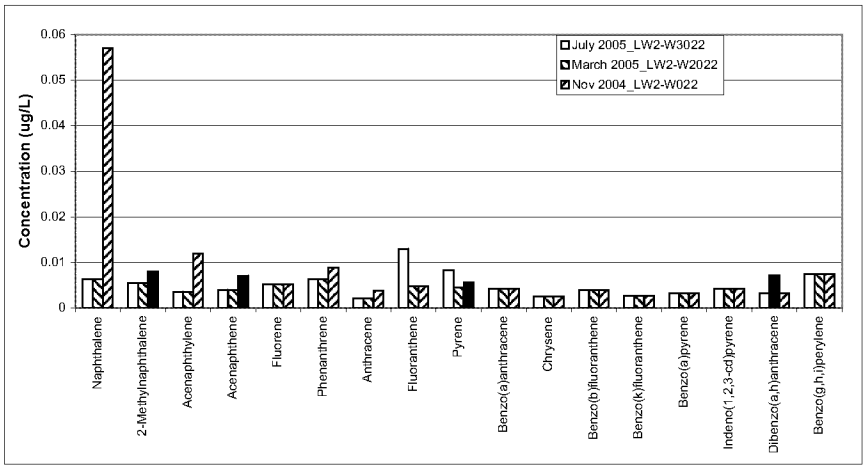


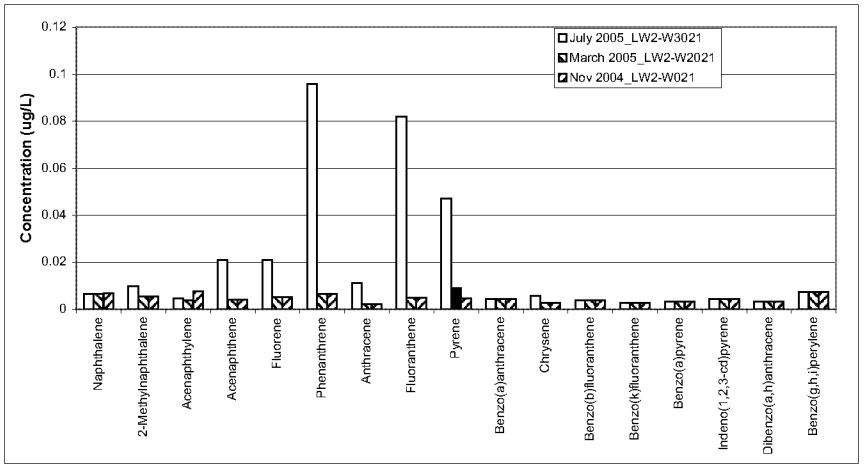
Note: Cross-hatched bars indicate that the PAH was not detected. The bar height represents the detection limit.

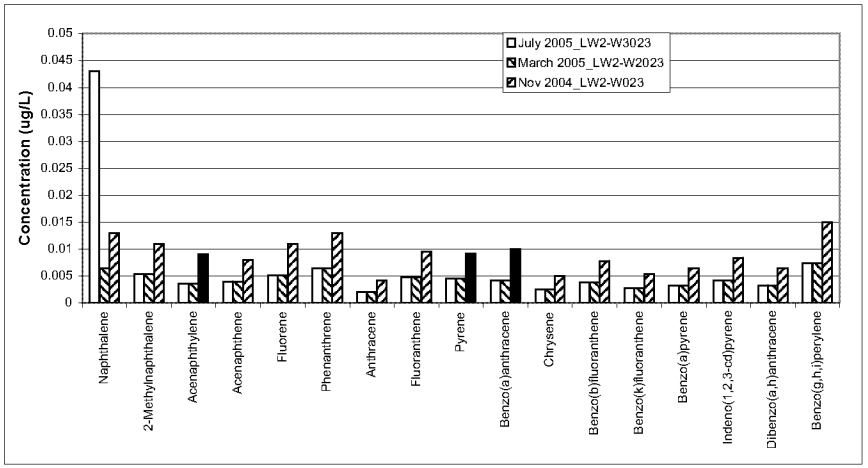
Figure 6.3-23 cont.
Portland Harbor RI/FS
Comprehensive Round 2 Report

Figure 6.3-23. PAH Composition in Surface Water Samples Collected by Peristaltic Pump.



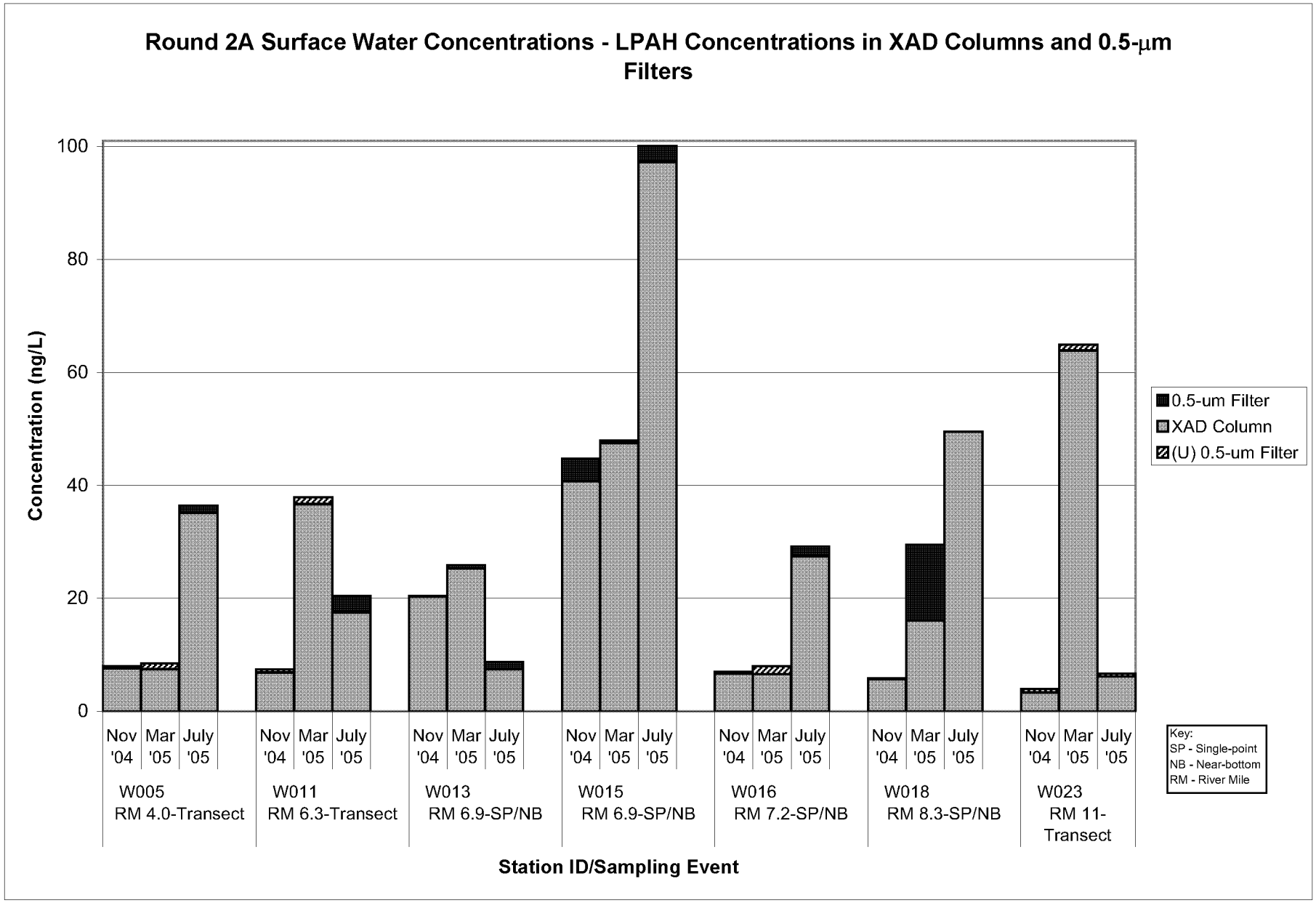






Note: Cross-hatched bars indicate that the PAH was not detected. The bar height represents the detection limit.

Figure 6.3-23 cont.
Portland Harbor RI/FS
Comprehensive Round 2 Report

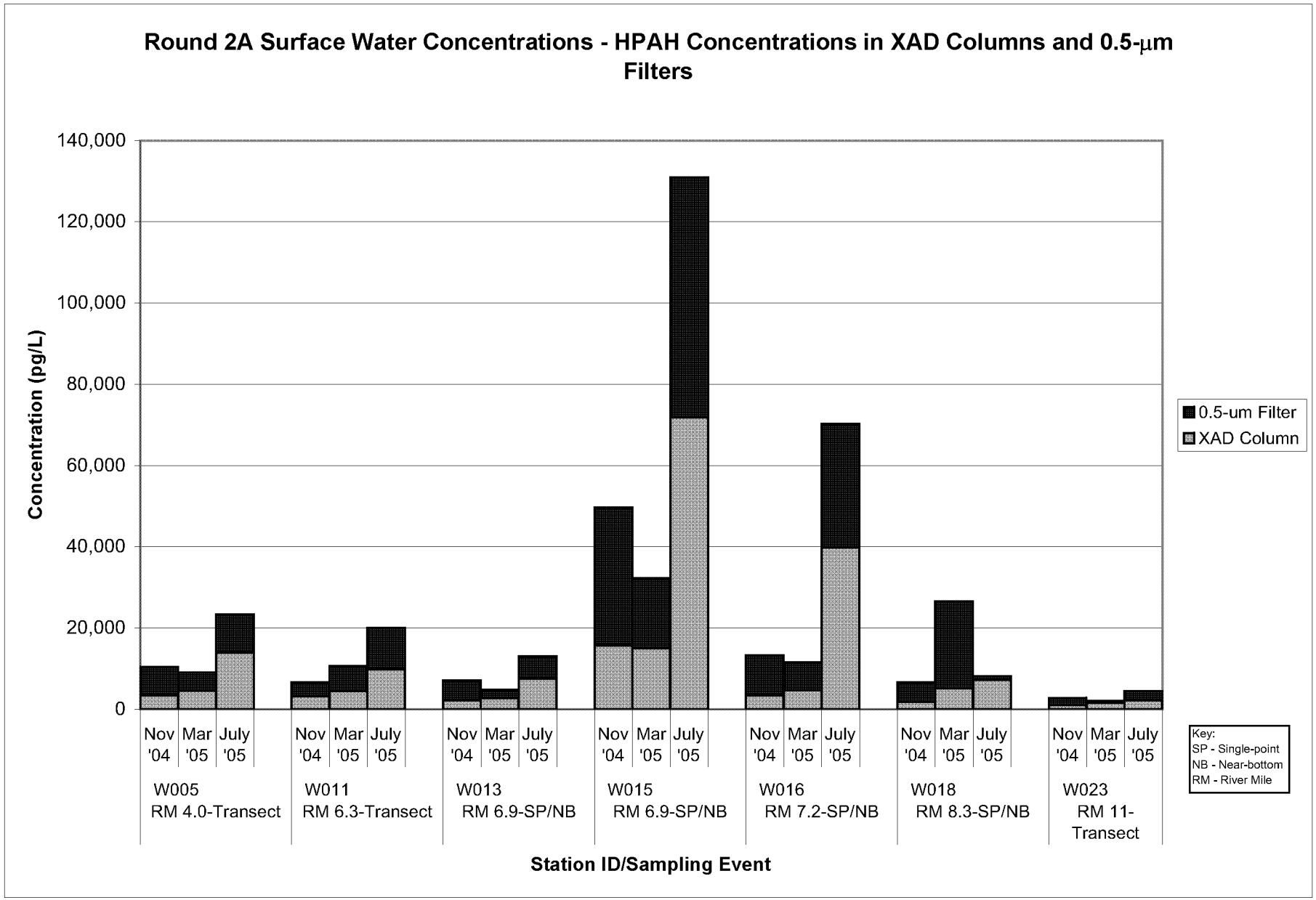


integral

LWG LOWER WILLAMETTE GROUP

Figure 6.3-24
Portland Harbor RI/FS
Comprehensive Round 2 Report

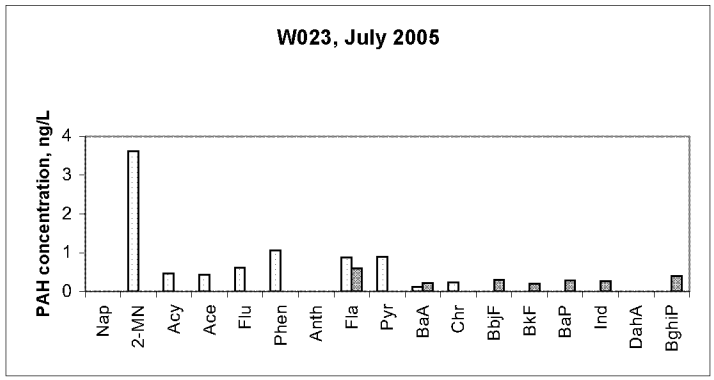
BZTO104(e)031605

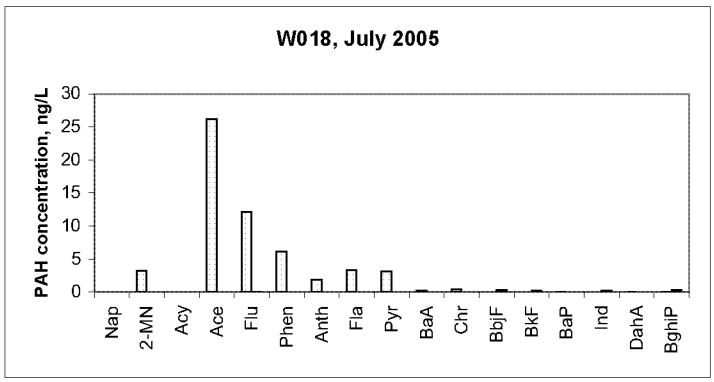


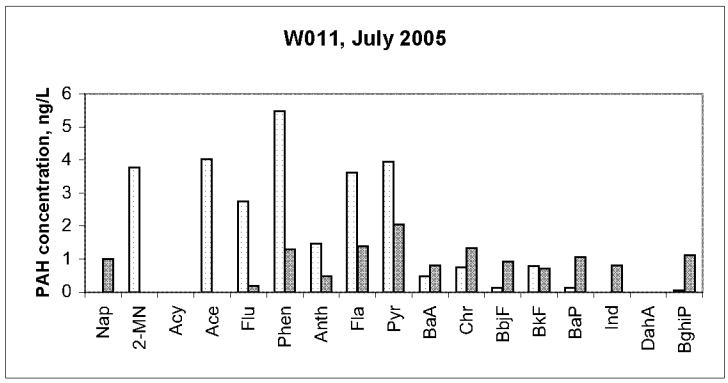
integral

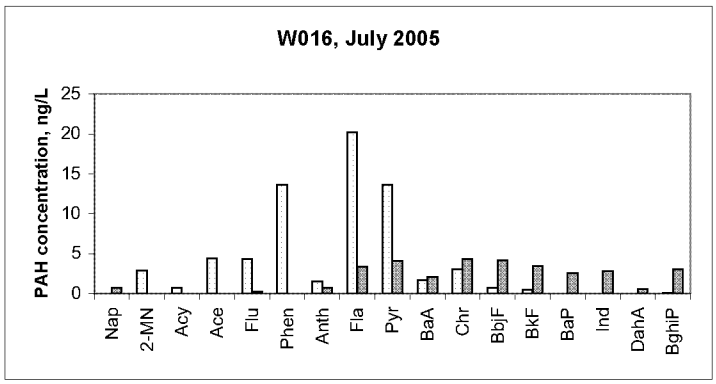
LWG LOWER WILLAMETTE GROUP

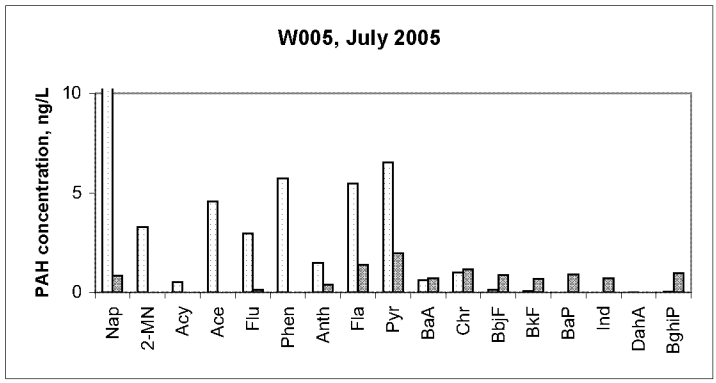
Figure 6.3-25
Portland Harbor RI/FS
Comprehensive Round 2 Report

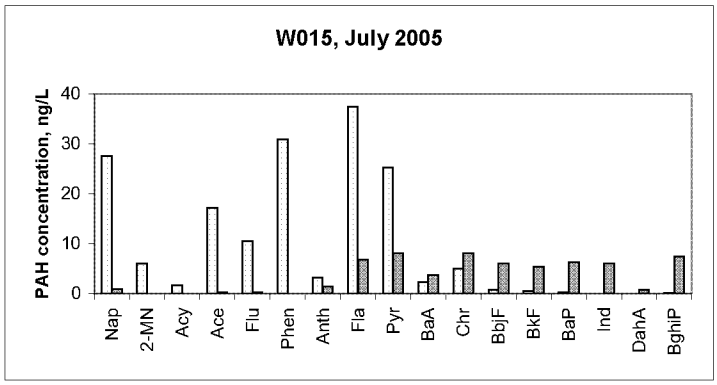








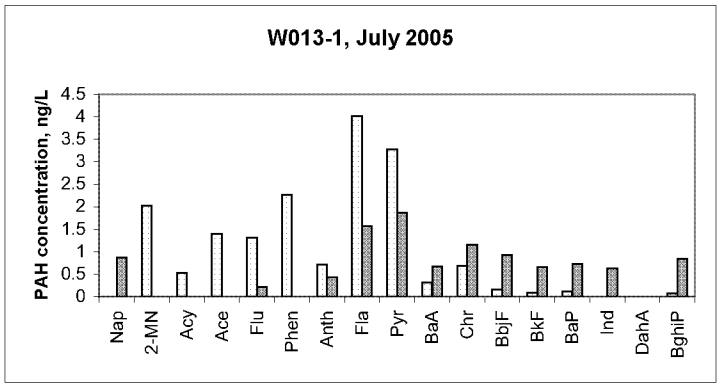




Legend

- XAD Column (dissolved)
- 0.5 µm filter (particulate)

Note: Profiles do not include detection limits when a PAH was not detected.

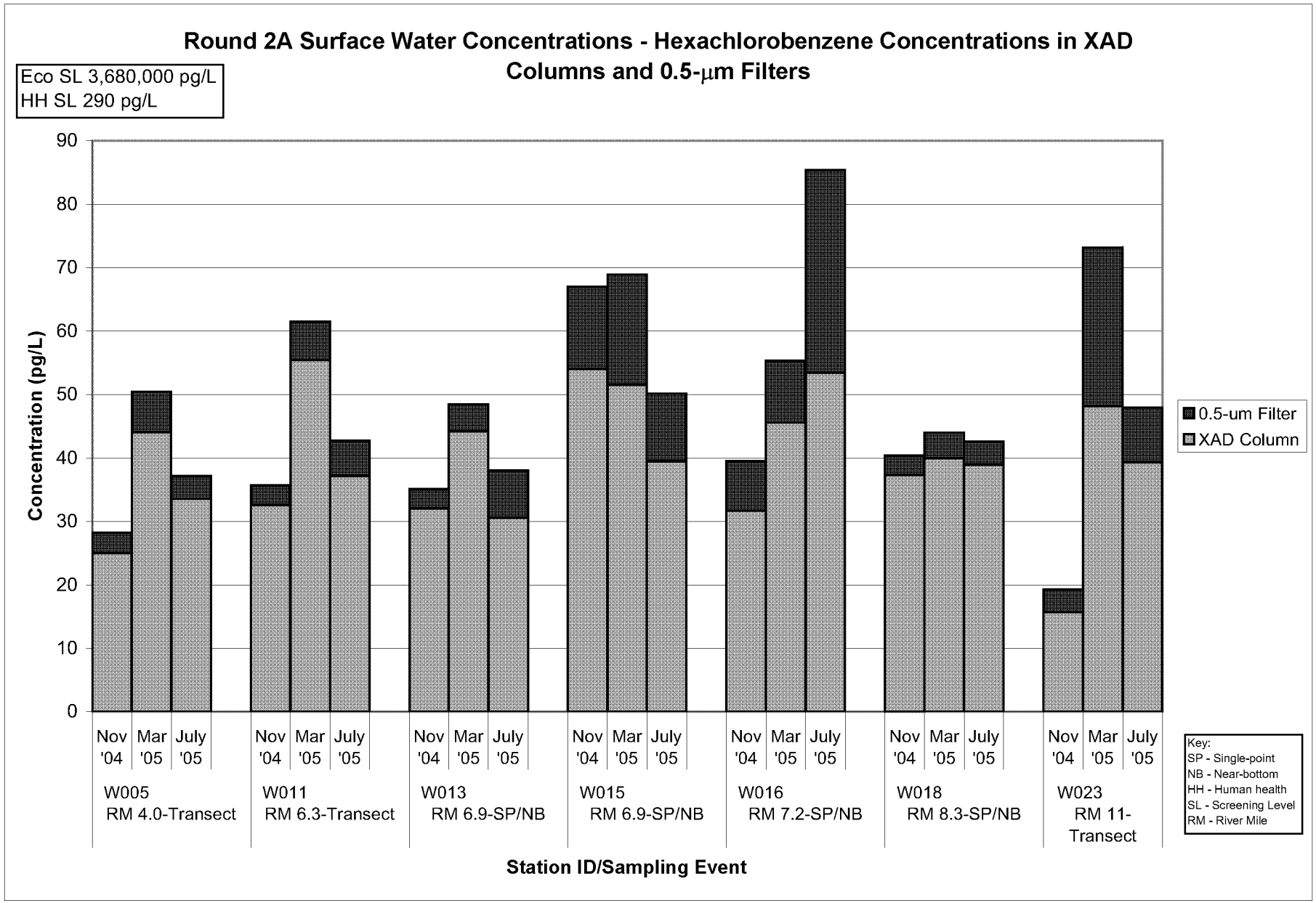


integral

LWG Lower Willamette Group

Map 6.3-26
Portland Harbor RI/FS
Comprehensive Round 2 Report
PAH Composition in XAD Columns and 0.5 µm Filters in July, 2005 Surface Water Samples

BZTO104(e)031607

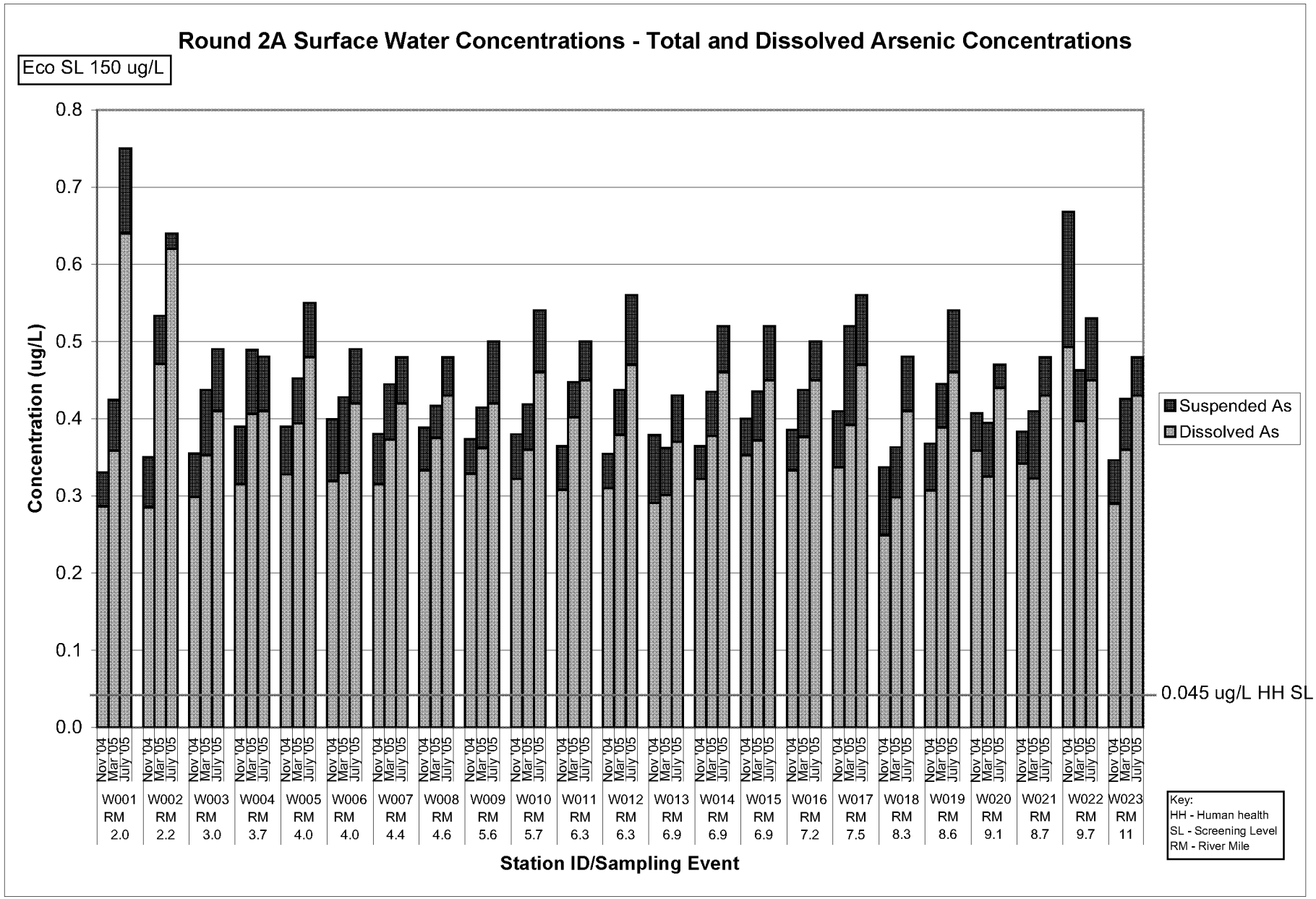


integral

LWG LOWER WILLAMETTE GROUP

Figure 6.3-27
Portland Harbor RI/FS
Comprehensive Round 2 Report

BZTO104(e)031608



integral

LWG LOWER WILLAMETTE GROUP

Figure 6.3-28
Portland Harbor RI/FS
Comprehensive Round 2 Report

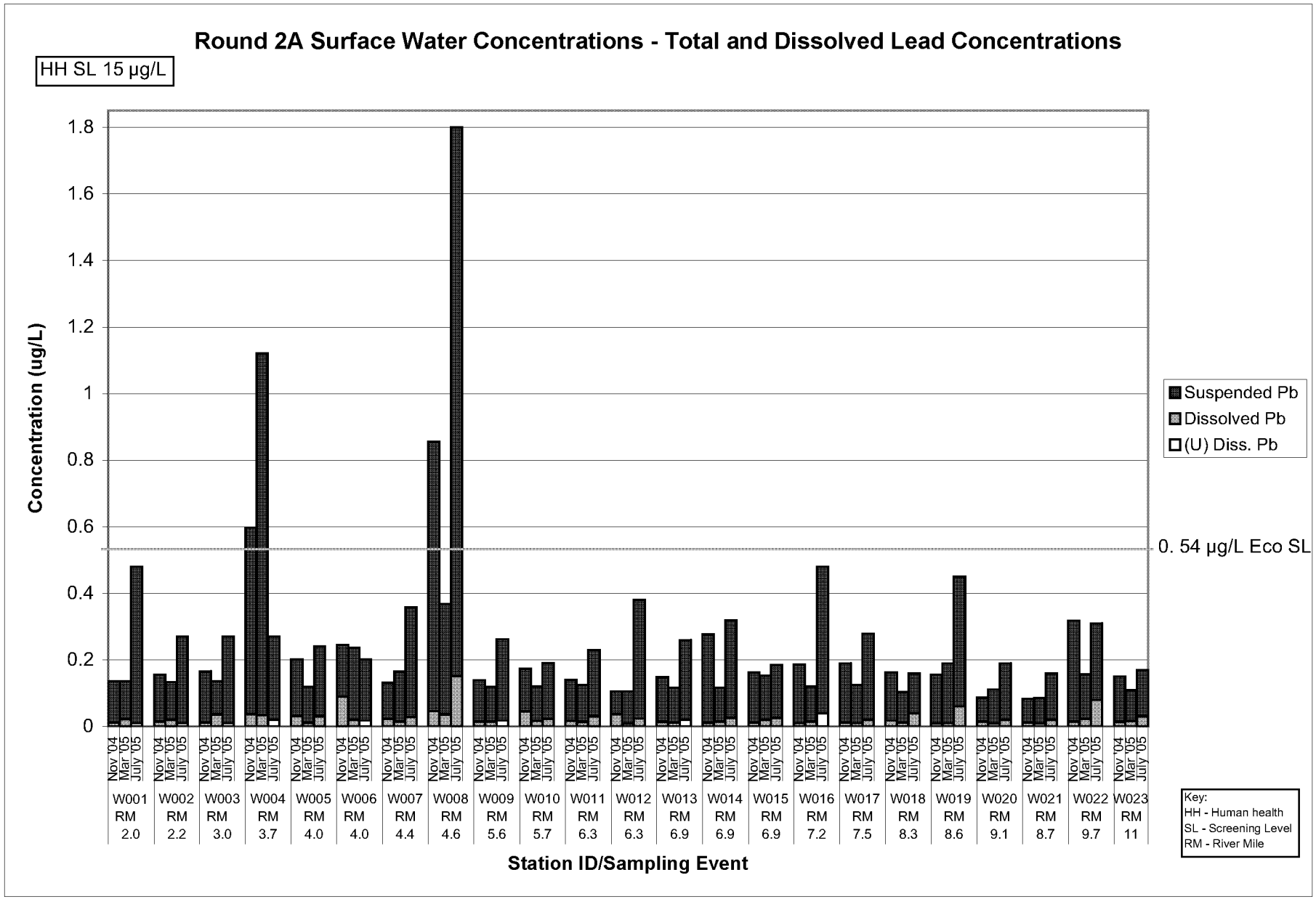


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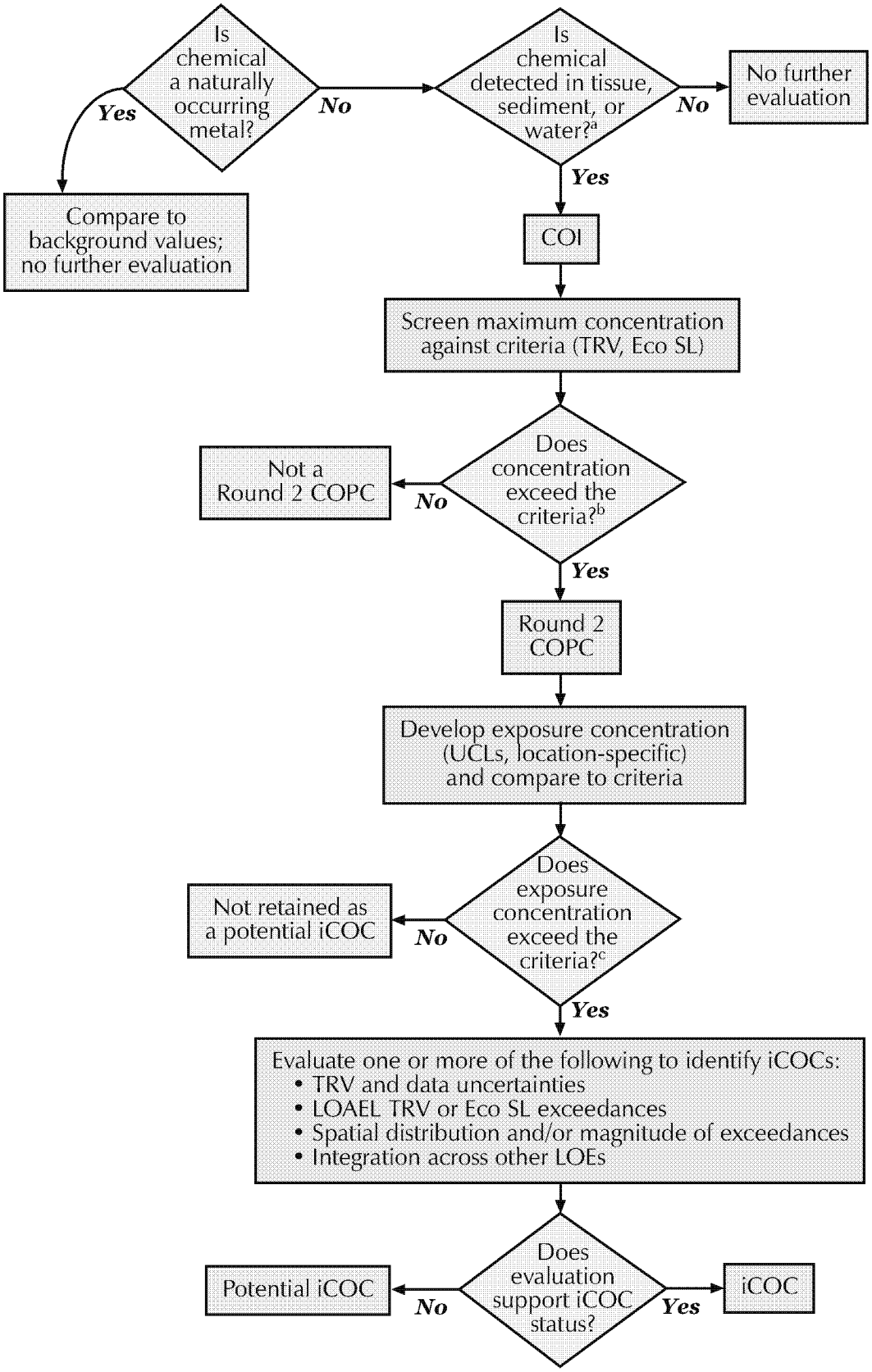
Figure 6.3-29
Portland Harbor RI/FS
Comprehensive Round 2 Report

BZTO104(e)031610



[a] For the benthic predicted toxicity LOE, COIs were identified as chemicals detected in more than 30 and 100 sediment samples for the FPM and LRM, respectively.

[b] For the benthic predicted toxicity LOE, COPCs were identified as chemicals associated with toxicity in either of the two models.

[c] For the benthic predicted toxicity LOE, potential iCOCs were identified as those chemicals associated with toxicity in the FPM.

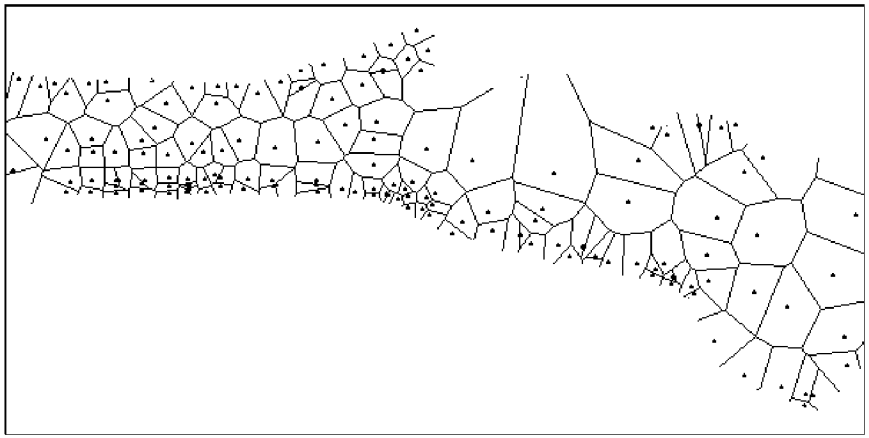
Figure 9.0-1
Process for Identification of Ecological iCOCs

Portland Harbor RI/FS
Comprehensive Round 2 Report

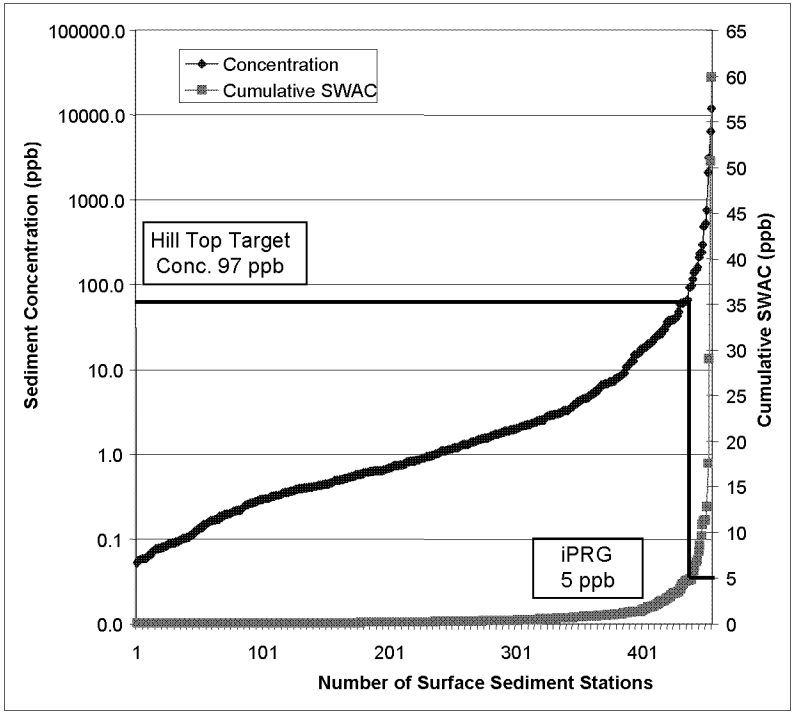
LWG Lower Willamette Group

Windward environmental LLC

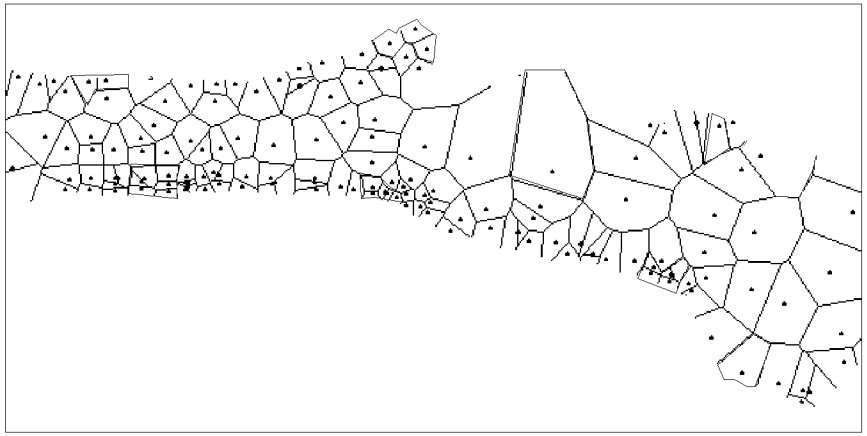
BZTO104(e)031611



Association of Areas with Sediment Stations

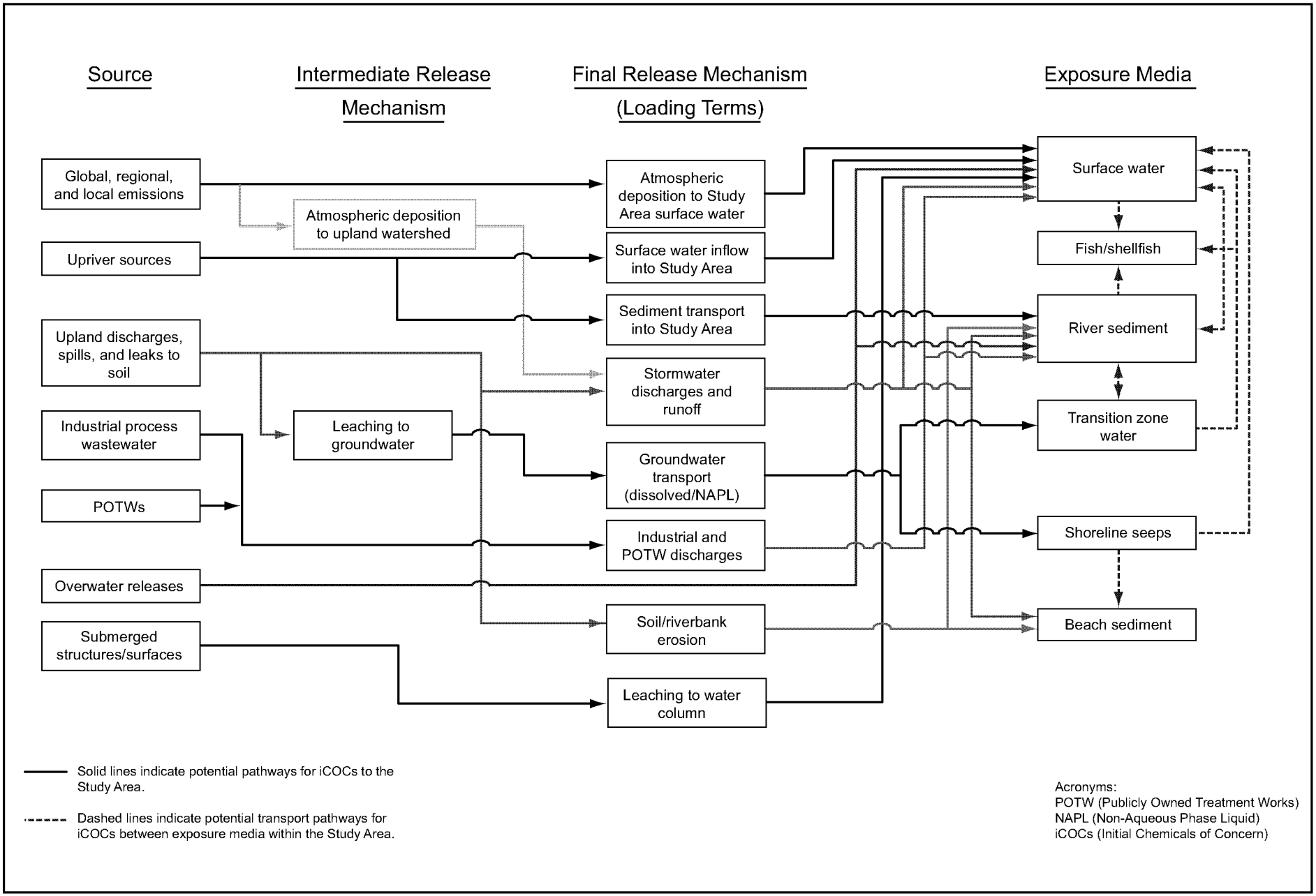


Determination of Hill Topping Target Sediment Concentration to Achieve iPRG Over Entire Site



Identification of Stations Above Target Sediment Concentration

Figure 10.1-1. Example of Hill Topping Procedure for iAOPC Development Based on Site-Wide Scale iPRG.



integral consulting inc.

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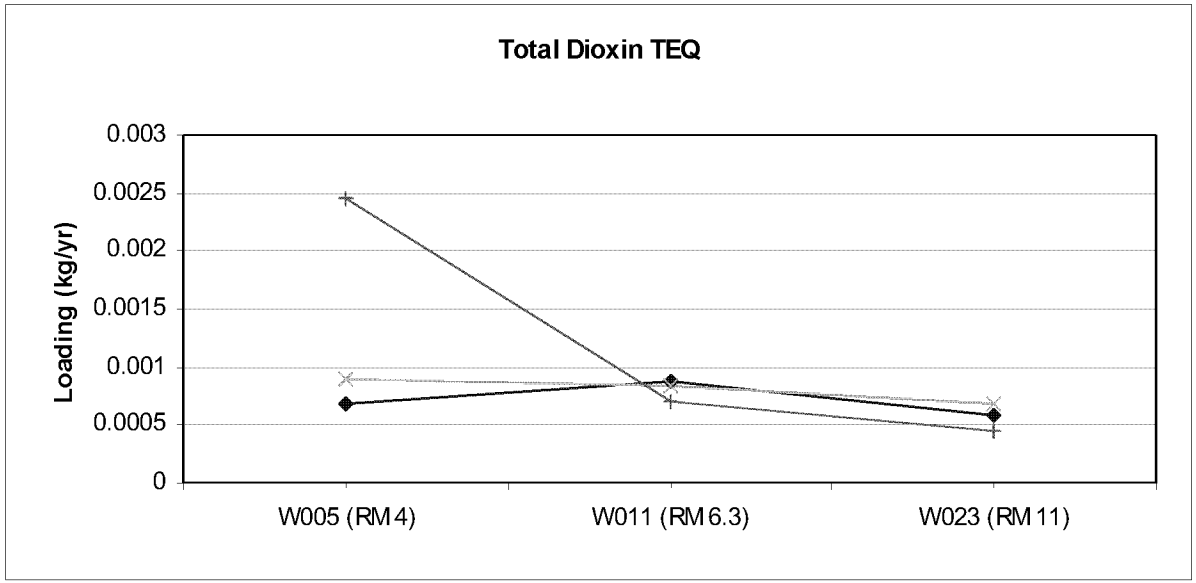
Figure 11.0-1
Portland Harbor RI/FS
Comprehensive Round 2 Report
Physical Conceptual Site Model

BZTO104(e)031613



Tributyltin

All samples below laboratory detection limit.
Loads estimated to be 0 kg/yr.

Total Nov 2004
Total Mar 2005
Total Jul 2005

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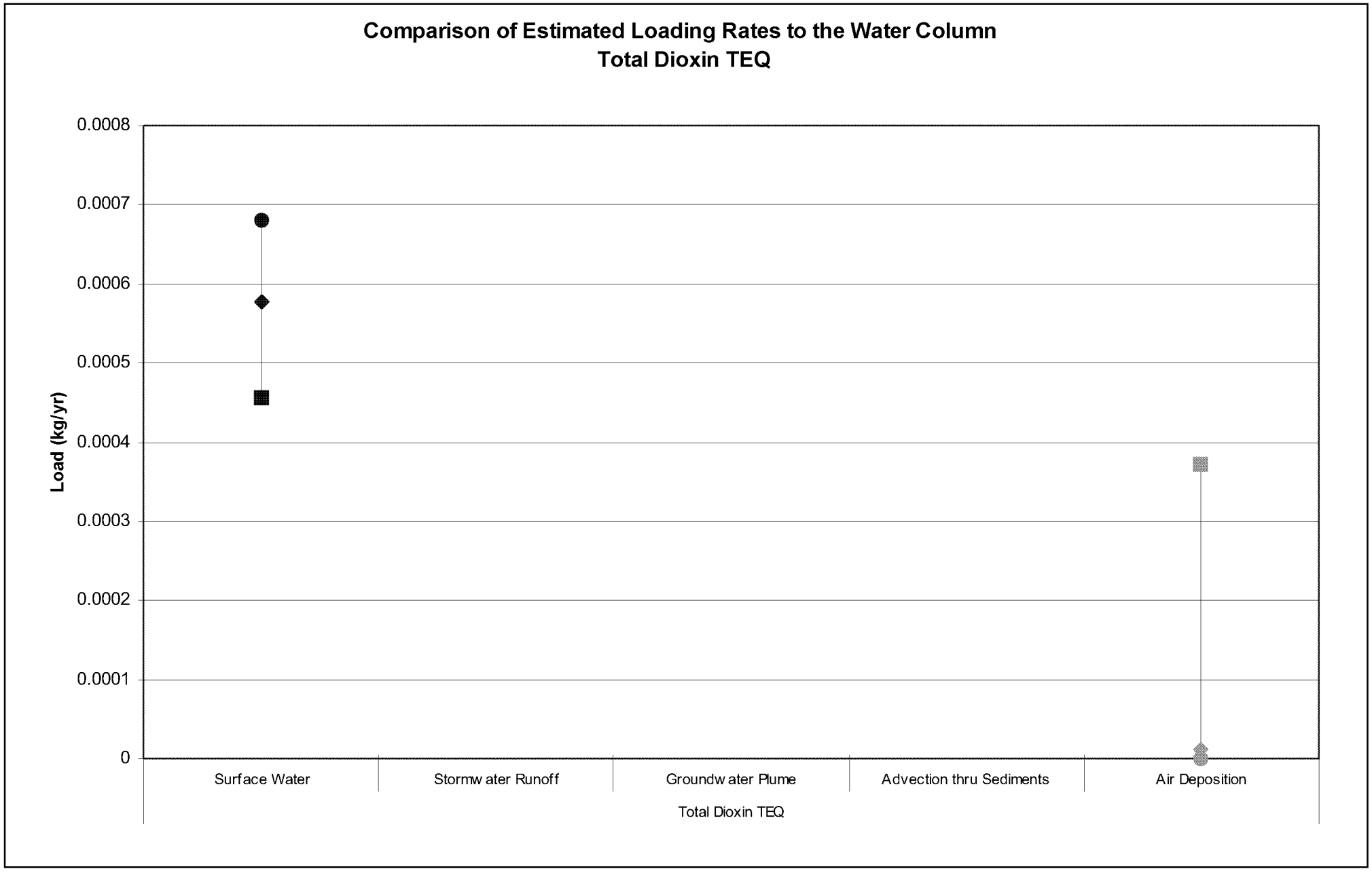
Figure 11.1-1
Portland Harbor RI/FS
Comprehensive Round 2 Report
Surface Water Loading by River Mile
Tributyltin and Dioxin TEQ

BZTO104(e)031614



Legend

Upstream Surface Water (RM 11), Total	Stormwater Runoff	Groundwater Plume, Unfiltered	Advection thru Sediments	Air Deposition
July 2005	Upper estimate	Upper flow estimate	Maximum K_{oc}	Upper estimate
November 2004	Central estimate	Mean flow estimate	Minimum K_{oc}	Central estimate
March 2004	Lower estimate			Lower estimate

Note: Hollow symbols indicate loads calculated with sampled concentrations below the laboratory detection limit. These loads were estimated at 0 kg/yr. No symbol indicates that a loading estimate was not developed for this term.

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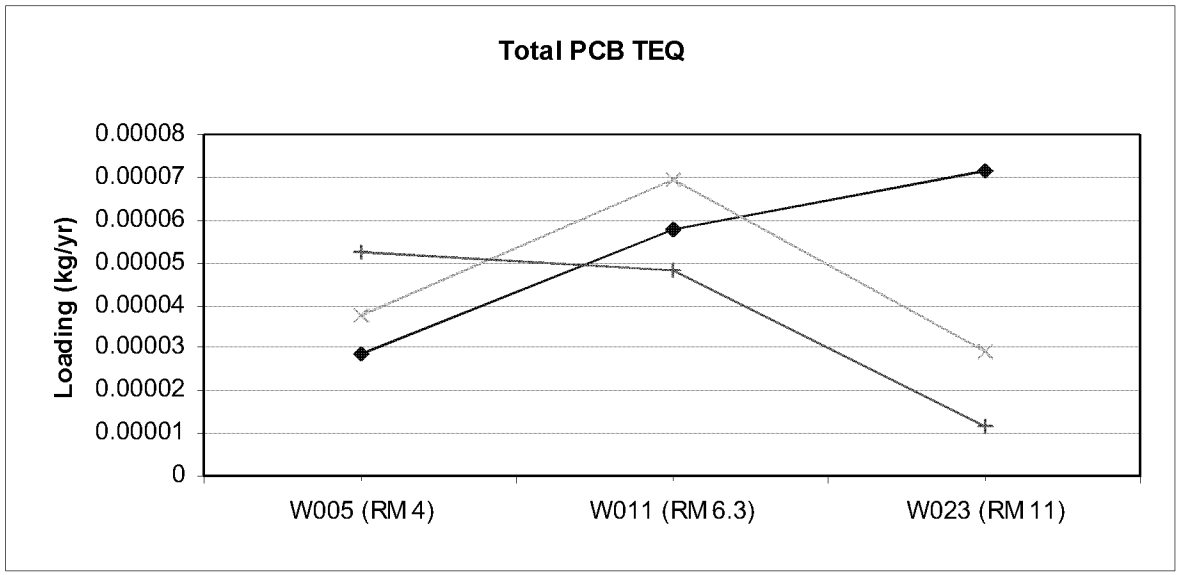
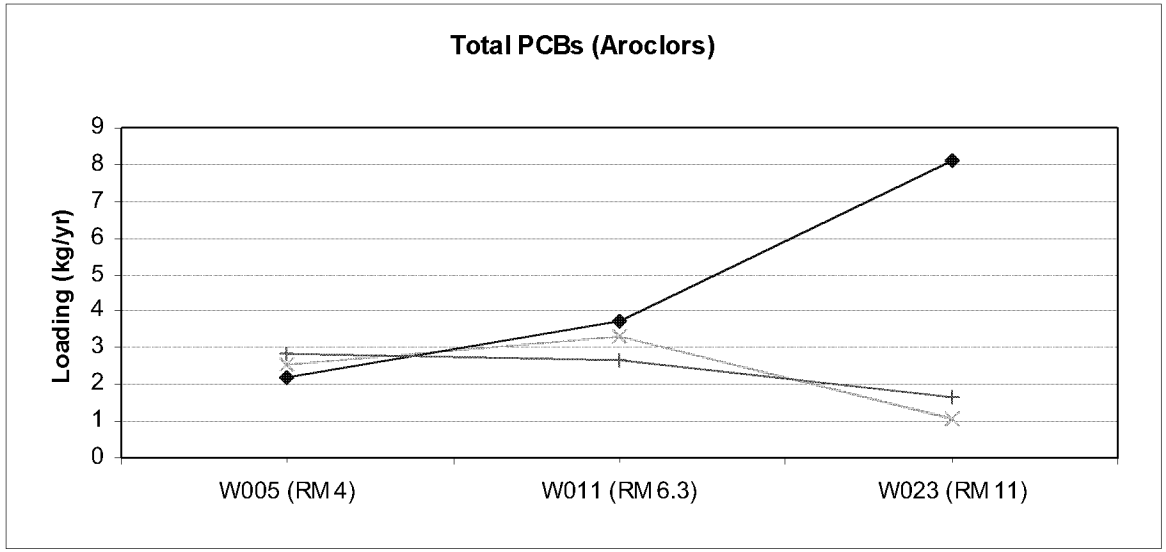
Figure 11.1-2
Portland Harbor RI/FS
Comprehensive Round 2 Report
Loading Estimate Comparison
Dioxin TEQ

BZTO104(e)031615





Total Nov 2004
Total Mar 2005
Total Jul 2005

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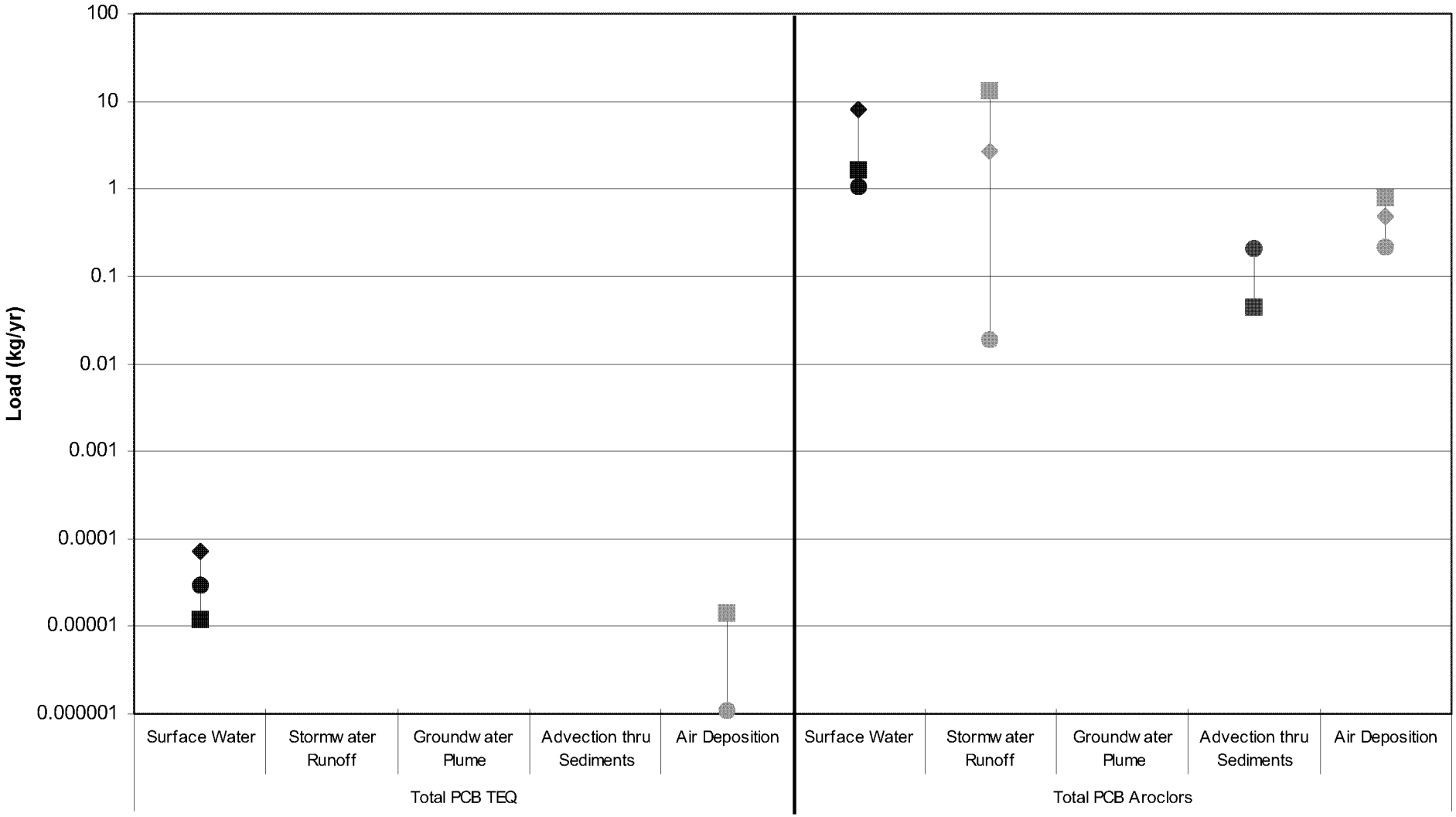
Figure 11.1-3
Portland Harbor RI/FS
Comprehensive Round 2 Report
Surface Water Loading by River Mile
PCBs

BZTO104(e)031616

Comparison of Estimated Loading Rates to the Water Column
PCB TEQ and PCB Aroclors



Legend

Upstream Surface Water (RM 11), Total	Stormwater Runoff	Groundwater Plume, Unfiltered	Advection thru Sediments	Air Deposition
July 2005	Upper estimate	Upper flow estimate	Maximum K_{oc}	Upper estimate
November 2004	Central estimate	Mean flow estimate	Minimum K_{oc}	Central estimate
March 2004	Lower estimate			Lower estimate

Note: Hollow symbols indicate loads calculated with sampled concentrations below the laboratory detection limit. These loads were estimated at 0 kg/yr . No symbol indicates that a loading estimate was not developed for this term.

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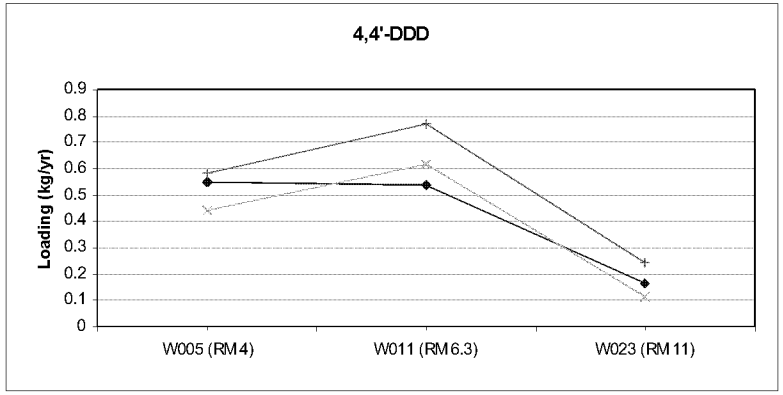
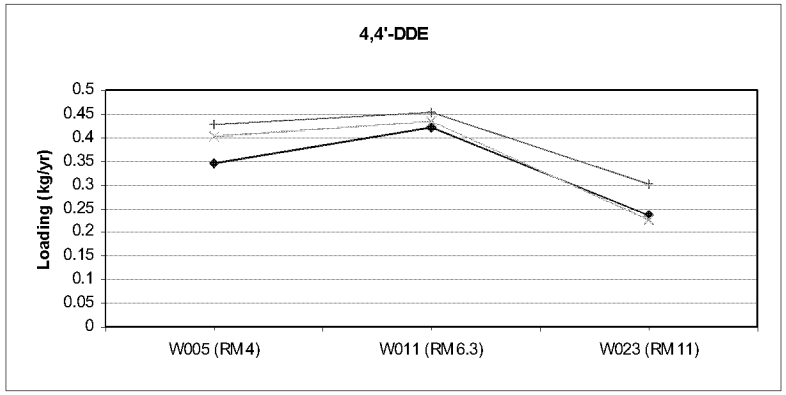
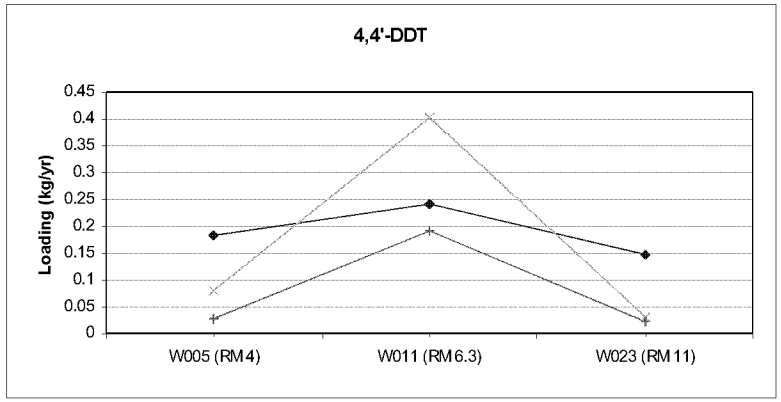
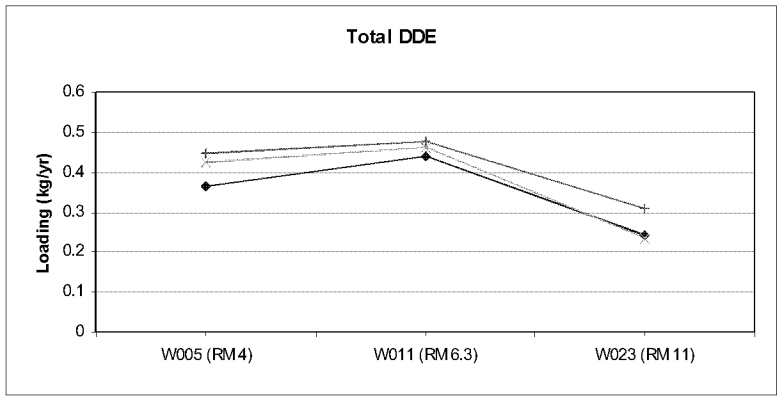
Figure 11.1-4
Portland Harbor RI/FS
Comprehensive Round 2 Report
Loading Estimate Comparison
PCBs

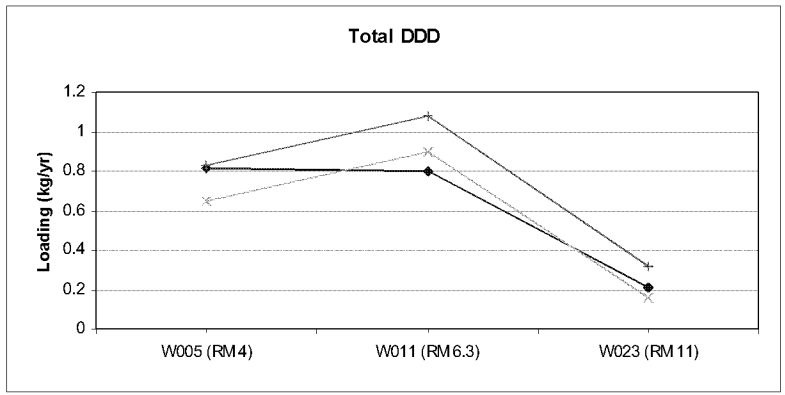
BZTO104(e)031617

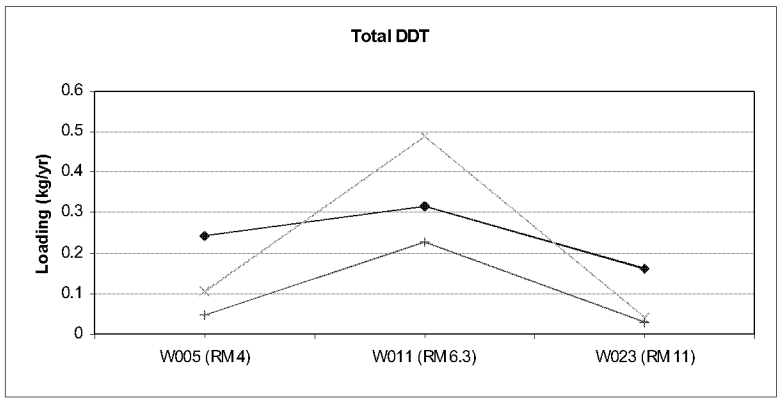












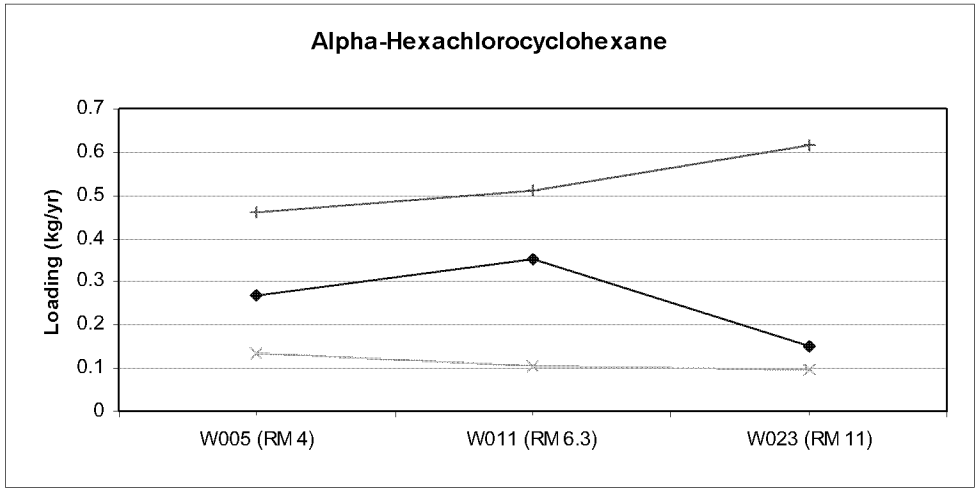
Total Nov 2004
Total Mar 2005
Total Jul 2005

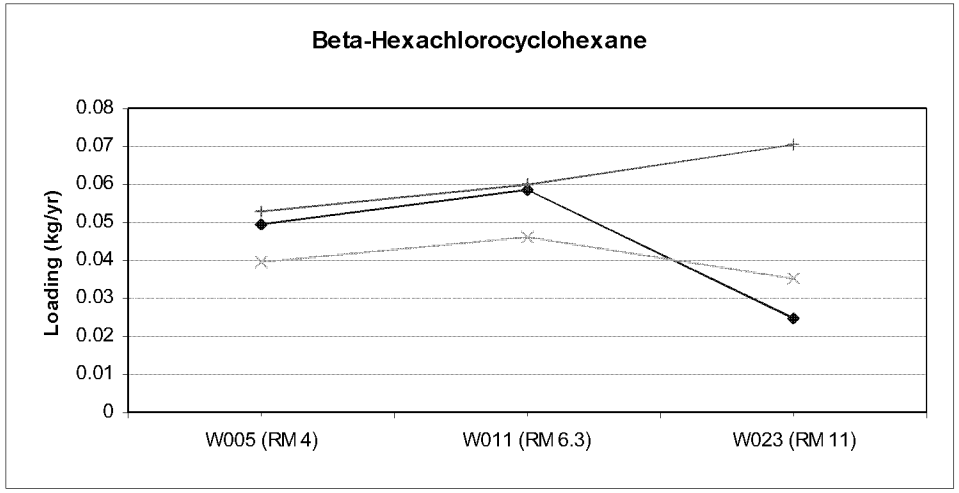
integral

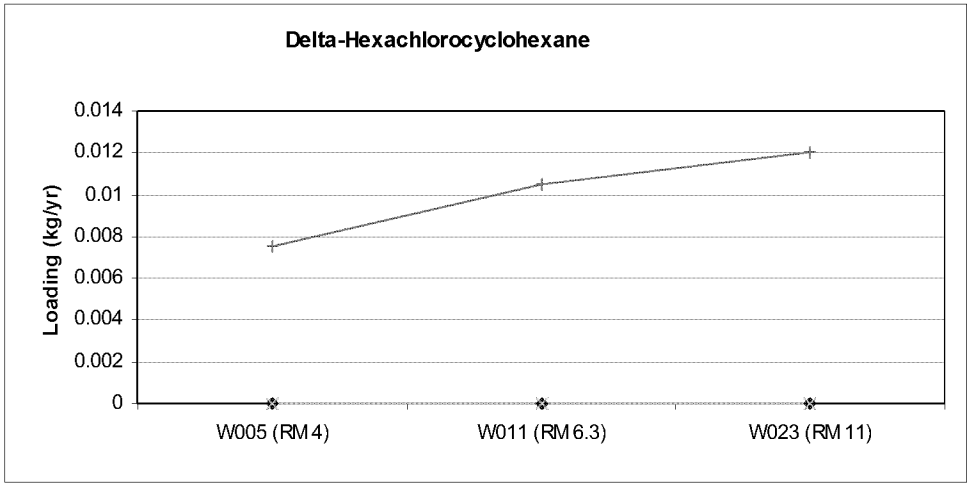
LWG Lower Willamette Group

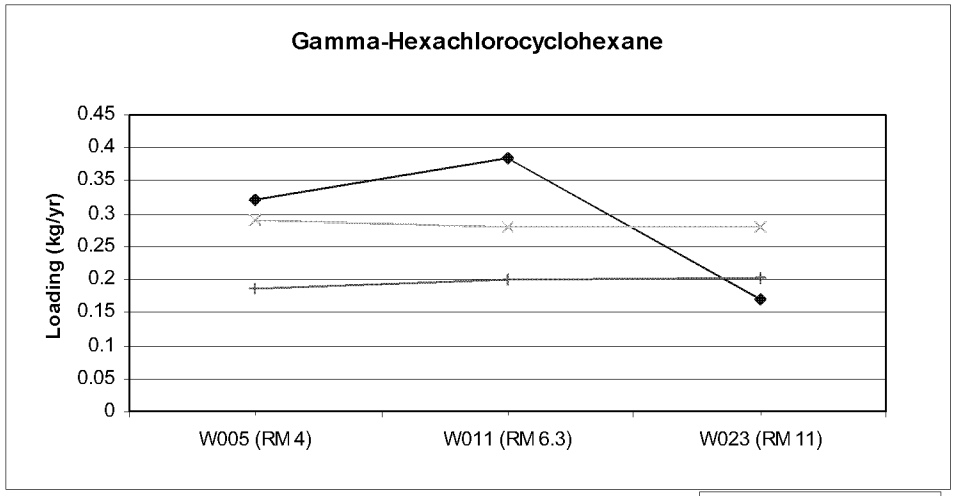
Figure 11.1-5a
Portland Harbor RI/FS
Comprehensive Round 2 Report
Surface Water Loading by River Mile
DDx Pesticides

BZTO104(e)031618









Total Nov 2004
Total Mar 2005
Total Jul 2005

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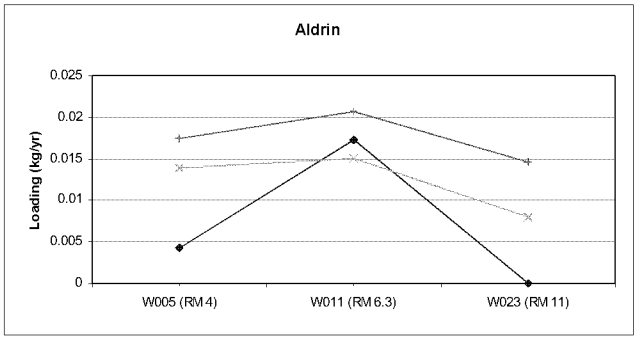
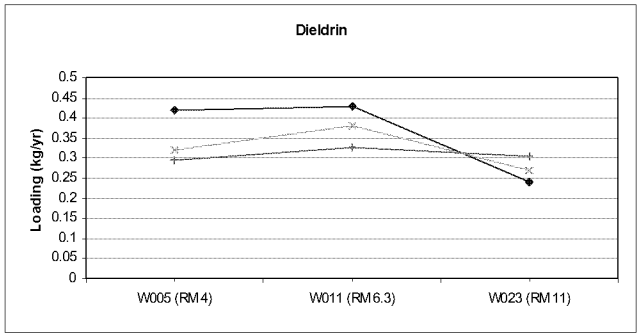
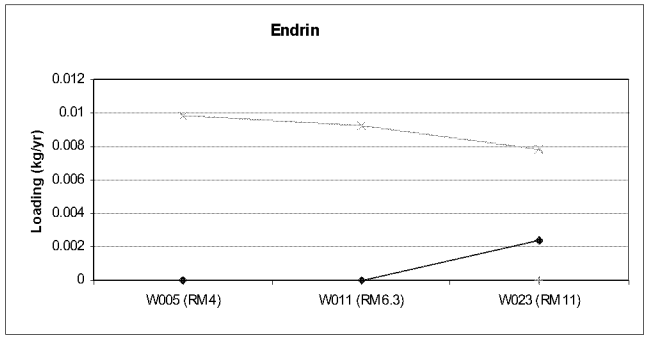
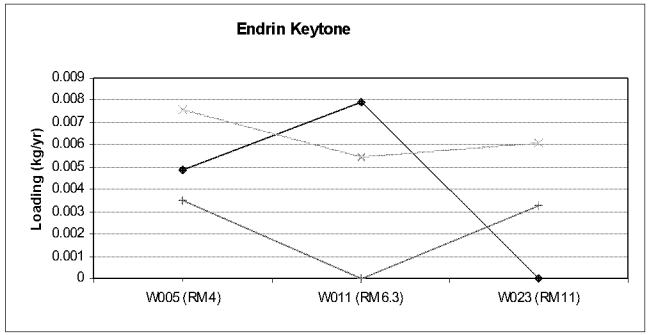
Figure 11.1-5b
Portland Harbor RI/FS
Comprehensive Round 2 Report
Surface Water Loading by River Mile
non-DDx Pesticides, Hexachlorocyclohexanes

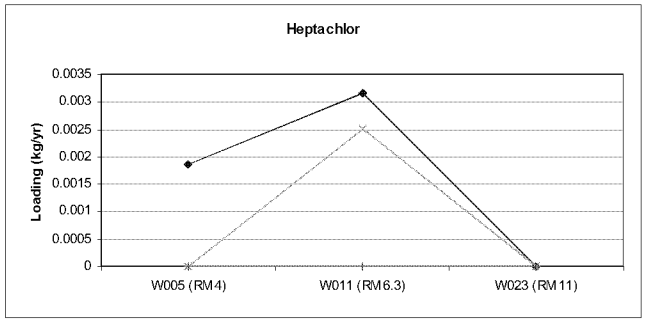
BZTO104(e)031619

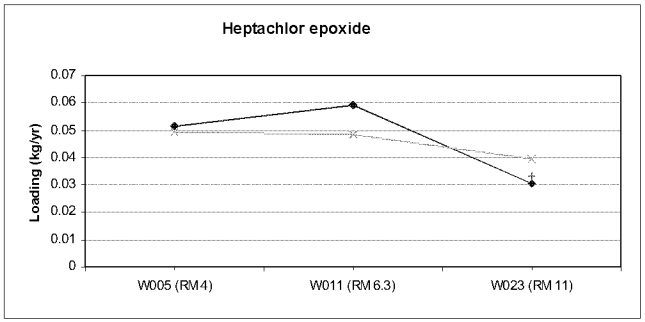


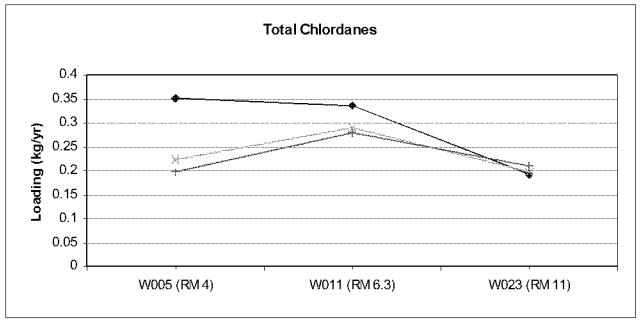












Total Nov 2004
Total Mar 2005
Total Jul 2005

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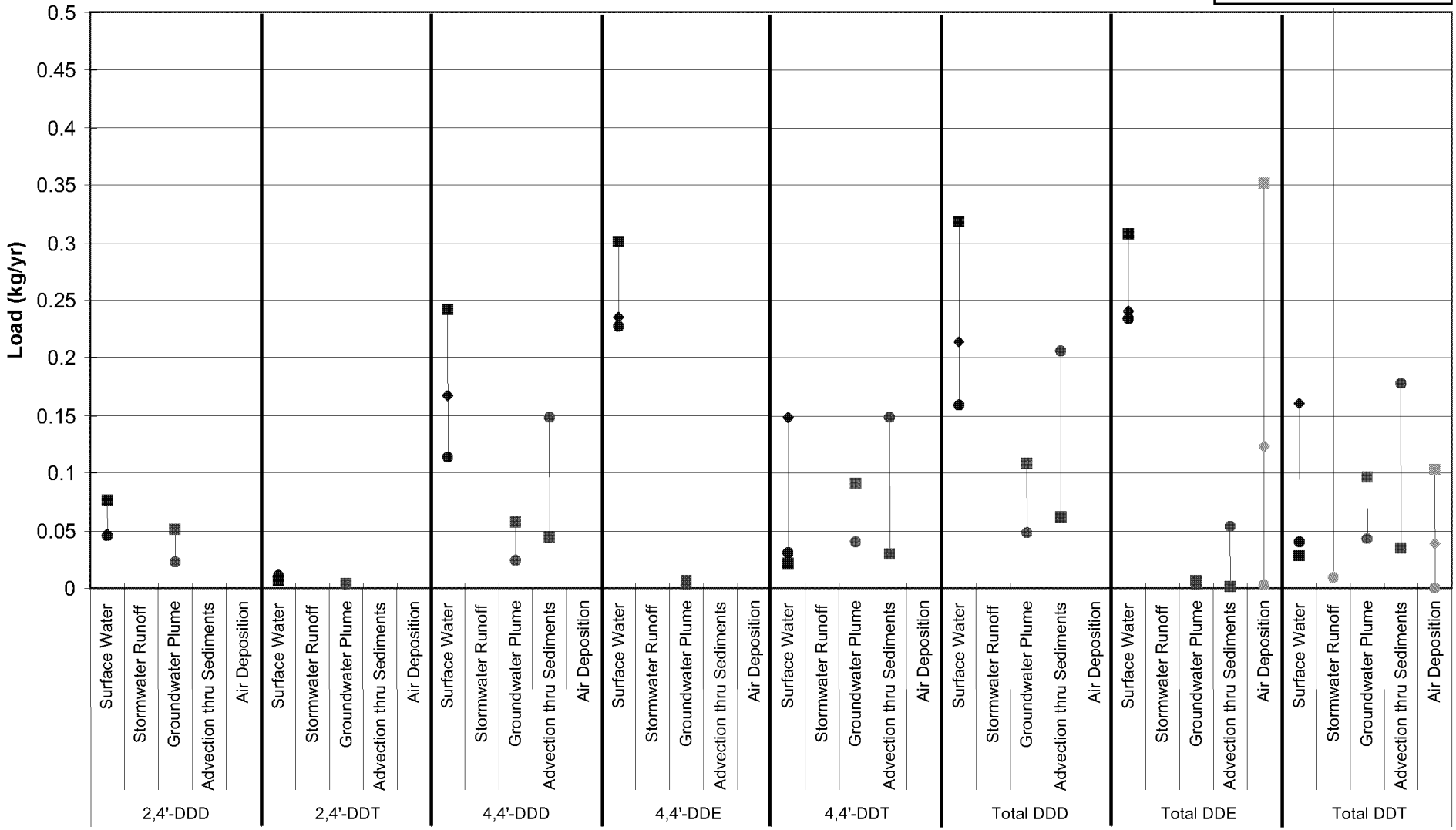
Figure 11.1-5c
Portland Harbor RI/FS
Comprehensive Round 2 Report
Surface Water Loading by River Mile
non-DDx Pesticides

BZTO104(e)031620

Comparison of Estimated Loading Rates to the Water Column
DDx Pesticides

Total DDT stormwater runoff maximum (4.32 kg/yr) and central (1.44 kg/yr) not shown at this scale.



Legend

Upstream Surface Water (RM 11), Total	Stormwater Runoff	Groundwater Plume, Unfiltered	Advection thru Sediments	Air Deposition
July 2005	Upper estimate	Upper flow estimate	Maximum K_{oc}	Upper estimate
November 2004	Central estimate	Mean flow estimate	Minimum K_{oc}	Central estimate
March 2004	Lower estimate			Lower estimate

Note: Hollow symbols indicate loads calculated with sampled concentrations below the laboratory detection limit. These loads were estimated at 0 kg/yr . No symbol indicates that a loading estimate was not developed for this term.

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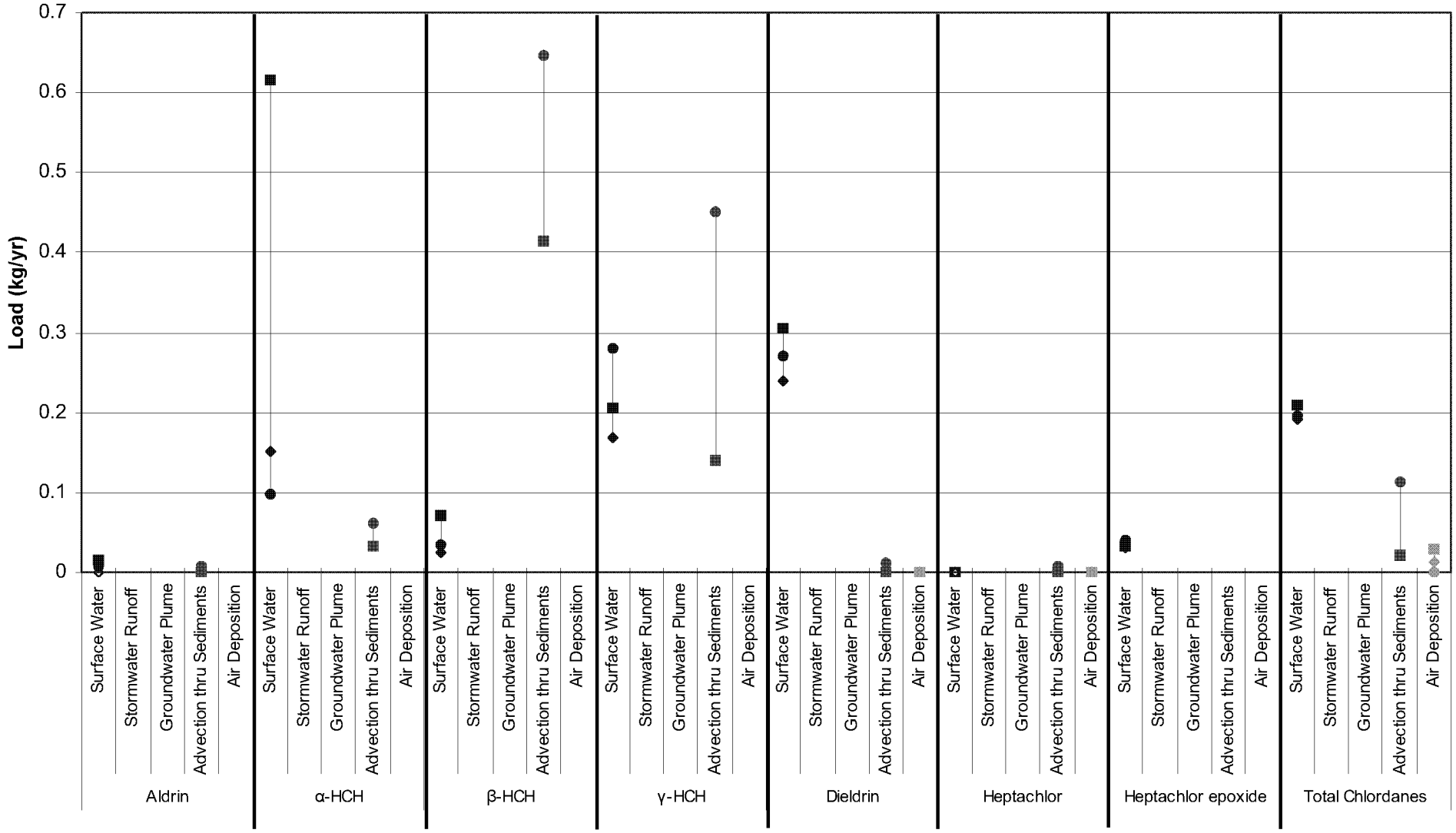
Figure 11.1-6a
Portland Harbor RI/FS
Comprehensive Round 2 Report
Loading Estimate Comparison
DDx Pesticides

Comparison of Estimated Loading Rates to the Water Column
non-DDx Pesticides



Legend

Upstream Surface Water (RM 11), Total	Stormwater Runoff	Groundwater Plume, Unfiltered	Advection thru Sediments	Air Deposition
July 2005	Upper estimate	Upper flow estimate	Maximum K_{oc}	Upper estimate
November 2004	Central estimate	Mean flow estimate	Minimum K_{oc}	Central estimate
March 2004	Lower estimate			Lower estimate

Note: Hollow symbols indicate loads calculated with sampled concentrations below the laboratory detection limit. These loads were estimated at 0 kg/yr . No symbol indicates that a loading estimate was not developed for this term.

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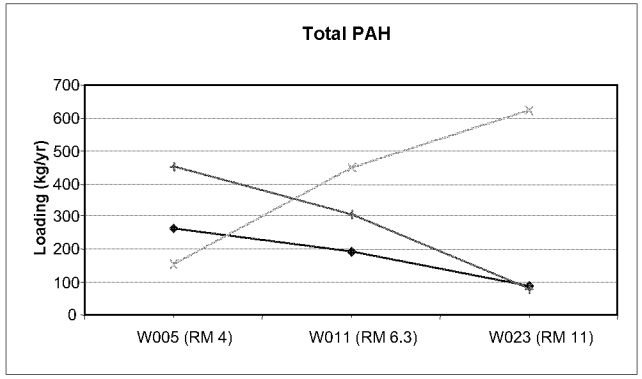
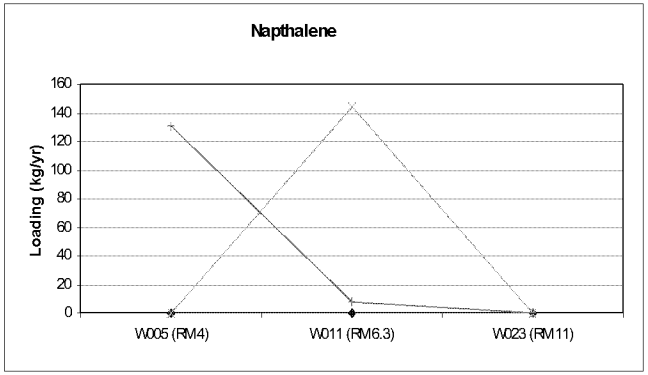
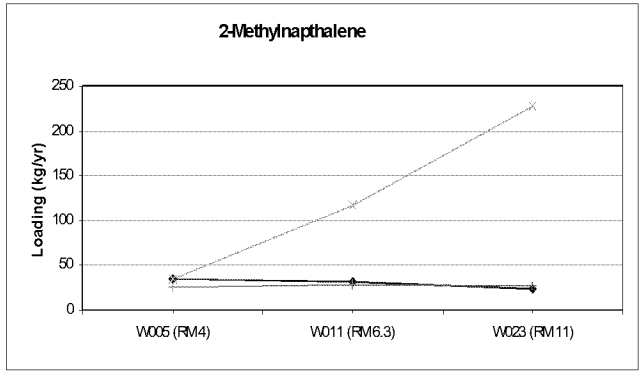
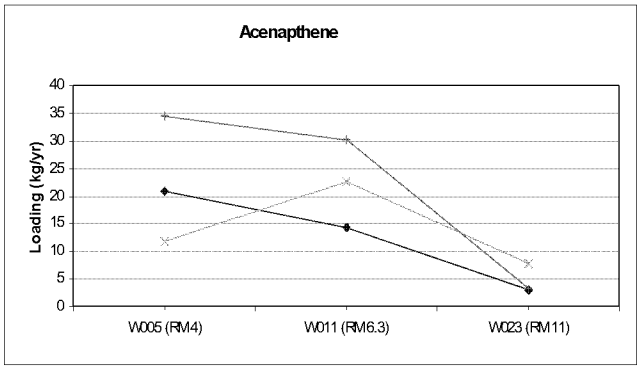
Figure 11.1-6b
Portland Harbor RI/FS
Comprehensive Round 2 Report
Loading Estimate Comparison
Non-DDx Pesticides

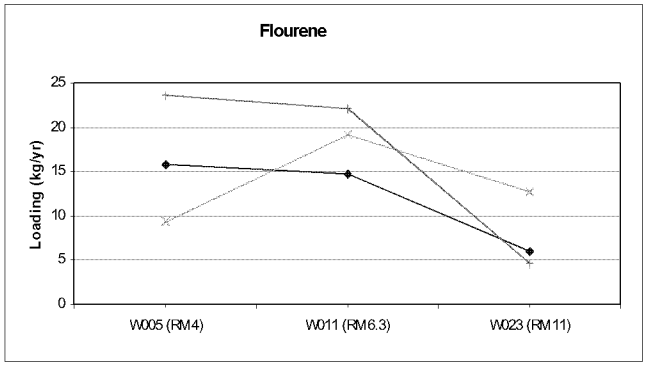
BZTO104(e)031622

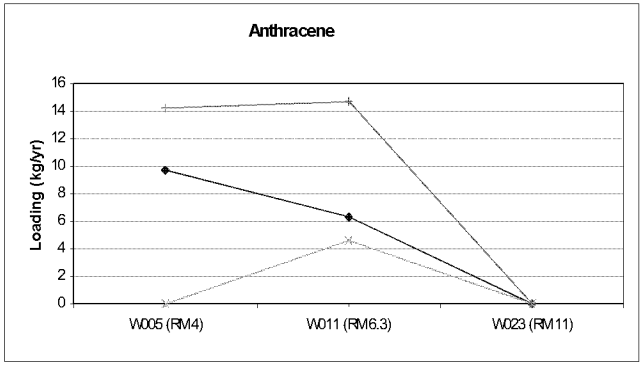


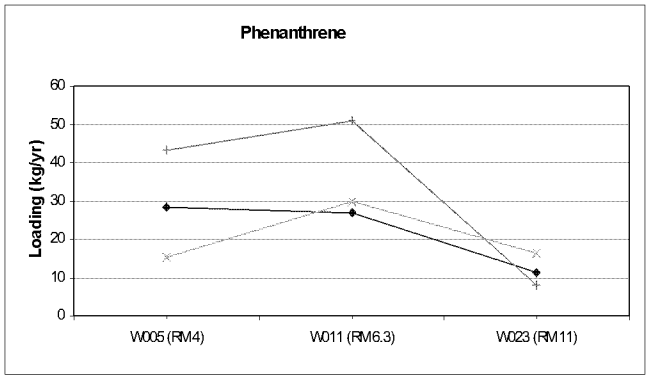










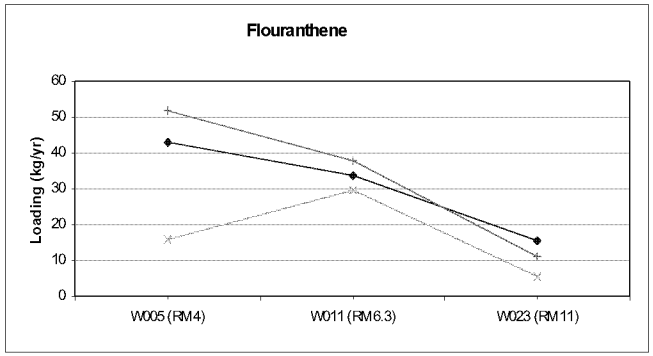


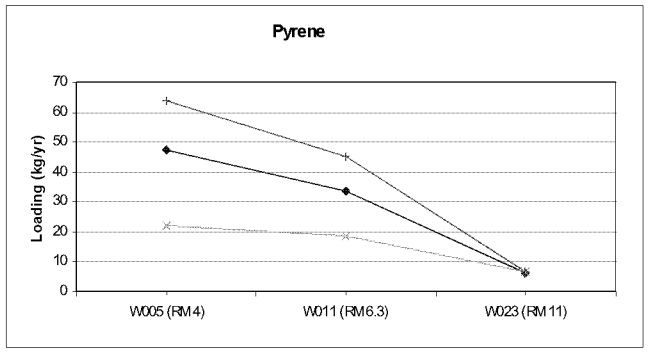
Total Nov 2004
Total Mar 2005
Total Jul 2005

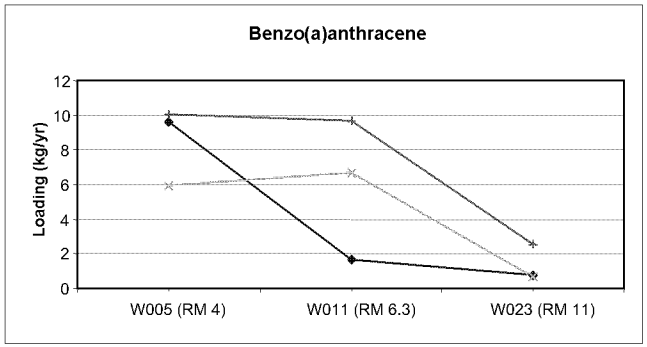
integral LWG Lower Willamette Group

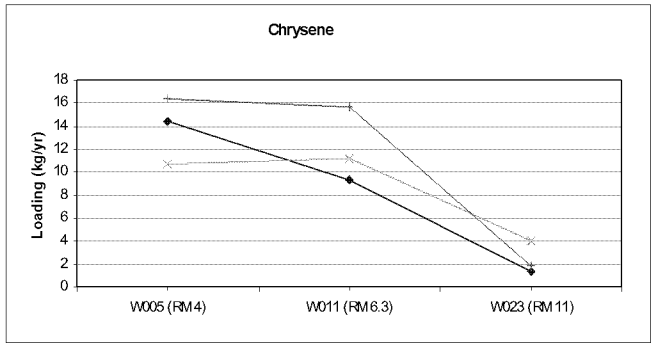
Figure 11.1-7a
Portland Harbor RI/FS
Comprehensive Round 2 Report
Surface Water Loading by River Mile
LPAHs

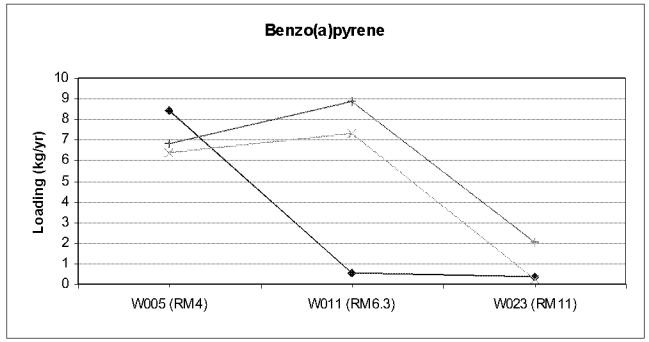
BZTO104(e)031623

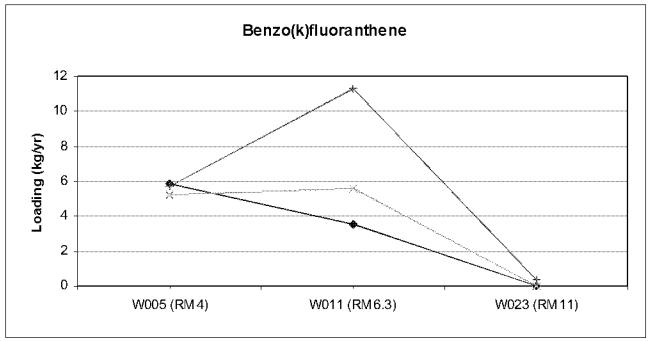


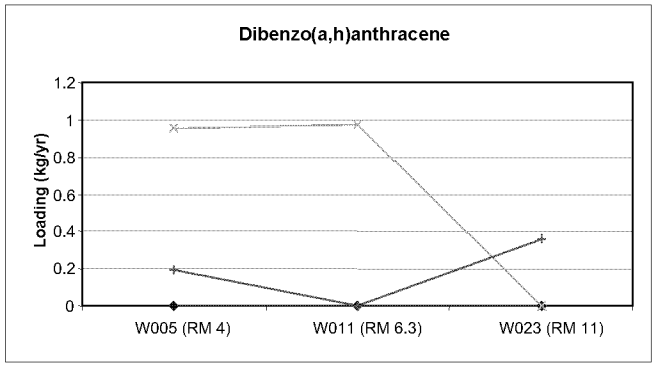


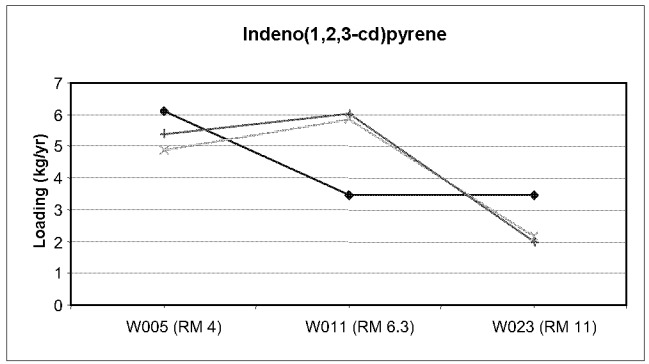


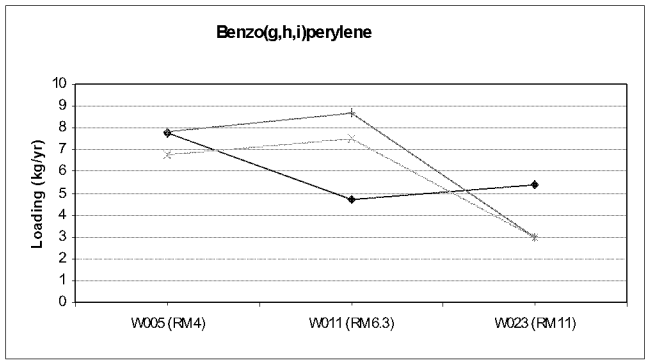












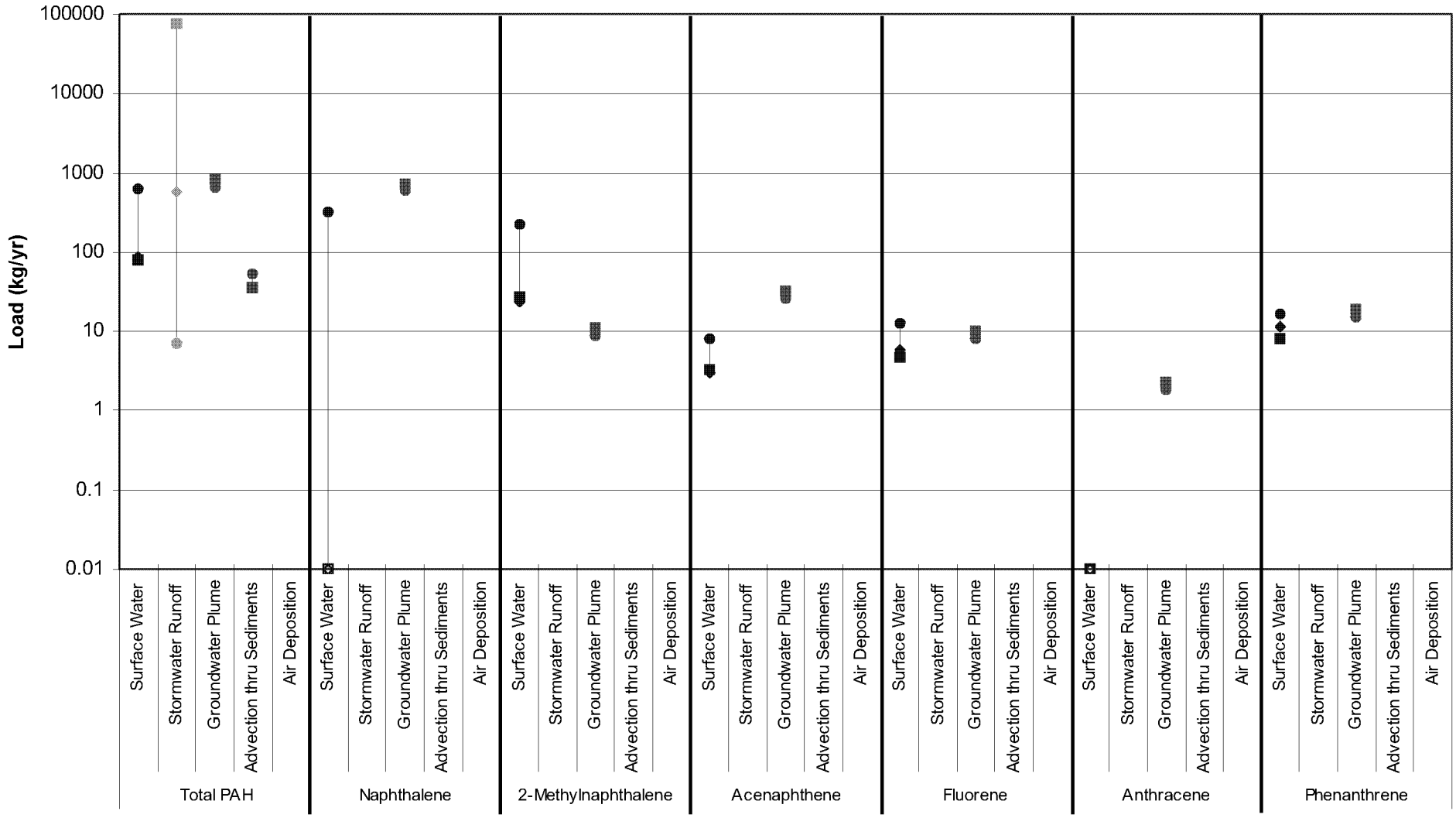
Total Nov 2004
Total Mar 2005
Total Jul 2005

integral LWG Lower Willamette Group

Figure 11.1-7b
Portland Harbor RI/FS
Comprehensive Round 2 Report
Surface Water Loading by River Mile
HPAHs

BZTO104(e)031624

Comparison of Estimated Loading Rates to the Water Column
Total PAH and LPAHs



Legend

Upstream Surface Water (RM 11), Total	Stormwater Runoff	Groundwater Plume, Unfiltered	Advection thru Sediments	Air Deposition
July 2005	Upper estimate	Upper flow estimate	Maximum K_{oc}	Upper estimate
November 2004	Central estimate	Mean flow estimate	Minimum K_{oc}	Central estimate
March 2004	Lower estimate			Lower estimate

Note: Hollow symbols indicate loads calculated with sampled concentrations below the laboratory detection limit. These loads were estimated at 0 kg/yr . No symbol indicates that a loading estimate was not developed for this term.

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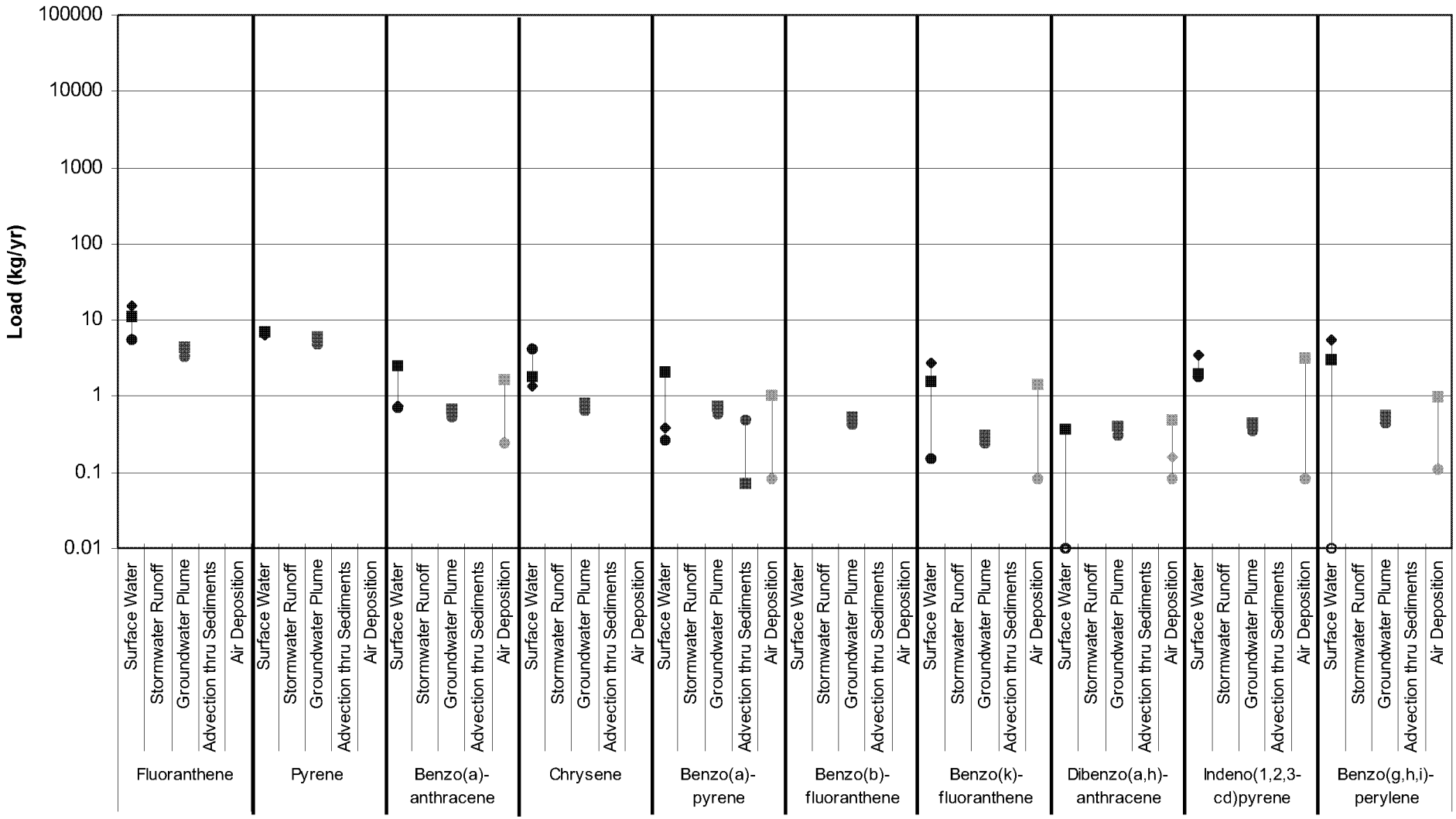
Figure 11.1-8a
Portland Harbor RI/FS
Comprehensive Round 2 Report
Loading Estimate Comparison
LPAHs

BZTO104(e)031625

Comparison of Estimated Loading Rates to the Water Column
HPAHs



Legend

Upstream Surface Water (RM 11), Total	Stormwater Runoff	Groundwater Plume, Unfiltered	Advection thru Sediments	Air Deposition
July 2005	Upper estimate	Upper flow estimate	Maximum K_{oc}	Upper estimate
November 2004	Central estimate	Mean flow estimate	Minimum K_{oc}	Central estimate
March 2004	Lower estimate			Lower estimate

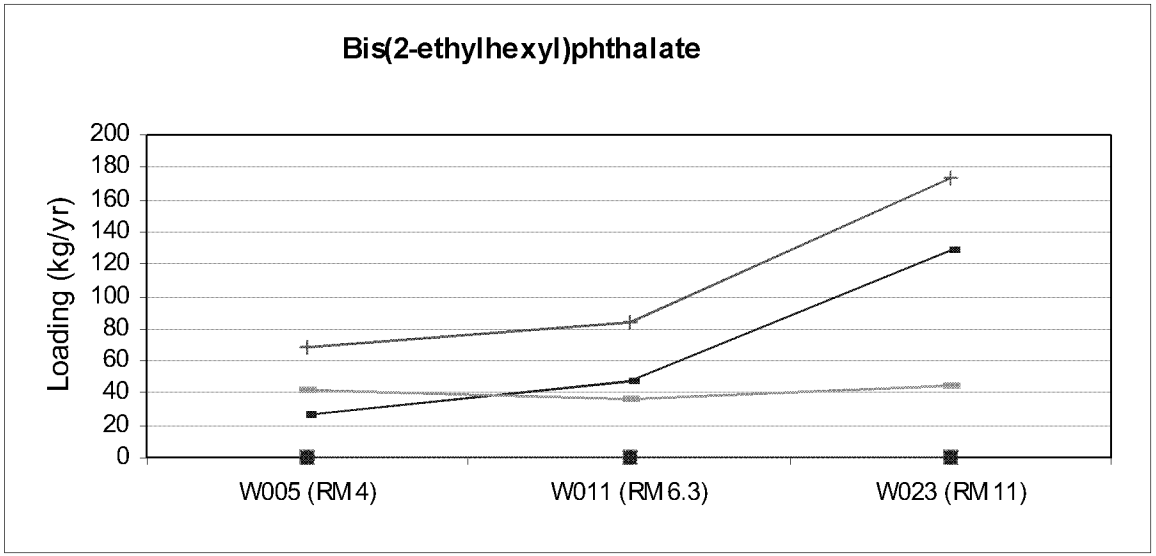
Note: Hollow symbols indicate loads calculated with sampled concentrations below the laboratory detection limit. These loads were estimated at 0 kg/yr . No symbol indicates that a loading estimate was not developed for this term.

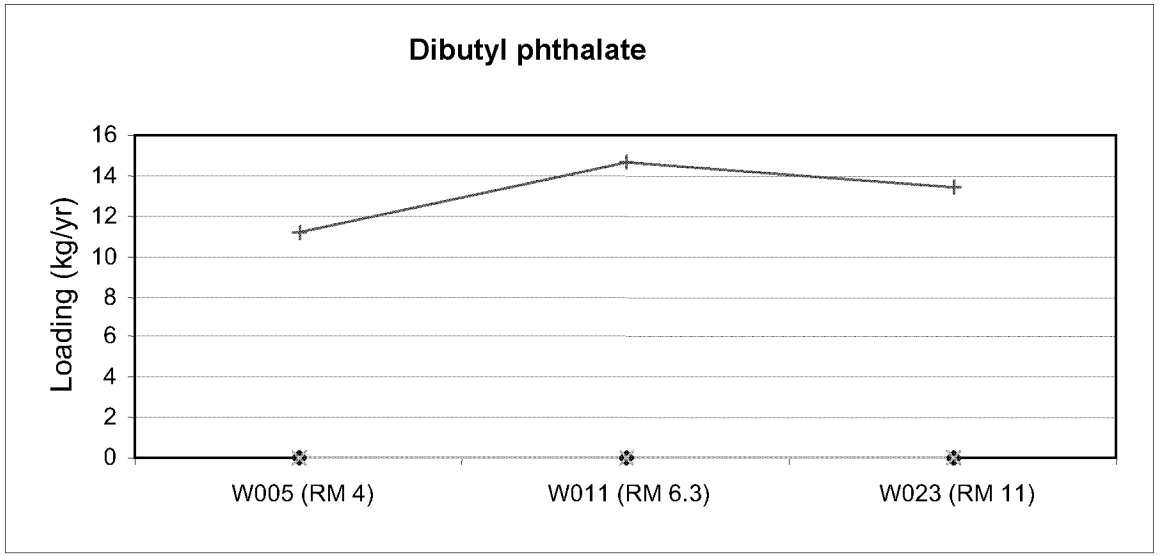
integral

LWG Lower Willamette Group

Figure 11.1-8b
Portland Harbor RI/FS
Comprehensive Round 2 Report
Loading Estimate Comparison
HPAHs

BZTO104(e)031626





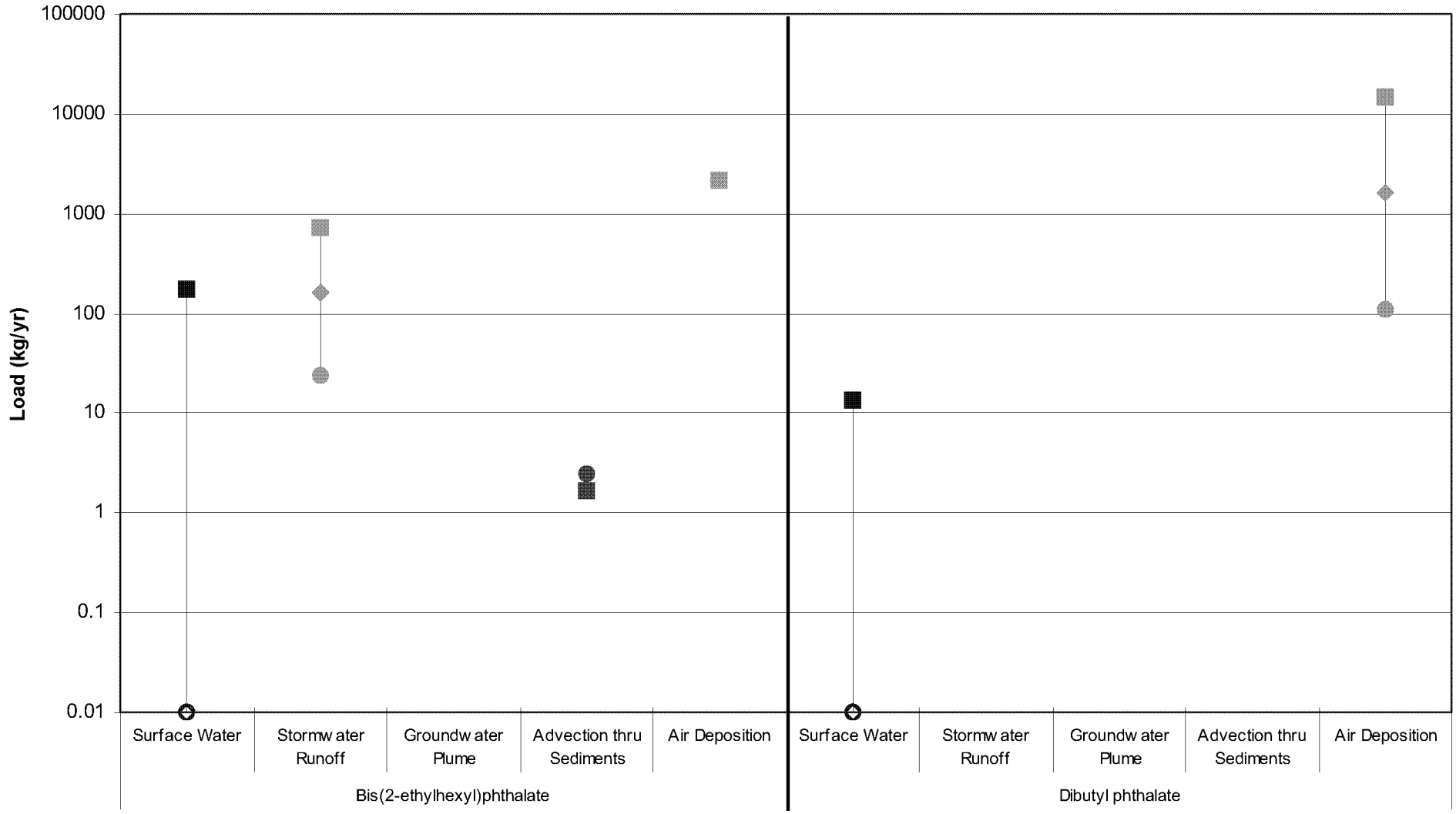
Total Nov 2004
Total Mar 2005
Total Jul 2005

integral LWG Lower Willamette Group

Figure 11.1-9
Portland Harbor RI/FS
Comprehensive Round 2 Report
Surface Water Loading by River Mile
Phthalate Esters

BZTO104(e)031627

Comparison of Estimated Loading Rates to the Water Column
Phthalate Esters



Legend

Upstream Surface Water (RM 11), Total	Stormwater Runoff	Groundwater Plume, Unfiltered	Advection thru Sediments	Air Deposition
July 2005	Upper estimate	Upper flow estimate	Maximum K_{oc}	Upper estimate
November 2004	Central estimate	Mean flow estimate	Minimum K_{oc}	Central estimate
March 2004	Lower estimate			Lower estimate

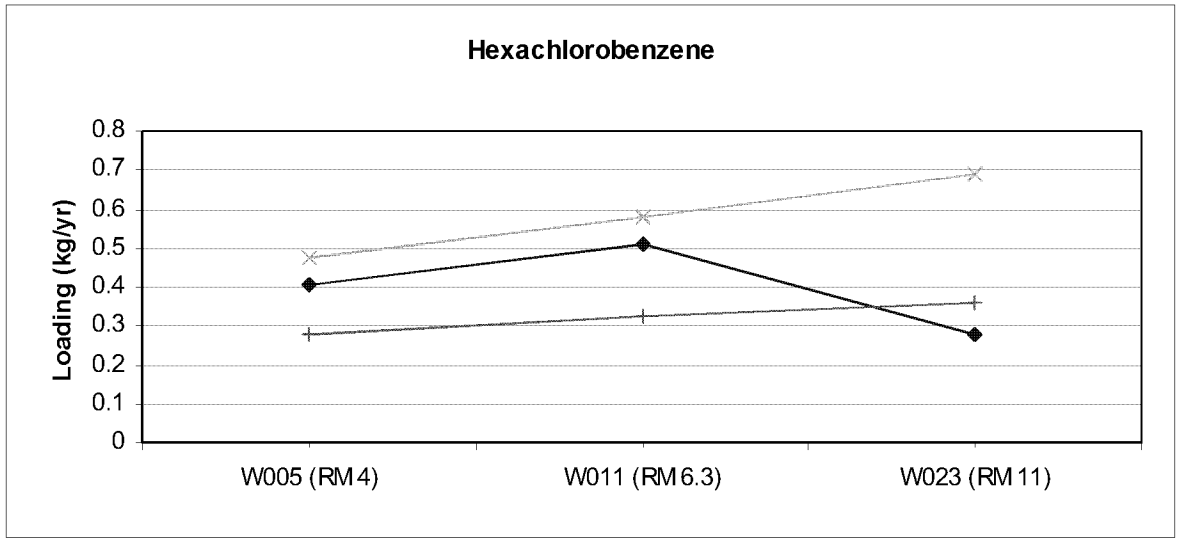
Note: Hollow symbols indicate loads calculated with sampled concentrations below the laboratory detection limit. These loads were estimated at 0 kg/yr . No symbol indicates that a loading estimate was not developed for this term.

integral

LWG Lower Willamette Group

Figure 11.1-10
Portland Harbor RI/FS
Comprehensive Round 2 Report
Loading Estimate Comparison
Phthalate Esters

BZTO104(e)031628



Pentachlorophenol

All samples below laboratory detection limit.
Loads estimated to be 0 kg/yr.

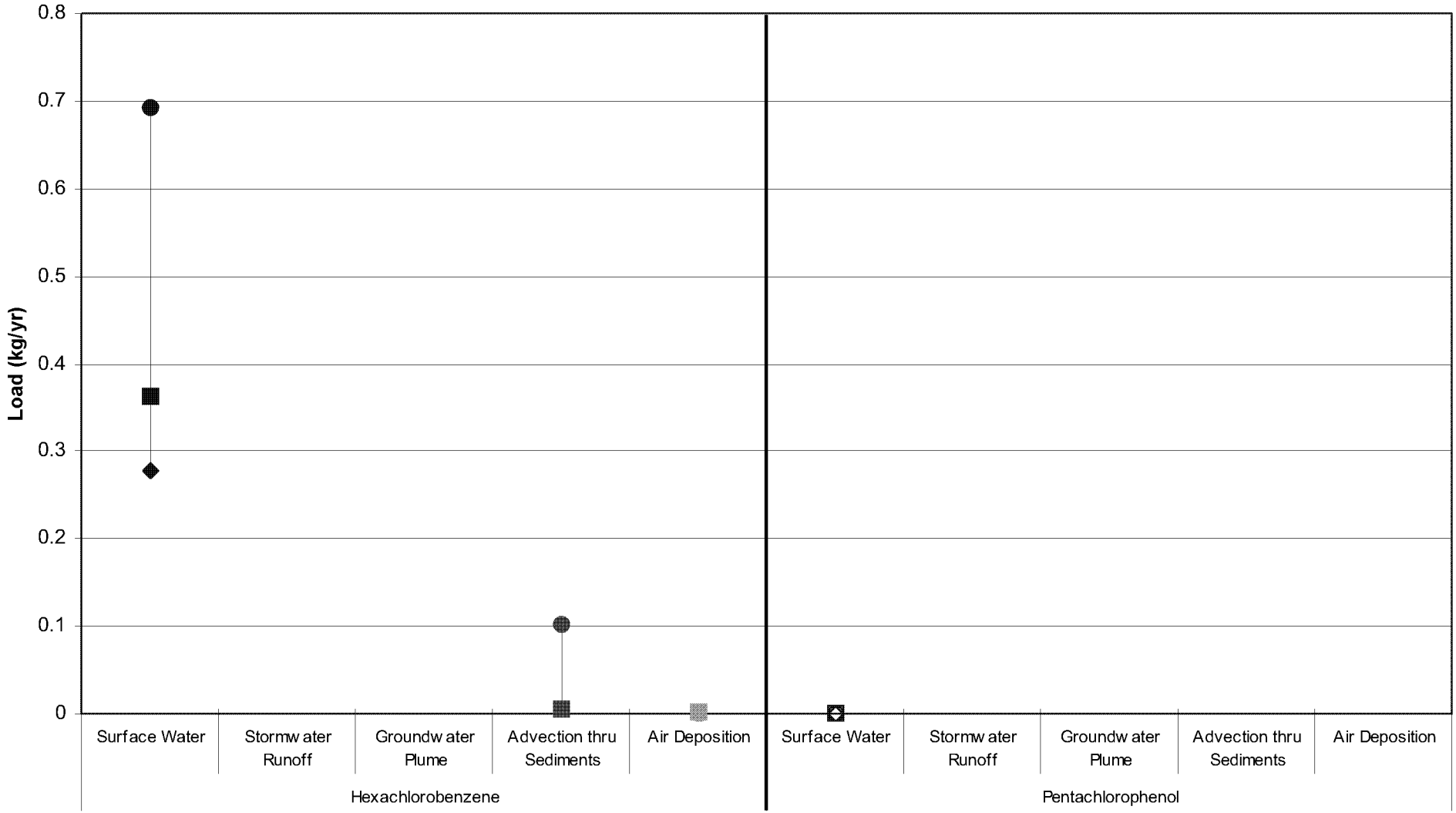
Total Nov 2004
Total Mar 2005
Total Jul 2005

integral LWG Lower Willamette Group

Figure 11.1-11
Portland Harbor RI/FS
Comprehensive Round 2 Report
Surface Water Loading by River Mile
SVOCs

BZTO104(e)031629

Comparison of Estimated Loading Rates to the Water Column
SVOCs



Legend

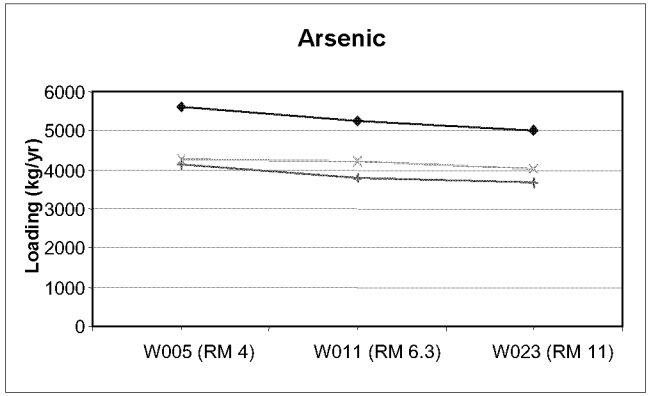
Upstream Surface Water (RM 11), Total	Stormwater Runoff	Groundwater Plume, Unfiltered	Advection thru Sediments	Air Deposition
July 2005	Upper estimate	Upper flow estimate	Maximum K_{oc}	Upper estimate
November 2004	Central estimate	Mean flow estimate	Minimum K_{oc}	Central estimate
March 2004	Lower estimate			Lower estimate

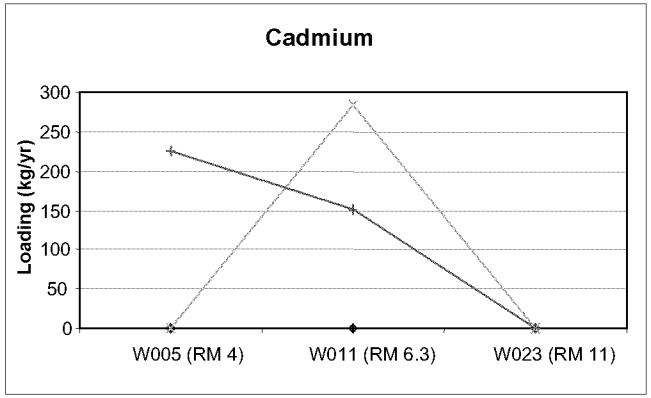
Note: Hollow symbols indicate loads calculated with sampled concentrations below the laboratory detection limit. These loads were estimated at 0 kg/yr . No symbol indicates that a loading estimate was not developed for this term.

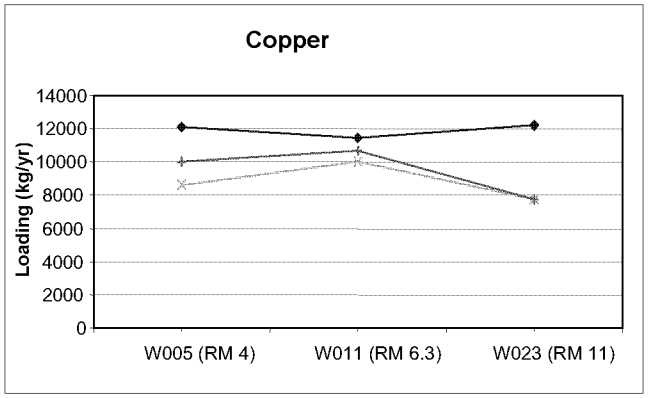
integral

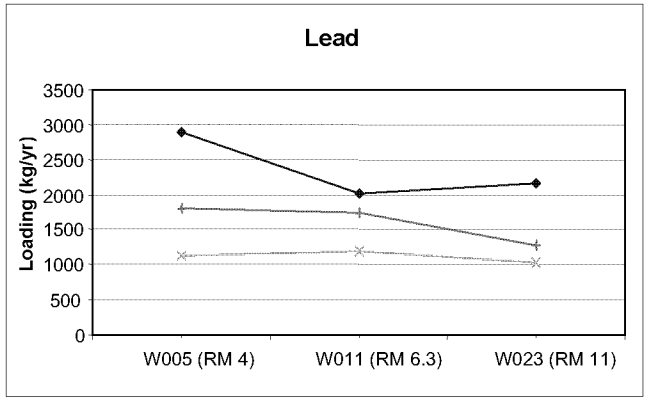
LWG Lower Willamette Group

Figure 11.1-12
Portland Harbor RI/FS
Comprehensive Round 2 Report
Loading Estimate Comparison
SVOCs







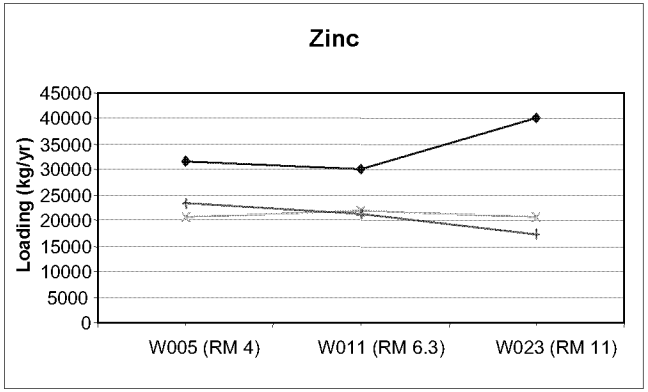


Mercury

All samples below laboratory detection limit.
Loads estimated to be 0 kg/yr.

Silver

All samples below laboratory detection limit.
Loads estimated to be 0 kg/yr.



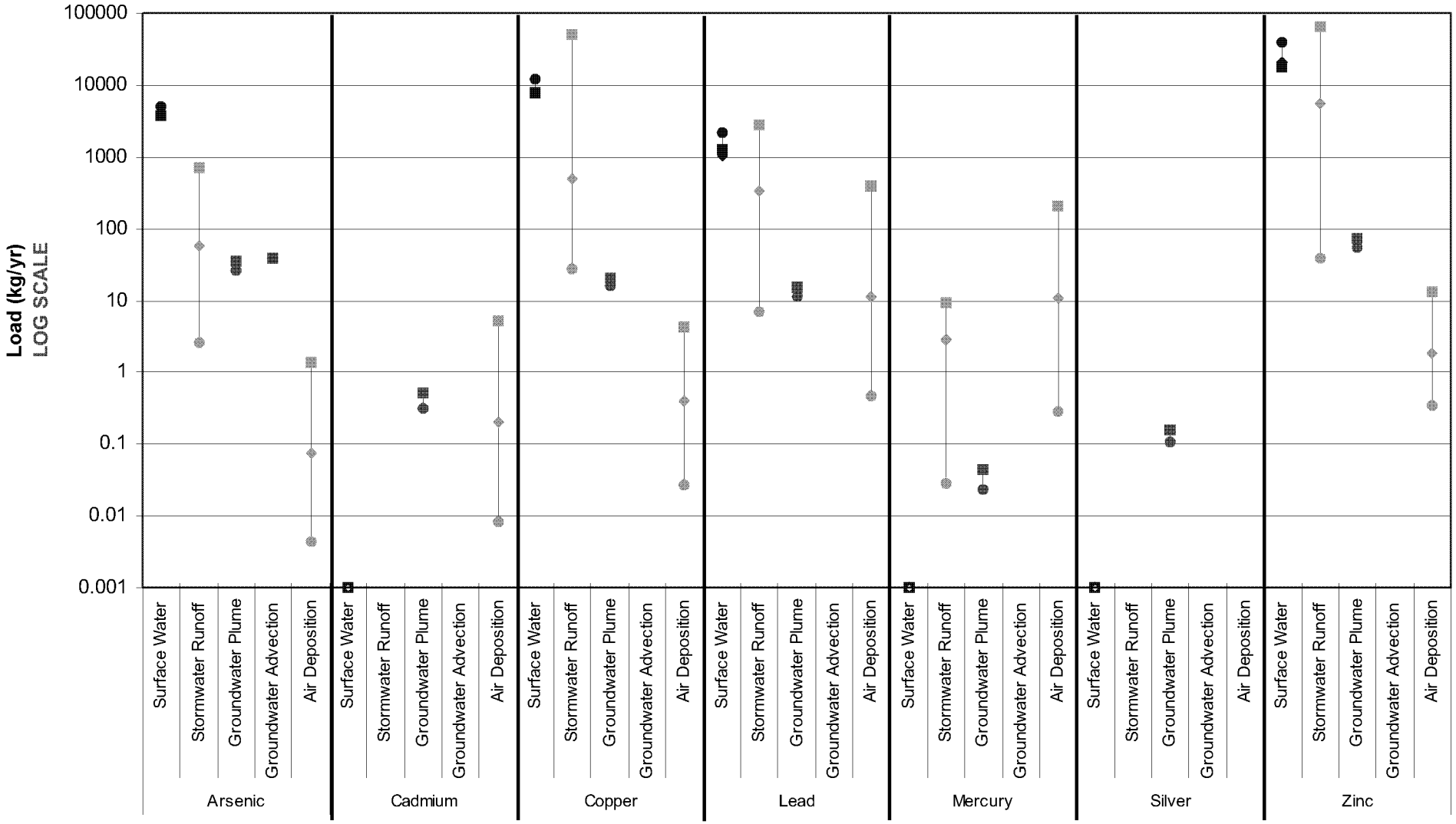
Total Nov 2004
Total Mar 2005
Total Jul 2005

integral LWG Lower Willamette Group

Figure 11.1-13
Portland Harbor RI/FS
Comprehensive Round 2 Report
Surface Water Loading by River Mile
Metals

BZTO104(e)031631

Comparison of Estimated Loading Rates to the Water Column
Metals



Legend

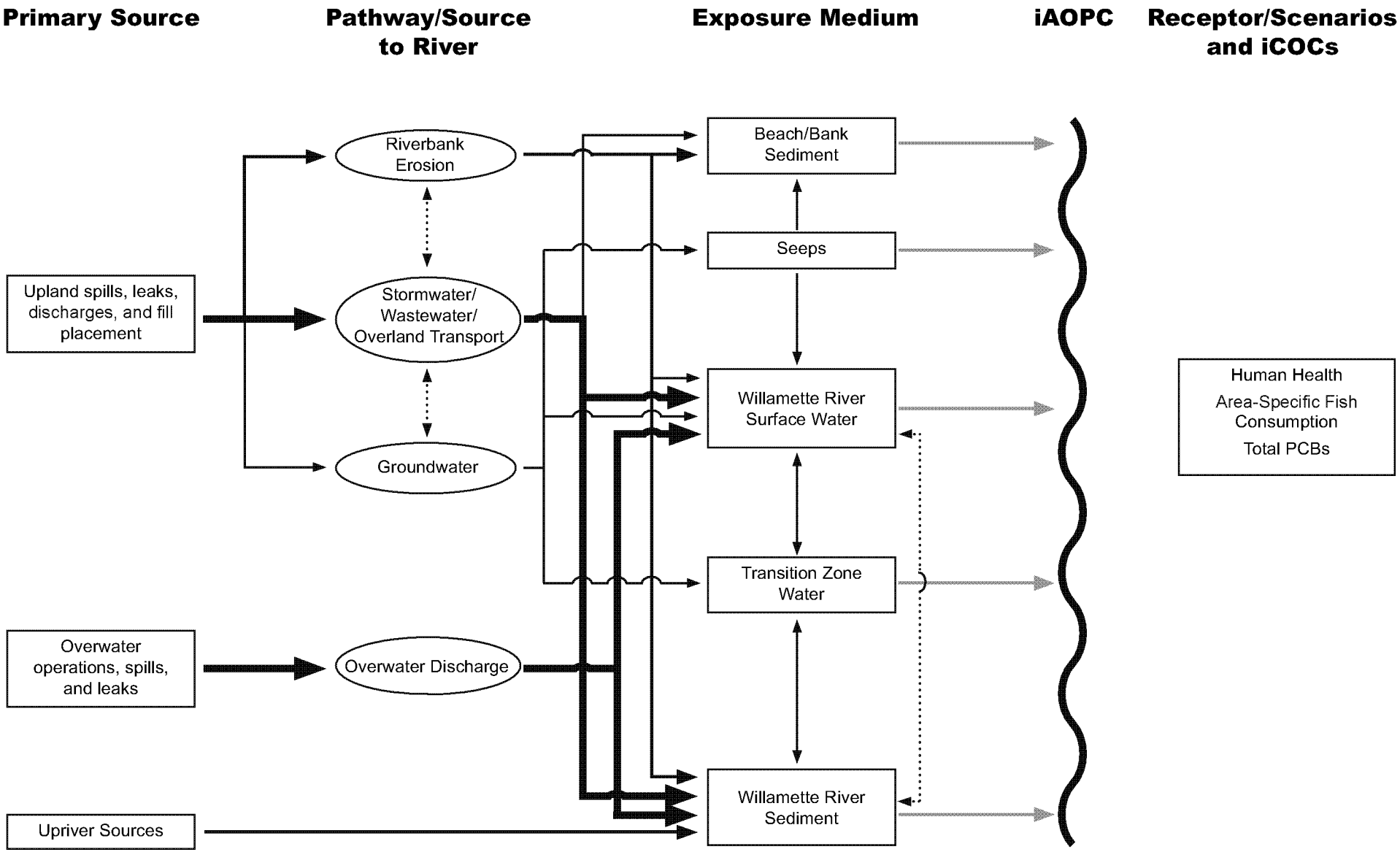
Upstream Surface Water (RM 11), Total	Stormwater Runoff	Groundwater Plume, Unfiltered	Advection thru Sediments	Air Deposition
July 2005	Upper estimate	Upper flow estimate	Maximum K_{oc}	Upper estimate
November 2004	Central estimate	Mean flow estimate	Minimum K_{oc}	Central estimate
March 2004	Lower estimate			Lower estimate

Note: Hollow symbols indicate loads calculated with sampled concentrations below the laboratory detection limit. These loads were estimated at 0 kg/yr . No symbol indicates that a loading estimate was not developed for this term.

integral

LWG Lower Willamette Group

Figure 11.1-14
Portland Harbor RI/FS
Comprehensive Round 2 Report
Loading Estimate Comparison
Metals



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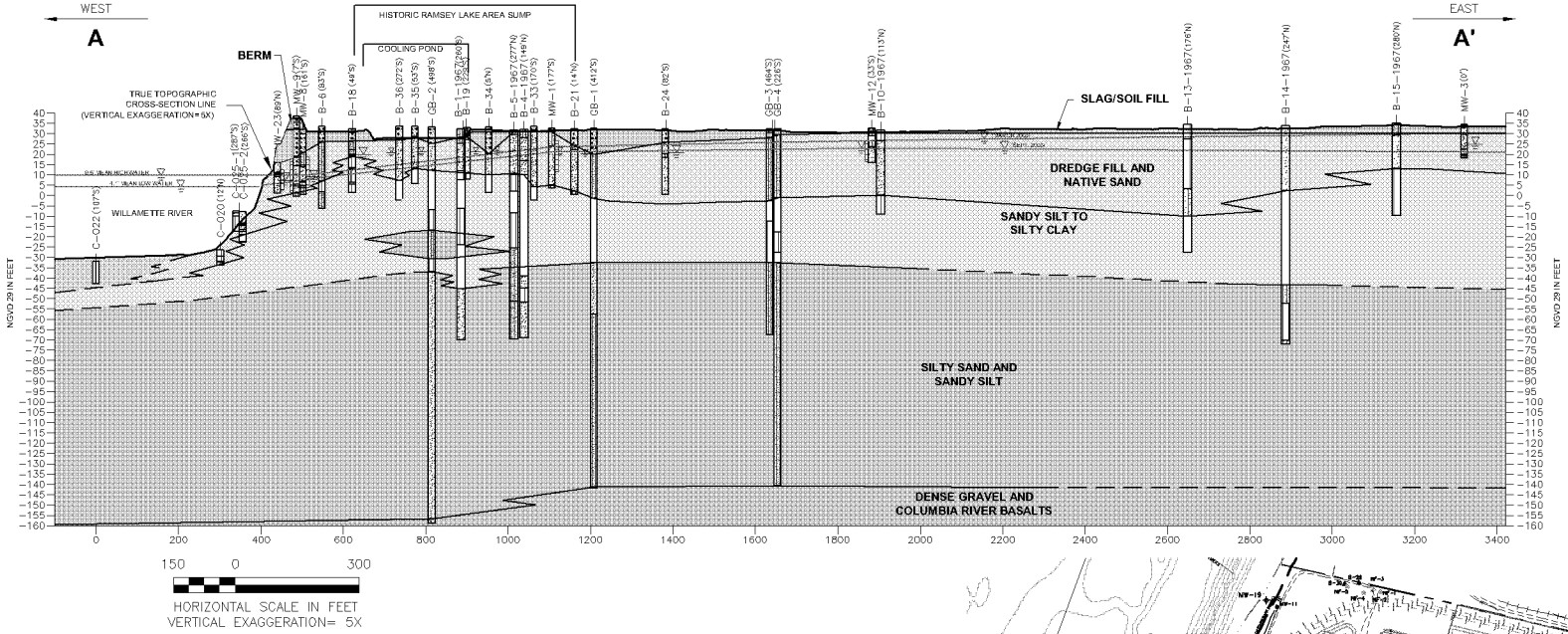
Complete Current and/or Historical Pathway, Relative Contribution Medium
Complete Current and/or Historical Pathway, Relative Contribution Low
Incomplete or Insignificant Pathway
Completeness Unknown
No assessment is made on the relative contribution to iAOPC

Notes:
* = Potenital iCOCs
Bold = Chemicals Mapped for iAOPC CSM

Figure 11.2-1
Portland Harbor RI/FS
Comprehensive Round 2 Report
Preliminary Conceptual Site Model Diagram for the site-wide iAOPC

integral consulting inc.
LWG Lower Willamette Group

BZTO104(e)031633



LEGEND

- CONCRETE
- CLAYEY SILT TO SILTY CLAY
- FILL: SANDY GRAVEL TO GRAVELLY SILT
- SAND TO FINE SAND
- SILTY SAND
- SANDY SILT
- SILT
- WATER LEVEL
- SCREEN

NOTES

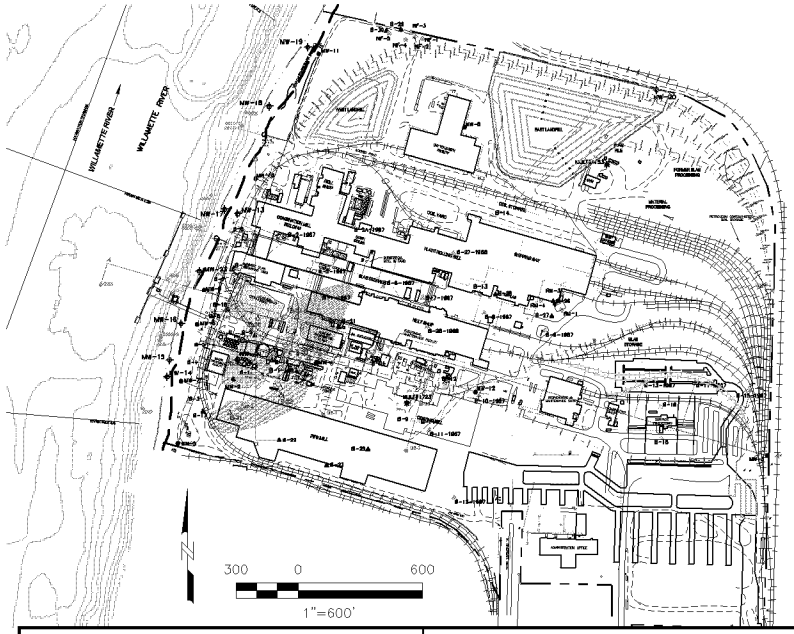
1. ALL VERTICAL DATA SHOWN IN NGVD29 IN FEET
2. UPLAND TOPOGRAPHY MAPPED FROM AERIAL PHOTOGRAPHY BY GEOGRAPHIX INC.
3. LWG BATHYMETRY DATA IN NAVDBB. SURVEYED FEB. 2004 FOR THE PORTLAND HARBOR SUPERFUND SITE BY INTEGRAL CONSULTING INC. SOUNDINGS FROM RESON SEABAT 8101 MULTIBEAM SONAR AT FREQUENCY OF 240khz. 5-FOOT CONTOURS.
4. PROFILES ARE PROJECTED.

Approximate expansion of former Ramsey Lake area sump by year (based on aerial photography):

1944 1948 1956 1960

LEGEND

- EXPONENT PHASE 1 RI MONITORING WELL LOCATION (2002)
- EXPONENT PHASE 1 RI BORING LOCATION (2002)
- EXPONENT, GEOTECHNICAL BORING LOCATION (2004)
- EXPONENT PRE-RI BORING LOCATION (2000)
- DAMES & MOORE BORING LOCATION (1966-68)
- LWG ROUND IIA SUBSURFACE LOCATION (2004)
- WATER SUPPLY WELL LOCATION
- PROPERTY LINE
- TOP OF RIVERBANK
- MEAN HIGH WATER LEVEL 9.6ft NGVD
- STORM DRAIN TRUNK LINE

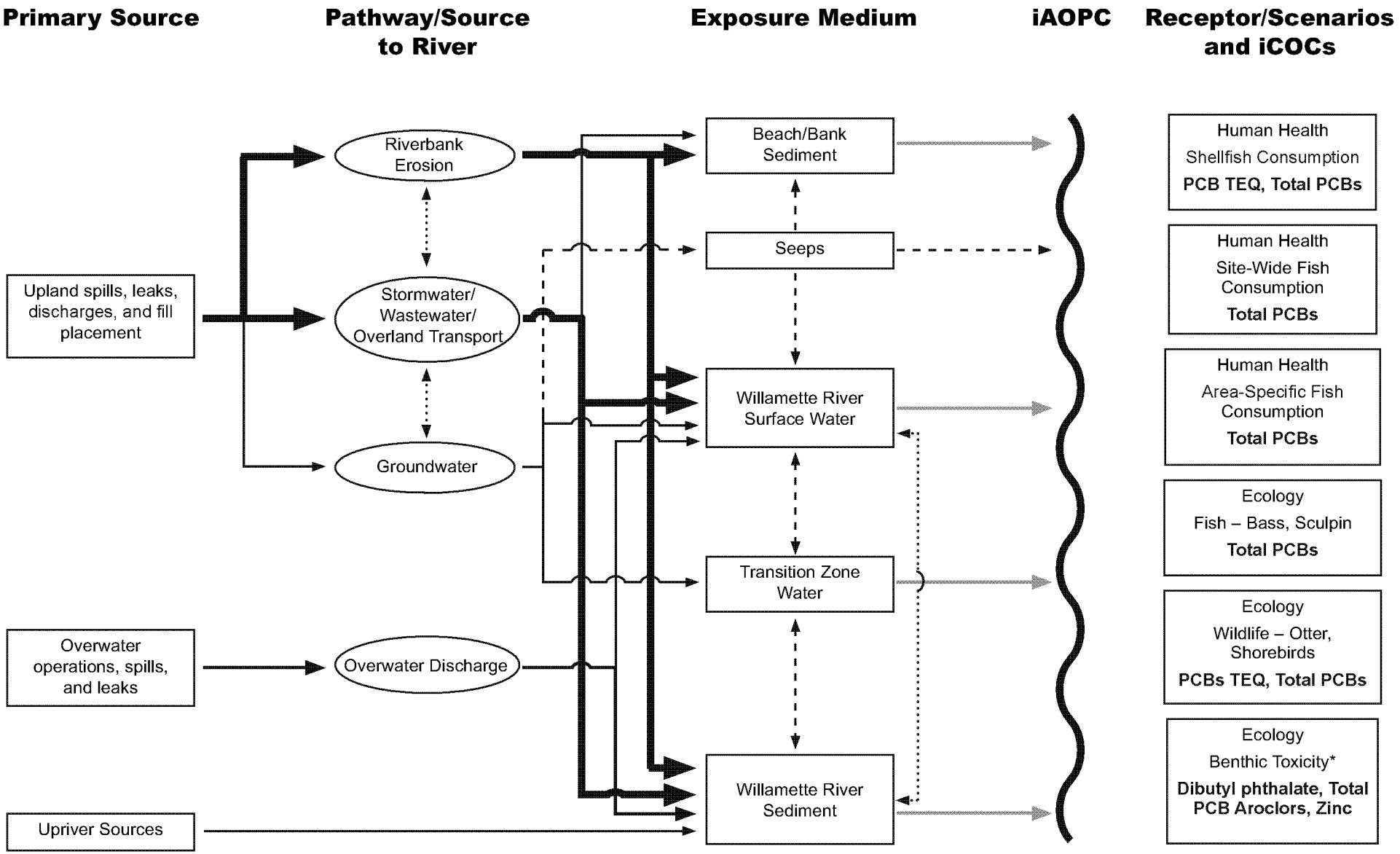


RETEC

OREGON STEEL MILLS PORTLAND, OREGON STRE1-18713-201			CROSS-SECTION A-A'
DATE: 1/5/07	DRWN: E.M./SEA		FIGURE 11.3.1-1

File: H:\18713\18713G042.dwg Layout: ANSI_B1-CP User: emarshall Plotted: Jan 05, 2007 - 12:43pm Xref's:

BZTO104(e)031634



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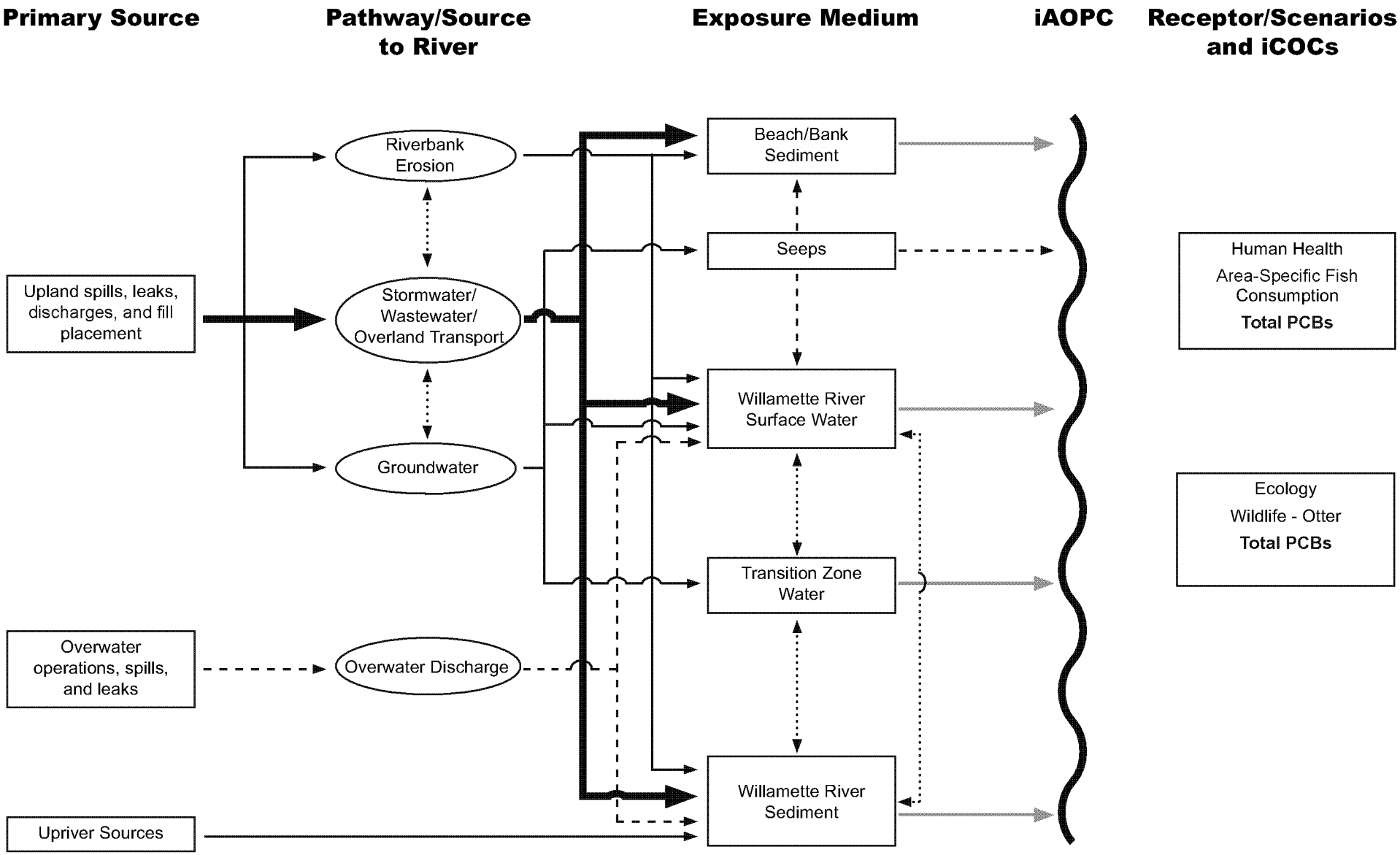
Complete Current and/or Historical Pathway, Relative Contribution Low
Incomplete or Insignificant Pathway
Completeness Unknown
No assessment is made on the relative contribution to iAOPC

Notes:
* = Potenital iCOCs
Bold = Chemicals Mapped for iAOPC CSM

Figure 11.3.1-2
Portland Harbor RI/FS
Comprehensive Round 2 Report
Preliminary Conceptual Site Model Diagram for iAOPC 1

integral consulting inc.
LWG Lower Willamette Group

BZTO104(e)031635



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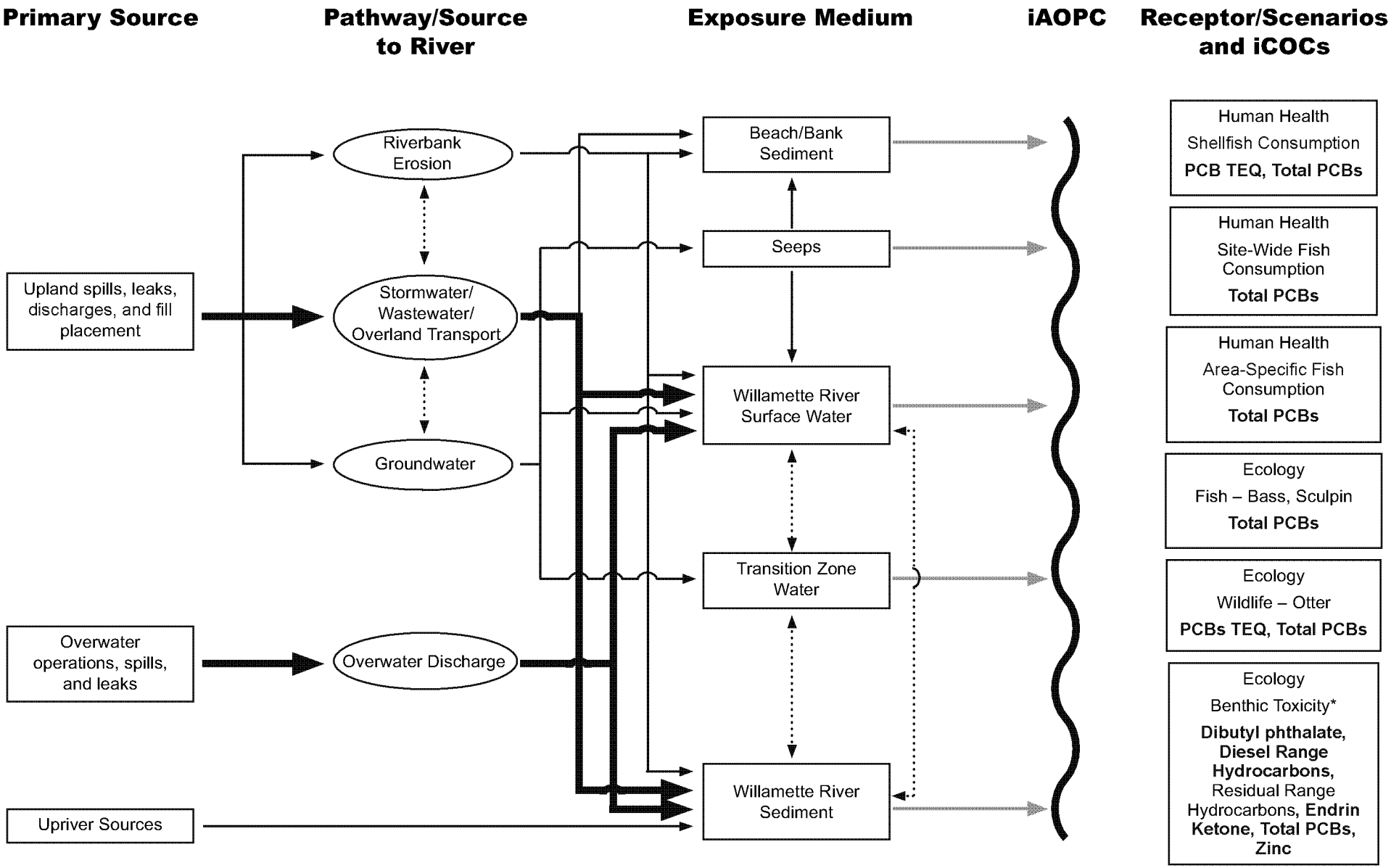
Complete Current and/or Historical Pathway, Relative Contribution Low
Incomplete or Insignificant Pathway
Completeness Unknown
No assessment is made on the relative contribution to iAOPC

Notes:
* = Potenital iCOCs
Bold = Chemicals Mapped for iAOPC CSM

Figure 11.3.2-1
Portland Harbor RI/FS
Comprehensive Round 2 Report
Preliminary Conceptual Site Model Diagram for iAOPC 2

integral consulting inc.
LWG Lower Willamette Group



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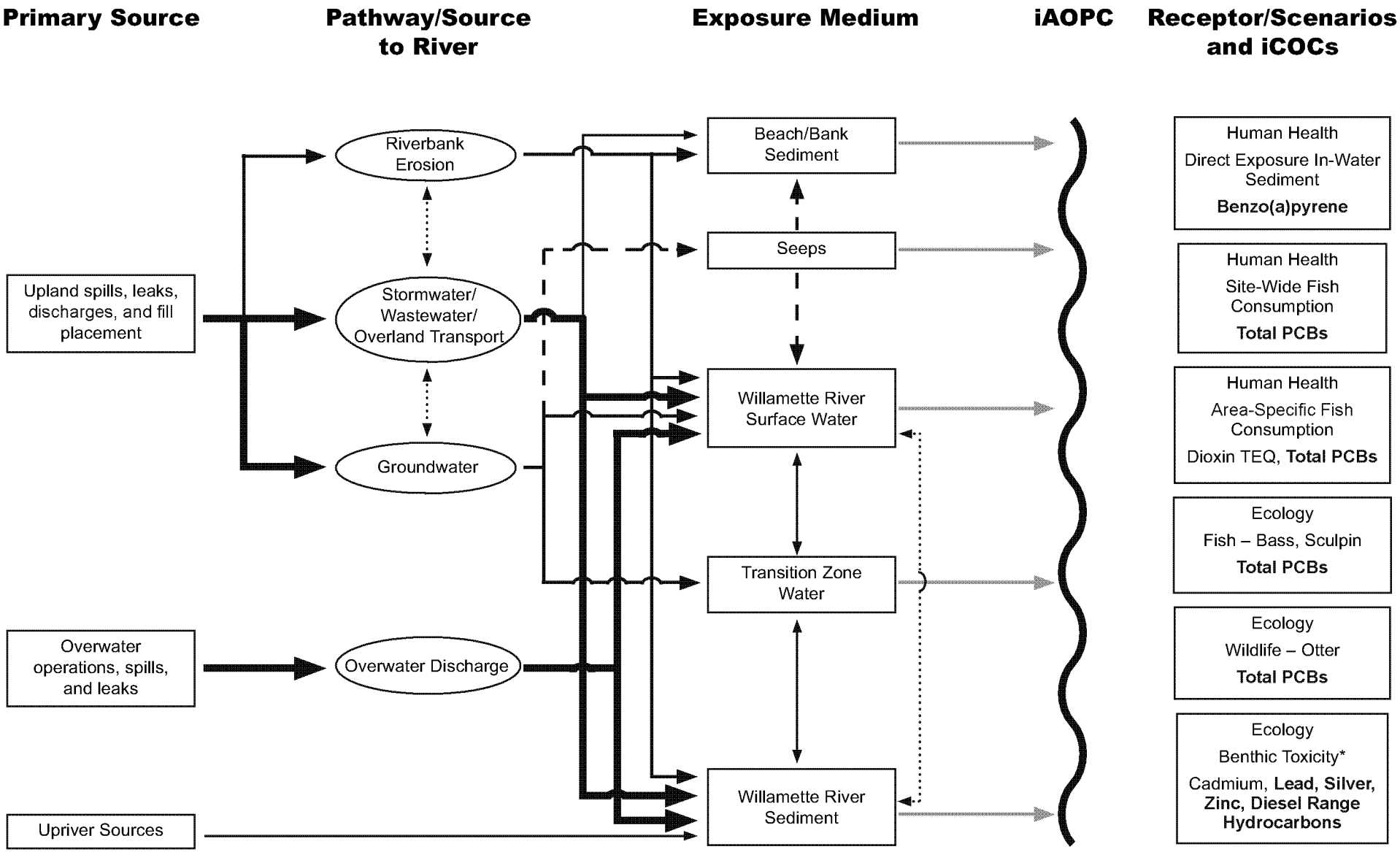
Complete Current and/or Historical Pathway, Relative Contribution Low
Incomplete or Insignificant Pathway
Completeness Unknown
No assessment is made on the relative contribution to iAOPC

Notes:
* = Potenital iCOCs
Bold = Chemicals Mapped for iAOPC CSM

Figure 11.3.3-1
Portland Harbor RI/FS
Comprehensive Round 2 Report
Preliminary Conceptual Site Model Diagram for iAOPCs 3, 4, and 5

integral consulting inc.
LWG Lower Willamette Group

BZTO104(e)031637



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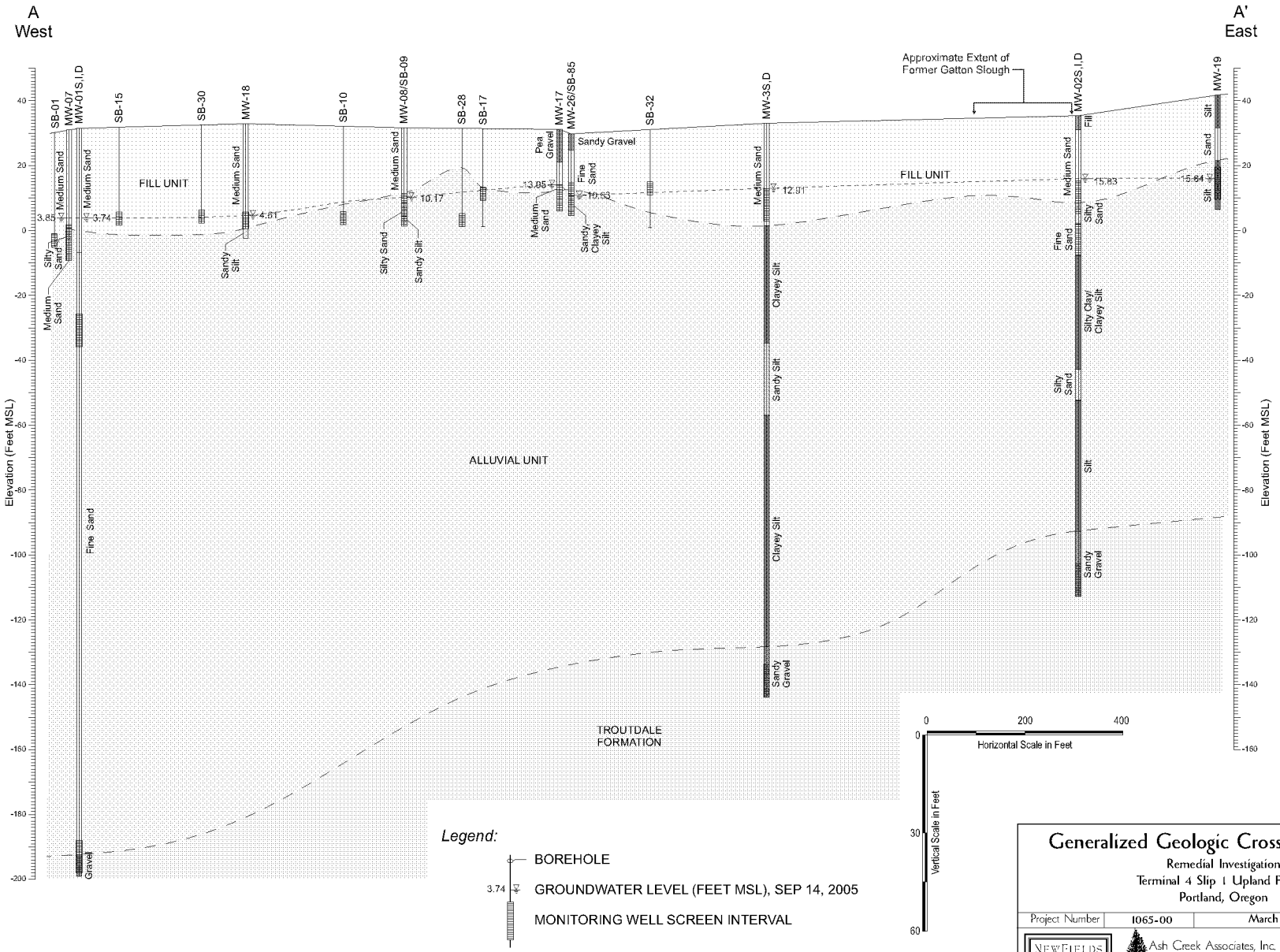
Completeness Unknown
No assessment is made on the relative contribution to iAOPC

Notes:
* = Potenital iCOCs
Bold = Chemicals Mapped for iAOPC CSM

Figure 11.3.4-1
Portland Harbor RI/FS
Comprehensive Round 2 Report
Preliminary Conceptual Site Model Diagram for iAOPC T4

integral consulting inc.
LWG Lower Willamette Group

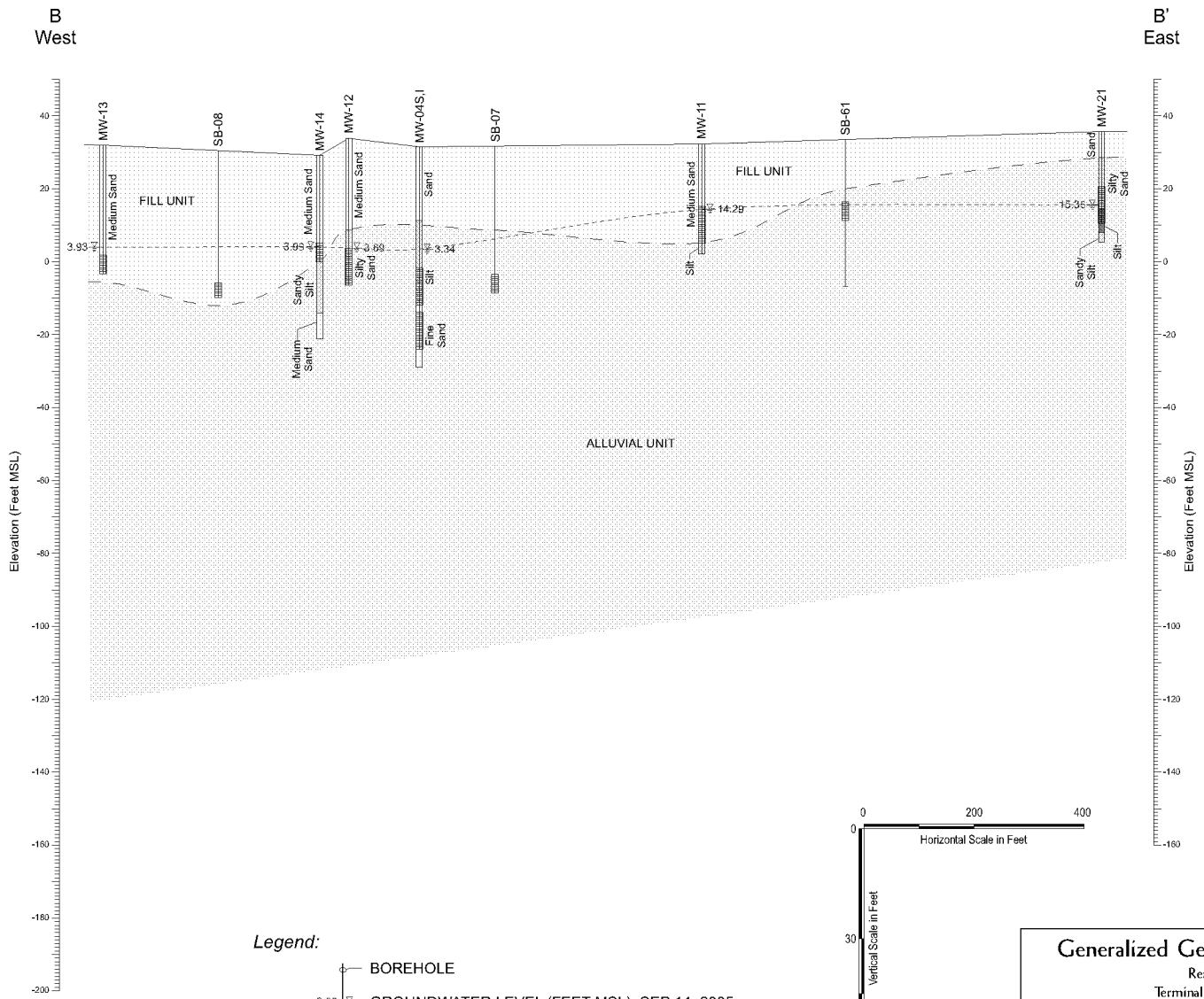


Generalized Geologic Cross Section A-A'

Remedial Investigation
Terminal 4 Slip 1 Upland Facility
Portland, Oregon

Project Number	1065-00	March 2006	Figure
NEWFIELDS	Ash Creek Associates, Inc. Environmental and Geotechnical Consultants	BBL	8

BZTO104(e)031639

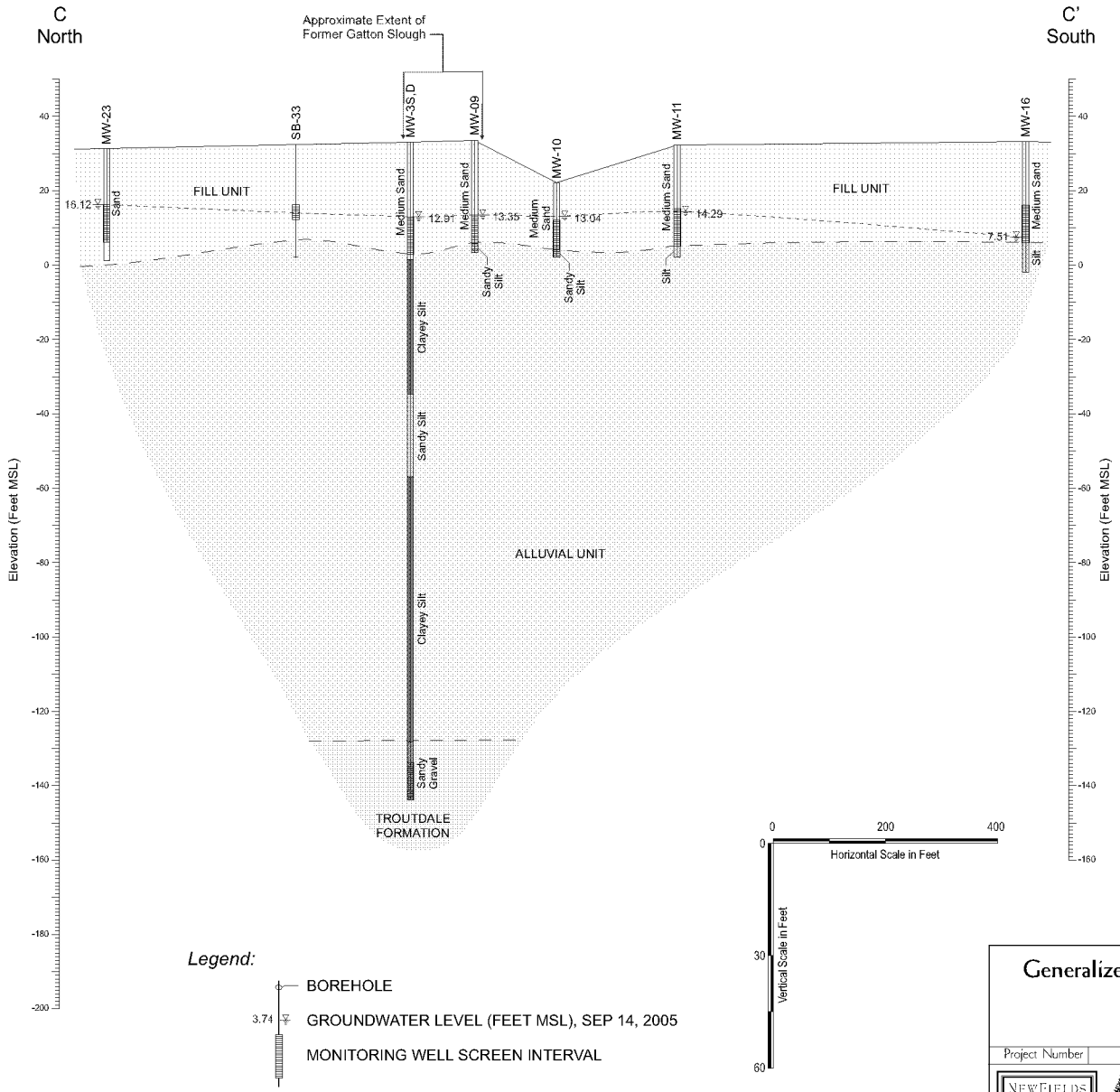


Generalized Geologic Cross Section B-B'

Remedial Investigation
Terminal 4 Slip 1 Upland Facility
Portland, Oregon

Project Number	1065-00	March 2006	Figure
NEWFIELDS	Ash Creek Associates, Inc. Environmental and Geotechnical Consultants	BBL	9

BZTO104(e)031640



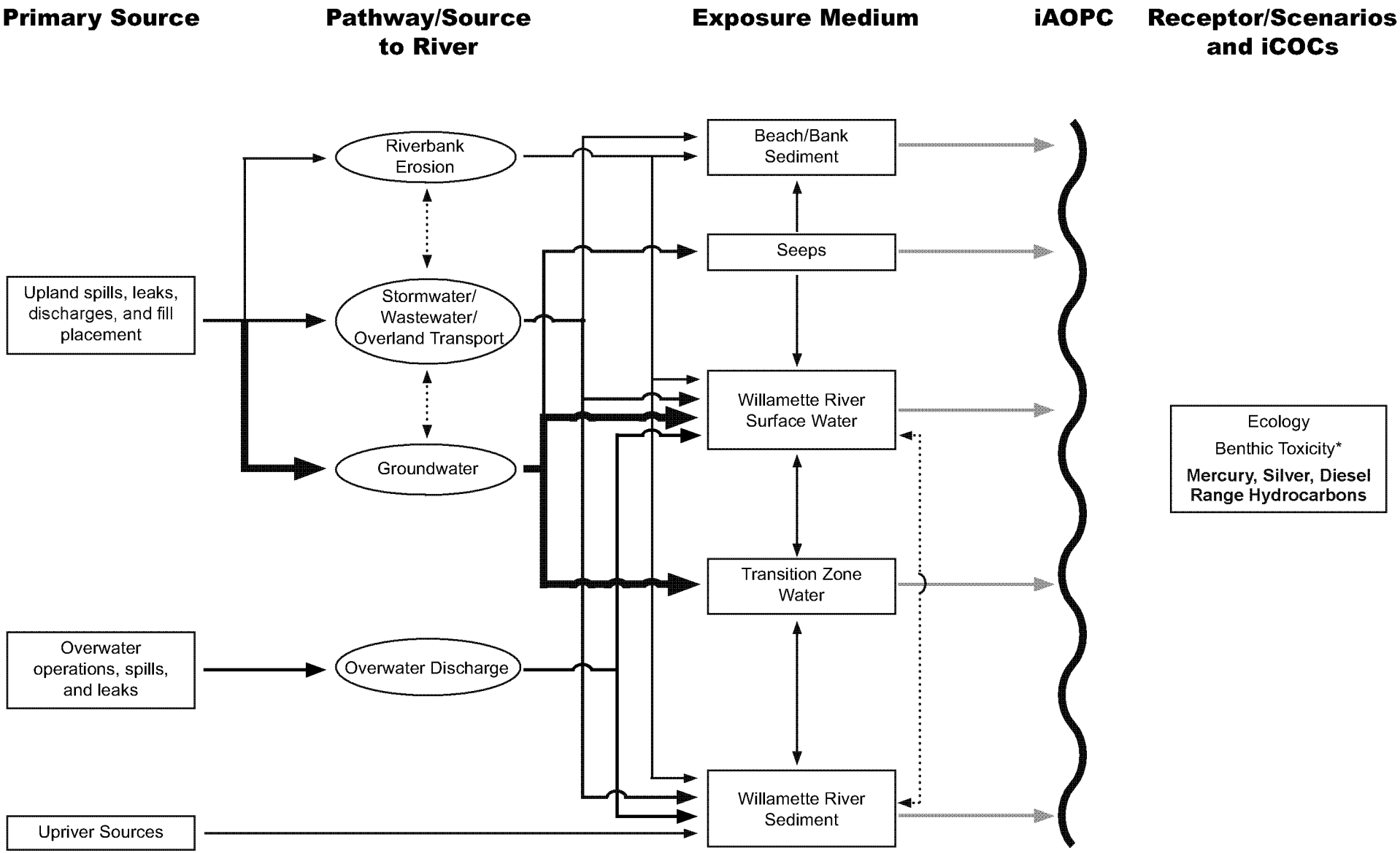
DRAFT

Generalized Geologic Cross Section C-C'

Remedial Investigation
Terminal 4 Slip 1 Upland Facility
Portland, Oregon

Project Number	1065-00	March 2006	Figure
NEWFIELDS	Ash Creek Associates, Inc. Environmental and Geotechnical Consultants	BBL	10

BZTO104(e)031641



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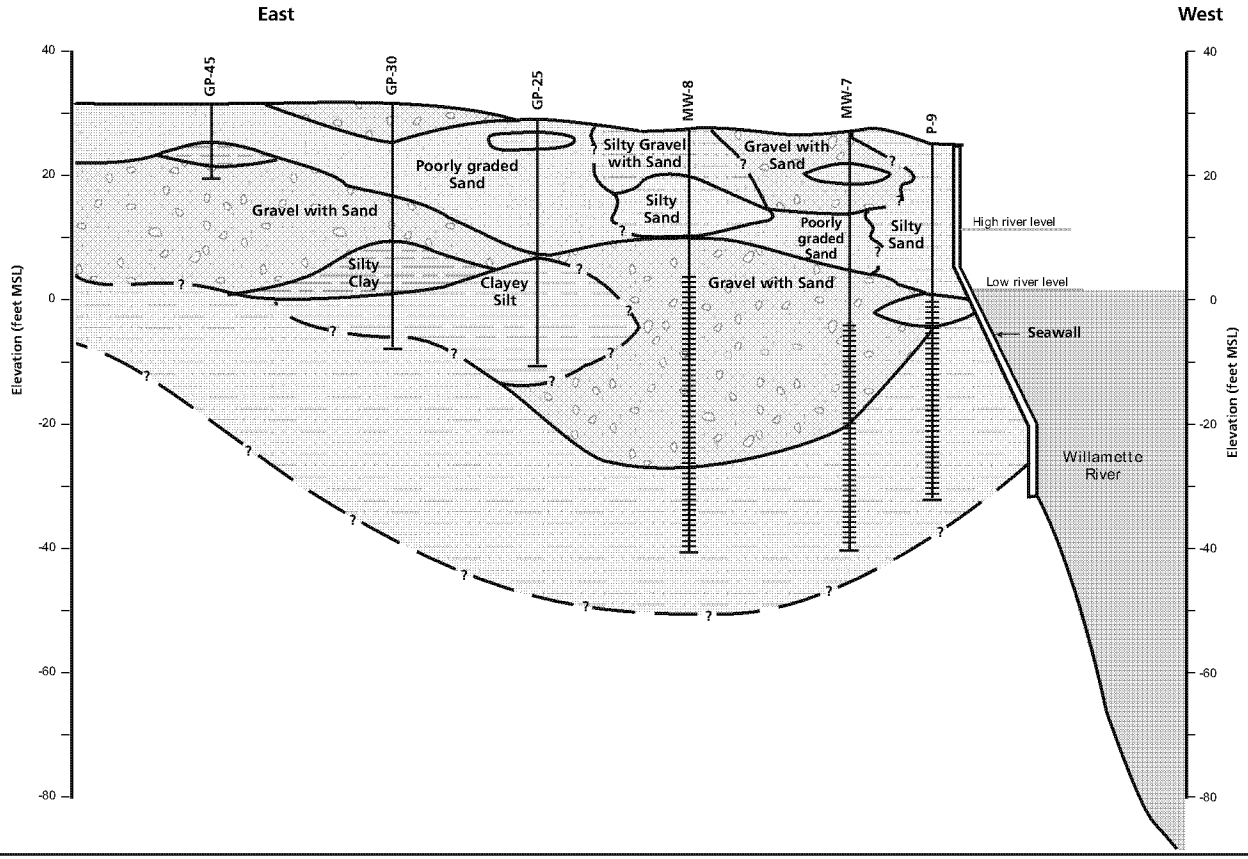
Complete Current and/or Historical Pathway, Relative Contribution Low
Incomplete or Insignificant Pathway
Completeness Unknown
No assessment is made on the relative contribution to iAOPC

Notes:
* = Potenital iCOCs
Bold = Chemicals Mapped for iAOPC CSM

Figure 11.3.5-1
Portland Harbor RI/FS
Comprehensive Round 2 Report
Preliminary Conceptual Site Model Diagram for iAOPC 6

integral consulting inc.
LWG Lower Willamette Group



DO NOT QUOTE OR CITE: This document is under review by US EPA and its federal, state and tribal partners, and is subject to in in whole or part.

LWG Lower Willamette Group

Groundwater Solutions Inc.

LEGEND

0 50 100
HORIZONTAL SCALE IN FEET
VERTICAL EXAGGERATION = 10X

Scale and elevations are approximate.

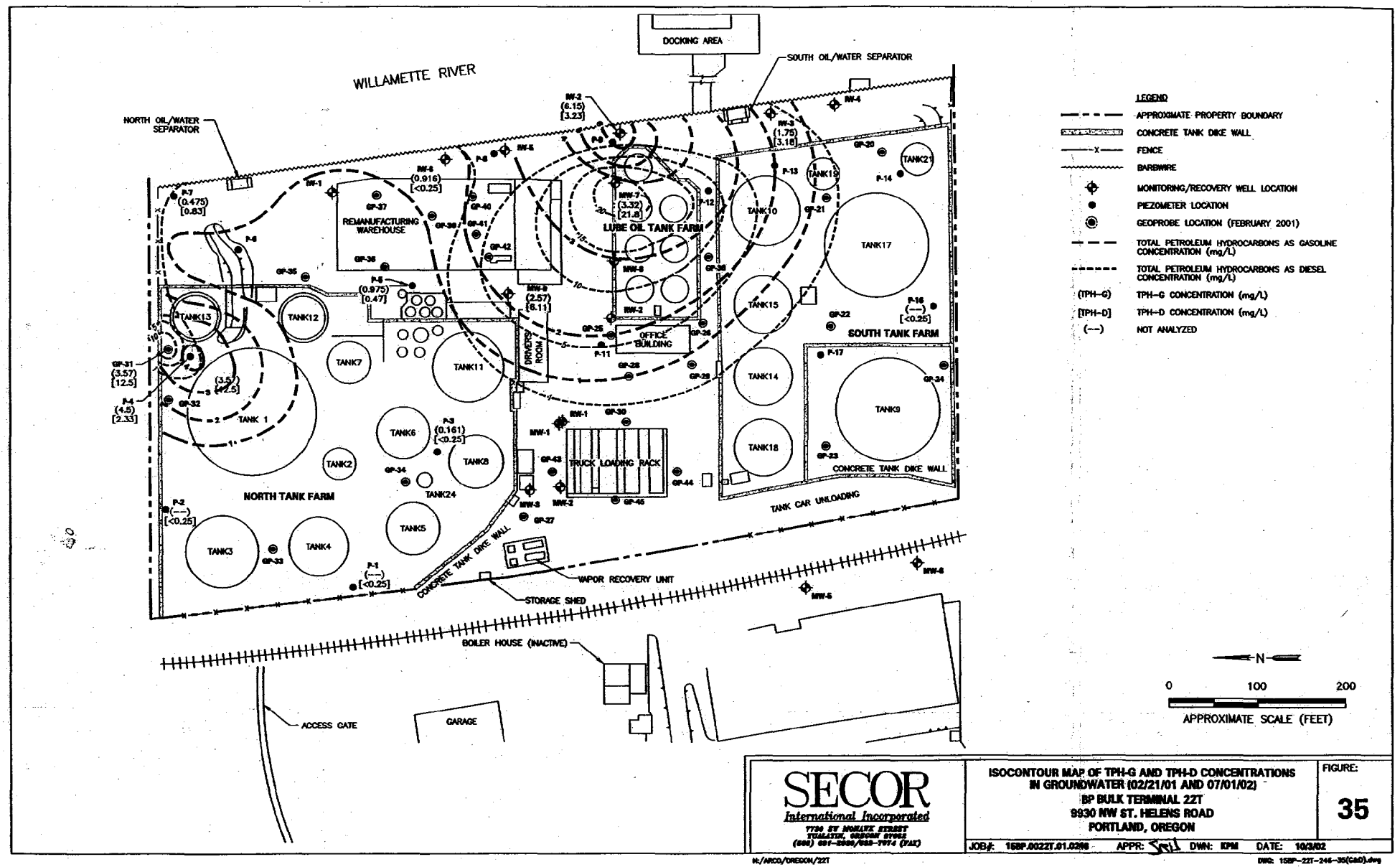
References: Final Remedial Investigation Report, ARCO Terminal 22T (SECOR, 2002) Bathymetric Survey (DEA, 2002)

LW-6D — Boring/Well ID
Surface elevation along profile
Groundwater level
Boring/Well, Projected
Bottom of boring/well

Pleistocene Flood Deposits (gravel):
- Gravel with Sand

Pleistocene Flood Deposits and Recent Alluvium (undifferentiated sand and silt):
- Silty Sand
- Poorly Graded Sand
- Silty Gravel with Sand
- Silty Clay
- Clayey Silt

Figure 2
Portland Harbor RI/FS
Hydrogeologic Cross Section
ARCO Terminal 22T
GROUNDWATER SOLUTIONS, INC.



SECOR International Incorporated
9720 SW MONLUX STREET
TIGARD, OREGON 97223
(503) 671-2000/620-7974 (FAX)

ISOCONTOUR MAP OF TPH-G AND TPH-D CONCENTRATIONS IN GROUNDWATER (02/21/01 AND 07/01/02)
BP BULK TERMINAL 22T
9930 NW ST. HELENS ROAD
PORTLAND, OREGON

FIGURE: 35

JOB#: 15BP.0022T.01.0206 APPR: SMH DWN: KPM DATE: 10/3/02

H:/ARCO/OREGON/22T

DWG: 15BP-22T-246-35(CAD).dwg

BZTO104(e)031644

DRAFT

Groundwater Solutions Inc.

LWG
LOWER WILLAMETTE GROUP

0 100 200 Feet

FEATURE SOURCES:
Transportation, Water, Property, Zoning or Boundaries: Metro RLIS.
ECSI site locations were summarized in December, 2002
and January, 2003 from ODEQ ECSI files.

Map Creation Date: August 11, 2004

File Name: Fig3_ARCO_SummaryMap.mxd

LEGEND

Site Boundary
Maximum Detection Location
General Groundwater Flow

Contaminant Type
Petroleum related

Extent of Impacted Groundwater
For details, refer to plume interpretation table in CSM document.

Single or isolated detection of COI's. Extent or continuity of impacted groundwater between sample points is uncertain. Color based on contaminant type.

Estimated extent of impacted groundwater area. Color based on contaminant type.

Figure 3
Portland Harbor RI/FS
ARCO Terminal 22-T
Upland Groundwater Quality Overview

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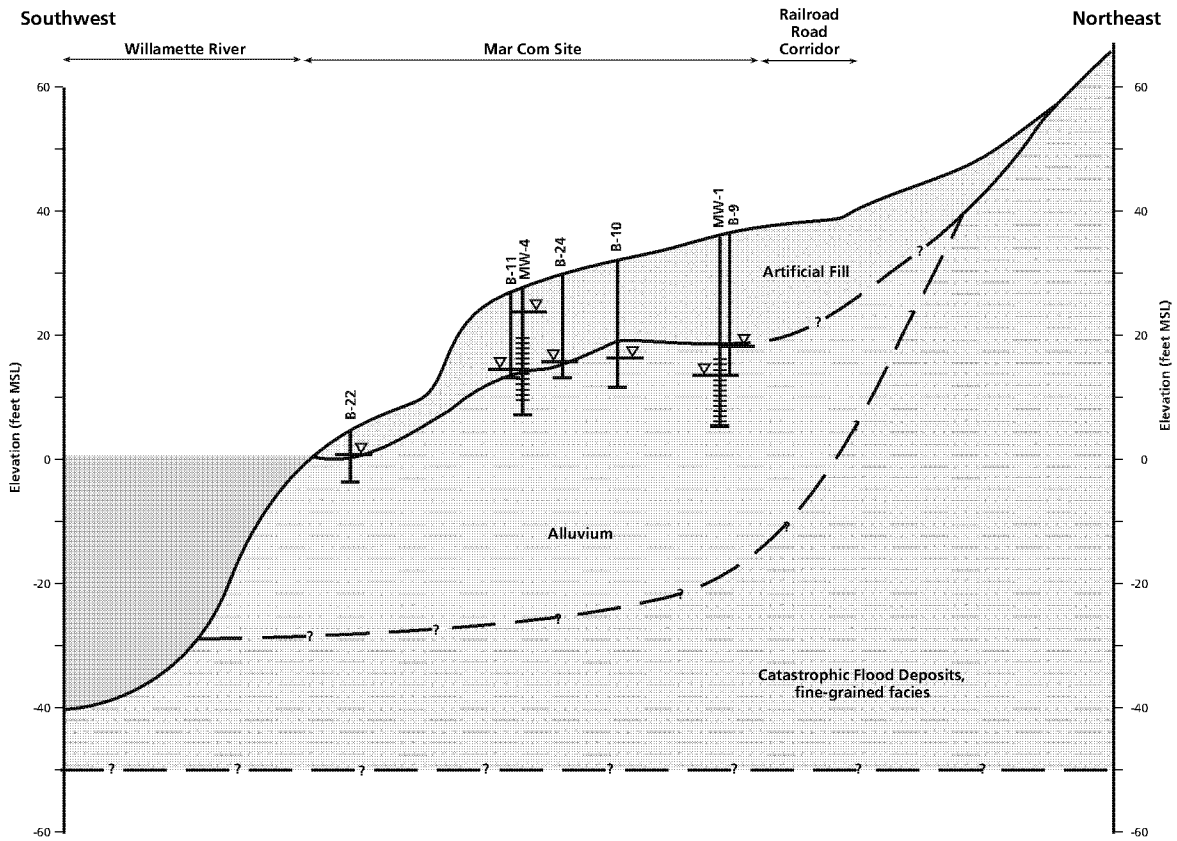
This document is currently under review by US EPA and its federal, state and tribal partners, and is subject to change in whole or part.



Privileged and Confidential Document
Prepared in Anticipation of Litigation.

LWG Lower Willamette Group

Groundwater Solutions Inc.

LEGEND

0 20 40
HORIZONTAL SCALE IN FEET
VERTICAL SCALE: 1" = 115'

Scale and elevations are approximate.

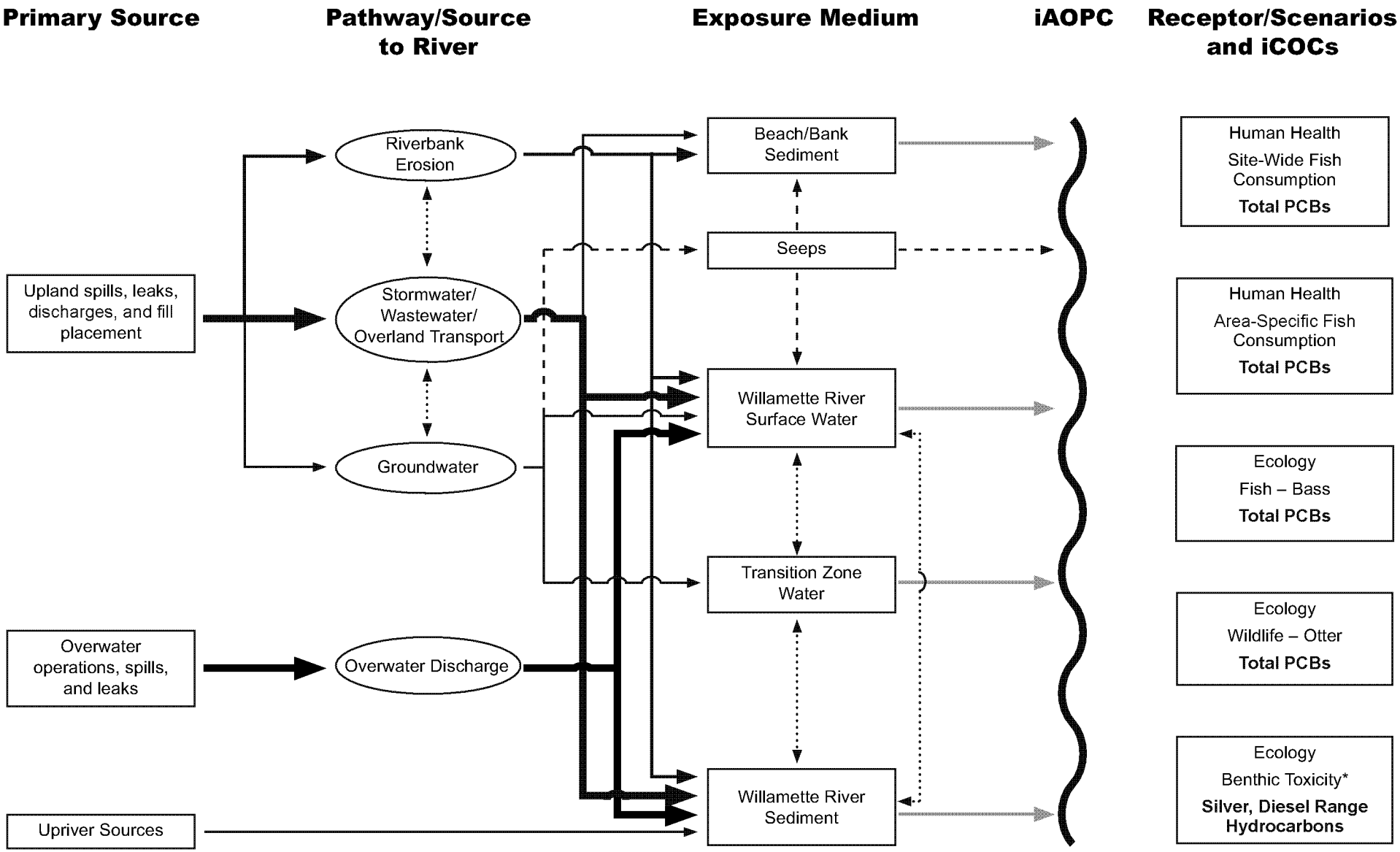
References: Expanded Preliminary Assessment, MarCom Ship Repair Facility (Parametrix, 2002) Bathymetric Survey (DEA, 2002)

Note: Mostly interbedded silt and sand was noted on the boring logs.

LW-6D — Boring/Well ID
Surface elevation along profile
Groundwater level
Groundwater Flow
Boring/Well, Projected
Well screen
Bottom of boring/well

Artificial Fill — Fill
Alluvium
Catastrophic Flood Deposits, fine-grained facies — Pleistocene Flood Deposits and Recent Alluvium (undifferentiated sand and silt)

Figure 11.3.6-1
Portland Harbor RI/FS
Comprehensive Round 2 Report
Hydrogeologic Cross Section - Mar Com
GROUNDWATER SOLUTIONS, INC.



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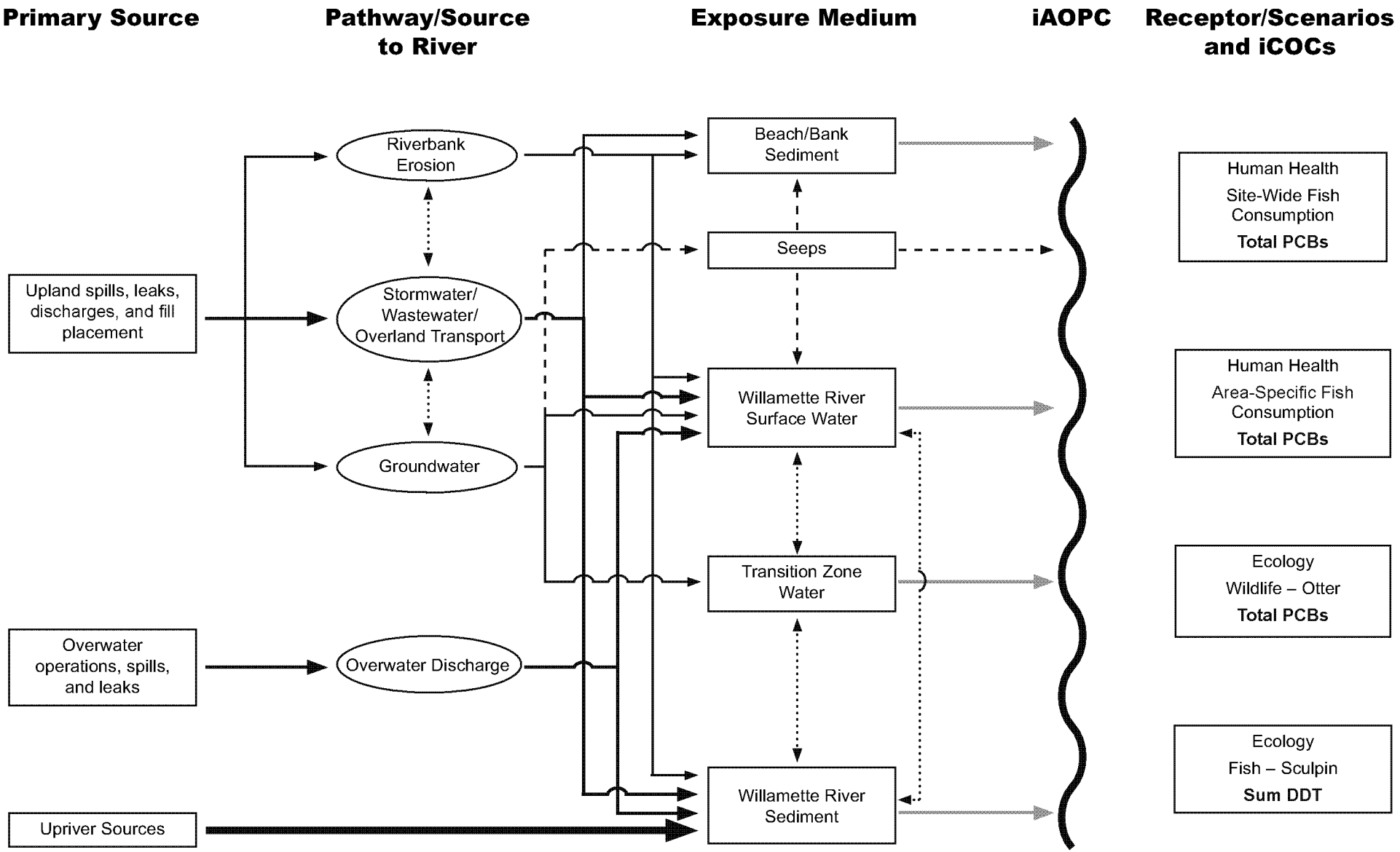
Complete Current and/or Historical Pathway, Relative Contribution Low
Incomplete or Insignificant Pathway
Completeness Unknown
No assessment is made on the relative contribution to iAOPC

Notes:
* = Potenital iCOCs
Bold = Chemicals Mapped for iAOPC CSM

Figure 11.3.6-2
Portland Harbor RI/FS
Comprehensive Round 2 Report
Preliminary Conceptual Site Model Diagram for iAOPC 7

integral consulting inc.
LWG Lower Willamette Group

BZTO104(e)031647



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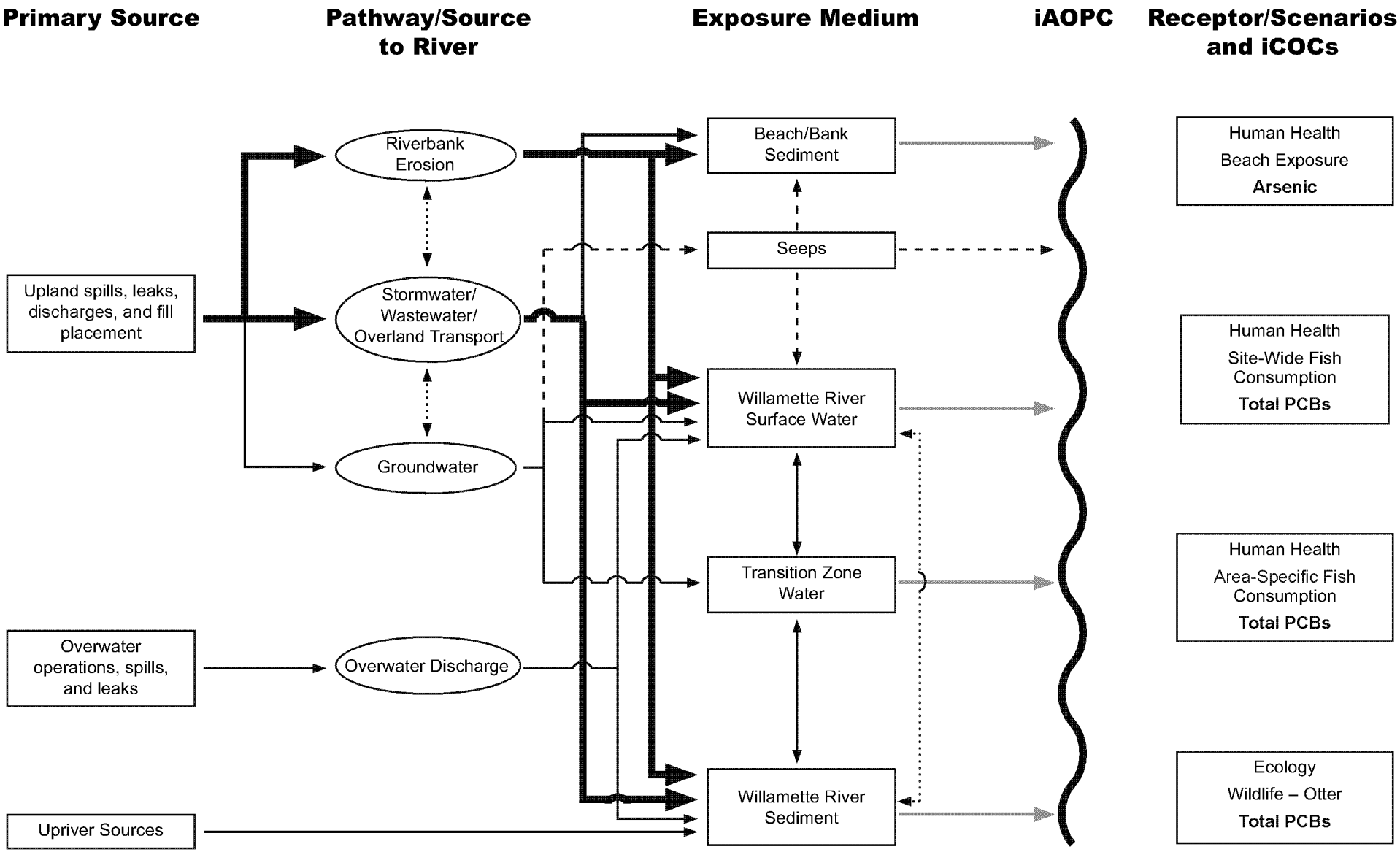
Complete Current and/or Historical Pathway, Relative Contribution Low
Incomplete or Insignificant Pathway
Completeness Unknown
No assessment is made on the relative contribution to iAOPC

Notes:
* = Potenital iCOCs
Bold = Chemicals Mapped for iAOPC CSM

Figure 11.3.7-1
Portland Harbor RI/FS
Comprehensive Round 2 Report
Preliminary Conceptual Site Model Diagram for iAOPC 8 and 9

integral consulting inc.
LWG Lower Willamette Group

BZTO104(e)031648



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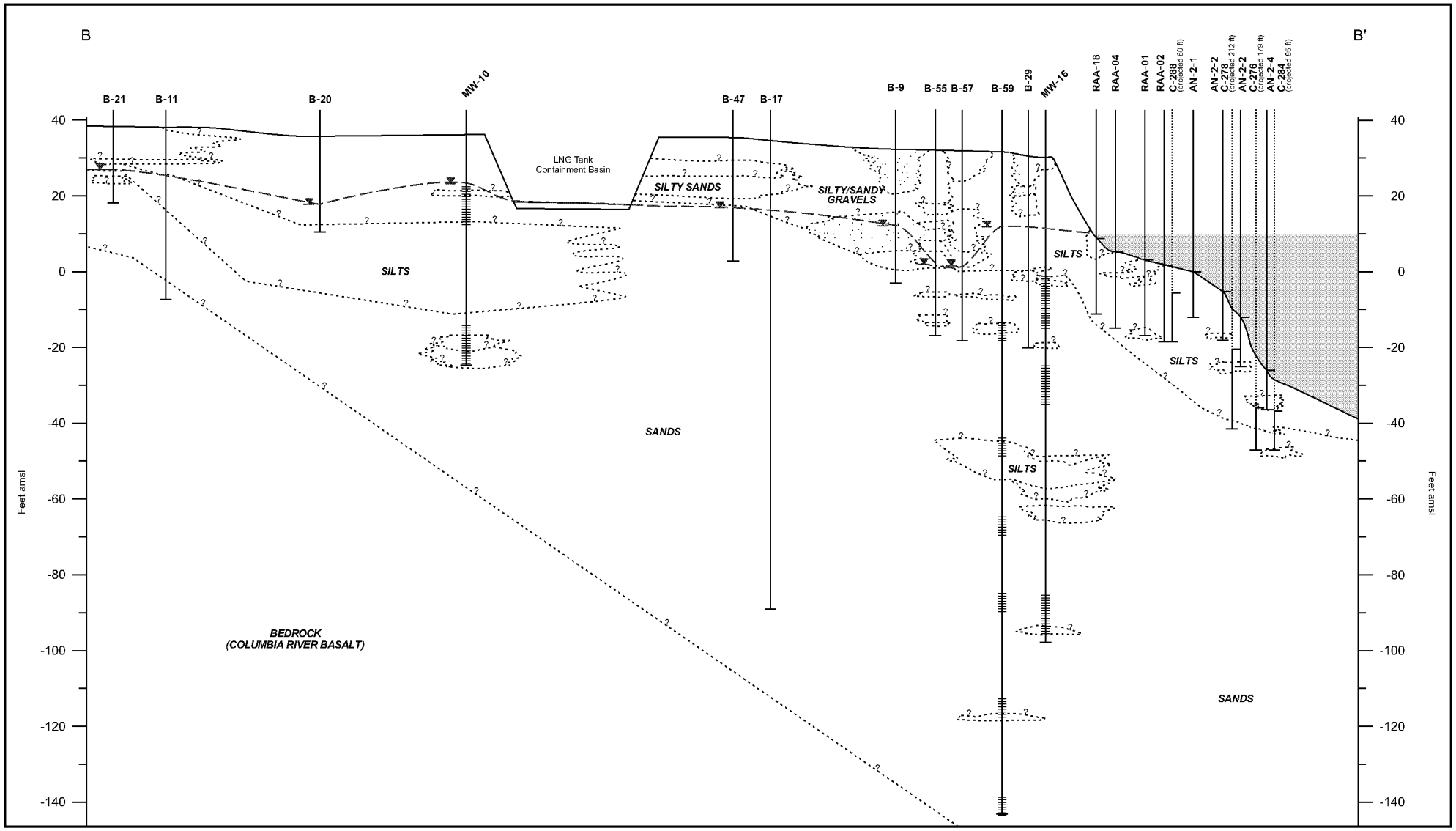
Complete Current and/or Historical Pathway, Relative Contribution Medium
Complete Current and/or Historical Pathway, Relative Contribution Low
Incomplete or Insignificant Pathway
Completeness Unknown
No assessment is made on the relative contribution to iAOPC

Notes:
* = Potenital iCOCs
Bold = Chemicals Mapped for iAOPC CSM

Figure 11.3.8-1
Portland Harbor RI/FS
Comprehensive Round 2 Report
Preliminary Conceptual Site Model Diagram for iAOPC 10

integral consulting inc.
LWG Lower Willamette Group

BZTO104(e)031649



integral

LWG

Base features from Hahn and Associates, Inc., 2004.

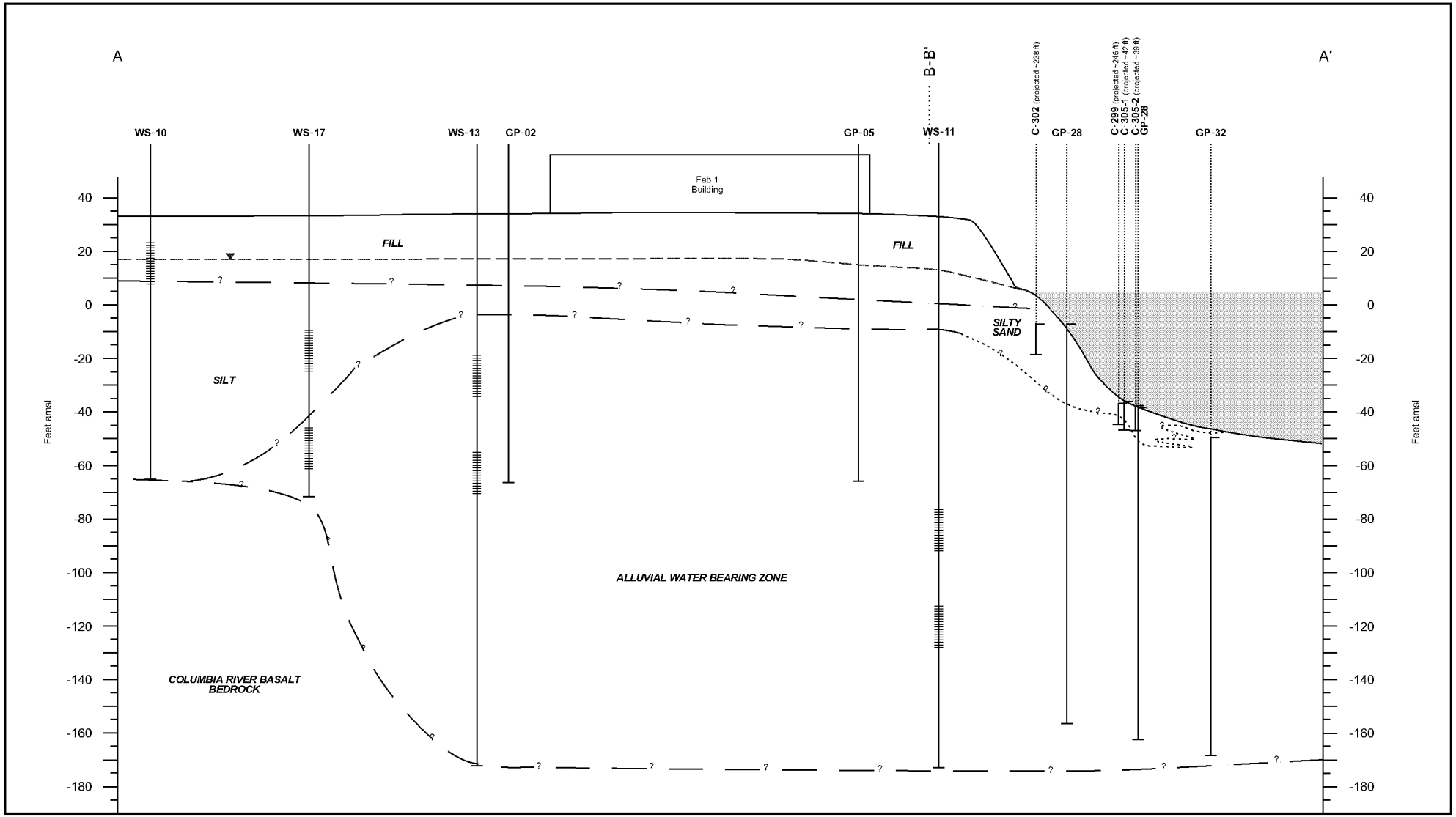
Offshore core and surface grab data adapted from Round 2 sampling events, Integral Consulting, Inc. 2004-2005.

Measured apparent groundwater elevation

0 20 40 Feet
Vertical scale

0 100 200 Feet
Horizontal scale

Figure 11.3.9-1a
Portland Harbor RI/FS
Round 2 Groundwater Pathway Assessment SAP
Attachment 2 Transition Zone Water FSP Addendum 1
Gasco Geologic Cross Section B-B'



integral LWG

Base features from Maul Foster Alongi, Inc., 2005.

Measured apparent groundwater elevation

0 30 60 Feet
Vertical scale
0 100 200
Horizontal scale

Figure 11.3.9-1b
Portland Harbor RI/FS
Round 2 Groundwater Pathway Assessment SAP
Attachment 2 Transition Zone Water FSP Addendum 1
Siltronic Geologic Cross Section A-A'

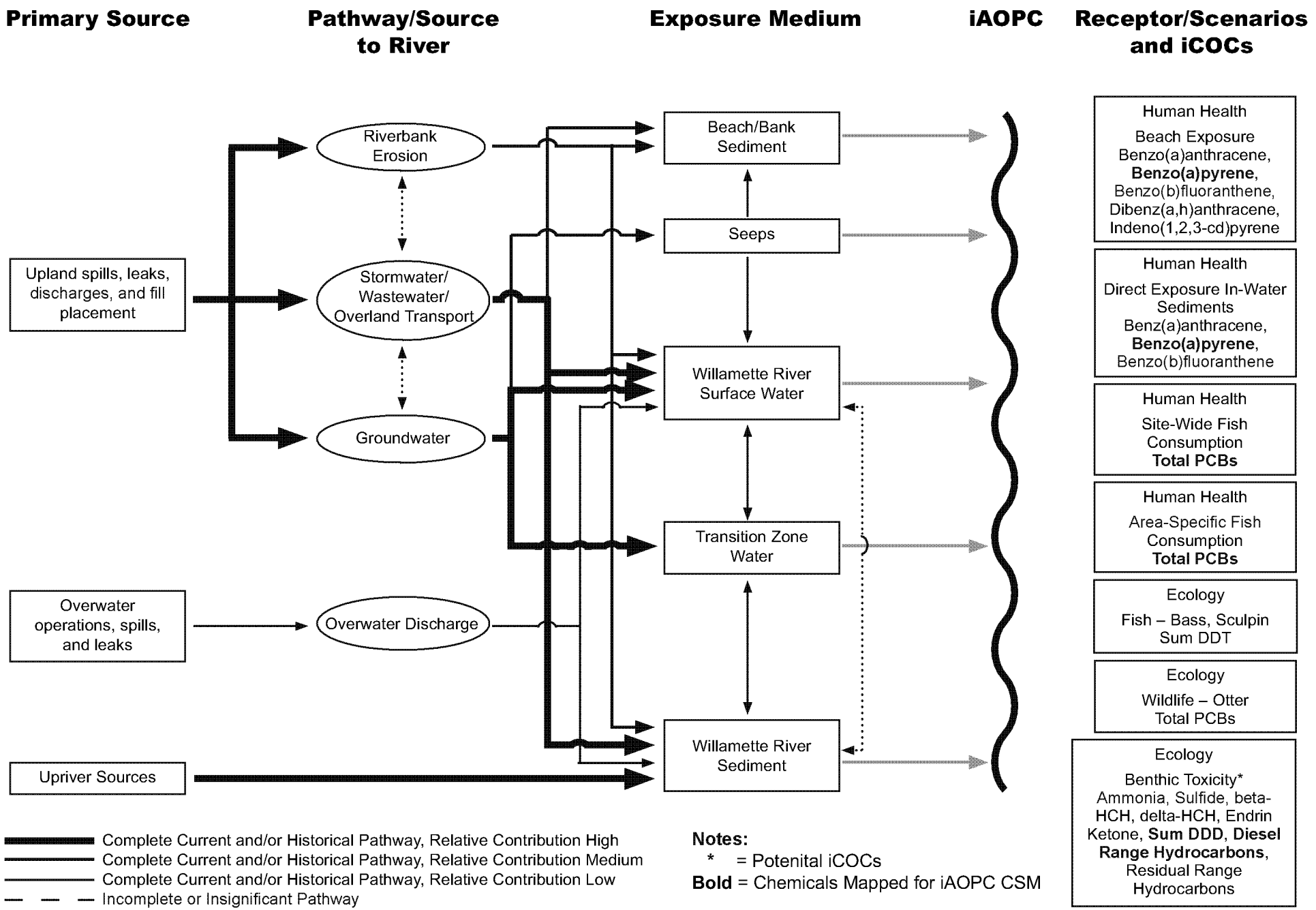
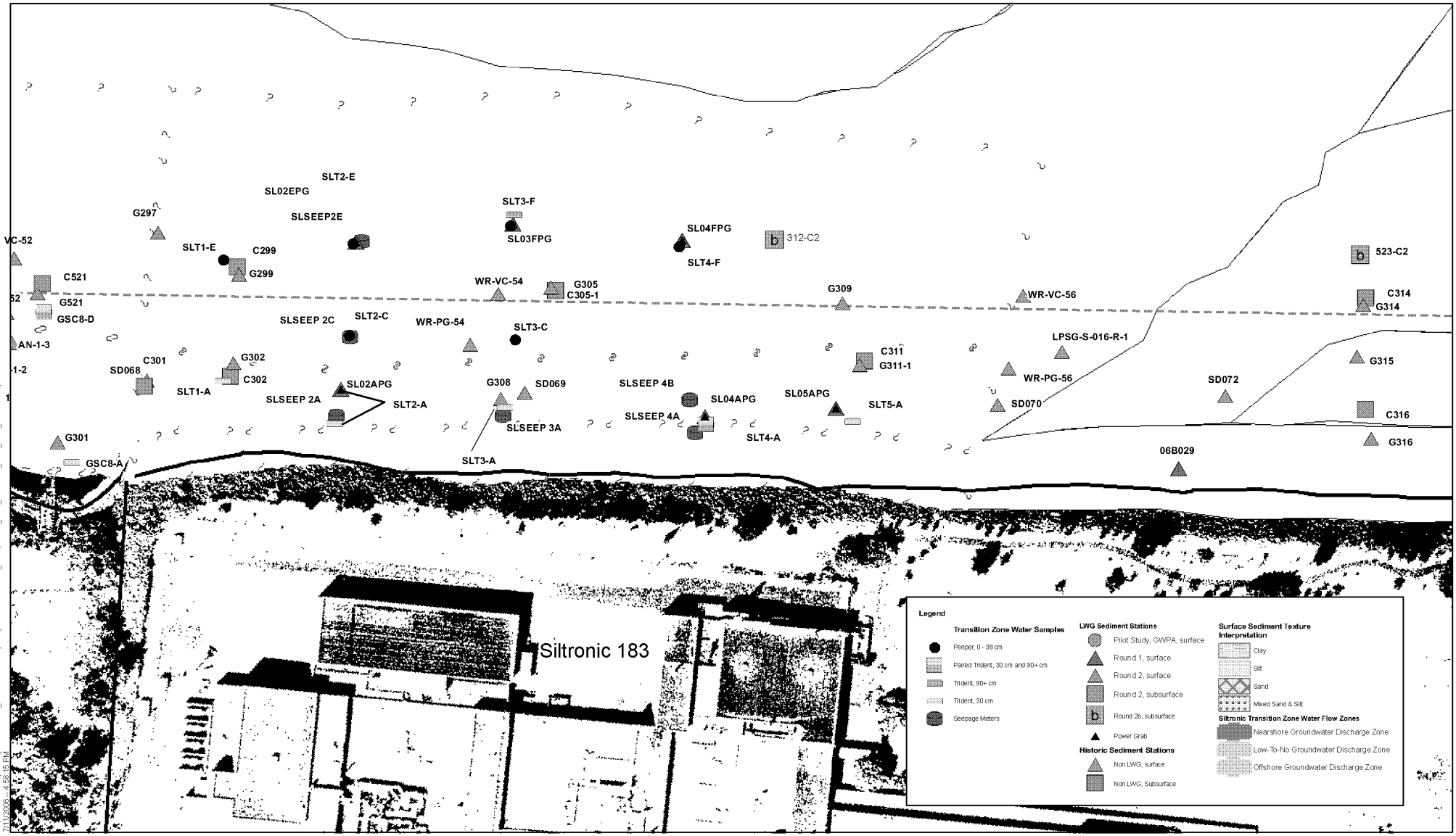


Figure 11.3.9-2
Portland Harbor RI/FS
Comprehensive Round 2 Report
Preliminary Conceptual Site Model Diagram for iAOPC 11

integral consulting inc.
LWG Lower Willamette Group



Map Document: (O:\Projects\Portland_Harbor\LWG-Map-Projects\Groundwater_Workplan\all_sites_Sediment_TZW_Flow_Zones.mxd)
7/12/2006 8:56 AM

integral consulting inc.

LWG Lower Willamette Group

FEATURE SOURCES:
RLIS Aerial Images of February 2005 'leaf off' flight (6" pixel).
Transportation, Property, or Boundaries: Metro RLIS.
Channel & River miles: US Army Corps of Engineers.
Bathymetric Information: David Evans and Associates, Inc., Winter 2004

N

0 25 50 100 150 Feet

Navigation Channel
Site Property Boundary
Docks & In-water Structures

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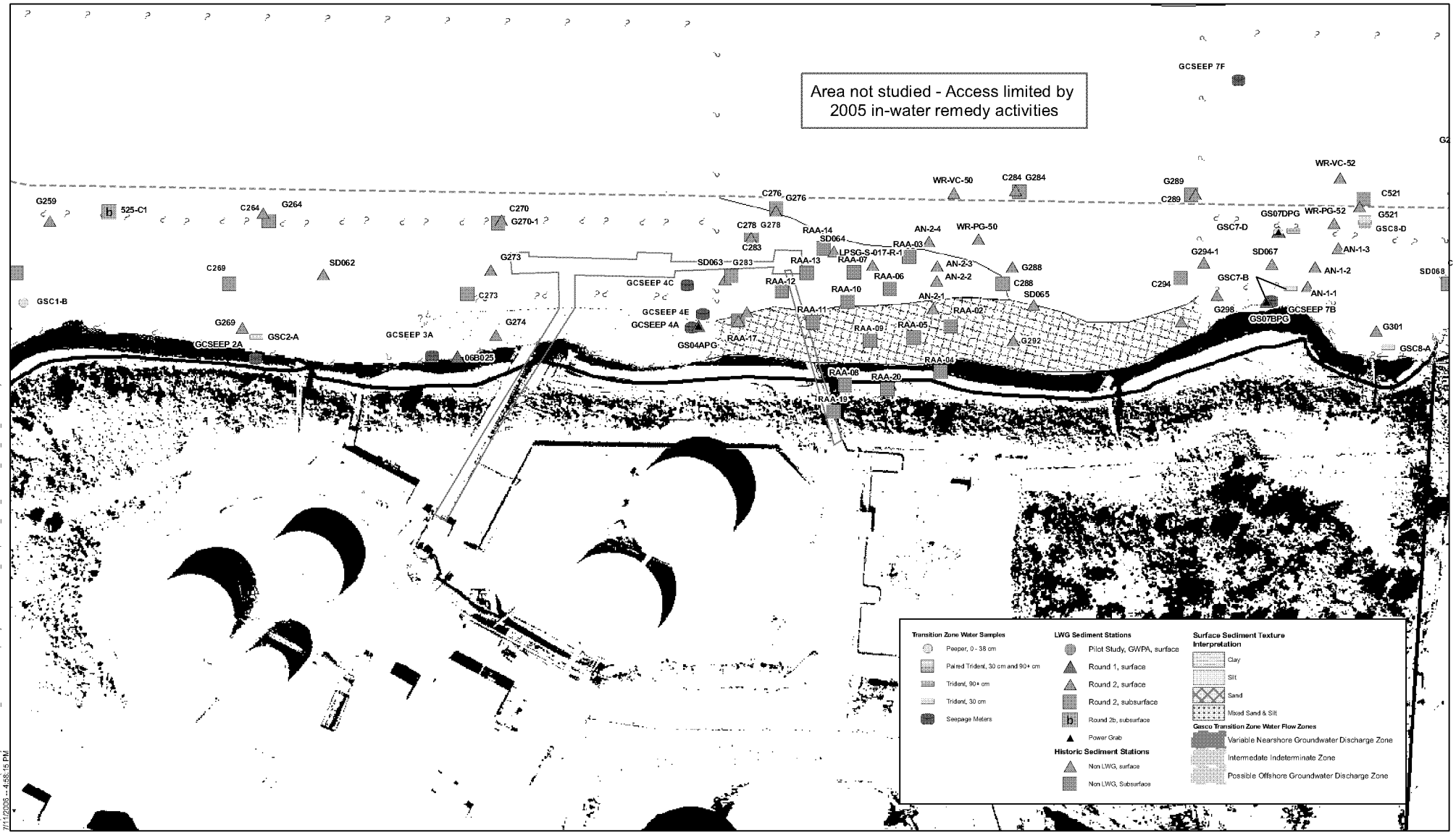
This document is currently under review by US EPA and its federal, state, and tribal partners, and is subject to change in whole or in part.
Privileged and Confidential

Figure 8-7
Portland Harbor RI/FS
Round 2 Groundwater Pathway Assessment
Site Characterization Summary Report
Siltronic Interpreted Groundwater Discharge Areas - Flow Zones



Map Document: (O:\Projects\Portland_Harbor\LWG-Map-Projects\Groundwater_Workplan\all_sites_Sediment_TZW_Flow_Zones.mxd)
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integral consulting inc.

LWG
LOWER WILLAMETTE GROUP

FEATURE SOURCES:
RLIS Aerial Images of February 2005 'leaf off' flight (6" pixel),
Transportation, Property, or Boundaries: Metro RLIS.
Channel & River miles: US Army Corps of Engineers.
Bathymetric Information: David Evans and Associates, Inc., Winter 2004

N

0 25 50 100 150 Feet

Navigation Channel
Site Property Boundary
Docks & In-water Structures

DRAFT
DO NOT QUOTE OR CITE
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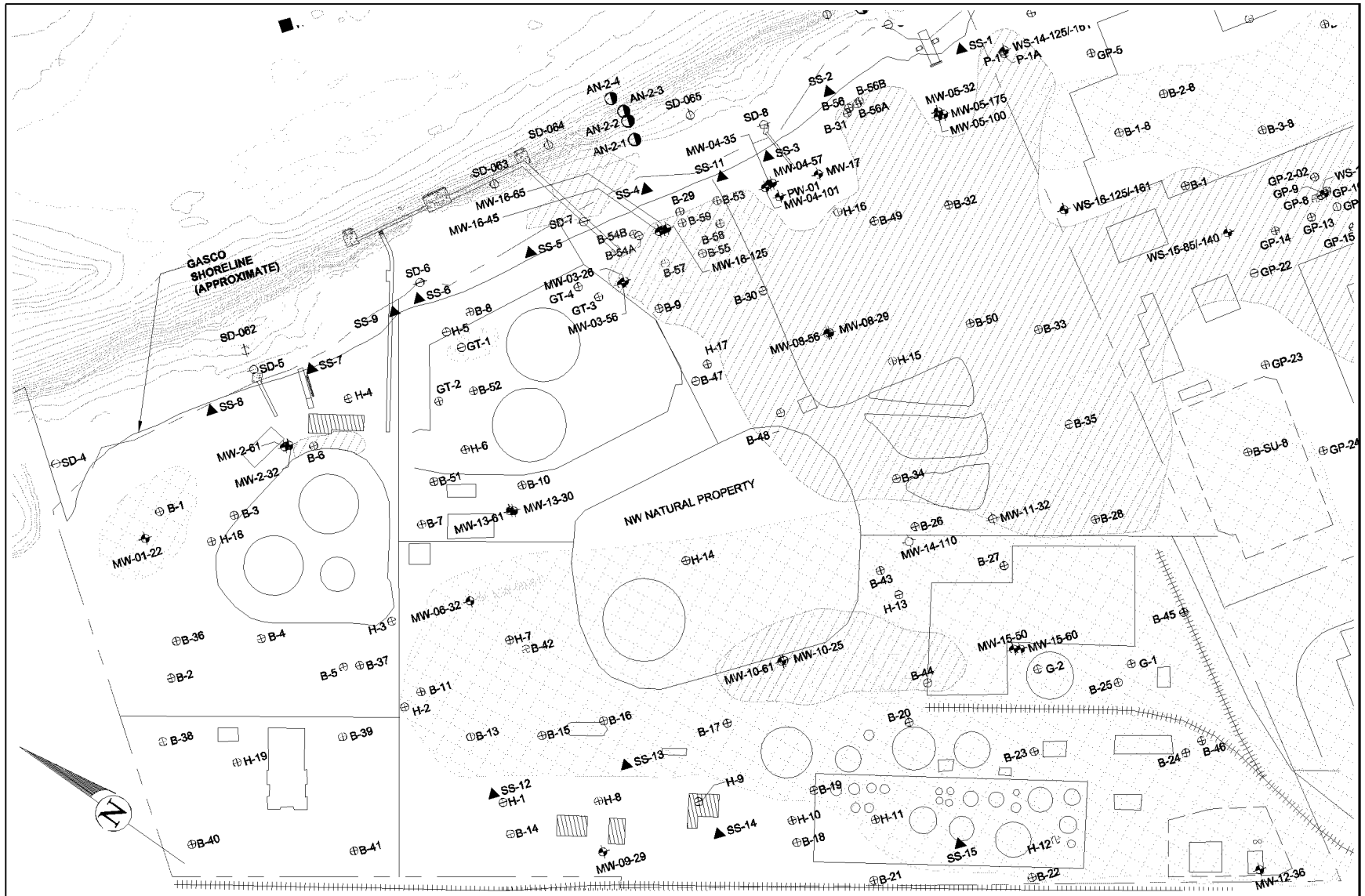
Figure 7-7
Portland HarborRI/FS
Round 2 Groundwater Pathway Assessment
Site Characterization Summary Report
Gasco Interpreted Groundwater Discharge Areas - Flow Zones



LEGEND

- Monitoring Well
- Soil Boring
- 2004 Boring
- Sediment Sample (Anchor)
- Oil in Soils - Surficial Fill Unit
- Tar in Soils - Surficial Fill Unit
- Surficial Tar Body - February 2001 delineation
- Approximate Property Line

HAHN AND ASSOCIATES, INC.

ENVIRONMENTAL CONSULTANTS
434 NW 6th AVENUE, SUITE 203
PORTLAND, OREGON 97209
503-796-0717

1"=100' 0 50' 100' 200' Scale in Feet

Project No. 2708-5237 SEPTEMBER 2005

FIGURE 15
ESTIMATED TAR AND OIL DISTRIBUTION
IN SOIL - SURFICIAL FILL UNIT

NW NATURAL & SILTRONIC PROPERTIES
PORTLAND OREGON

NOTES:
Oil and tar in soils occur as patches, stringers, and layers. Borings within outlined areas identified the presence of oil and/or tar as such an occurance at some depth or depth interval within the fill unit. The magnitude of tarry or oily soil identified at any boring may range from a zone of a few inches to a zone of multiple feet.

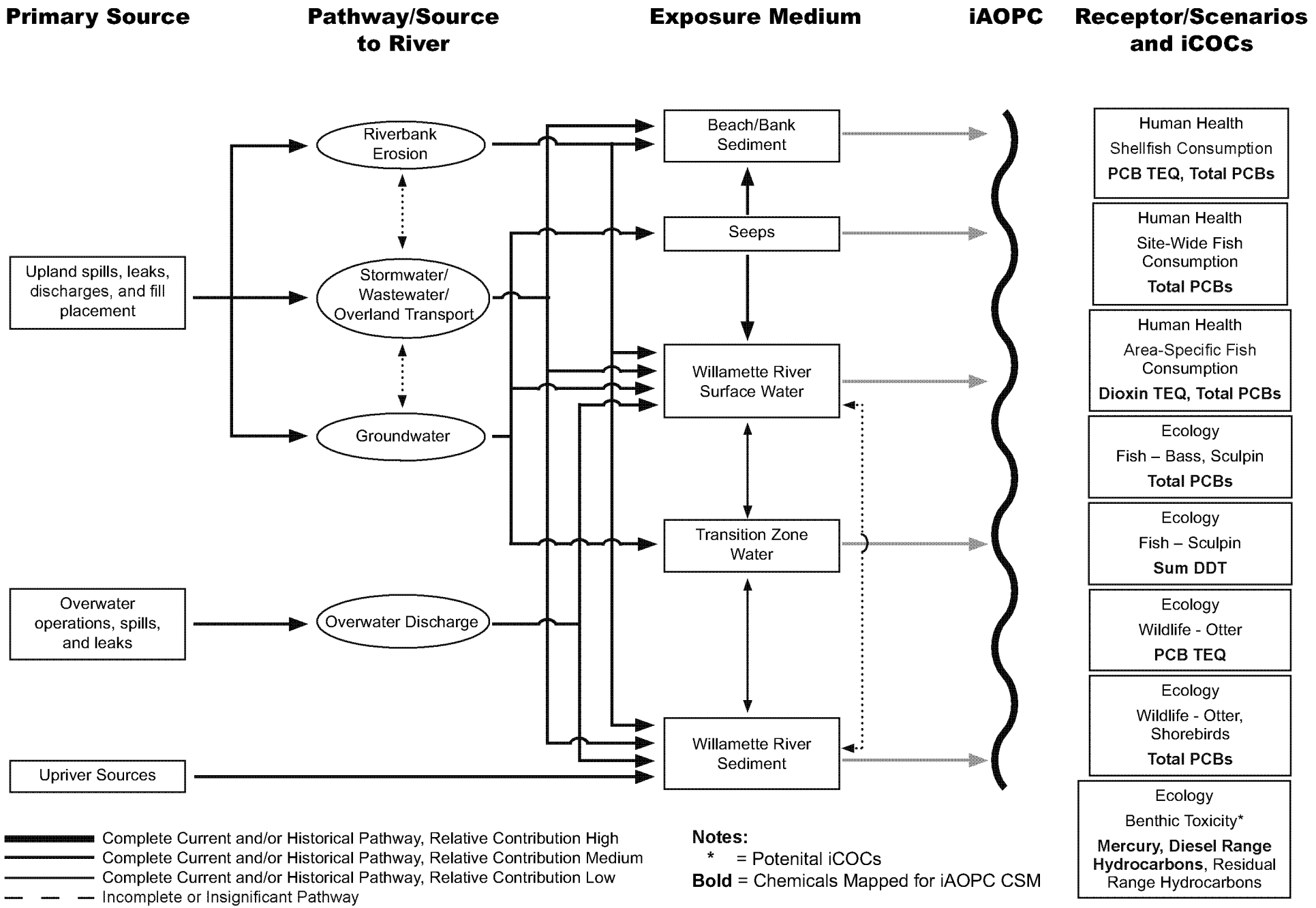


Figure 11.3.10-1
Portland Harbor RI/FS
Comprehensive Round 2 Report
Preliminary Conceptual Site Model Diagram for iAOPCs 12 and 13

integral consulting inc.
LWG Lower Willamette Group

BZTO104(e)031656

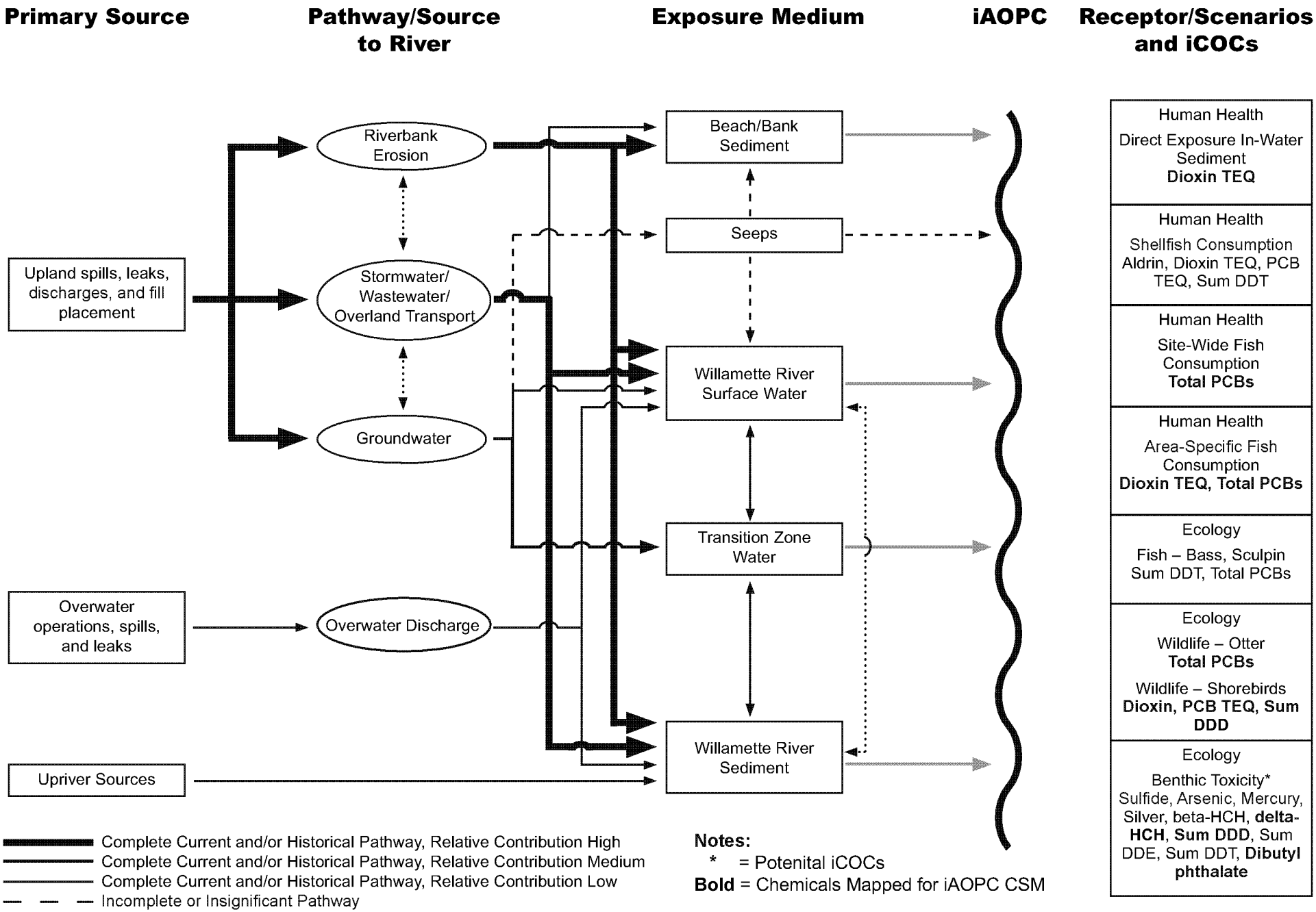
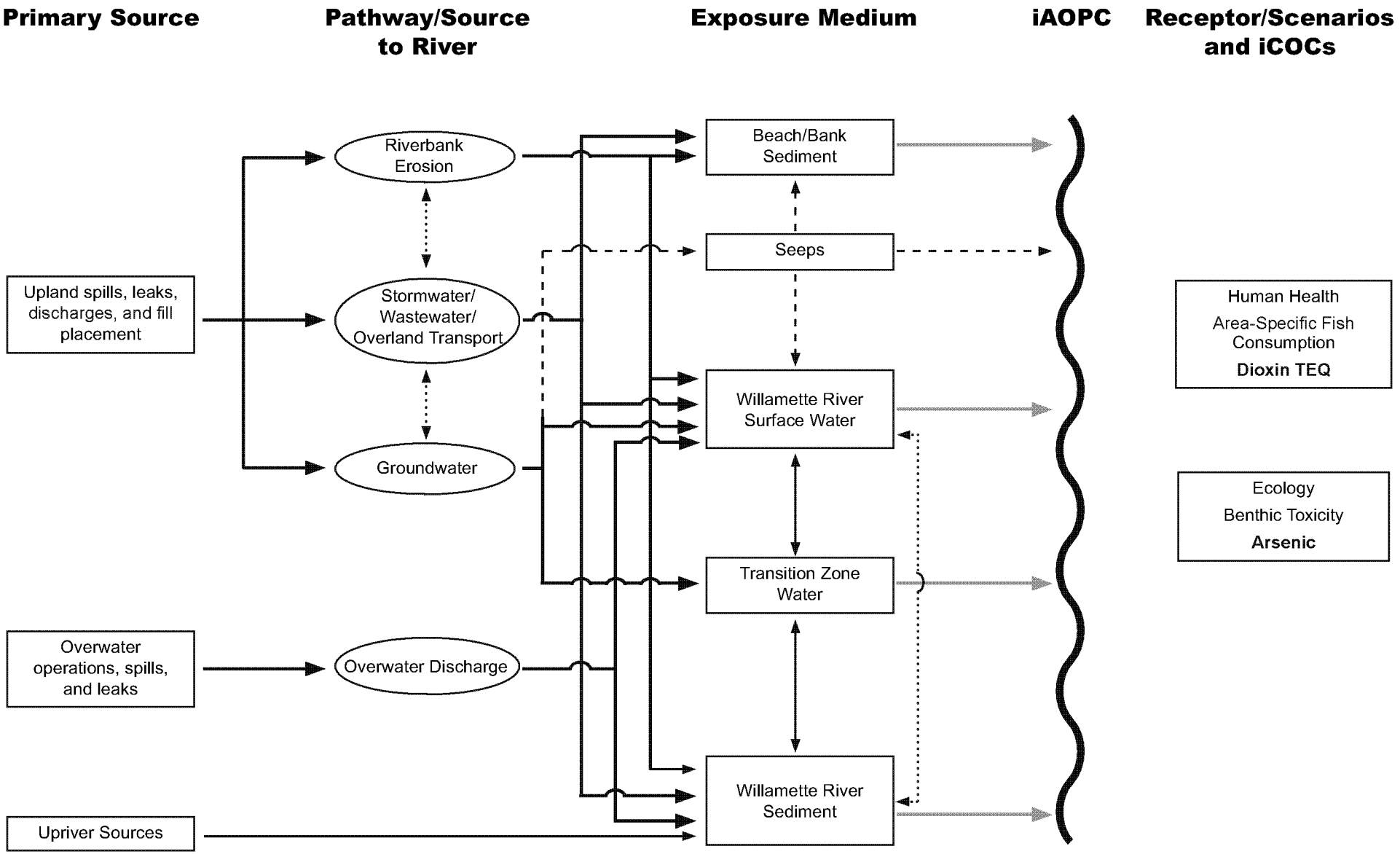


Figure 11.3.11-1
Portland Harbor RI/FS
Comprehensive Round 2 Report
Preliminary Conceptual Site Model Diagram for iAOPC 14

integral consulting inc.
LWG Lower Willamette Group

BZTO104(e)031657

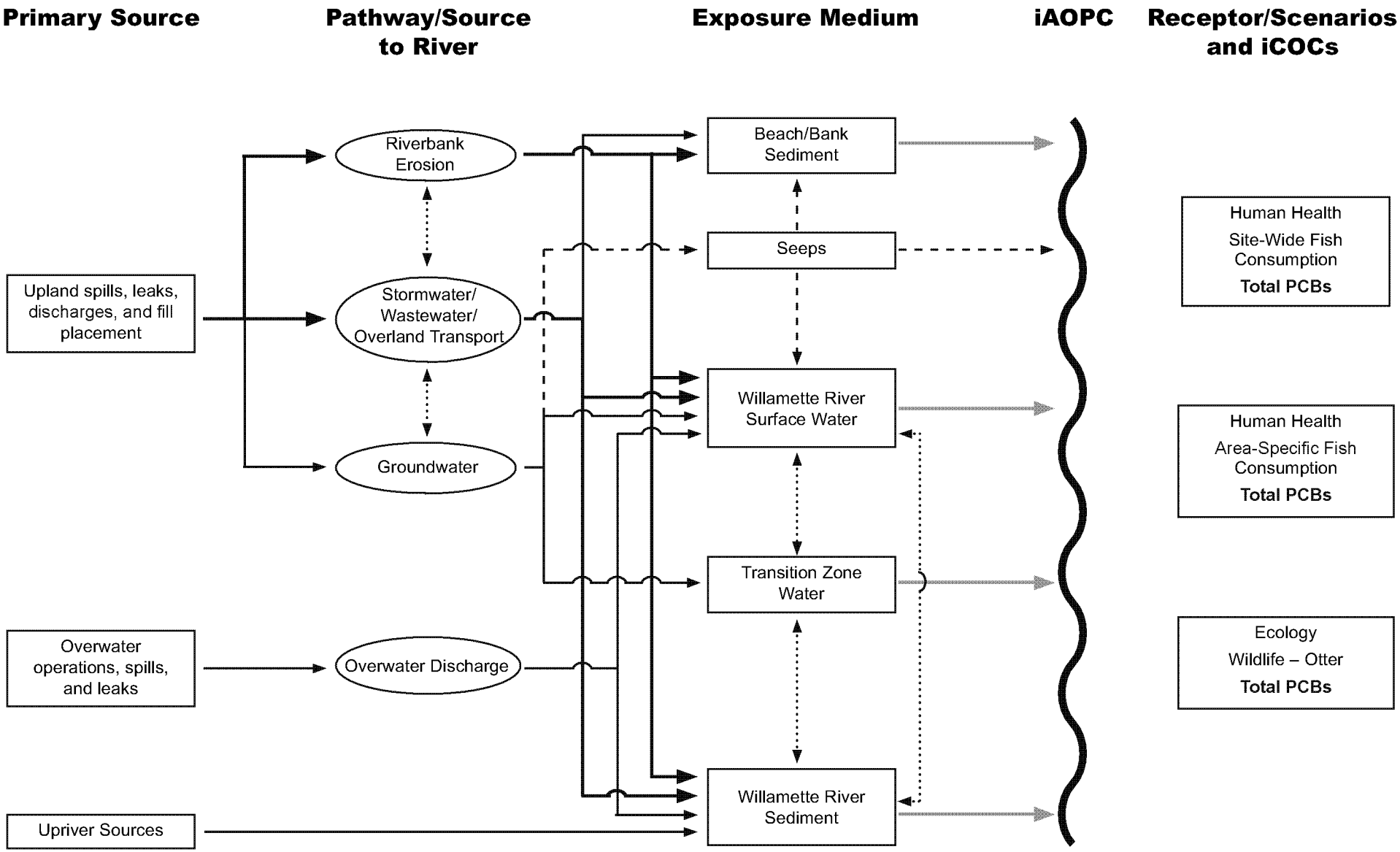


Complete Current and/or Historical Pathway, Relative Contribution High
Complete Current and/or Historical Pathway, Relative Contribution Medium
Complete Current and/or Historical Pathway, Relative Contribution Low
Incomplete or Insignificant Pathway
Completeness Unknown
No assessment is made on the relative contribution to iAOPC

Notes:
* = Potenital iCOCs
Bold = Chemicals Mapped for iAOPC CSM

Figure 11.3.12-1a
Portland Harbor RI/FS
Comprehensive Round 2 Report
Preliminary Conceptual Site Model Diagram for iAOPC 15

integral consulting inc.
LWG Lower Willamette Group

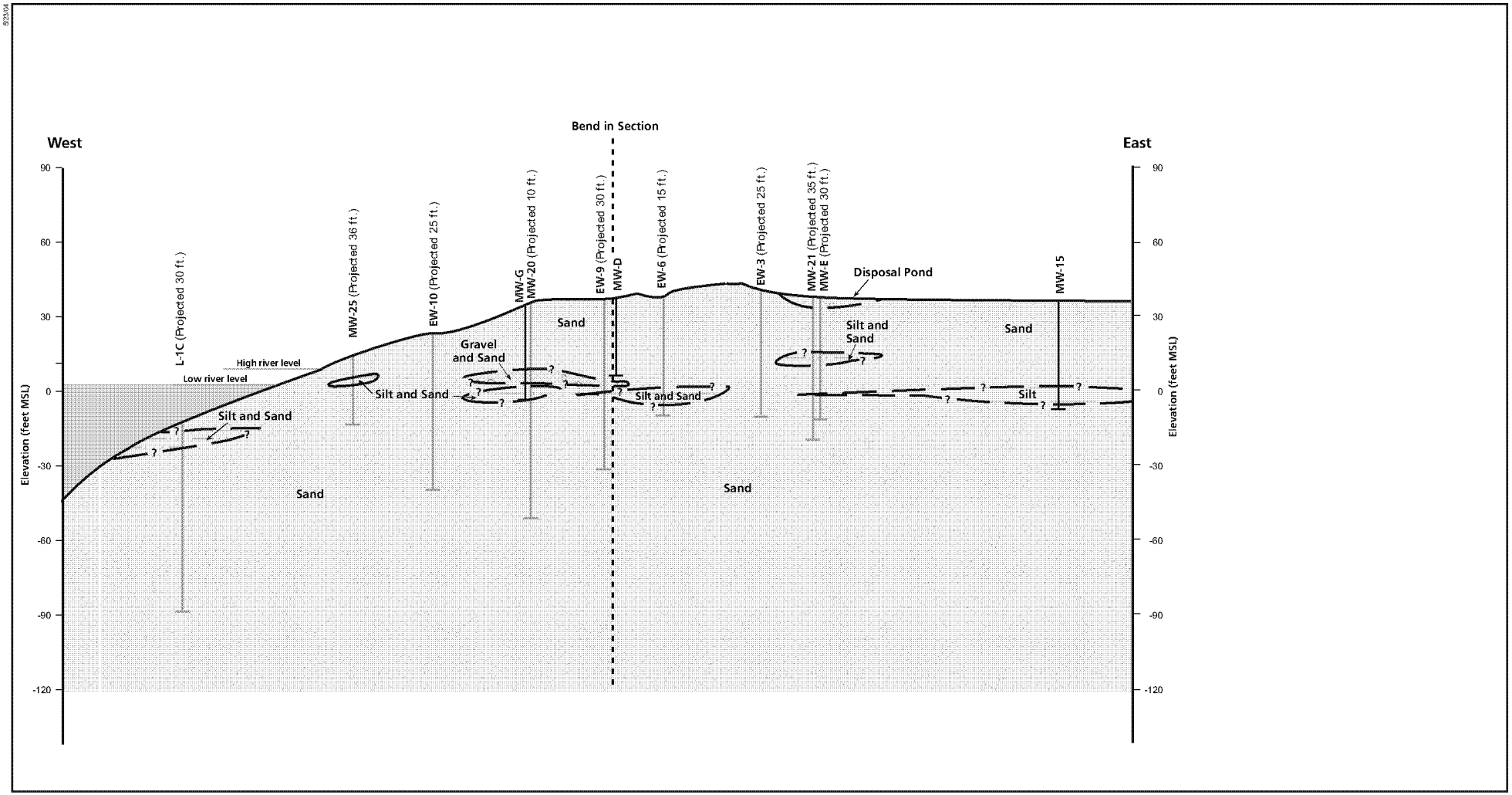


Complete Current and/or Historical Pathway, Relative Contribution High
Complete Current and/or Historical Pathway, Relative Contribution Medium
Complete Current and/or Historical Pathway, Relative Contribution Low
Incomplete or Insignificant Pathway
Completeness Unknown
No assessment is made on the relative contribution to iAOPC

Notes:
* = Potenital iCOCs
Bold = Chemicals Mapped for iAOPC CSM

Figure 11.3.12-1b
Portland Harbor RI/FS
Comprehensive Round 2 Report
Preliminary Conceptual Site Model Diagram for iAOPC 16

integral consulting inc.
LWG Lower Willamette Group



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LWG Lower Willamette Group

Groundwater Solutions Inc.

LEGEND

0 100 200

HORIZONTAL SCALE IN FEET
VERTICAL EXAGGERATION = 2X

Scale and elevations are approximate.

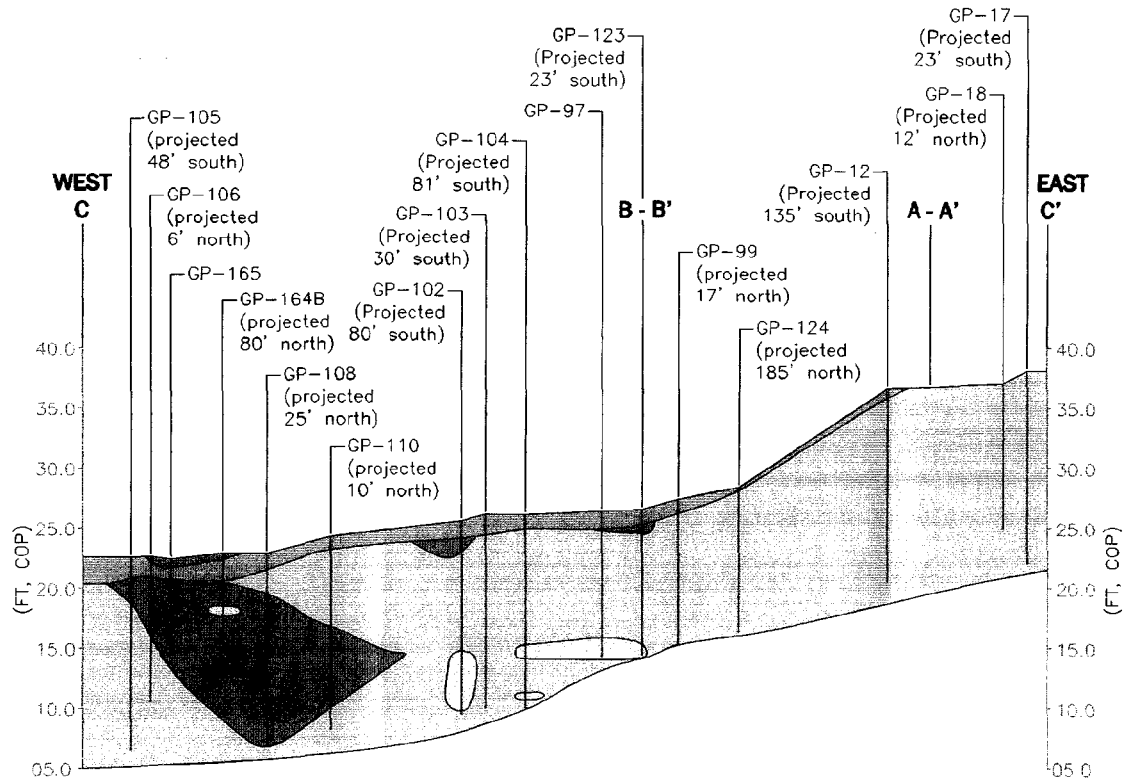
References: Modified from Figures 7 and 15 in Nonaqueous Phase Liquid Transport and Fate and the McCormick and Baxter Site, Barnett, S., 1993 MS Thesis, Portland State University

LW-6D — Boring/Well ID
Surface elevation along profile
Groundwater level
Boring/Well, Projected
Bottom of boring/well

Fill:
- Wood Debris and Sawdust with Sand

Pleistocene Flood Deposits and Recent Alluvium (undifferentiated sand and silt):
- Silt
- Sand, Fine to Medium, Well Sorted
- Interbedded Silt and Medium-Fine Sand
- Gravel and Sand, Well Sorted

Figure 2
Portland Harbor RI/FS
Hydrogeologic Cross Section
McCormick and Baxter
GROUNDWATER SOLUTIONS, INC.



LEGEND:

- SAND (FILL)
- SILT, SANDY SILT (FILL)
- GRAVEL (FILL)
- CONCRETE OR ASPHALT
- WOODY DEBRIS

NOTE:
ELEVATIONS REFERENCED TO CITY OF PORTLAND DATUM (COP-1.375=NGVD)

SCALE IN FEET

HORIZONTAL 0 150 300

VERTICAL 0 10 20

Suite B
7223 NE Hazel Dell Ave.
Vancouver, WA 98665
P 360.694.2691
F 360.906.1958
MAUL FOSTER ALONGI

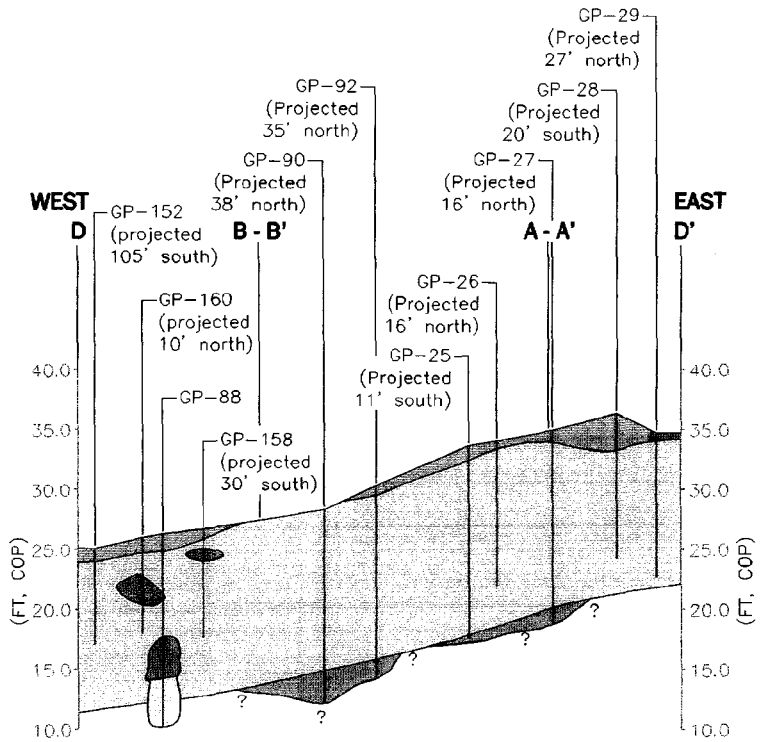
DATE 04/02/02
DWN. JLN
APPR.
REVIS.
PROJECT NO. 8016.01.05

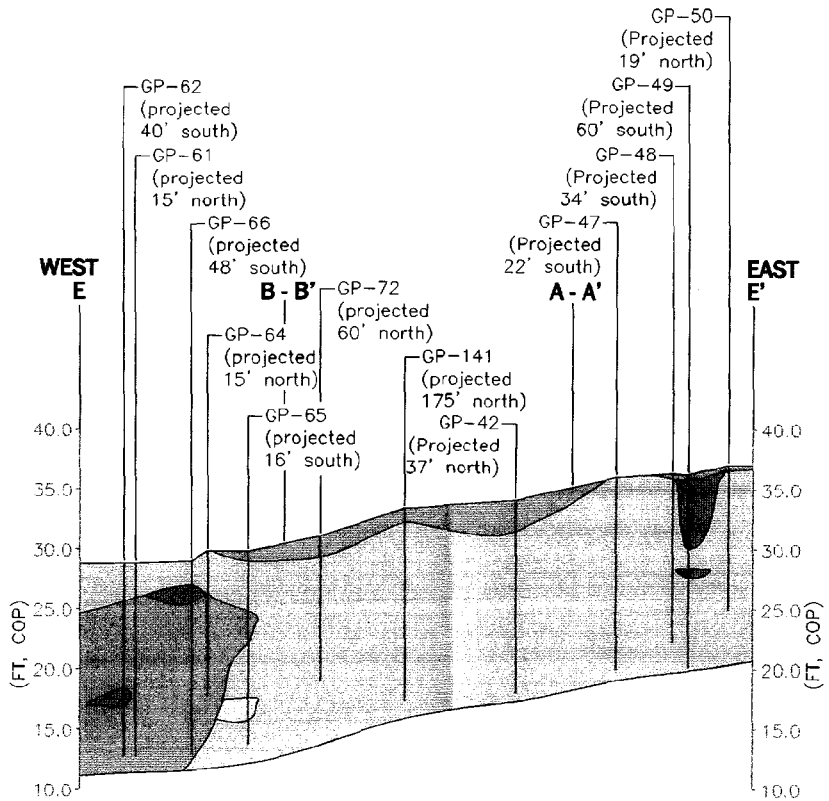
Figure 4-4
TRIANGLE PARK, LLC
PORTLAND, OREGON

GENERALIZED GEOLOGIC CROSS SECTION C-C'

File: G:\8000\8016-TRIANGLE\001\005\PI-2002\001-CROSS SECTIONS.DWG Last edited: JUN 07, 2002 @ 2:21 p.m. by: JNESS Xrefs: sections.xref 50210.dwg

LAYOUT: 3





LEGEND:

- SAND (FILL)
- SILT, SANDY SILT (FILL)
- GRAVEL (FILL)
- CONCRETE OR ASPHALT
- SAND (Qal)
- WOODY DEBRIS

NOTE:
ELEVATIONS REFERENCED TO CITY OF PORTLAND DATUM
(COP-1.375=NGVD)

SCALE IN FEET

HORIZONTAL 0 150 300

VERTICAL 0 10 20

Suite B
7223 NE Hazel Dell Ave.
Vancouver, WA 98665
P 360.694.2691
F 360.906.1958
MAUL FOSTER ALONGI

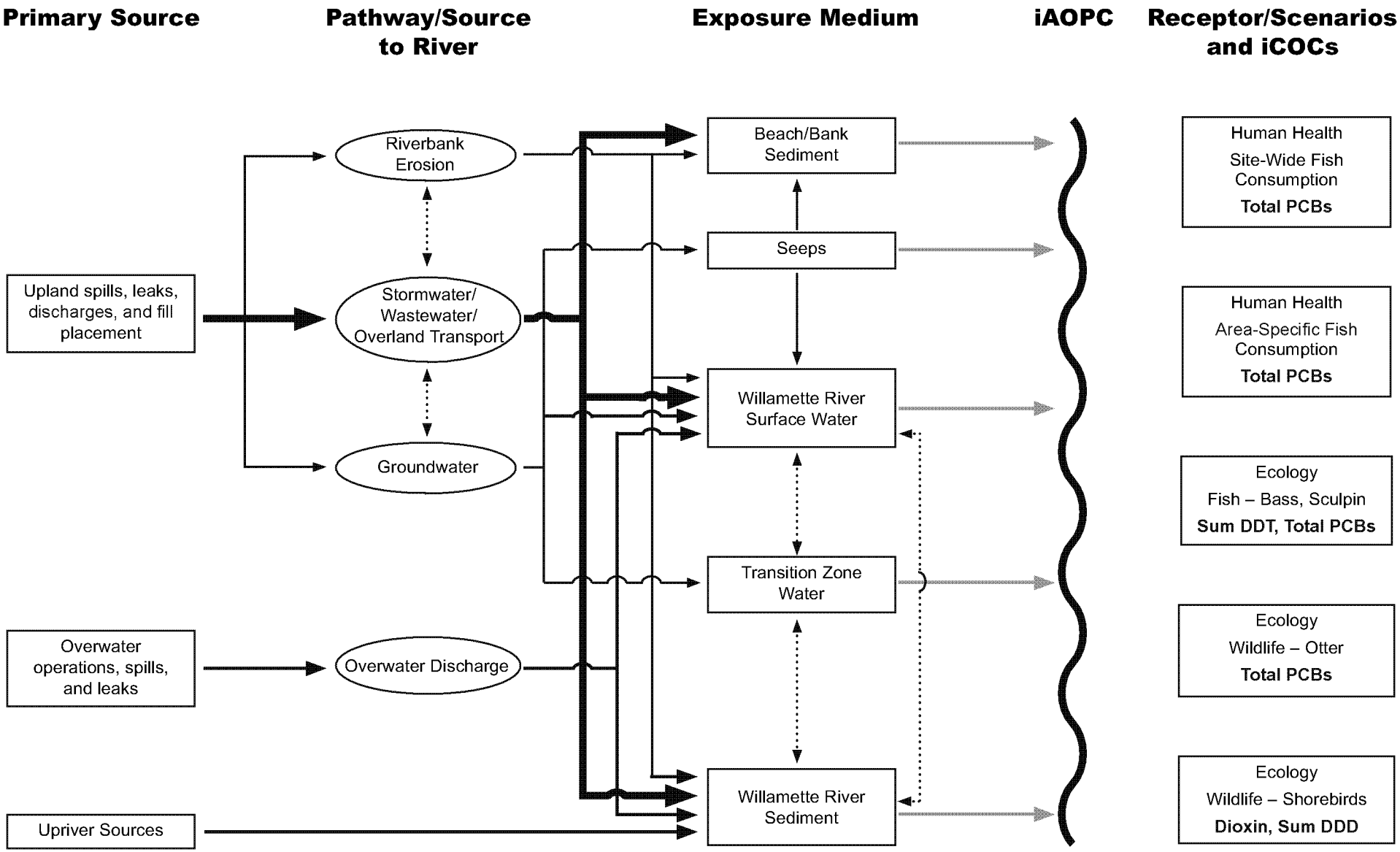
DATE 04/02/02
DWN. JLN
APPR.
REVIS.
PROJECT NO.
8016.01.05

Figure 4-5
TRIANGLE PARK, LLC
PORTLAND, OREGON

GENERALIZED GEOLOGIC CROSS SECTIONS D-D' AND E-E'

File: G:\8000\8016-TRIANGLE\001\005\RI-2002\001-CROSS SECTIONS.DWG Last edited: JUN. 07, 2002 @ 2:21 p.m. by: JNESS Xrefs: sections xref 50%Color

LAYOUT: 4

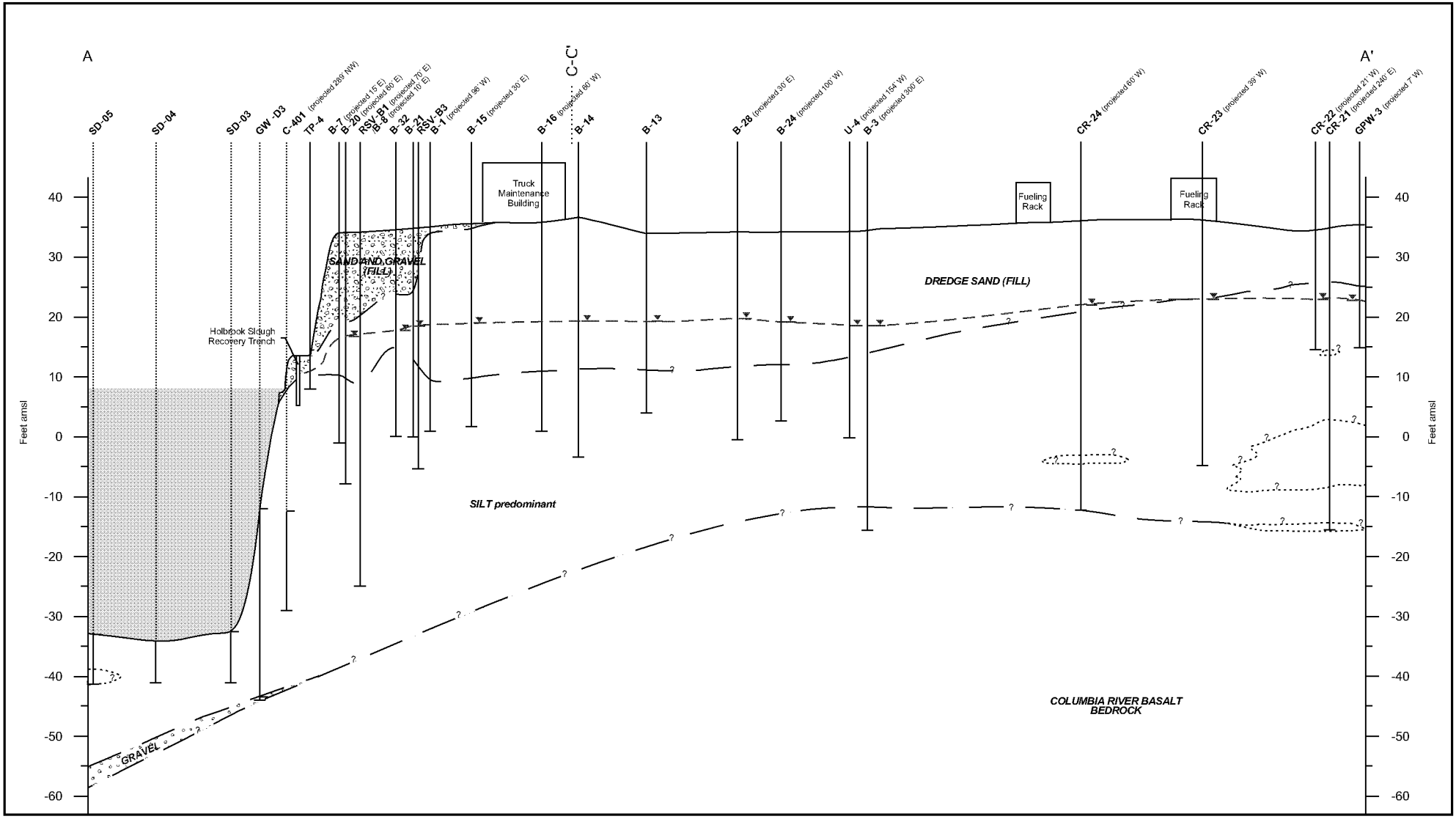


Complete Current and/or Historical Pathway, Relative Contribution High
Complete Current and/or Historical Pathway, Relative Contribution Medium
Complete Current and/or Historical Pathway, Relative Contribution Low
Incomplete or Insignificant Pathway
Completeness Unknown
No assessment is made on the relative contribution to iAOPC

Notes:
* = Potenital iCOCs
Bold = Chemicals Mapped for iAOPC CSM

Figure 11.3.13-1
Portland Harbor RI/FS
Comprehensive Round 2 Report
Preliminary Conceptual Site Model Diagram for iAOPC 17

integral consulting inc.
LWG Lower Willamette Group



integral

LWG LOWER WILLAMETTE GROUP

Base features from SAIC, 2005.

Measured apparent groundwater elevation

0 10 20 Feet
Vertical scale

0 200 400 Feet
Horizontal scale

Figure 5-2a
Portland Harbor RI/FS
Round 2 Groundwater Pathway Assessment SAP
Attachment 2 Transition Zone Water FSP Addendum 2
Willbridge Geological Cross Section A-A'

Map Document: (U:\Projects\Portland_Harbor\LWG-Map-Projects\Groundwater_Workplan\all_sites_Sediment_LZW_Flow_Zones.mxd)
7/11/2006 -- 4:35:15 PM

integral consulting inc.

LWG LOWER WILLAMETTE GROUP

FEATURE SOURCES:
RLIS Aerial Images of February 2005 'leaf off' flight (6" pixel),
Transportation, Property, or Boundaries: Metro RLIS.
Channel & River miles: US Army Corps of Engineers.
Bathymetric Information: David Evans and Associates, Inc., Winter 2004

0 25 50 100 150 Feet

LEGEND
- Navigation Channel
- Site Property Boundary
- Docks & In-water Structures

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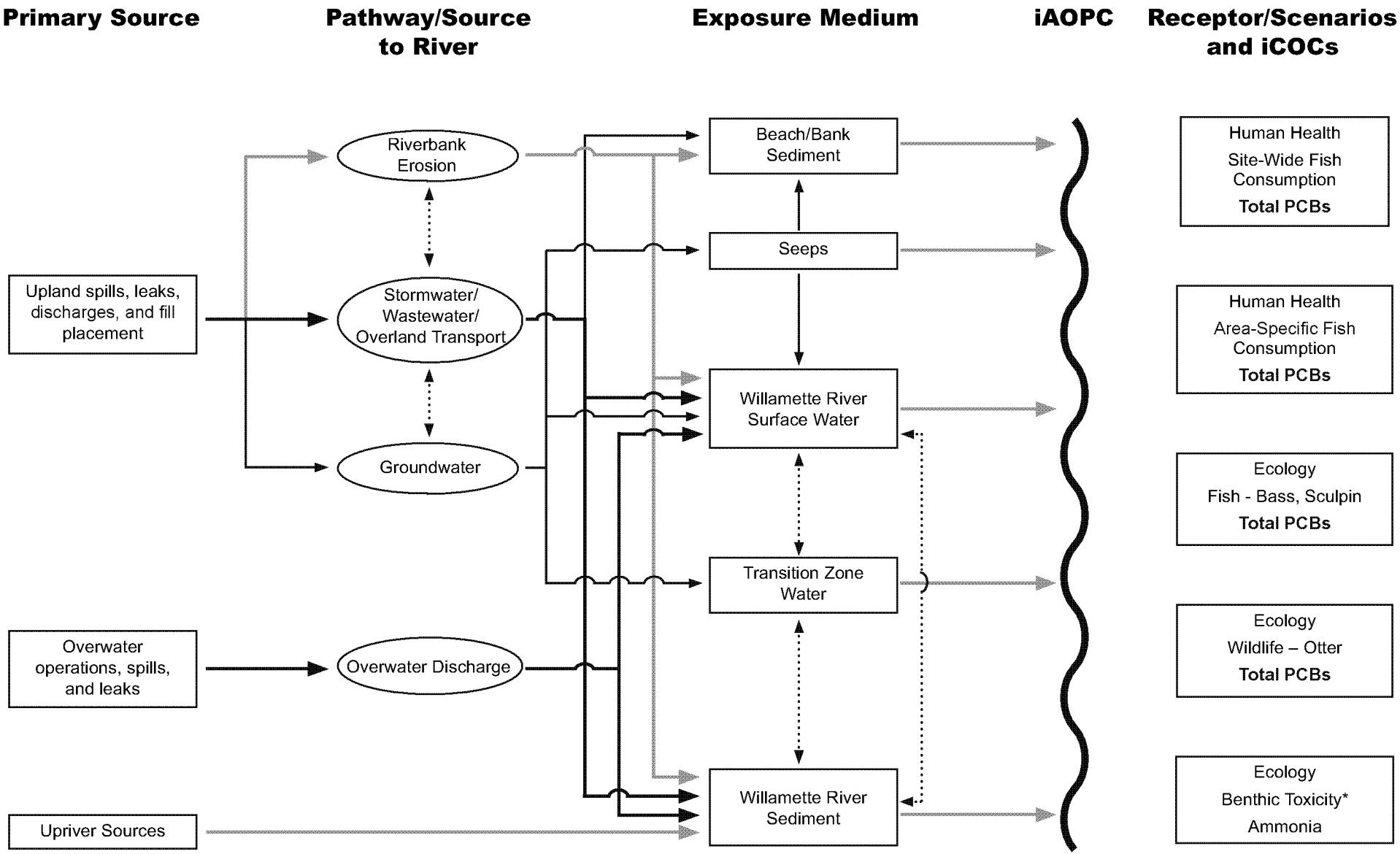
This document is currently under review by US EPA and its federal, state, and tribal partners, and is subject to change in whole or in part.

Figure 11-7
Portland Harbor RI/FS
Round 2 Groundwater Pathway Assessment
Site Characterization Summary Report
Willbridge Interpreted Groundwater Discharge Areas - Flow Zones



Complete Current and/or Historical Pathway, Relative Contribution High
Complete Current and/or Historical Pathway, Relative Contribution Medium
Complete Current and/or Historical Pathway, Relative Contribution Low
Incomplete or Insignificant Pathway
Completeness Unknown
No assessment is made on the relative contribution to iAOPC

Notes:
* = Potenital iCOCs
Bold = Chemicals Mapped for iAOPC CSM

Figure 11.3.14-1
Portland Harbor RI/FS
Comprehensive Round 2 Report
Preliminary Conceptual Site Model Diagram for iAOPC 18

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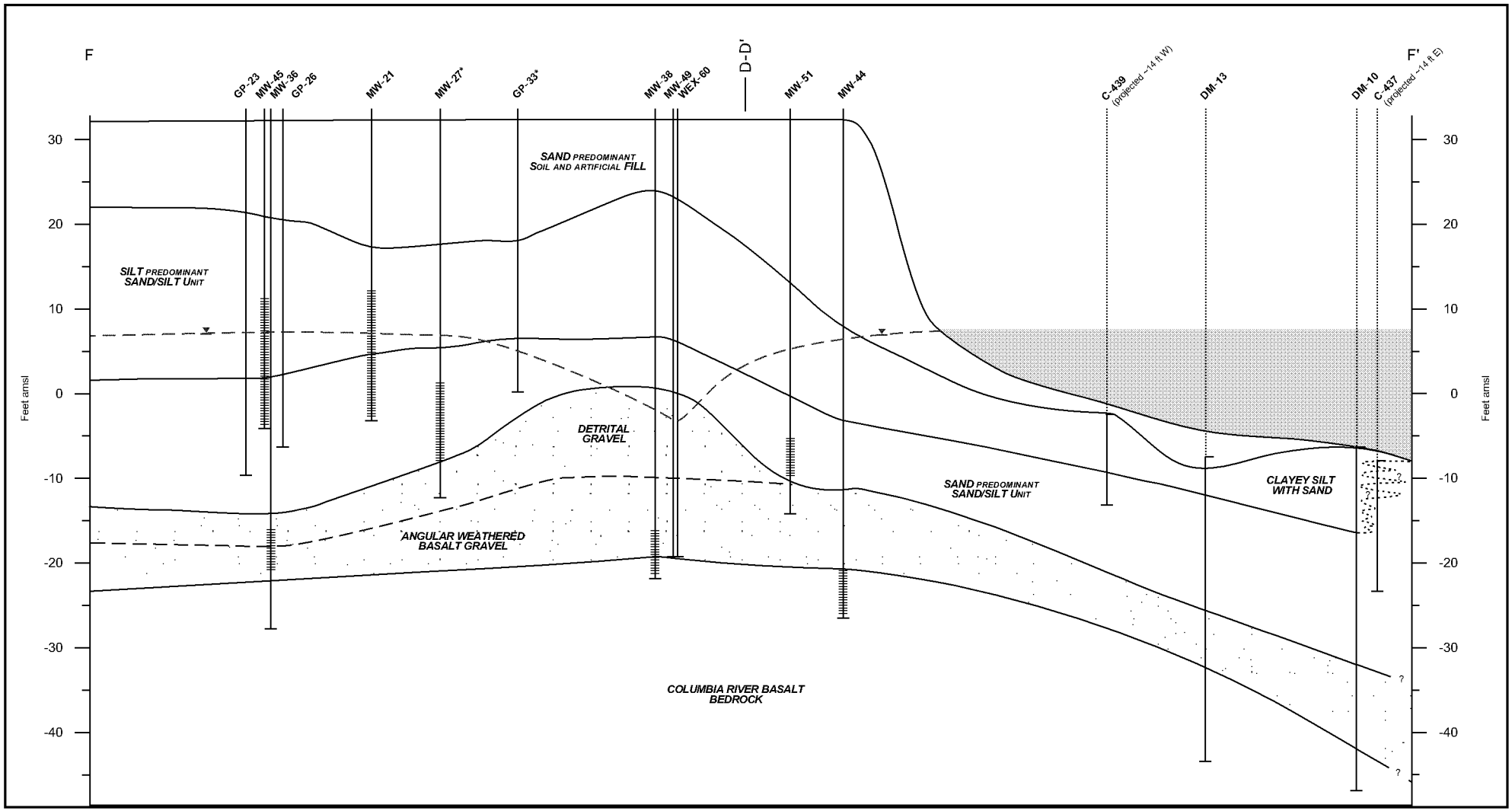
LWG Lower Willamette Group



integral

LWG

Base features from SQUIER Associates, 2003.

Top of bank assumed at 32' amsl.

*MW-27 is located on the basalt bench. Not used to develop this cross-section.

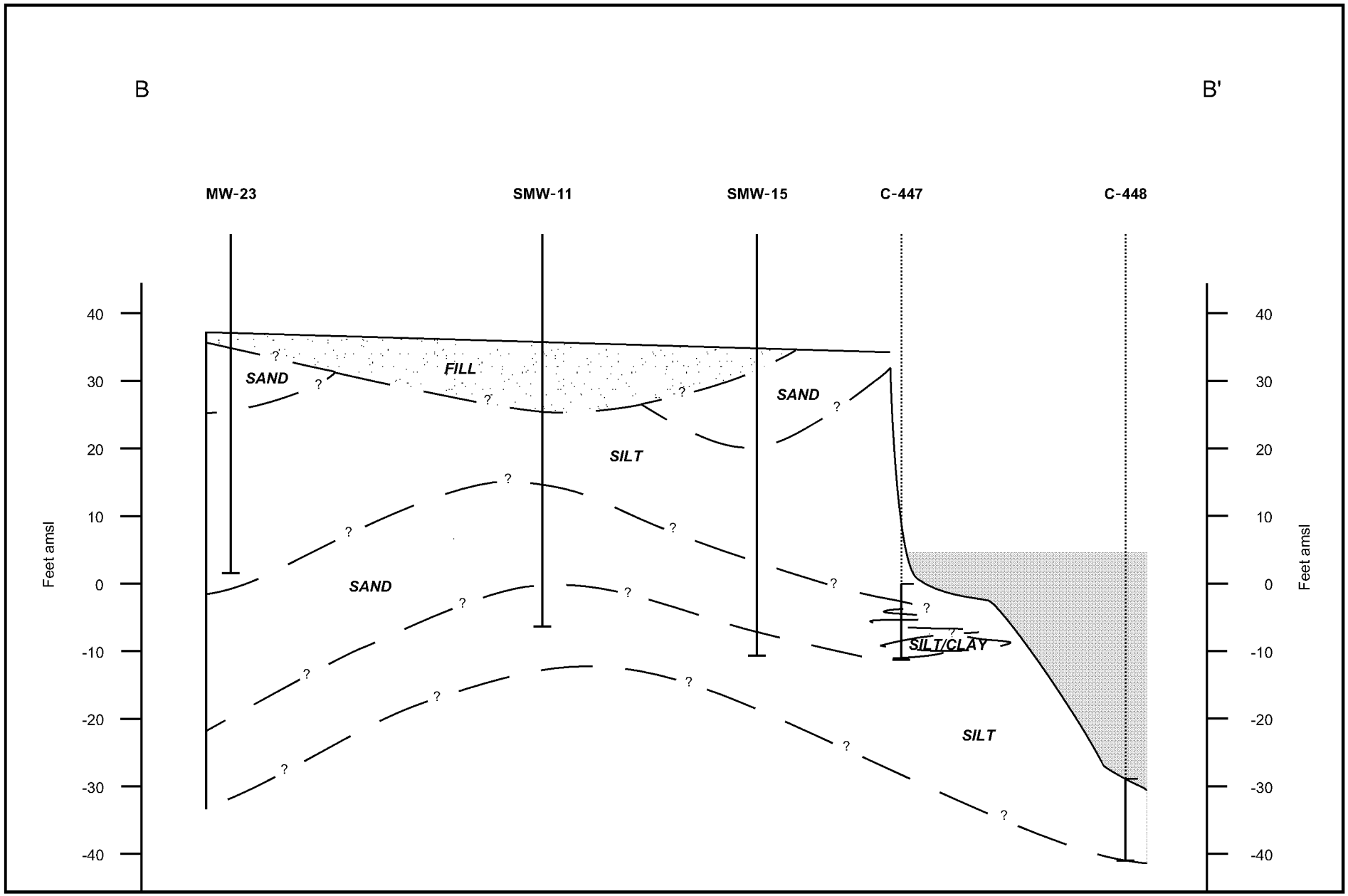
DM-10 and DM-13 are historical borings conducted off Lakeside Properties in 1973 (King 2005, pers. comm.)

0 10 20 Feet
Vertical scale

0 100 200 Feet
Horizontal scale

1.3.15-1a
Portland Harbor RI/FS
Gunderson
Geological Cross Section F-F'

BZTO104(e)031667



integral

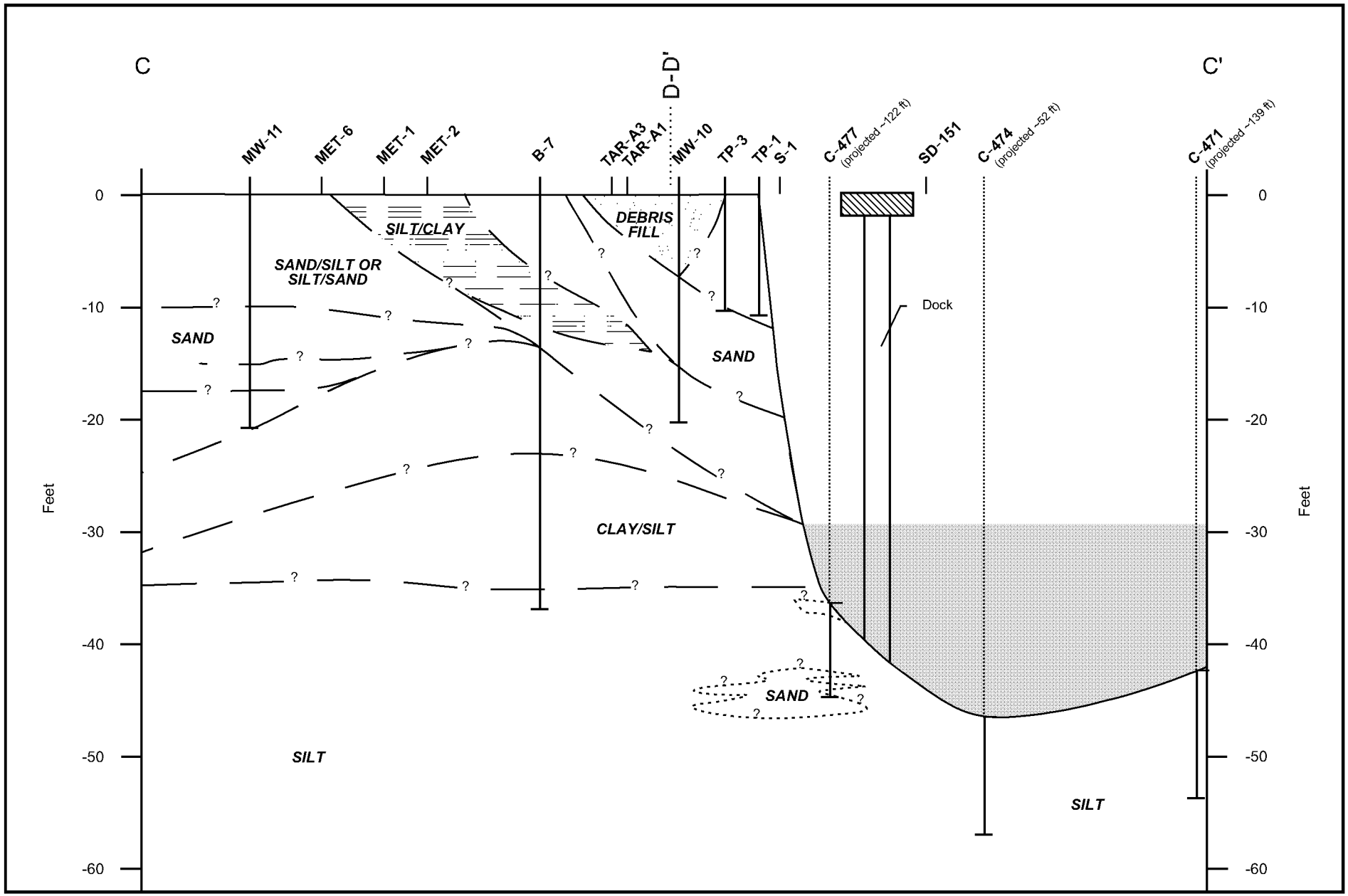
LWG Lower Willamette Group

Base features from Kleinfelder, 2005.

0 10 20 Feet
Vertical scale

0 100 200 Feet
Horizontal scale

Figure11.3.15-1b
Portland Harbor RI/FS
Gunderson
Geological Cross Section B-B'



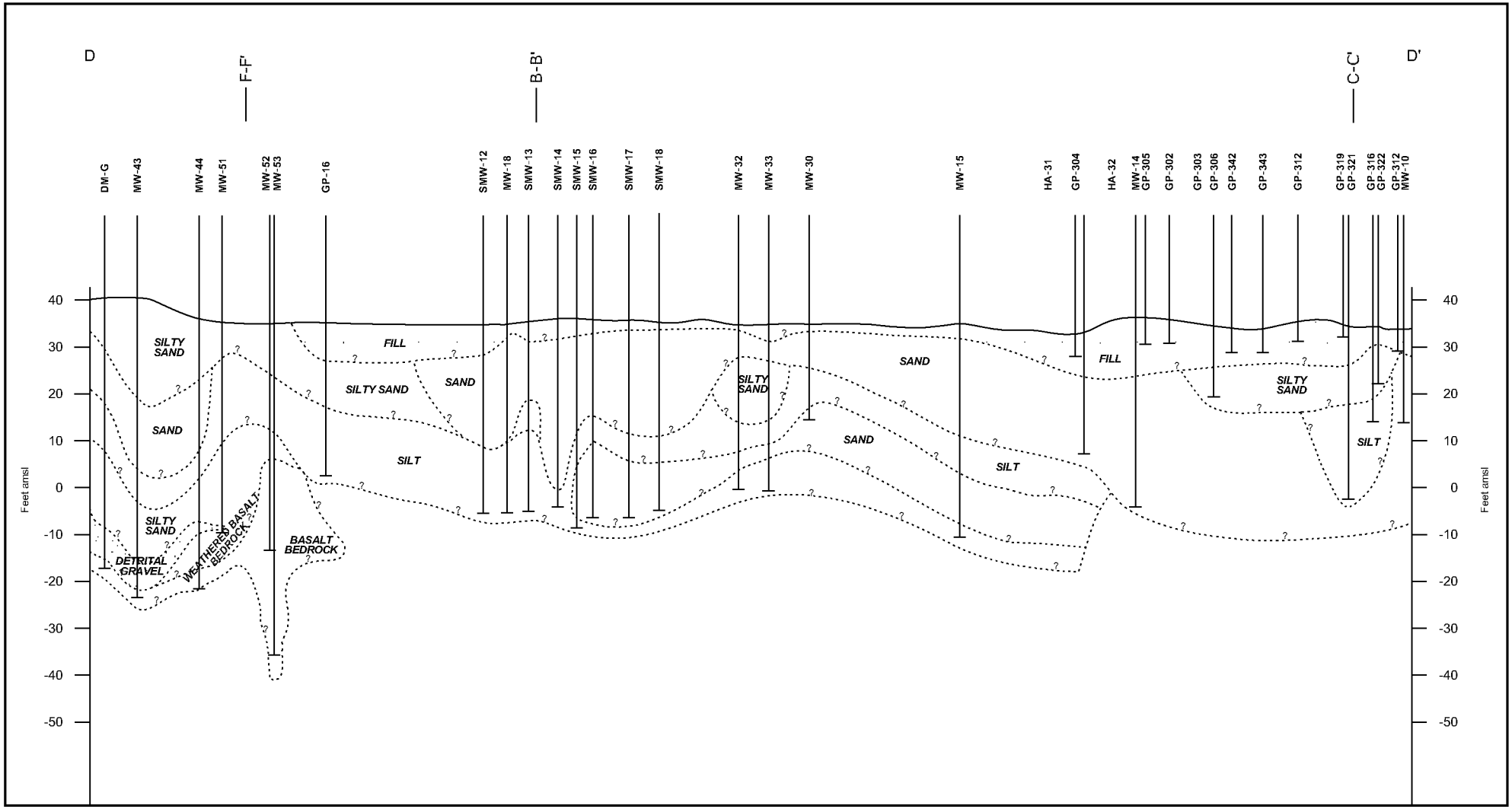
integral

LWG Lower Willamette Group

Base features from Kleinfelder, 2005.
Top of bank assumed approximately 30 ft amsl.

0 10 20 Feet
Vertical scale
0 100 200 Feet
Horizontal scale

Figure11.3.15-1c
Portland Harbor RI/FS
Gunderson
Geological Cross Section C-C'



integral

LWG

Base features from Kleinfelder, 2005.

0 10 20 Feet
Vertical scale

0 200 400 Feet
Horizontal scale

Figure11.3.15-1d
Portland Harbor RI/FS
Gunderson
Geological Cross Section D-D'

BZTO104(e)031670

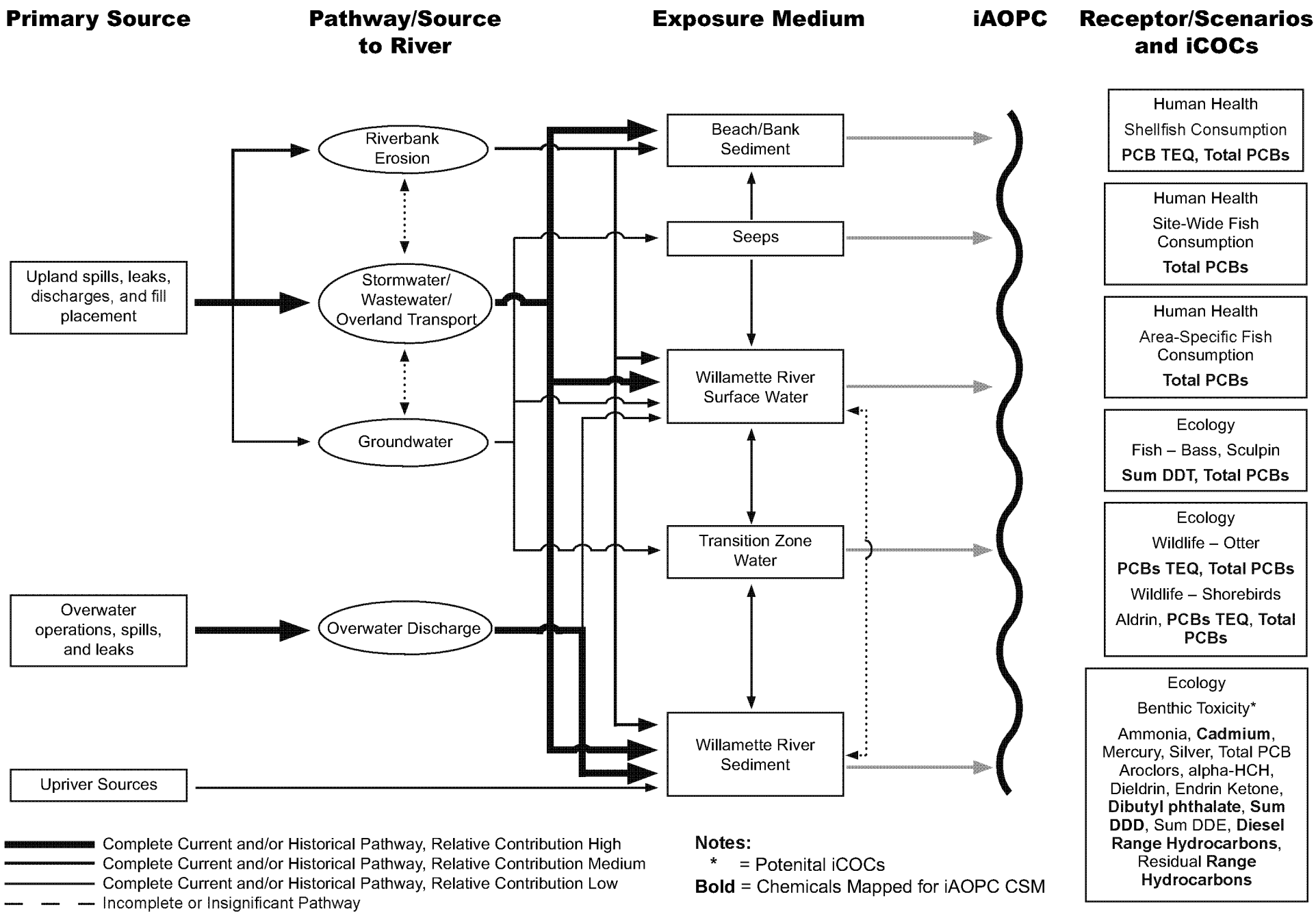


Figure 11.3.15-2
Portland Harbor RI/FS
Comprehensive Round 2 Report
Preliminary Conceptual Site Model Diagram for iAOPC 19

integral consulting inc.
LWG Lower Willamette Group

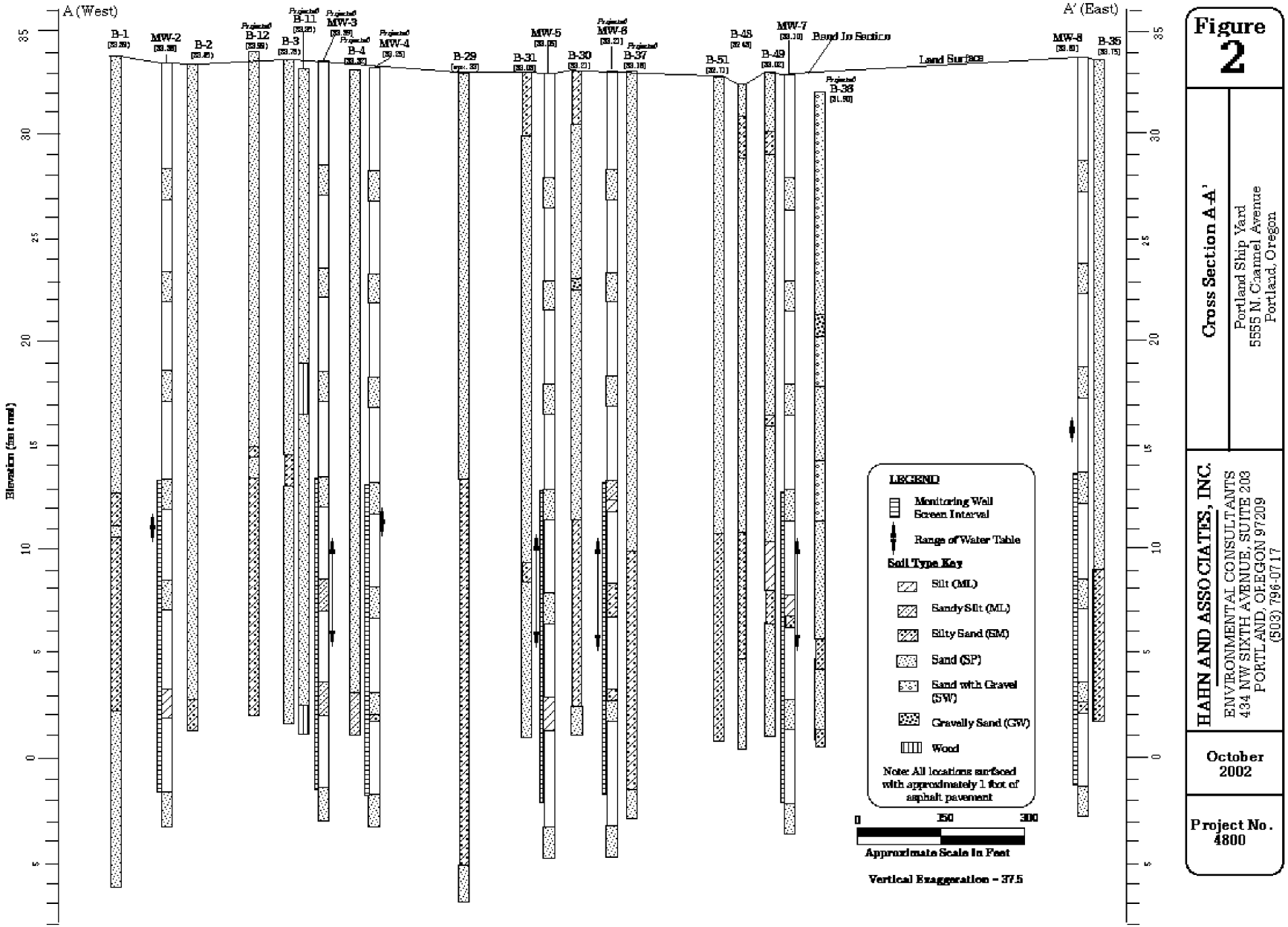


Figure 11.3.16-1a. Cross-Section A-A' for the Cascade General Ship Repair Yard Site

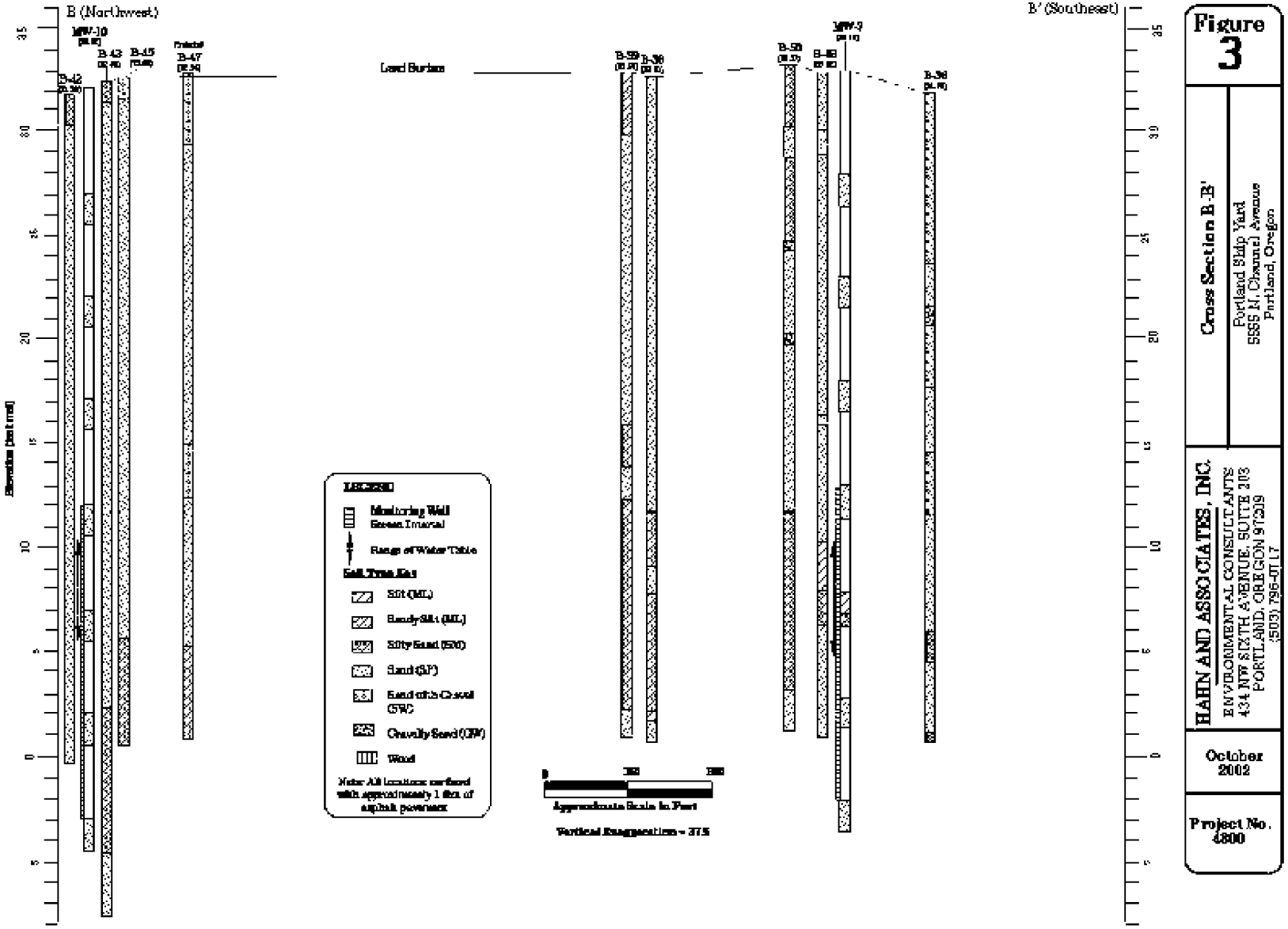
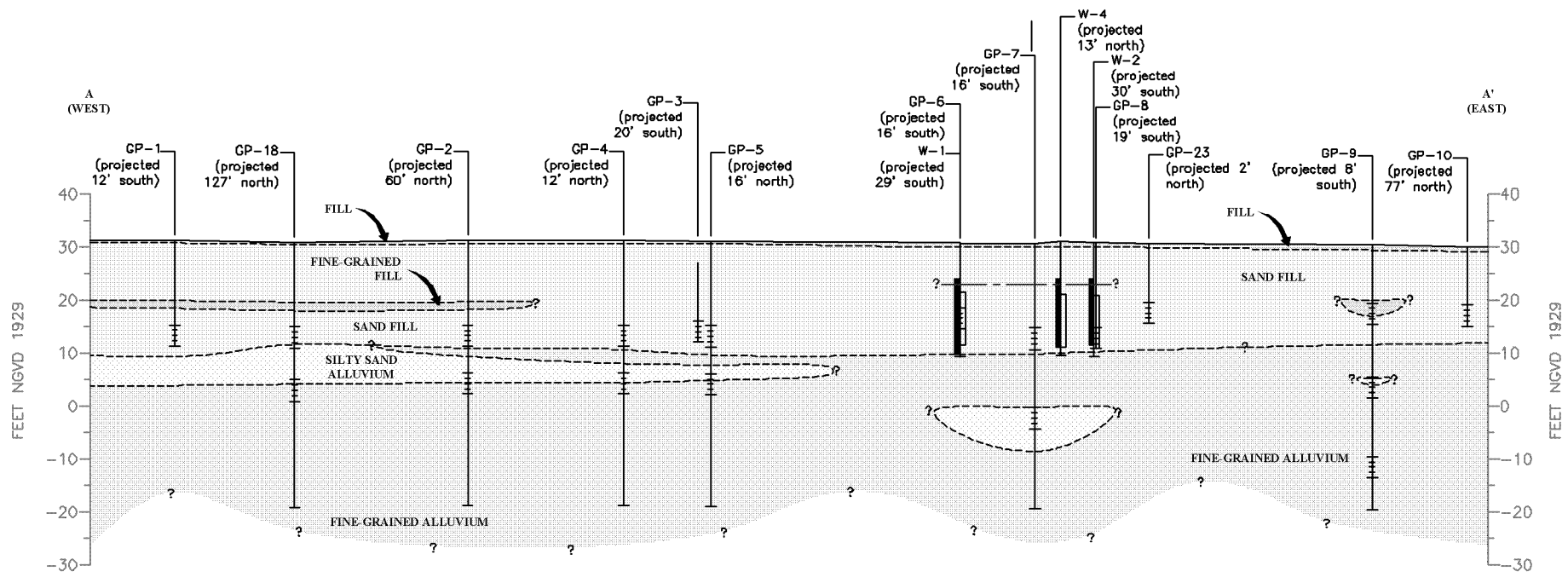


Figure 11.3.16-1b. Cross-Section B-B' for the Cascade General Ship Repair Yard Site



EXPLANATION

MONITORING WELL (W) → W-1 (projected 10' south)
PROJECTED DISTANCE TO PLANE OF CROSS SECTION →

GROUND SURFACE
TOP OF SAND PACK → TOP OF SCREEN
SAND PACK INTERVAL → SCREEN INTERVAL
BOTTOM OF SAND PACK → BOTTOM OF SCREEN
BORING
TOTAL DEPTH OF BORING

GP-1 (projected 13' north) ← EXPLORATORY BORING (GP)
← PROJECTED DISTANCE TO CROSS SECTION LINE

GROUND SURFACE
BORING OR EXCAVATION
TOP OF SCREEN
TEMPORARY SCREENED INTERVAL
BOTTOM OF SCREEN
TOTAL DEPTH OF BORING

SCALE IN FEET

HORIZONTAL 0 100 200
VERTICAL 0 20 40

FILL – SURFACE COMPLETION (ASPHALT, CONCRETE & SUBROCK).
SAND FILL – FINE SAND WITH TRACE AMOUNTS OF FINES.
FINE-GRAINED FILL – CLAYEY SILT TO SILT.
SILTY SAND ALLUVIUM – SILTY SAND TO SAND WITH SILT.
FINE-GRAINED ALLUVIUM – CLAYEY SILT TO SILT WITH TRACE ORGANICS & WOODY DEBRIS.
ESTIMATED LITHOLOGIC CONTACT
ESTIMATED WATER TABLE FROM FEBRUARY 19, 1997

Vancouver: (360) 694-2691
Portland: (971) 544-2139

MAUL FOSTER ALONGI INC.

DATE 02/17/05
DWN. DLG
APPR. ASJ
REVIS.
PROJECT NO.
8006.11.01

Figure 11.3.16-2a
FREIGHTLINER LLC
TRUCK MANUFACTURING PLANT II
PORTLAND, OREGON

GEOLOGIC CROSS SECTION A-A'

File: G:\8000\8006.11_FREIGHTLINER (PMP)\01\CSM FIGURES\FIG_03_CROSS SECTIONS.DWG Last edited: FEB. 17, 2005 @ 12:40 p.m. by: dglaus 50% Color

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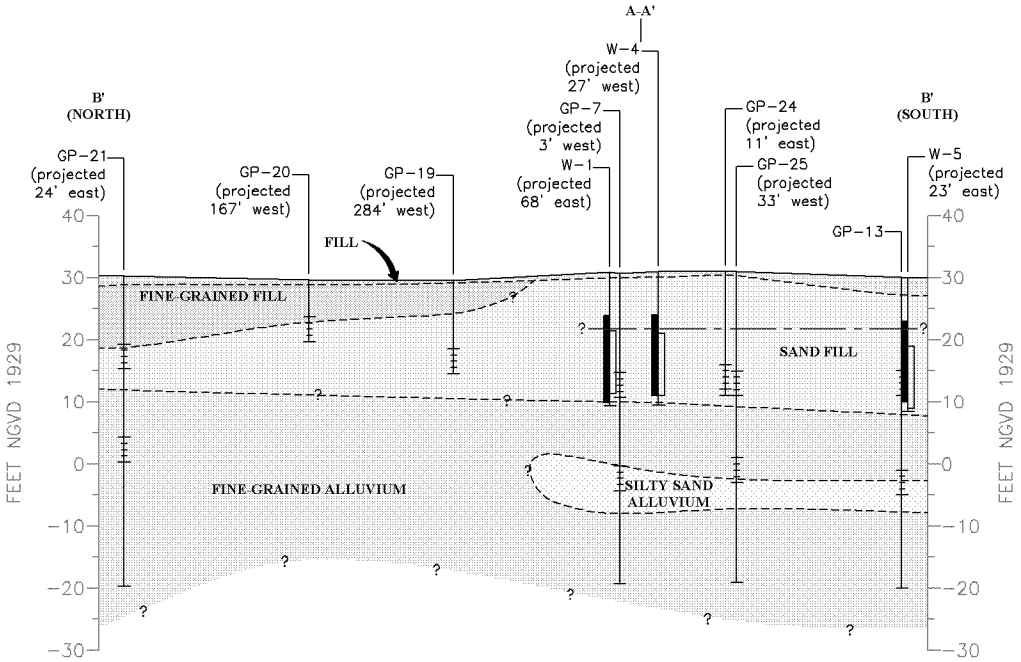
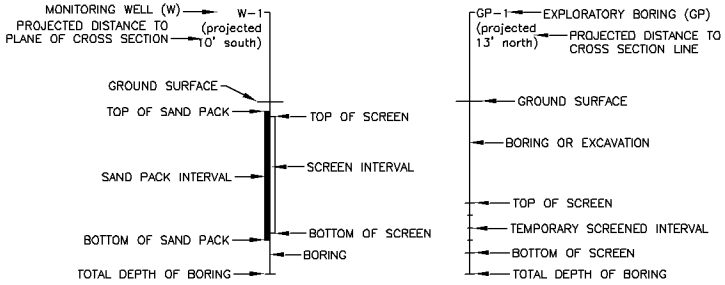


EXPLANATION



FILL – SURFACE COMPLETION (ASPHALT, CONCRETE & SUBROCK).

SAND FILL – FINE SAND WITH TRACE AMOUNTS OF FINES.

FINE-GRAINED FILL – CLAYEY SILT TO SILT.

SILTY SAND ALLUVIUM – SILTY SAND TO SAND WITH SILT.

FINE-GRAINED ALLUVIUM – CLAYEY SILT TO SILT WITH TRACE ORGANICS & WOODY DEBRIS.

- - - - - - - ESTIMATED LITHOLOGIC CONTACT

—— – —— ESTIMATED WATER TABLE FROM FEBRUARY 19, 1997

SCALE IN FEET

HORIZONTAL 0 100 200

VERTICAL 0 20 40

Vancouver: (360) 694-2691
Portland: (971) 544-2139

MAUL FOSTER ALONGI INC.

DATE	02/17/05
DWN.	DLG
APPR.	ASJ
REVIS.	
PROJECT NO.	8006.11.01

Figure 11.3.16-2b
FREIGHTLINER LLC
TRUCK MANUFACTURING PLANT II
PORTLAND, OREGON

GEOLOGIC CROSS SECTION B-B'

File: G:\8000\8006.11_FREIGHTLINER (PMP)\01\CSM FIGURES\FIG_04_CROSS SECTIONS.DWG Last edited: FEB 17, 2005 @ 12:40 p.m. by: dglous 50% Color

LAYOUT: 3

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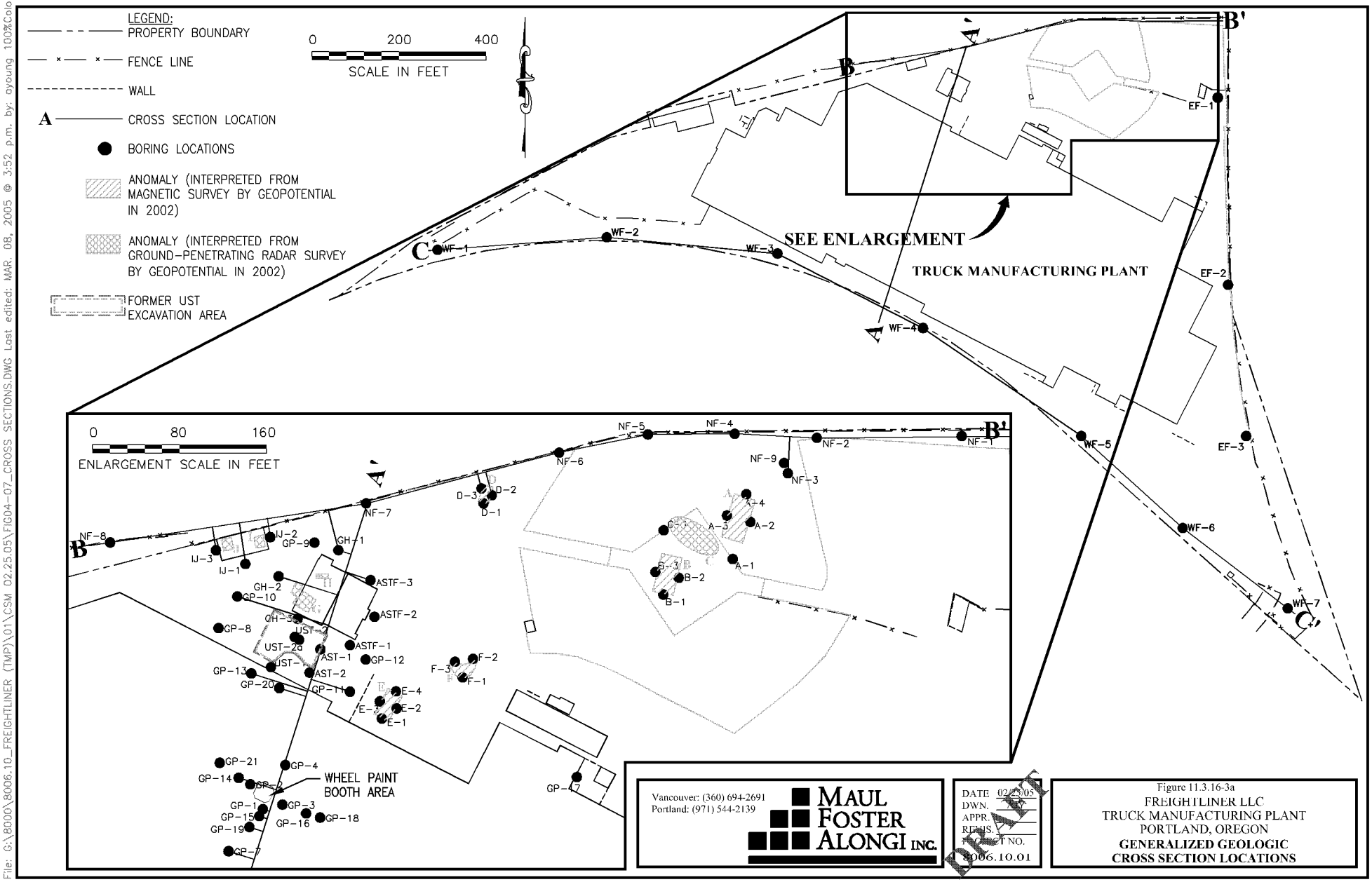

File: G:\8000\8006.10_FREIGHTLINER (TMP)\01\CSM 02.25.05\FIG04-07_CROSS SECTIONS.DWG Last edited: MAR 08, 2005 @ 3:52 p.m. by: ayoung 100%Color

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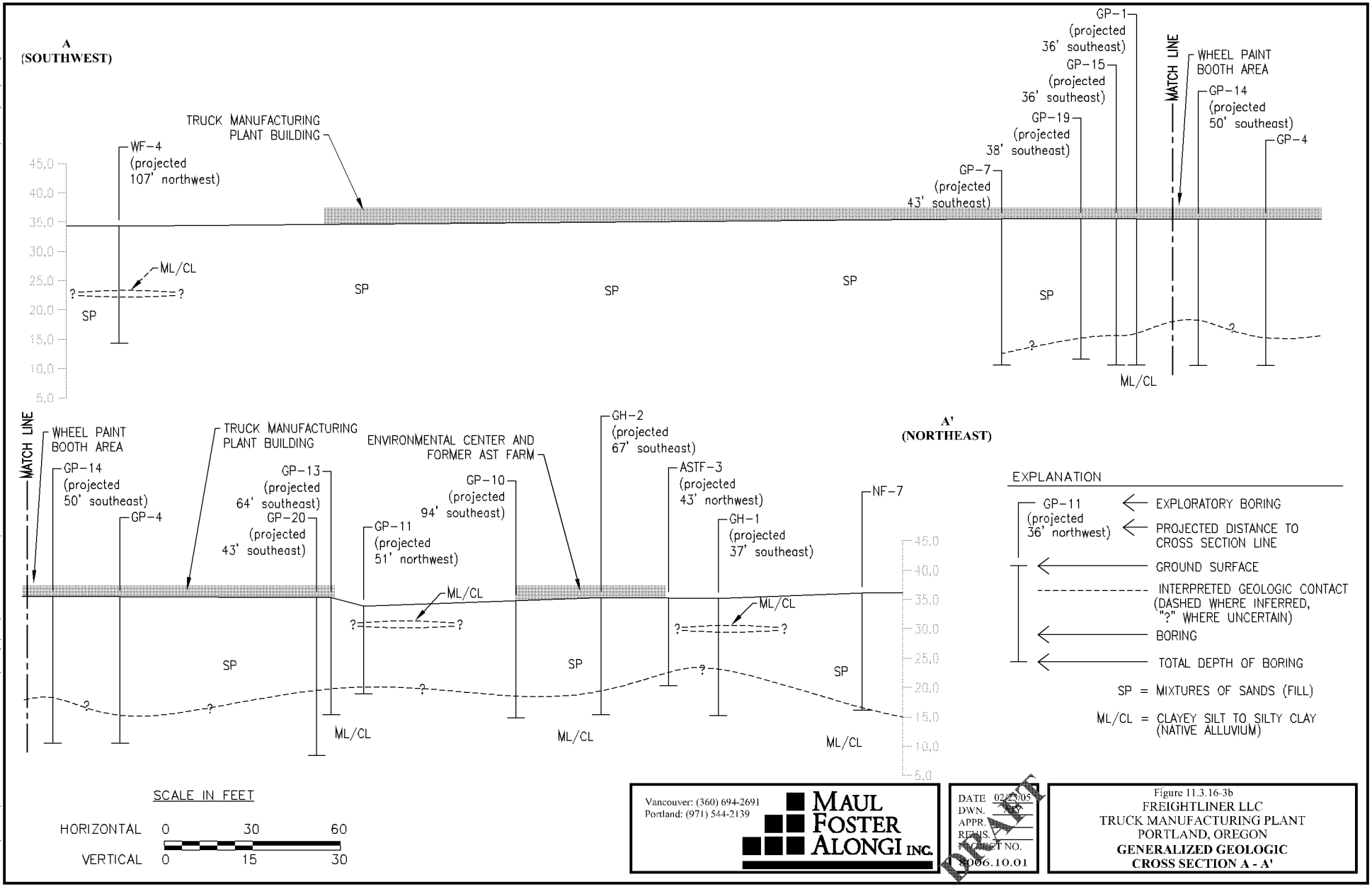

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MAUL FOSTER ALONGI INC.

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REVS.
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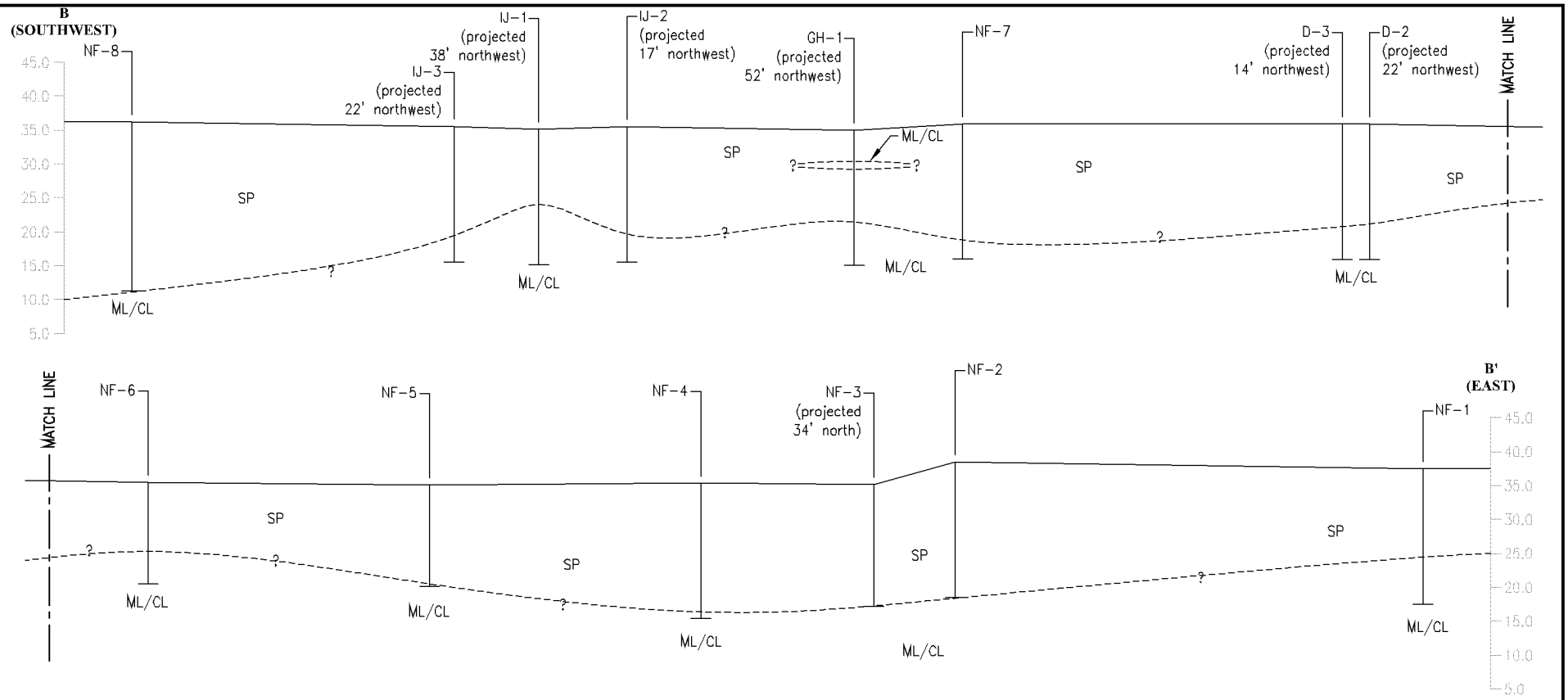
Figure 11.3.16-3b
FREIGHTLINER LLC
TRUCK MANUFACTURING PLANT
PORTLAND, OREGON
GENERALIZED GEOLOGIC CROSS SECTION A - A'

File: G:\8000\8006.10_FREIGHTLINER (TMP)\01\CSM 02.25.05\FIG04-07_CROSS SECTIONS.DWG Last edited: MAR. 08, 2005 @ 3:53 p.m. by: ayoung 100%Color

LAYOUT: 2



EXPLANATION

GH-1 (projected 52' northwest) ← EXPLORATORY BORING

← PROJECTED DISTANCE TO CROSS SECTION LINE

← GROUND SURFACE

---------- INTERPRETED GEOLOGIC CONTACT (DASHED WHERE INFERRED, "?" WHERE UNCERTAIN)

← BORING

← TOTAL DEPTH OF BORING

SP = MIXTURES OF SANDS (FILL)

ML/CL = CLAYEY SILT TO SILTY CLAY (NATIVE ALLUVIUM)

SCALE IN FEET

HORIZONTAL 0 30 60

VERTICAL 0 15 30

Vancouver: (360) 694-2691
Portland: (971) 544-2139
MAUL FOSTER ALONGI INC.

DATE 02/23/05
DWN. [illegible]
APPR. [illegible]
REVS. [illegible]
PROJECT NO. 8006.10.01

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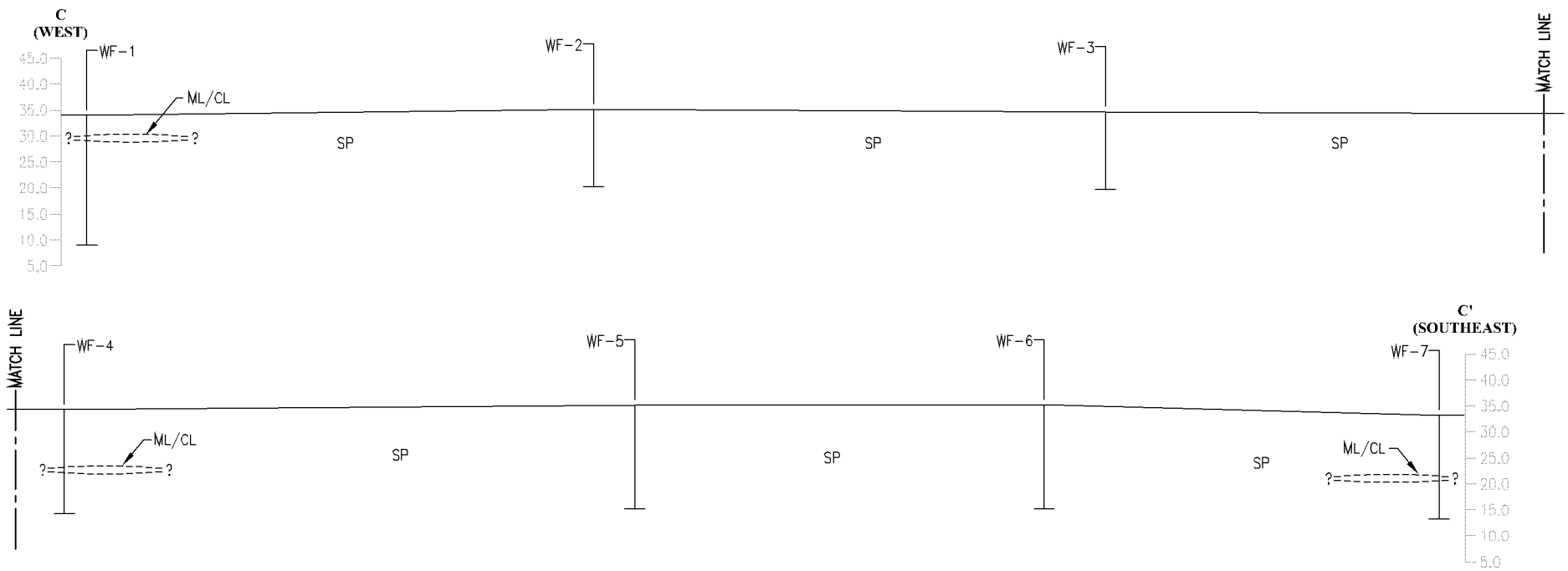
Figure 11.3.16-3c
FREIGHTLINER LLC
TRUCK MANUFACTURING PLANT
PORTLAND, OREGON
GENERALIZED GEOLOGIC CROSS SECTION B - B'

File: G:\8000\8006.10_FREIGHTLINER (TMP)\01\CSM 02.25.05\FIG04-07_CROSS SECTIONS.DWG Last edited: MAR. 08, 2005 @ 3:53 p.m. by: ayoung 100%Color

LAYOUT: 3



EXPLANATION

WF-2 ← EXPLORATORY BORING

← GROUND SURFACE

---------- INTERPRETED GEOLOGIC CONTACT (DASHED WHERE INFERRED, "?" WHERE UNCERTAIN)

← BORING

← TOTAL DEPTH OF BORING

SP = MIXTURES OF SANDS (FILL)

ML/CL = CLAYEY SILT TO SILTY CLAY (NATIVE ALLUVIUM)

SCALE IN FEET

HORIZONTAL 0 80 160

VERTICAL 0 20 40

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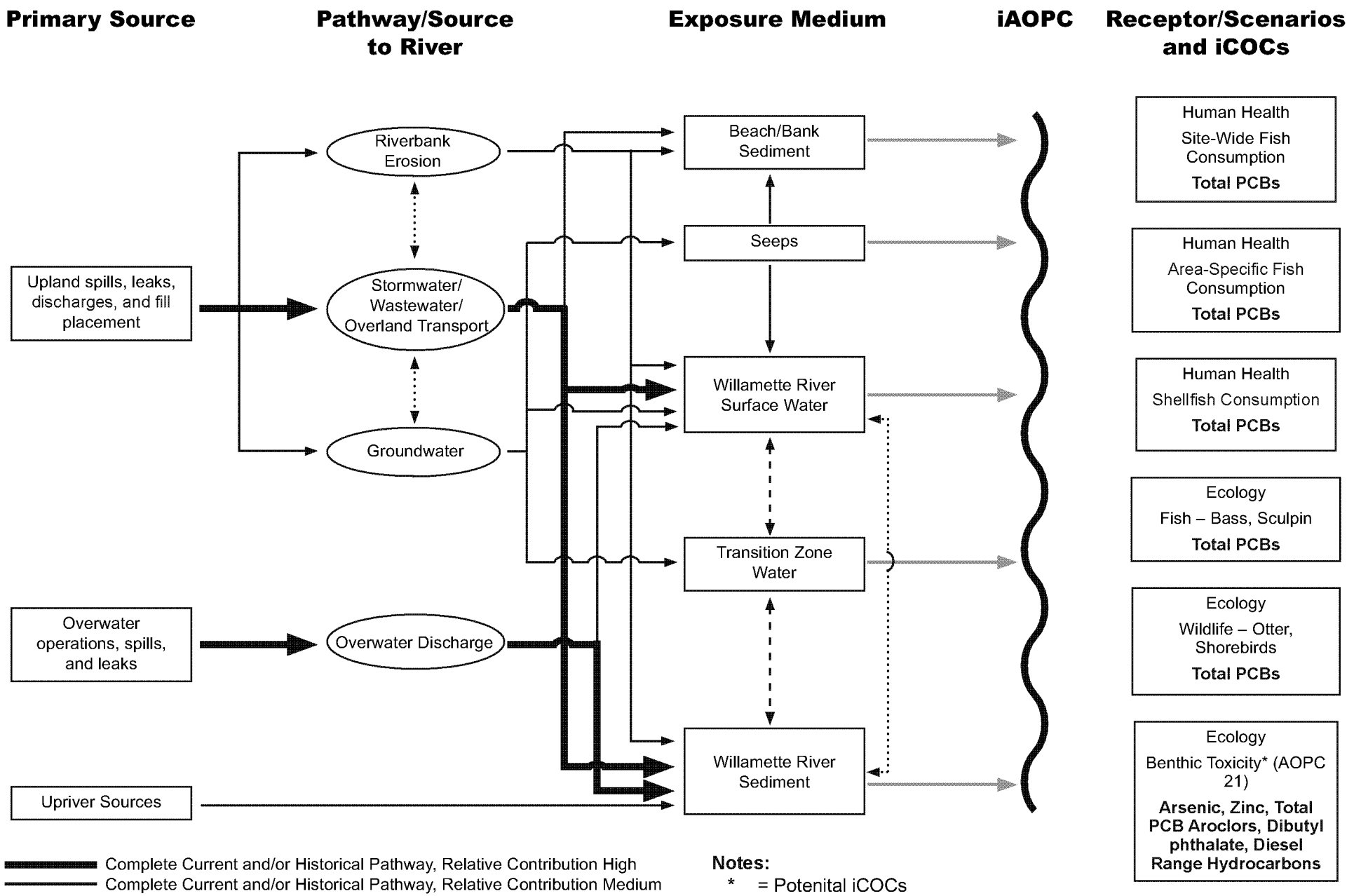
Figure 11.3.16-3d
FREIGHTLINER LLC
TRUCK MANUFACTURING PLANT
PORTLAND, OREGON
GENERALIZED GEOLOGIC CROSS SECTION C - C'

File: G:\8000\8006.10_FREIGHTLINER (TMP)\01\CSM 02.25.05\FIG04-07_CROSS SECTIONS.DWG Last edited: MAR. 08, 2005 @ 3:54 p.m. by: ayoung 100%Color

LAYOUT: 4



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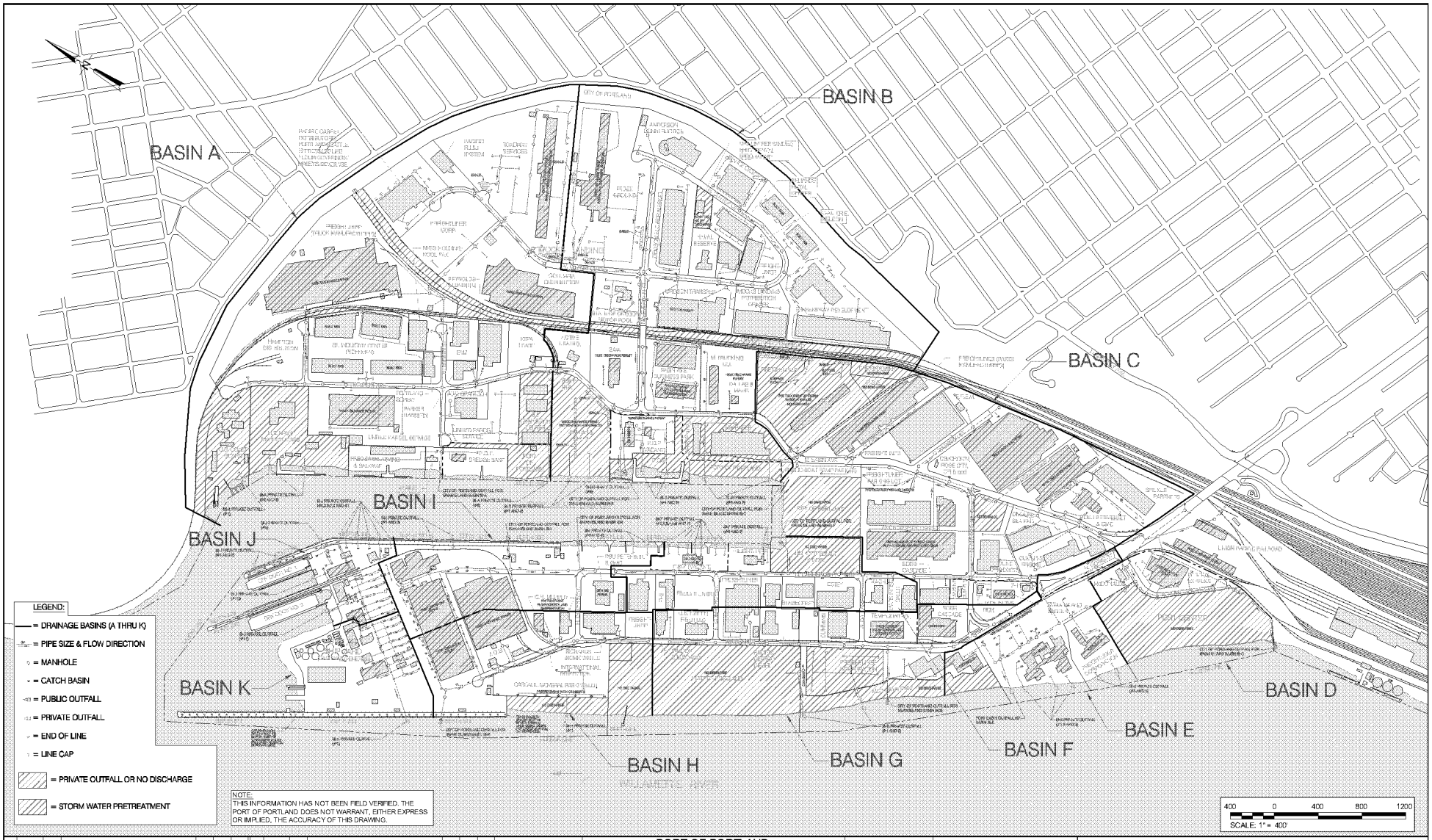
Complete Current and/or Historical Pathway, Relative Contribution Medium
Complete Current and/or Historical Pathway, Relative Contribution Low
Incomplete or Insignificant Pathway
Completeness Unknown
No assessment is made on the relative contribution to iAOPC

Notes:
* = Potenital iCOCs
Bold = Chemicals Mapped for iAOPC CSM

Figure 11.3.16-4
Portland Harbor RI/FS
Comprehensive Round 2 Report
Preliminary Conceptual Site Model Diagram for iAOPCs 20, 21, 22, and 23

integral consulting inc.
LWG Lower Willamette Group



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1	3/4/04	L.V.	REVISIONS AS PER DEAN MCCARGAR	D.M.							

PORT OF PORTLAND
PORTLAND, OREGON

2002PGEN — PROJECT NUMBER
52094-216 — PROJECT NUMBER

DESIGNED BY: L. VOGT
DRAWN BY: L. VOGT
CHECKED BY: D. GILKISON / D. MCCARGAR
DATE: OCT 2002
SCALE: 1"= 400'

SWAN ISLAND INDUSTRIAL PARK

STORM WATER BASIN MAPS
SITE PLAN

SUBMITTED BY — PROJECT MANAGER

TYPE: PD
DRAWING NO.: ANZ 2002-4190 1/5 P-1

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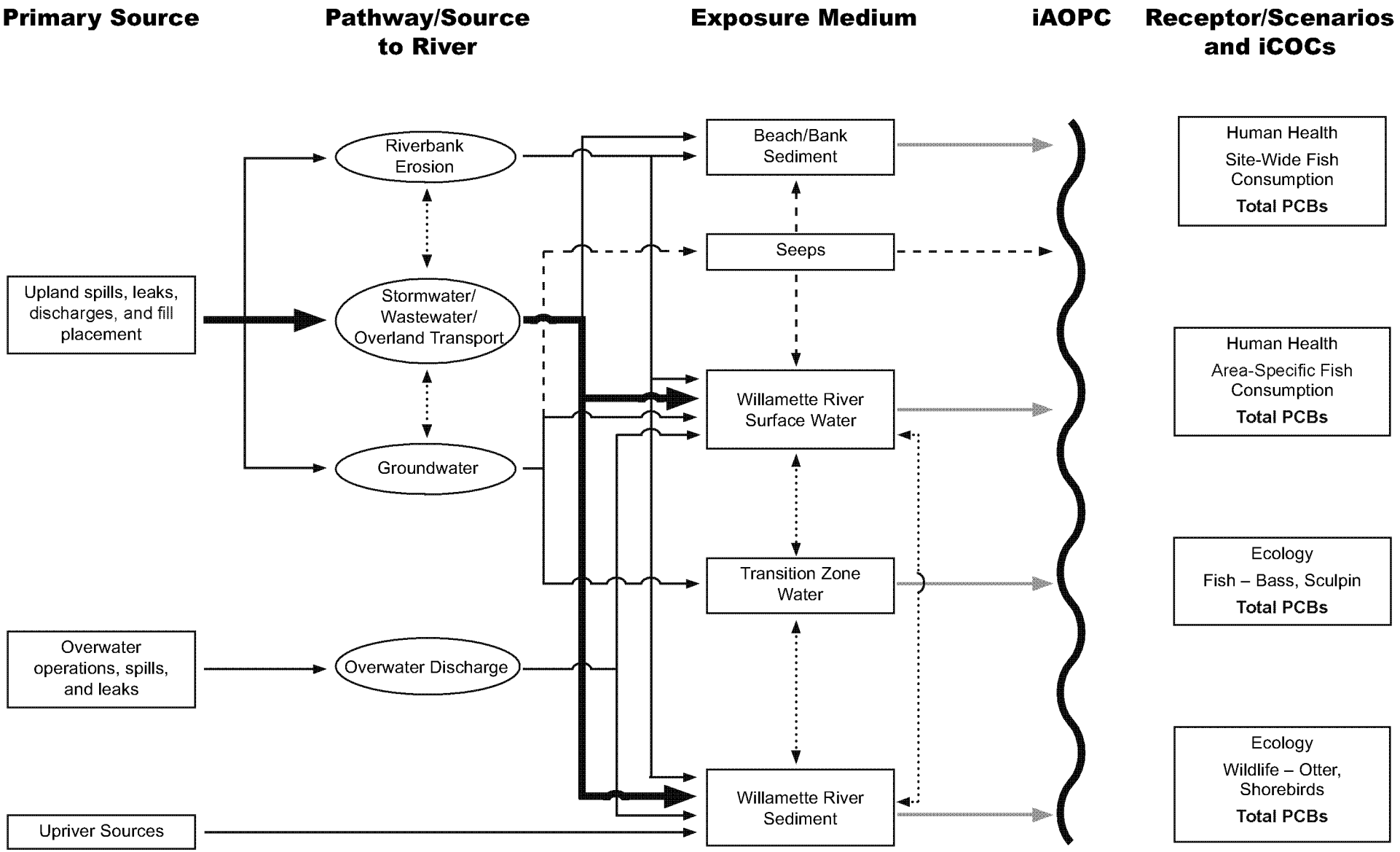

Complete Current and/or Historical Pathway, Relative Contribution High
Complete Current and/or Historical Pathway, Relative Contribution Medium
Complete Current and/or Historical Pathway, Relative Contribution Low
Incomplete or Insignificant Pathway
Completeness Unknown
No assessment is made on the relative contribution to iAOPC

Notes:
* = Potenital iCOCs
Bold = Chemicals Mapped for iAOPC CSM

Figure 11.3.17-1
Portland Harbor RI/FS
Comprehensive Round 2 Report
Preliminary Conceptual Site Model Diagram for iAOPC 24

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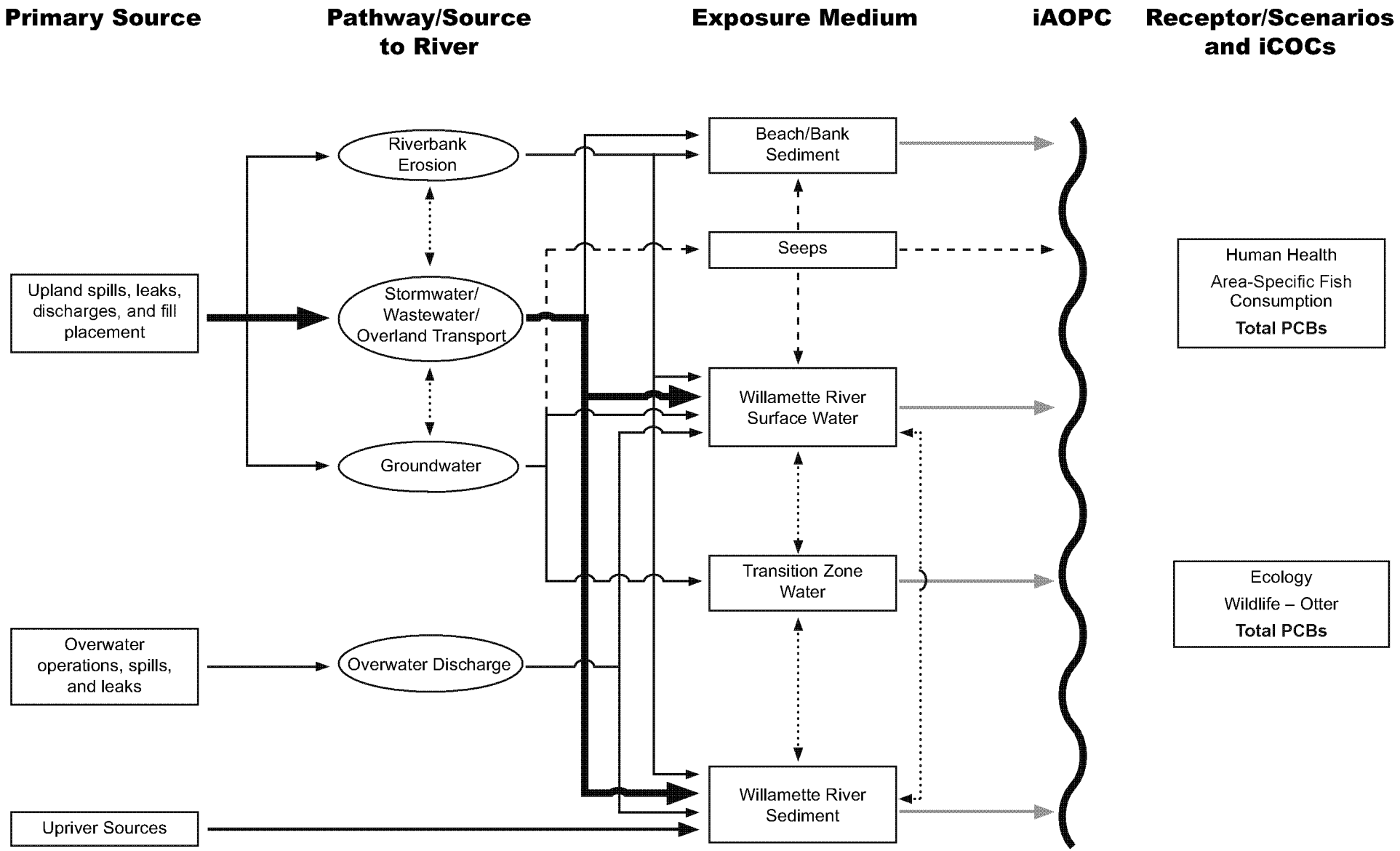

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Complete Current and/or Historical Pathway, Relative Contribution Medium
Complete Current and/or Historical Pathway, Relative Contribution Low
Incomplete or Insignificant Pathway
Completeness Unknown
No assessment is made on the relative contribution to iAOPC

Notes:
* = Potenital iCOCs
Bold = Chemicals Mapped for iAOPC CSM

Figure 11.3.18-1
Portland Harbor RI/FS
Comprehensive Round 2 Report
Preliminary Conceptual Site Model Diagram for iAOPC 25

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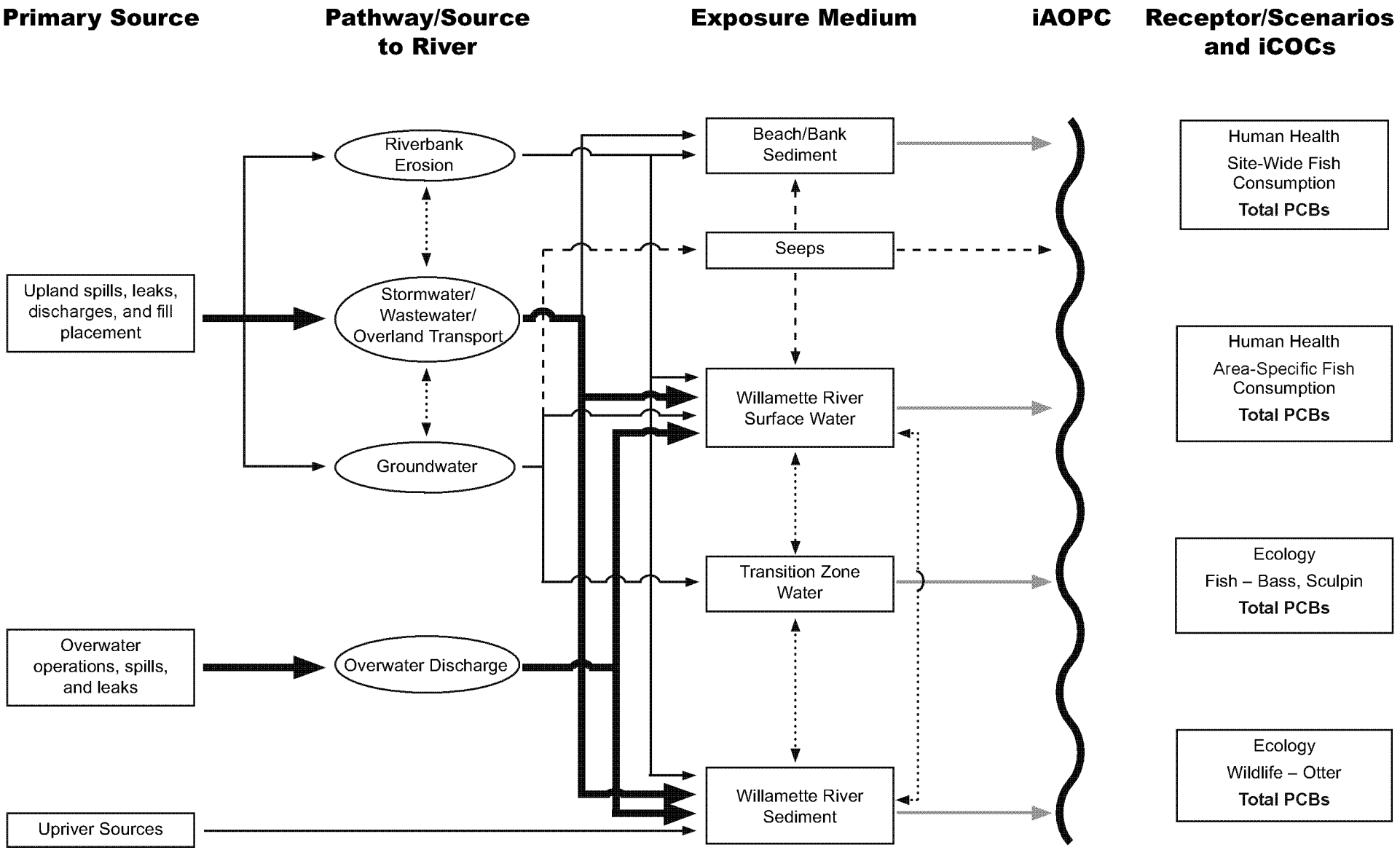

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Complete Current and/or Historical Pathway, Relative Contribution Low
Incomplete or Insignificant Pathway
Completeness Unknown
No assessment is made on the relative contribution to iAOPC

Notes:
* = Potenital iCOCs
Bold = Chemicals Mapped for iAOPC CSM

Figure 11.3.19-1
Portland Harbor RI/FS
Comprehensive Round 2 Report
Preliminary Conceptual Site Model Diagram for iAOPC 26

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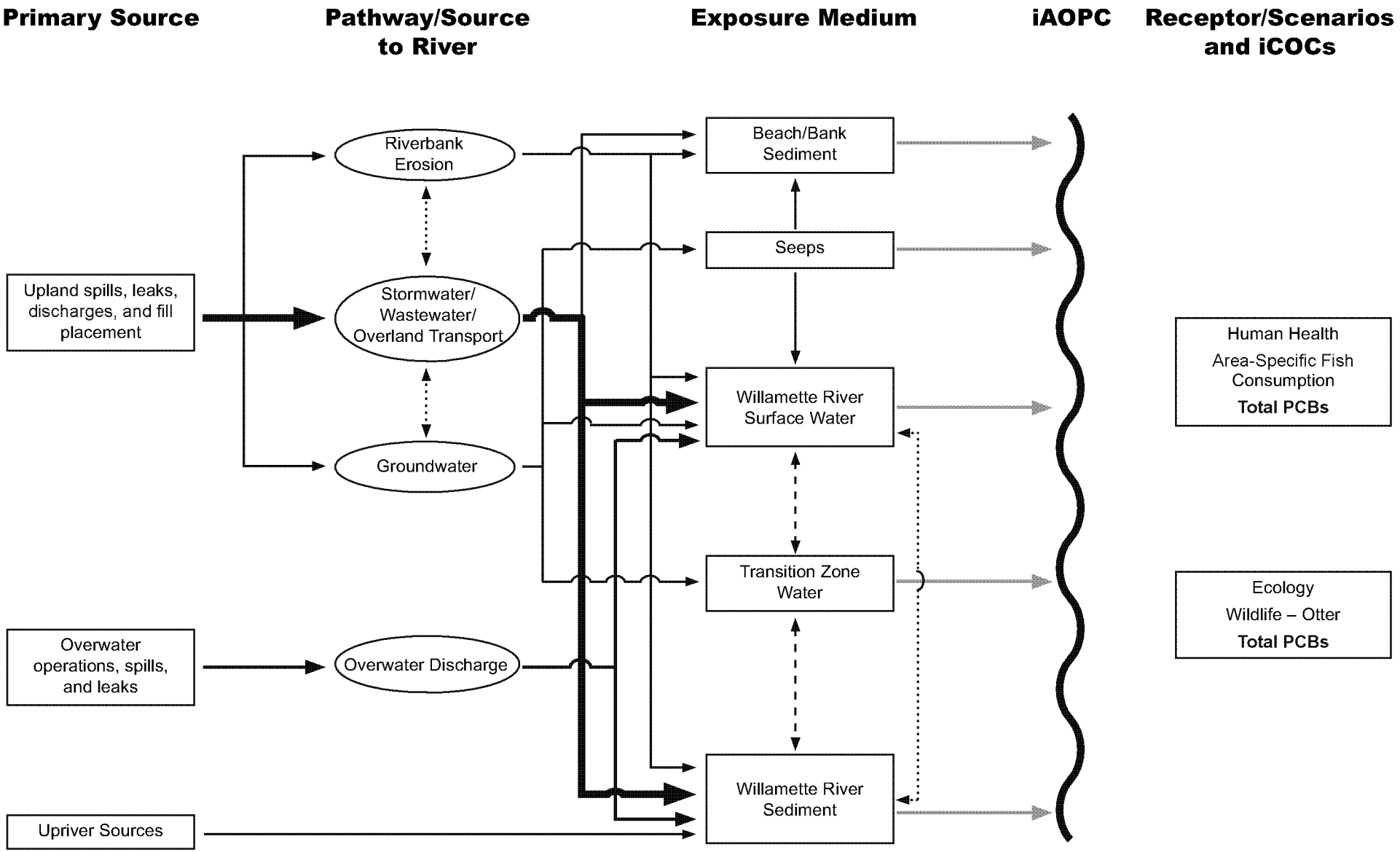

Complete Current and/or Historical Pathway, Relative Contribution High
Complete Current and/or Historical Pathway, Relative Contribution Medium
Complete Current and/or Historical Pathway, Relative Contribution Low
Incomplete or Insignificant Pathway
Completeness Unknown
No assessment is made on the relative contribution to iAOPC

Notes:
* = Potenital iCOCs
Bold = Chemicals Mapped for iAOPC CSM

Figure 11.3.20-1
Portland Harbor RI/FS
Comprehensive Round 2 Report
Preliminary Conceptual Site Model Diagram for iAOPC 27

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LWG
LOWER WILLAMETTE GROUP

PORTLAND HARBOR RI/FS

COMPREHENSIVE ROUND 2 SITE CHARACTERIZATION SUMMARY AND DATA GAPS ANALYSIS REPORT

February 21, 2007

Prepared for
The Lower Willamette Group

Prepared by
Integral Consulting Inc.
Windward Environmental LLC
Kennedy/Jenks Consultants
Anchor Environmental L.L.C.

IC07-0004

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LIST OF ACRONYMS

2,4,5-T	2,4,5-trichlorophenoxyacetic acid
2,4-DB	4-(2,4-dichlorophenoxy)butyric acid/esters
AAC	Advanced American Construction
AACP	Advanced American Construction Properties
ADCP	acoustic doppler current profiler
AOC	Admistrative Order on Consent
AOPC	area of potential concern
ARAR	Applicable or Relevant and Appropriate Requirement
AS/SVE	air sparging/soil vapor extraction
ASA	auto storage area
ASFO	Amended Stipulation and Final Order
AST	aboveground storage tank
ATSDR	Agency for Toxic Substances and Disease Registry
AVS	acid-volatile sulfildes
AWQC	Ambient Water Quality Criteria
BAA	benzo(a)anthracene
BAP	benzo(a)pyrene
bbls	barrels
BEBRA	bank excavation and backfill remedial action
BEHP	bis-2(ethylhexyl) phthalate
BERA	baseline ecological risk assessment
BES	City of Portland Bureau of Environmental Services
bgs	below ground surface
bml	below mudline
BMP	best management practice
BNSF	Burlington Northern Santa Fe (Railroad Company)
BOD	biological oxygen demand
BPA	Bonneville Power Administration
BPTCP	Bay Protection and Toxic Cleanup Program
BSAF	biota-sediment accumulation factor
BSAR	biota-sediment accumulation regression
BTEX	benzene, toluene, ethylbenzene, and xylenes
$CaCO_3$	calcium carbonate
CAS	Columbia Analtytical Services
CBWTP	Columbia Boulevard Wastewater Treatment Plant
CCA	chromium copper arsenate
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFMW	Columbia Forge and Machine Works
cfs	cubic feet per second
CGC	Coast Guard Cutter
CLP	EPA Contract Laboratory Program
cm	centimeter
cm/s	centimeters per second

COI	chemical of interest
COPC	chemical of potential concern
CPAH	carcinogenic polycyclic aromatic hydrocarbon
CPD	Commission of Public Docks
CRAG	Columbia Region Association of Governments
CRBG	Columbia River Basalt Group
CRCD	Columbia River Channel Deepening
CRD	Columbia River datum
CRITFC	Columbia River Inter-Tribal Fish Commission
CRSG	Columbia River Sand and Gravel
C_s	concentration of the chemical associated with solids
CSM	conceptual site model
CSO	combined sewer overflow
CT	central tendency
CUP	Oregon Department of Environmental Quality Cleanup Program
CVOCs	chlorinated volatile organic compound
C_w	concentration of the chemical in solution
d/year	days per year
DBP	dibutyl phthalate
DCE	dichloroethene
DDD	dichloro-diphenyl-dichloroethane
DDE	dichloro-diphenyl-dichloroethene
DDT	dichloro-diphenyl-trichloroethane
DDx	2,4'- and 4,4'-DDD, -DDE, -DDT
DEA	David Evans and Associates
decaCBs	decachlorobiphenyls
DEHP	di-2(ethylhexyl) phthalate
DEQ	Oregon Department of Environmental Quality
diCBs	dichlorobiphenyls
DJC	Daily Journal of Commerce
DL	detection limit
DNAPL	dense nonaqueous-phase liquid
DQO	data quality objective
DRD	direct reduction division
DRH	diesel-range hydrocarbons
DSL	Oregon Division of State Lands
Eco SL	ecological screening level
Eco SSL	ecological soil screening level
ECSI	Oregon Environmental Cleanup Site Inventory
EDIs	equal discharge intervals
EE/CA	engineering evaluation/cost analysis
EFDC	Environment Fluid Dynamics Code
EPA	U.S. Environmental Protection Agency
EPC	exposure point concentration
ERA	ecological risk assessment

ERAGS	Ecological Risk Assessment Guidance for Superfund
ERIS	Emergency Response Information System
ERM	Environmental Resources Management
ESA	environmental site assessment
FAMM	Fuel and Marine Marketing Inc.
FDDS	Fred Devine Diving and Salvage
FFS	focused feasibility study
f_{oc}	fractional organic matter content of the solids
FPM	floating percentile model
FS	feasibility study
FSP	field sampling plan
ft	feet
FPM	floating percentile model
FWM	food web model
FY	fiscal year
g	gram
g/day	grams per day
gal	gallons
GC/ECD	gas chromatography-electron capture detection
GIS	geographic information system
GLISP	Guild's Lake Industrial Sanctuary Plan
GRH	gasoline-range hydrocarbons
GS Roofing	Genstar Roofing
GSI	Groundwater Solutions Inc.
GWPA	groundwater pathway assessment
hazmat	hazardous material
HCH	hexachlorocyclohexane
HCN	hyrdrogen cyanide
HDPE	high-density polyethylene
heptaCBs	heptachlorobiphenyls
hexaCBs	hexachlorinated biphenyls
HHRA	human health risk assessment
HI	hazard index
HPAH	high-molecular-weight polycyclic aromatic hydrocarbon
HPCDD	heptachlorodibenzodioxin
HQ	hazard quotient
HRGC	high resolution gas chromatography
HRMS	high resolution mass spectrometry
HSBD	Hazardous Substances Data Bank
HXCDD	hexachlorodibenzodioxin
HXCDF	hexachlorodibenzofuran
iAOPC	initial area of potential concern
iCOCs	initial chemical of concern
iCSM	initial conceptual site model
iPRG	initial preliminary remedial goal

IRAM	Interim Remedial Action Measure
IRIS	Integrated Risk Information System
IRM	interim remedial measure
ISA	initial study area
JSCS	joint source control strategy
K_d	solid/water partitioning coefficient
kg	kilogram
kg/day	kilograms per day
kg/year	kilograms per year
KI	Koppers Industries
KMBT	Kinder Morgan Bulk Terminals
KMLT	Kinder Morgan Linnton Terminal
K_{oc}	organic carbon partitioning coefficient
KOH	potassium hydroxide
K_{ow}	octanol-water partitioning coefficient
K_{sp}	solubility product
L/ft^3	liter per cubic foot
LISST	laser in situ scattering and transmissometry
LLC	limited liability company
LNAPL	light nonaqueous-phase liquid
LNG	liquefied natural gas
LOAEL	lowest-observed-adverse-effect level
LOE	line of evidence
LPAH	low-molecular-weight polycyclic aromatic hydrocarbon
LPH	liquid petroleum hydrocarbon
LRM	logistic regression model
LUST	leaking underground storage tank
LWG	Lower Willamette Group
LWR	lower Willamette River
m	meter
M&B	McCormick & Baxter
MCB	monochlorobenzene
MCL	Maximum Contaminant Level
MCPA	4-chloro-2-methylphenoxyacetic acid
MCPP	herbicide
MFA	Maul Foster and Alongi, Inc.
mg	milligram
µg/L	microgram per liter
µm	micrometer
mg/L	milligram per liter
MGP	manufactured gas plant
MHWM	mean high water mark
MLLW	mean low-low water
MNR	monitored natural recovery
MOU	memorandum of understanding

MPR	manufacturing process residue
MS4	municipal separated storm sewer system
MSL	mean sea level
MTBE	methyl tert-butyl ether
N/A	not applicable
N/m^2	Newton per square meter
NaOH	sodium hyroxide
NAPL	non-aqueous phase liquid
NATA	National Air Toxics Assessment modeling program
NAVD	North American Vertical Datum
NDL	North Doane Lake
NE	not estimated
NFA	no further action
NGVD	National Geodetic Vertical Datum
NOAEL	no-observed-adverse-effect level
nonaCBs	nonachlorobiphenyls
NPDES	National Pollutant Dishcarge Elimination System
NPL	National Priorities List
NRC	National Response Center
NREENC	non-reinforced concrete
NS	not sampled
O&M	operation and maintenance
O/W	oil/water
OCDD	octachlorodibenzodioxin
OCDF	octachlorodibenzofuran
octaCBs	octachlorinated biphenyls
ODFW	Oregon Department of Fish & Wildlife
ODHS	Oregon Department of Human services
ODOT	Oregon Department of Transportation
OERS	Oregon Emergency Response System
OHSU	Oregon Health Sciences University
OHWM	ordinary high water mark
OMSI	Oregon Museum of Science and Industry
ORNL	Oak Ridge National Laboratories
ORP	oxidation-reduction potential
OSM	Oregon Steel Mills
OSSA	Oregon State Sanitary Service Authority
OSU	Oregon State University
P&T	pump and treat
PAH	polycylic aromatic hydrocarbon
PBDE	polybrominated diphenyl ether
PCB	polychlorinated biphenyl
PCDD	polychlorinated dibenzo-p-dioxin
PCDD/F	polychlorinated dibenzo-p-dioxin/furan
PCE	perchloroethylene

PCP	pentachlorophenol
PDF	portable digital format
PECDD	pentachlorodibenzodioxin
PECDF	pentachlorodibenzofuran
PECs	Probable Effects Concentrations
pentaCBs	pentachlorinated biphenyls
PEO	Premier Edible Oils
PG&C	Portland Gas & Coke
PG&E	Portland Gas & Electric
pg/L	picograms per liter
PGE	Portland General Electric
PM	project mananger
POTW	publicly owned treatment works
ppb	parts per billion
PPRTVs	Provisional Peer Reviewed Toxicity Values
PRD	Portland River Datum
PRE	preliminary risk evaluation
PRG	Preliminary Remediation Goal
PSY	Portland Shipyard
PTI	PTI Environmental Services, Inc.
PVC	polyvinyl chloride
QA/QC	quality assurance and quality control
QAPP	quality assurance project plan
RAIS	Risk Assessment Information System
RAO	remedial action objective
RBC	risk-based concentration
RCP	reinforced steel pipe
RCRA	Resource Conservation and Recovery Act
RD/RA	remedial design/remedial action
RI	remedial investigation
RI/FS	remedial investigation and feasibility study
RL	reporting limit
RLIS	Regional Land Information System
RM	river mile
RMA	river mile area
RME	reasonable maximum exposure
ROD	Record of Decision
ROS	regression on order statistics
ROW	right-of-way
RRH	residual-range hydrocarbons
s/d	seconds per day
SAP	sampling and analysis plan
SCD	source control decision
SCE	source control evaluation
SCM	source control measure

SCRA	site characterization and risk assessment
SCSR	site characterization summary report
SD	standard deviation
SECOR	SECOR International Inc., Tualatin, OR
SFO	Stipulation and Final Order
SFPP	Santa Fe Pacific Pipeline
SHP	Steel Hammer Properties
SIC	Schnitzer Investment Corporation
SLERA	screening-level ecological risk assessment
SLV	screening level value
SMA	sediment management area
SOW	statement of work
SPH	separate-phase hydrocarbons
SPI	Sediment Profile Imagery
SPMD	semipermeable membrane device
SQVs	sediment quality value
SSA	Stevedoring Services of America
SSI	Schnitzer Steel Industries
STA®	Sediment Trend Analysis®
SUF	site use factor
SVE	soil vapor extraction
SVOC	semivolatile organic compound
SWAC	spatially weighted average concentrations
SWDA	Safe Water Drinking Act
SWPCP	storm water pollution control plan
TBT	tributyltin
TCA	trichloroethane
TCDD	tetrachlorodibenzodioxin
TCE	trichloroethylene
T_{cr}	critical shear stresses
TEF	toxicity equivalency factor
TEQ	toxic equivalent concentration
tetraCBs	tetrachlorinated biphenyls
TFA	tank farm area
TIFF	tagged image file format
TMDL	total maximum daily load
TOC	total organic carbon
TMP	truck manufacturing plant
TPH	total petroleum hydrocarbons
triCBs	trichlorobiphenyls
TRV	toxicity reference value
TSS	total suspended solids
TTL	target tissue level
TZW	transition zone water
UCL	upper confidence level

UF	uncertainty factor
UIC	underground injection control
UPRR	Union Pacific Rail Road
URS	URS Corporation
USACE	U.S. Army Corps of Engineers
USCG	U.S. Coast Guard
UST	underground storage tank
UV	ultraviolet
VCP	Voluntary Cleanup Program
VOC	volatile organic compound
WBZ	water-bearing zone
WHO	World Health Organization
WISCO	Willamette Iron and Steel Company
WPCL	Water Pollution Control Laboratory
WRCC	Western Regional Climate Center
WWTP	wastewater treatment plant
XPA	expanded preliminary assessment

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EXECUTIVE SUMMARY

This Comprehensive Round 2 Site Characterization Summary Report evaluates the physical, chemical, and biological information collected through the Round 2 sampling effort in order to focus the Round 3 data collection effort and, to the extent practicable, determine the final data needs for the RI/FS. In order to meet this objective, the following topics are covered in the Round 2 Report:

- Review of the investigative activities, including major sample collection phases and goals (Section 2)
- Description of the upland and in-water physical characteristics of the Site (Section 4)
- Identification of potential historical and current contaminant sources and transport pathways to the Study Area (Section 5)
- Identification and mapping of the nature and distribution of chemical concentrations in sediments, transition zone water, surface water, and tissue (Section 6)
- Initial evaluation of chemical loading, fate, and transport processes (Section 7)
- Documentation of the results of the Round 2 human health and ecological risk assessments (Sections 8 and 9)
- Identification of initial Preliminary Remediation Goals (iPRGs) and initial areas of potential concern (iAOPCs) based on the Round 2 human and ecological risk assessment results (Section 10)
- Presentation of a revised conceptual site model at the scale of the entire Study Area and for individual iAOPCs, portraying the relationships among sources, chemicals, transport mechanisms, and receptors, including evaluation of the relative contribution of known sources to the iAOPCs (Sections 3 and 11)
- Identification of data needed to complete the RI/FS and next steps (Section 13).

Based on the results of the data analysis, the majority of potential human health risk at this site is from consumption of resident fish contaminated with PCBs, and higher levels of PCBs in sediment are confined to discrete near-shore locations along both banks of the Study Area. PCBs are also the chemicals with the greatest potential to pose ecological risk.

The data needed to complete the in-water RI/FS have also been identified and include:

- Additional data for sediment, surface water, and stormwater at specific locations in order to fill spatial gaps and reduce uncertainties, and
- Additional benthic community, lamprey, and sturgeon data to evaluate species-specific considerations.

Sampling plans have already been initiated for several of these media through the Round 3A collection effort. The remaining data needs will be collected in Round 3B later in 2007.

Although these additional data will be useful in addressing specific questions and reducing some uncertainties, and recognizing that the final remedial investigation and baseline risk assessments may include analyses not presented in this report, the Lower Willamette Group (LWG) does not anticipate that these efforts will have an appreciable effect on the general results and conclusions presented in this report (e.g., PCBs will still be the most significant contributors to potential risks at this site).

Sources of Data

According to the EPA-approved Programmatic Work Plan for the Portland Harbor Superfund Site, the field work for the physical, biological, and chemical systems is divided into four stages: pre-AOC (including characterization of the physical system), Round 1 (including tissue collection and compilation of historical data), Round 2 (including characterization of nature and extent, additional biological testing, and collection of feasibility study data), and Round 3. Rounds 1 and 2 were intended to collect the majority of data needed to complete the remedial investigation and feasibility study, and Round 3 is to fill any remaining data gaps or data needs.

The Round 2 Report presents an analysis of all data collected by the LWG since 2001, as well as historical data that meet quality assurance criteria. The data sources are summarized in Section 2 and include:

- 2000 individual fish and invertebrate samples
- 1,800 subsurface sediment chemistry samples (from about 660 coring locations)
- 1,650 surface sediment chemistry samples
- 800 sediment trend analysis sample points
- 500 Sediment Profile Images
- 225 transition zone water samples from 108 stations at 9 sites
- 130 surface water samples from 25 point and transect stations
- 4 major annual bathymetry surveys of 16 miles of the lower Willamette River (LWR)
- 3 wildlife habitat surveys.

Physical Setting

Over the past 150 years the Portland Harbor area of the LWR has been redirected, straightened, filled, and deepened by dredging. Most of the riverbank has been filled, stabilized, and/or engineered for industrial or port operations with riprap, bulkheads, and overwater piers and docks. Portland Harbor remains today the industrial sanctuary for the Portland metropolitan area, yet includes some residential enclaves and recreational facilities.

River flow varies dramatically with the seasons, with low late-summer dry-season levels and high rainy season and spring snow melt levels; periodic flow reversals within the LWR also occur due to tidal effects.

The Willamette River flows into both the Columbia River and Multnomah Channel. Under certain conditions, more than half of the LWR flow is directed into Multnomah Channel. The width and depth of the river affect the flow velocities and determine in part where sediment is eroded and deposited. A federally maintained navigation channel throughout the Study Area has been dredged historically to a level of -40 feet. Section 4 provides additional detail on the physical setting of the LWR.

Conceptual Site Model

In order to focus sampling and other investigations, a conceptual site model (CSM) for the Portland Harbor RI/FS Study Area was developed and is periodically updated. The CSM describes the current understanding of potential chemical sources, pathways, and receptors in the Study Area and evaluates the relative importance of different pathways for both historical and current potential sources. The primary function of the CSM at this stage in the RI/FS is threefold: 1) to structure an initial evaluation of sources of iCOCs to the Study Area and individual iAOPCs, 2) to assess the relative contribution of those sources and pathways, and 3) to identify data gaps for completion of the RI/FS. This information will also be used to help inform the DEQ source control program. The CSM is described generally in Section 3 and in detail in Section 11.

Other sections of the report also support the CSM. Section 7 presents the Round 2 assessment of contaminant loading, fate, and transport processes in the Study Area. Sections 8 and 9 identify the exposure media, exposure scenarios, iCOCs, and potential iCOCs for the human health and ecological risk assessments, respectively. Development of iPRGs and iAOPCs is described in Section 10.

Potential Sources/Pathways

The evaluation of potential sources included reviewing available upland source information and assessing the likelihood that chemicals associated with facility operations or other potential sources, such as stormwater, may have migrated or been released to the river. Additionally, potential sources outside the Study Area from other reaches of the LWR were identified. Potential source and pathway information is summarized in Section 5 and will be updated in the final RI report.

This evaluation of potential sources concludes:

- There probably were numerous historical sources that contributed contamination to the river via all pathways (surface water, sediment transport, groundwater, stormwater and process wastewater discharge, overland flow, bank erosion, overwater activities and spills, and atmospheric deposition).
- Most historical sources are no longer active or have been significantly diminished.
- Upstream surface water, sediment transport, and stormwater from within and upstream of the Study Area remain the most likely significant pathways.

Distribution of Chemicals

The LWG analyzed samples for more than 540 chemicals of interest. The distribution of key indicator chemicals is discussed in Section 6. Taken as a whole, these data show that sediment concentrations tend to be fairly uniform across the Study Area except in nearshore or off-channel areas that are generally associated with known or suspected historical or current sources, where concentrations tend to be higher. In general, except for arsenic and mercury, sediment data from areas outside the Study Area show lower concentrations of indicator chemicals than the Study Area.

Round 2 Human Health Risk Assessment

The Round 2 Human Health Risk Assessment (HHRA) evaluated potential risks to human health resulting from exposure to chemicals of potential concern through direct exposure to beach sediment, in-water sediment, surface water and groundwater seeps, and through fish and shellfish consumption. For the Round 2 Report, conservative exposure assumptions were used to assess potential risks. The Round 2 HHRA is not the baseline HHRA (which will be presented in the RI report). The Round 2 analysis was intended to identify potential data gaps remaining for the RI/FS and was not intended to develop final cleanup levels or identify areas in need of remediation. The Round 2 HHRA is summarized in Section 8, and detailed information is provided in Appendix F.

The Round 2 HHRA evaluated the following exposure scenarios, as provided in the approved Programmatic Work Plan:

- Dockside worker — direct exposure to beach sediment
- In-water worker — direct exposure to in-water sediment
- Adult and child recreational beach user — direct exposure to beach sediment and surface water (for swimming scenarios)
- Transient — direct exposure to beach sediment, surface water (for bathing and drinking water scenarios), and groundwater seeps
- Native American fisher — direct exposure to beach sediment or in-water sediment and fish consumption
- Non-tribal fisher — direct exposure to beach sediment or in-water sediment, fish consumption, and shellfish consumption.

The key conclusions of the Round 2 HHRA are:

- Potential risks from consumption of fish or shellfish are generally orders of magnitude higher than any of the other exposure scenarios.
- Potential risks from consumption of fish or shellfish are within or above the EPA target cancer risk range of 10^{-4} to 10^{-6} and exceed the target noncancer hazard index of 1.

- Potential risks from consumption of upstream (Willamette Falls) fish also are within or above the EPA target cancer risk range of 10^{-4} to 10^{-6} and exceed the target noncancer hazard index of one.
- PCBs result in the highest potential cancer and noncancer risks from fish consumption.
- With the exception of a single in-water sediment exposure scenario at two 0.5-mile river segments, potential risks from direct exposure to beach sediment, in-water sediment, surface water, and groundwater seeps are within or below EPA's target 1one.
- No additional data collection is needed to complete the baseline HHRA; however, existing data, particularly tissue data, and the exposure assumptions used to evaluate fish consumption risks will be evaluated further.

Round 2 Ecological Risk Assessment

The Round 2 Ecological Risk Assessment (ERA) presents an evaluation of potential risks to ecological receptors within the Study Area. The baseline ERA will be developed for the RI report. Again, the Round 2 analysis was intended to identify potential data gaps remaining for the RI/FS and was not intended to develop final cleanup levels or identify areas in need of remediation. The Round 2 ERA is summarized in Section 9, and detailed information is provided in Appendix G.

The Round 2 ERA evaluated potential risks to the following groups of ecological receptors, as provided in the approved Programmatic Work Plan:

- Benthic community
- Fish
- Wildlife
- Amphibians and reptiles
- Aquatic plants.

The conservative screening-level ecological risk assessment identified numerous chemicals of potential concern (Round 2 COPCs). These Round 2 COPCs will be considered in refining the list of chemicals of concern for the baseline ERA. The key conclusions of the Round 2 ERA are:

<u>Benthic Community</u>

- Areas of potential risk to the benthic community were identified using benthic toxicity testing, predictive models of benthic toxicity, and other lines of evidence (LOE). These areas are located primarily nearshore adjacent to known or suspected chemical sources.
- A high percentage (79 percent) of the sampled sites was classified as nontoxic to benthic invertebrates. Only 13 percent were classified as toxic, with the remaining

stations (8 percent) either not evaluated due to limited chemistry data and no sediment toxicity data, or identified as indeterminate.

- Initial chemicals of concern (iCOCs) for benthic invertebrates based on multiple lines of evidence include 3 metals, PCBs, 3 individual PAHs, total PAHs, and DDTs.
- Other potential iCOCs for benthic invertebrates were identified as those chemicals associated with high uncertainty or identified solely based on transition zone water exceedances of surface water screening levels, but not supported by other LOEs, as posing risks to benthic invertebrates. These potential iCOCs are not expected to pose significant risks to benthic invertebrates because there is limited potential for exposure.

Fish

- Potential risks to fish were identified through the Round 2 ERA. The chemicals that have the greatest potential for posing risk to fish are PCBs.
- Other iCOCs for fish include DDTs, phthalates, mercury, and tributyl tin.

Wildlife

- Potential risks to wildlife were identified through the Round 2 ERA. The iCOCs are PCBs, dioxins, mercury, DDTs, and aldrin.
- Potential risks to most wildlife receptors were identified based on dietary exposure to PCBs, dioxins and furans, and DDE. DDE also represented a potential risk to osprey and bald eagle based on the bird egg tissue LOE.
- Potential localized risks to shorebirds (represented by spotted sandpiper) were associated with six specific foraging beach areas and based on dietary exposure to PCBs, dioxins and furans, DDD, and aldrin.

Amphibians, Reptiles, and Aquatic plants

- No iCOCs were identified for amphibians, reptiles, and aquatic plants.

Most of the data needed to complete a baseline ERA have already been collected. The remaining data needs have been identified, and the sampling efforts are either underway or achievable through the Round 3 sampling program.

Initial Areas of Potential Concern

Initial areas of potential concern (iAOPCs) within the Study Area were identified to help identify data needs to complete the RI/FS. iAOPC development is described in Section 10. Chemical-specific iPRGs were developed for iCOCs identified through the Round 2 HHRA and ERA. iPRGs and other risk information were then applied to generate maps of areas where chemical concentrations are high enough to be of potential concern, based on the conservative assumptions used for the Round 2 HHRA and ERA. Finally, these maps were combined to

identify areas of overlapping or contiguous potential risks. iAOPCs for the Round 2 report were based solely on surface sediment data and will be refined to develop AOPCs for the RI report. Based upon the Round 2 evaluations:

- 29 iAOPCs were identified (28 specific sites and one "site-wide" area for the risks associated with PCBs).
- Specific iAOPC sites range from under 0.2 acres to just over 40 acres:
  - 5 are less than one acre
  - 10 are between 1 and 10 acres
  - 13 are between 10 and 40 acres
- Typically, the more receptors and scenarios at potential risk the higher the iCOC concentrations at that area.
- PCBs are the most widespread chemical causing the identification of iAOPCs, and PCB risks are present in almost every iAOPC.

RI/FS Data Gaps

As a result of data collection and analysis through Round 2, the following data are needed to complete the RI/FS:

- Sediment trap data
- Surface sediment data
- Subsurface sediment data
- Surface water data
- Stormwater data
- Lamprey and sturgeon tissue data
- Lamprey and benthic toxicity data.

Other specific data needs were identified for specific iAOPCs (e.g., side scan sonar). Data types and proposed general locations are discussed in Section 12. Most of the identified data gaps will address the spatial distribution of sample locations and reduce uncertainties, while other data gaps will address species-specific toxicity questions.

Of these remaining data needs, sediment trap, surface sediment, subsurface sediment, surface water, stormwater, lamprey and sturgeon tissue, and lamprey toxicity data are already being addressed through Round 3A data collection activities.

Additional surface sediment and subsurface sediment data, along with benthic toxicity data, have been identified as Round 3B data needs. The LWG will work collaboratively with EPA

and its partners to generate the field sampling plans for Round 3B. Once these data are collected and analyzed, the LWG will complete the final Remedial Investigation (including baseline risk assessments) and Feasibility Study for the Study Area.

1.0 INTRODUCTION

This Round 2 Comprehensive Site Characterization Summary and Data Gaps Analysis Report (Comprehensive Round 2 Report) presents an interim evaluation of the data collected and compiled by the Lower Willamette Group (LWG) through Round 2 of the Portland Harbor Remedial Investigation and Feasibility Study (RI/FS). Round 2 sampling activities took place during multiple field efforts in the fall/winter of 2004 and the spring/summer/fall of 2005. Several Round 2 site characterization reports for specific media investigations including sediment, surface water, and transition zone water (TZW) were submitted prior to this Comprehensive Round 2 Report (Integral 2005c, 2006g,l). Round 1 sampling activities are documented in the Round 1 Site Characterization Summary Report (SCSR), which was submitted to the U.S. Environmental Protection Agency (EPA) on October 12, 2004 (Integral 2004b).

The LWG is performing the Portland Harbor RI/FS pursuant to an EPA Administrative Settlement Agreement and Order on Consent for Remedial Investigation/Feasibility Study (AOC) (EPA 2001a and amendments). As provided in the Statement of Work (SOW) to the AOC, the objectives of the Portland Harbor RI/FS are:

- Investigate the nature and extent of contamination for the in-water portion of the Site
- Assess potential risk to human health and the environment
- Develop and evaluate potential remedial alternatives to reduce risks to acceptable levels
- Recommend a preferred alternative for cleanup.

This Comprehensive Round 2 Report addresses the first objective and provides a screening-level assessment of risk preliminary to the baseline Round 2 human health and ecological risk assessments (HHRA and ERA).

The required content of this Comprehensive Round 2 Report is specified in Section 7.8.1 of the SOW:

> This summary will review the investigative activities that have taken place, and describe and display Site information and data documenting the location and characteristics of surface and subsurface features and contamination at the Site, including sample locations, chemical concentration distributions and the results of any biological testing. This evaluation will include, to the extent practicable, chemical distributions relative to known sources, the location and varying concentrations of contaminants in areas influenced by sources, and the extent of contaminant migration through the in-water portion of the Site.

In general, this report assembles data collected by the LWG and others, characterizes the Site based on those data, updates the conceptual site model (CSM), develops initial

areas of potential concern (iAOPCs), identifies sources of contaminants to the iAOPCs, identifies data gaps for assessing the nature and extent of contamination, and identifies data gaps for human health and ecological risk assessment and for the feasibility study.

1.1 AREA OF STUDY

The remedial investigation initially focused on the stretch of the Willamette River from river mile (RM) 3.5 to RM 9.2 and adjacent areas logically associated with an evaluation of the in-water portion of this stretch of the river. The SOW and the Programmatic Work Plan for the Portland Harbor RI/FS (Integral et al. 2004b) refers to that initial study area as "the ISA." Since then the area of investigation has been broadened to include areas of the river extending from approximately RM 2 to RM 11; this expanded area has been termed the "Study Area" (Map 1.1-1). This Comprehensive Round 2 Report presents the evaluation for the Study Area. The ISA and the Study Area do not define the Superfund Site, the boundaries of which will be determined by EPA upon issuance of a Record of Decision (ROD).

1.2 PURPOSE OF REPORT

The ultimate purpose of the Comprehensive Round 2 Report is to evaluate the current data gaps for the Site and identify the data needed to complete the RI/FS. This will be accomplished by analyzing all of the available data for the Site and using initial human health and ecological preliminary risk evaluations to develop initial chemicals of concern (iCOCs), initial Preliminary Remediation Goals (iPRGs), and iAOPCs. Through the initial risk evaluations, data gaps related to specific lines of evidence and uncertainty are identified. Following identification of the iCOCs and iAOPCs, the data gaps related to the initial risk evaluations can then be focused toward the actual data needed to complete the baseline risk assessments. Similarly, data needed to refine the nature and extent of contamination within the Site and the associated relationships to potential sources are also focused by identification of iCOCs and iAOPCs. Detailed CSMs for each iAOPC provide for an analysis of these data gaps at a scale appropriate to the feasibility study. It is important to note that the LWG and EPA and its partners have already identified several data needs that are being addressed by the ongoing Round 3A sampling effort. Thus, many of the data gaps identified in this report will be addressed by sampling efforts currently underway and therefore will not have associated data needs for Round 3B.

The Comprehensive Round 2 Report is an interim evaluation consistent with EPA guidance (EPA 1988, page 1-3, 2nd paragraph):

> The objective of the RI/FS process is not the unobtainable goal of removing all uncertainty, but rather to gather information sufficient to support an informed risk management decision regarding which remedy appears to be most appropriate for a given site. The appropriate level of analysis to meet this objective can only be reached through constant

strategic thinking and careful planning concerning the essential data needed to reach a remedy selection decision. As hypotheses are tested and either rejected or confirmed, adjustments or choices as to the appropriate course for further investigations and analyses are required. These choices, like the remedy selection itself, involve the balancing of a wide variety of factors and the exercise of best professional judgment.

The iPRGs and iAOPCs presented in this report were developed at EPA's request. They represent an interim assessment of those areas contributing most to conservative, preliminary risk values, and were developed explicitly for identifying data gaps. This interim development of iPRGs and iAOPCs required risk analysis beyond the screening-level analyses that typically precede the definitive RI/FS. Although this Round 2 data gaps assessment includes simple identification of spatial data gaps, it is also an interim assessment of whether available data are adequate to make risk-based remedial decisions for the feasibility study.

Ultimately, the primary information needed to make risk management decisions includes:

a. Identification of the receptors, exposure scenarios, and chemicals that are associated with potentially unacceptable risk from exposure to in-water media.

b. For the above, identification of the pathways (including media) and, to the extent practicable, locations that contribute most to a finding of unacceptable risk.

c. For the receptor/pathway/chemicals identified in items "a" and "b" above, determination of whether the most important sources of contaminants to the river are ongoing or historical (not current releases), so that risk management actions can be taken to reduce exposures. For in-water sources, actions associated with this RI/FS will include active cleanup or other management of contaminated sediments in the river. The RI/FS must also identify potential sources that are not in the river, but that are important ongoing sources of contamination to sediments, surface water, or biota and therefore contribute significantly to unacceptable risk in the river. Management of these sources will be referred to the Oregon Department of Environmental Quality (DEQ).

Specific objectives of the Comprehensive Round 2 Report (as stated in the Programmatic Work Plan) include:

1. Summarize pre-AOC, Round 1, and Round 2 investigation results (see Sections 4, 6, and 7 of this report).
2. Present preliminary evaluation of risks to human health (Section 8) and ecological receptors (Section 9) based on site-specific data for purposes of

identifying iCOC "risk drivers" and data gaps to be addressed in Round 3 sampling (Section 12).

3. Provide a comprehensive update of the CSM (Sections 3 and 11);
4. Provide iPRGs (Section 10).
5. Present a screening of pre-AOC, Round 1, and Round 2 data relative to Preliminary Remediation Goals (PRGs) (Section 10) and identify any data gaps to be addressed in Round 3 (Section 12).
6. Provide the most current results of the food web model (FWM), its application to development of iPRGs, and food web modeling data gaps (Sections 9 and 10);
7. Review the investigative activities (Section 2).
8. Display Site information and data documenting the location and characteristics of surface and subsurface features and contamination at the Site, including sample locations, chemical concentration distributions, and the results of any biological testing (Sections 2, 4, and 6).
9. Include, to the extent practicable, iCOC concentration distributions relative to known sources (Sections 5 and 11).
10. Provide the location and varying concentrations of contaminants in areas influenced by sources (Section 11).
11. Define the extent of contaminant migration through the in-water portion of the Site (Section 7).

1.3 SITE BACKGROUND

Portland Harbor is a heavily industrialized reach of the lower Willamette River (LWR) in Portland, Oregon. The harbor has been the site of numerous manufacturing, shipbuilding, petroleum storage and distribution, metals salvaging, and electrical power generation activities for over a century. Since the late 1800s, the harbor has been extensively modified by wetland draining, channelization, and dredging to accommodate a thriving shipping industry. Public and private outfalls are located on both shores of the river and discharge stormwater from numerous drainage basins that have a variety of types of land use and facilities. These activities, in addition to agricultural, industrial, and municipal activities upstream of the harbor, have contributed to chemical contamination of sediments in the LWR. Although private industries and municipalities within the river watershed began installing state-of-the-art waste control systems beginning in the 1950s, the legacy of past waste management practices remains in the river bottom sediments.

In March 1997, DEQ and EPA initiated a joint study of shallow, nearshore river sediment contamination in the Portland Harbor area. Sediments containing metals, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), chlorinated pesticides, and dioxins were found throughout the harbor area (Weston

1998). Based on the concentrations of these contaminants, EPA determined in December 2000 that Portland Harbor qualified for placement on the National Priorities List (NPL, also known as Superfund). In the listing, EPA and DEQ are the lead agencies for the in-water and upland portions, respectively, of the Portland Harbor Superfund Site. Both agencies coordinate their efforts through a Memorandum of Understanding (MOU) with six tribal governments and several state and federal natural resource trustees that was signed by these government stakeholders in 2001.

In September 2001, EPA and the LWG entered into the AOC to complete an RI/FS of the Portland Harbor Superfund Site. The LWG includes private property owners along the Willamette River, the Port of Portland, and the City of Portland, all of whom have a vested interest in cleaning up contaminated sediments in Portland Harbor. The final Programmatic Work Plan (Integral et al. 2004b) was approved by EPA in June 2004. The Programmatic Work Plan provides an outline and schedule for the sampling activities performed to support the RI/FS. The entire RI/FS process is dynamic and iterative, with each sampling round incorporating new information and refined task objectives. All field sampling activities are documented in a series of field sampling plans (FSPs), quality assurance project plans (QAPPs), health and safety plans, field sampling reports (FSRs, or cruise reports), and site characterization summary reports (SCSRs).

Meanwhile, DEQ is working closely with the City of Portland and various upland property owners to identify and voluntarily clean up their sites. DEQ's focus is on identifying and controlling upland sources of contamination that may be affecting river sediments through such pathways as overland runoff, bank erosion, stormwater discharge, or groundwater seepage. Four early action sites—Port of Portland's Terminal 4, the former Gasco site, Arkema, and Triangle Park—are in various stages of assessment and cleanup, which will precede any remediation that occurs within the Portland Harbor Superfund site. Two other Superfund cleanup projects within Portland Harbor (Gould and McCormick & Baxter) are complete. Nearly 60 other upland sites are in various phases of cleanup, ranging from agreement negotiation to source control implementation.

1.4 REPORT ORGANIZATION

The remaining sections of this report include the following information:

- **Section 2: Sources of Environmental Data.** This section summarizes the LWG investigative activities that have occurred since the Portland Harbor RI/FS began in 2001, including sediment, surface water, and biota sampling, as well as physical characterizations. Historical and concurrent investigations used in risk evaluations are described and nature and extent of chemicals are discussed.
- **Section 3: Conceptual Site Model Summary**. This section provides a concise introductory summary of the overall general conceptual model for the Site.

- **Section 4: Physical Setting.** This section reviews the physical characteristics of the Site, including land use, geology, hydrogeology, bathymetry and sediment characteristics, habitat, and public access.
- **Section 5: Identification of Sources.** This section identifies by river mile the types of chemical sources that potentially affect the Study Area. This section augments general information on sources provided in the Programmatic Work Plan.
- **Section 6: In-river Chemical Distribution.** This section describes the nature and extent of indicator chemicals in surface and subsurface sediment, TZW, surface water, and biota.
- **Section 7: Overview of Fate and Transport Processes.** This section presents an overview of the primary known sources to the river and the processes affecting the source, transport, and fate of iCOCs within the Study Area.
- **Section 8: Round 2 Human Health Risk Assessment Summary.** This section provides a summary of the Round 2 Human Health Risk Assessment included in Appendix F.
- **Section 9: Round 2 Ecological Risk Assessment Summary.** This section provides a summary of the Round 2 Ecological Risk Assessment included in Appendix G.
- **Section 10: Preliminary Identification of Areas of Potential Concern.** This section describes the approach and specific methods used to identify and delineate iAOPCs, summarizes the derivation of iPRGs, and presents the combined iAOPCs for human and ecological receptors.
- **Section 11: Conceptual Site Model.** This section presents the results of the contaminant fate and transport assessment and associated loading estimates for potential sources to the river; it also describes the likely sources, key contaminant migration pathways, and the nature and extent of iCOCs for each iAOPC.
- **Section 12: Data Gaps and Additional Data Needs.** This section briefly summarizes the findings of the Comprehensive Round 2 Report, and presents an analysis of additional data needed to complete the risk assessments, other components of the RI, and the FS.
- **Section 13: Next Steps.** This section identifies the process for completing the RI/FS after the completion of this Comprehensive Round 2 Report.
- **Section 14: References**. Citations noted in this report are found in this section.
- **Section 15**: **Glossary of Terms.**

Ten appendices are included with this document:

- **Appendix A: Data Sources and Site Characterization/Risk Assessment Database.** This appendix briefly summarizes the studies from which data in the report were obtained and includes the complete database in Access® files on compact disc.
- **Appendix B: Identification of Sources.** This appendix includes DEQ's Joint Source Control Strategy (JSCS) Milestone Report from July 2006 (DEQ 2006c) and maps depicting stormwater outfall basins in the Study Area.
- **Appendix C: Nature and Extent.** This appendix provides summary statistics of the chemical and physical data for all media. It includes constituent concentrations used in each summed analyte group for all media, and statistics on sediment samples used to develop preliminary background concentrations.
- **Appendix D: Loading, Fate and Transport.** This appendix provides the analyses used to develop loading estimates for upstream surface water, stormwater, groundwater plumes, advection through sediments, and atmospheric deposition. It also includes riverbank erosion information and a geochemical analysis of arsenic, barium, and manganese in TZW.
- **Appendix E: Food Web Model and Biota-Sediment Accumulation Factor (BSAF) Development.** This appendix describes the FWM development and calibration process and results and summarizes the BSAF development process.
- **Appendix F: Round 2 Human Health Risk Assessment.** This appendix provides the complete Round 2 risk assessment for human health.
- **Appendix G: Round 2 Ecological Risk Assessment.** This appendix provides the complete Round 2 risk assessment for ecological receptors.
- **Appendix H: Derivation of Initial Areas of Potential Concern.** This appendix includes maps depicting the iAOPCs for each of the individual human health exposure scenarios and ecological receptors used in development of the overall iAOPCs.
- **Appendix I: iAOPC CSM Data Tables.** This appendix provides summary statistics of the chemical and physical data for each iAOPC.
- **Appendix J: Upland CSM Site Summary Table.** This appendix is a list of Coceptual Site Model Summaries submitted to EPA.

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2.0 SOURCES OF ENVIRONMENTAL DATA

This section describes the sequence of major investigative work performed by the LWG since the inception of the Portland Harbor RI/FS in 2001. Historical and concurrent studies that have taken place in the Study Area by other parties, such as remedial investigations and environmental site assessments, are also briefly described in this section and summarized in Table 2.0-1. The quality and usability of sampling data collected during these studies are also evaluated.

2.1 LOWER WILLAMETTE GROUP

To characterize the Site, the LWG has collected data on sediment and tissue chemistry, sediment toxicity, physical sediment characteristics, surface water chemistry, groundwater/transition zone chemistry, habitat type and distribution, species occurrence, hydrodynamic/sediment transport processes, upland sources and pathways, and cultural resources. The characterization process is multifaceted and iterative, involving several rounds of sampling for different data needs often timed around varying river stages, river flows, and storm events. Currently, in addition to pre-AOC data, two rounds (Rounds 1 and 2) of sampling have been completed, and an additional round of sampling (Round 3) to fill data gaps was initiated in 2006. Round 1 and 2 data collection efforts are described in the following sections. A summary of all LWG and non-LWG nature and extent data by media is provided in Table 2.1-1. Numbers of samples and analyses performed on each sample are summarized in Tables 2.1-2 (sediment), 2.1-3 and 2.1-4 (biota), 2.1-5 (TZW), and 2.1-6 (surface water).

2.1.1 Pre-AOC Sampling Activities

Some time-critical data collection activities occurred within the LWR prior to the execution of the AOC. These activities were necessary to scope the work plan for conducting the RI. The following activities were detailed in a stipulated agreement, which is Attachment B to the AOC (EPA 2001a):

- Sediment profile imaging field study (SEA 2002b)
- Baseline bathymetry survey from RM 0 to Ross Island (DEA 2002a)
- Juvenile salmonid residence time field study (EES 2002)
- Integrated evaluation of historical navigation channel bathymetry and a Sediment Trend Analysis (STA) (SEA 2002a).

Of these four tasks, the first three involved fieldwork undertaken by the LWG. The fourth task consisted of analyzing two pre-existing data sets. Other field efforts not included in the stipulated agreement, which were conducted by the LWG in the spring of 2002, involved the collection of water current profiles at several transects across Portland Harbor (see Programmatic Work Plan, Integral et al. 2004b, Section 2.2.2).

These tasks provided essential information that was useful for developing and refining the physical and biological preliminary CSM, as presented in Integral et al. (2004b).

2.1.2 Round 1 Sampling Activities

Round 1 sampling activities were conducted in the summer and fall of 2002; other data collection activities occurred through June 2004 (i.e., sediment stake monitoring and time- series bathymetric surveying). These sampling activities were seasonally dependent tasks that were performed to understand more completely the physical dynamics of the river system, to support the HHRA and ERA, or to identify future RI/FS data needs. Physical system measurements occurred within the LWR, while field sampling was concentrated in the ISA. Results are documented in the Round 1 SCSR (Integral 2004b). Round 1 sampling activities are described in the following sections.

2.1.2.1 Physical System

Many Round 1 activities were designed to develop a greater understanding of the Portland Harbor physical system. These included time-series bathymetric surveys, nearshore bank elevation change monitoring, and river flow measurements during high- and low-flow events. Along with existing information about the LWR, these data were used to develop the physical CSM and the scoping, development, and calibration of a numerical hydrodynamic/sediment transport model for the Site (WEST Consultants 2004). An understanding of physical processes in the river over a full range of hydrologic conditions is needed to support the evaluation of risk (e.g., where are buried contaminated sediments likely to be re-exposed?), and ultimately to develop and evaluate remedial alternatives (e.g., where are sediments relatively stable?). The model continues to be refined using additional physical system data collected in Round 2.

Three physical system data types were collected during Round 1 and are briefly described in the following sections:

- Four precision multibeam bathymetric surveys to document riverbed elevation changes over time
- Time-series sediment stake measurements to document nearshore bank elevation changes
- Three acoustic doppler current profiler (ADCP) surveys to provide flow measurements during specific hydrological conditions, including a high-flow event and across tidal cycles.

2.1.2.1.1 Multibeam Bathymetric Surveys

Four multibeam bathymetric surveys extending from the convergence of the LWR with the Columbia River (RM 0) to the upstream end of Ross Island (RM 15.6) were conducted between January 2002 and February 2004 (DEA 2002b; DEA 2003a; SEA and DEA 2003; Integral and DEA 2004). The February 2004 survey immediately followed a relatively high-flow event (approximately 130,000 cfs) in the LWR.

Methods used to conduct these surveys and to process the data were provided to EPA in the referenced documents.

2.1.2.1.2 Sediment Stake Surveys

From July 2002 to June 2004, shoreline/beach sediment erosion/accretion rates were monitored periodically at eight facilities between RM 2 and 9 along the LWR (Anchor 2004). The sites included Portland General Electric (PGE), Port of Portland's Terminal 4, Gasco, Willamette Cove, Arkema, GATX, Coast Guard, and Shell Equilon (Anchor 2004). Attempts to monitor the Schnitzer Burgard shoreline were unsuccessful because no suitable area for deployment and monitoring was available. Polyvinyl chloride (PVC) stakes were driven into the sediment at three different elevations along a transect perpendicular to the shoreline at each facility. Target elevations for the stake locations were the 10th percentile (low elevation), the 50th percentile (median elevation), and the 90th percentile (high elevation) of the river stage measured at a nearby U.S. Geological Survey (USGS) gauge station.

The 3-ft stakes were installed so that the top of each was approximately 1 ft above the sediment surface. Monitoring of erosion/accretion at each location consisted of periodic measurements of the distance from the top of the stake to the existing sediment surface. Measurements were recorded each month during the first 5 months of the study (August through December 2002), in March, July, and October 2003, and in January and June 2004 when the investigation ended.

2.1.2.1.3 Acoustic Doppler Profile Surveys

Three single-day ADCP surveys were conducted in the LWR (DEA 2003a, 2003b, 2004b). The first was conducted during a high-water event on April 19, 2002, along 16 transects from RM 1 to 11. On May 13, 2003, multiple ADCP profiles at various tide stages were collected along three transects in the vicinity of Multnomah Channel (RM 3). In addition, a fourth transect was located in Multnomah Channel. On January 31, 2004, an ADCP survey was conducted during a relatively high-flow event along 17 transects in the LWR between RM 0 and 11. Survey methods and results are discussed in DEA (2002c,, 2003a,b, 2004b).

2.1.2.2 Sediment and Tissue

Sediment (river and beach sediments) and tissue samples were collected during Round 1 throughout the ISA to support the evaluation of the nature and extent of contaminants and the ERA and HHRA. The majority of the Round 1 sediment samples were collected from beaches; a few in-river sediment samples were collected primarily collocated with tissue samples. Round 1 sediment and biota sampling locations are shown on Maps 2.1-1 and 2.1-2a–d, respectively.

Round 1 sediment and tissue collection activities included the following tasks:

- Collection of beach sediments in human use areas

- Collection of surface sediments collocated with sculpin, crayfish, and benthic infauna stations
- Collection of nearshore and in-channel sediments to supplement the distribution of collocated sediments
- Collection of benthic invertebrates at a subset of surface sediment chemistry stations and tissue sampling locations
- Collection of tissue from nine fish species, one crayfish species, and one clam species for chemical analysis
- Reconnaissance survey for benthic tissue and lamprey ammocoete tissue.

These data collection activities are briefly described below and summarized in Tables 2.1-2 and 2.1-3. Substantive information on task methods and results is discussed in detail in the Round 1 SCSR (Integral 2004b).

2.1.2.2.1 River and Beach Sediment

To support the ERA, 26 surface sediment (0-15 cm) samples were collected in the ISA using a van Veen grab sampler in October and November 2002 at collocated tissue (sculpin, crayfish, and clams) sampling locations. Surface sediments were also collected at 10 additional collocated benthic infauna sampling locations in the ISA (see Table 2.1-3).

To support the HHRA, composite surface beach sediment samples were collected at 20 beaches in October 2002 (see Map 2.1-1). Multiple locations at randomly pre-selected distances along one of three transects parallel to the shoreline were sampled using hand cores and combined to create one composite sample per beach. The sample compositing scheme is described in the Round 1 FSP (SEA et al. 2002).

2.1.2.2.2 Fish and Crayfish

To support the ERA and HHRA, 1,870 fish were collected during the late summer and fall of 2002 for tissue chemistry analysis; these data are summarized in Table 2.1-3. Sampling locations are shown on Maps 2.1-2a–d. The target species for the ERA were smallmouth bass, sculpin, subyearling Chinook salmon, largescale sucker, peamouth, northern pikeminnow, Pacific lamprey ammocoetes, and crayfish. For the HHRA, the target species were carp, black crappie, bullhead, smallmouth bass, and crayfish. In addition, walleye and largescale sucker were collected as alternative species for bullhead and carp, respectively. However, they were not used for the HHRA since adequate numbers of bullhead and carp were collected. Fish were composited according to an EPA-approved species-by-species compositing scheme. Whole-body and fillet tissue types were composited separately.

The upstream sampling effort was initiated at the end of October 2002. The upstream sampling took place at two locations, one above and one below Willamette Falls. The first location was designated RM 20 and included fish collected between approximately RM 20 to RM 24.5. The second location was designated RM 28 and included fish

collected between RM 28 to RM 34.5. Brown bullhead and smallmouth bass, which are target fish species for the Round 2 HHRA, were collected at both upstream sampling locations and were used in the evaluation of upstream tissue.

The catch included 863 sculpin, 419 crayfish, 128 largescale sucker, 90 smallmouth bass, 78 carp, 92 subyearling Chinook salmon, 64 brown bullhead, 35 northern pikeminnow, 48 black crappie, 30 peamouth, 18 yellow bullhead, 3 lamprey ammocoetes, and 2 walleye. Numbers of fish species included in the composited samples are listed in Table 2.1-4.

Despite repeated backpack electrofishing and surface sediment grab sampling efforts during Round 1, only three lamprey ammocoetes were collected in the ISA. Later, reconnaissance surveys were conducted to determine whether it would be possible to collect sufficient lamprey ammocoete biomass from sampling locations within Portland Harbor. In the first reconnaissance survey in September 2002, backpack electroshockers were used and sediment grabs were taken in an attempt to collect ammocoetes from 21 of the collocated sediment and tissue sampling locations. Only one ammocoete was collected using the electroshocker or from sediment grab samples. In the second reconnaissance survey in October 2002, fisheries biologists from the Umatilla Tribe assisted in targeting favorable ammocoete habitat. Eleven locations with fine sediments, low current velocities, and in depositional areas along the river margins were selected and sampled with backpack electroshockers. No ammocoetes were collected in this survey. Due to insufficient lamprey tissue volume, no tissue chemical analyses were conducted on this species.

2.1.2.2.3 Macroinvertebrates

Benthic Invertebrate Sampling

Crayfish were collected in the late summer and fall of 2002 for tissue chemistry as part of the fish sampling effort. A total of 419 individuals were used to create 27 composite samples for chemical analyses (see Table 2.1-4).

Prior to the infaunal community sampling, a benthic field reconnaissance was conducted in September 2002 to assess whether there was adequate benthic invertebrate tissue mass in near-surface sediments (0-15 cm depth) for chemical analysis. Because the soft-bottom benthic community is dominated by very small organisms (e.g., midges and oligochaetes), the results of the reconnaissance concluded that it would not be possible to collect adequate infaunal biomass from the soft-bottom habitats in the ISA. During the 2002 reconnaissance survey, clams were not widely prevalent, however, the non-native bivalve species *Corbicula fluminea* was found to possibly provide sufficient invertebrate tissue samples for tissue body burden analyses. Sampling efforts in October and November 2002 resulted in collection of sufficient clam biomass for laboratory analysis at three of five stations sampled. Two locations near the center of the ISA (east and west banks at RM 6.8 and 7.3) yielded more than 150 grams of tissue. Fifty-three grams were collected at a third station (west bank RM 7.4), while the

remaining two stations yielded only nominal biomass. As noted above, surface sediment chemistry samples were also collected at all benthic invertebrate stations.

Multiplate Sampling

The epifaunal macroinvertebrate community was quantitatively sampled at 22 stations in the ISA using artificial substrates (multiplate samplers) suspended from the river bottom (see Maps 2.1-2a–d). Epifaunal macroinvertebrates were collected at 12 of the sculpin/crayfish collocated sediment stations and at 10 additional stations located in both nearshore areas and in the navigation channel from October 22 through 25, 2002 (see Table 2.1-3). As noted above, surface sediment chemistry samples were also collected at all benthic invertebrate stations. These multiplate samplers were used to characterize the composition of the epibenthic community utilizing hard-substrate habitats within the ISA. This information is used to understand potential exposure pathways for fish that might feed on organisms associated with riprap and other hard-bottom habitats

2.1.3 Round 2 Sampling Activities

Round 2 sampling was performed during multiple field efforts in the fall and winter of 2004 (Round 2A); in the spring, summer, and fall of 2005 (Round 2B); and in the spring of 2006 (hydrodynamic sediment transport model sampling). This sampling was intended to refine the understanding of the physical dynamics of the river system, to characterize contaminant distribution and potential source effects, to provide data necessary for the risk assessments, and to initiate collection of data for the FS. The majority of data collection for the FS will likely occur during Round 3.

Round 2 sampling activities included collection of the following types of data:

- Physical system data to calibrate the hydrodynamic sedimentation model
- Surface and subsurface sediment chemistry and physical data to characterize the nature and extent of contamination, including contaminant distribution and potential source effects to the river, and to support the FS
- Surface water chemistry data to characterize the nature and extent of water contamination and to support the ERA, HHRA, and FS
- In-river groundwater discharge mapping data and TZW samples to support ERA and HHRA evaluation of the potential impact of groundwater chemicals transported to the Study Area via the groundwater pathway
- Preliminary natural attenuation sampling (e.g., radioisotope cores) targeted for areas that may have potential natural processes to support this alternative
- A cultural resources survey to support procedures for protecting and addressing cultural resources before, during, and after the RI/FS and remedial design is complete.

These activities are briefly described in the following sections.

2.1.3.3 Physical System

The hydrodynamic sedimentation model is designed to provide both an assessment of more short-term or "typical" sediment transport regimes in the river and estimates of flow velocities and sediment transport under rare high-flow events. Data collected during the pre-AOC and Round 1 surveys were used to parameterize and calibrate the model, but additional site-specific data were needed to refine and enhance the model's performance (WEST Consultants 2005a,b). The critical data needs for Round 2 included total suspended solids (TSS) concentrations, cohesive suspended sediment settling velocities, erosion rates and critical erosion velocities, and short-term bed responses to high-flow events. TSS sampling took place from late fall 2005 to April 2006, and *in situ* sediment settling velocity and measurements, near-surface bed properties, and erodibility (Sedflume study) were conducted in April 2006 (Integral 2006h).

2.1.3.4 Sediment

The purpose of Round 2A sediment sampling was to collect the major sediment data set for the RI and risk assessments, and to initiate data collection for the FS. The Round 2 sediment sampling program involved the following tasks:

- Collection of sediment samples along the shoreline in potential shorebird and human use beaches
- Collection of surface sediment samples in the riverbed
- Collection of subsurface sediment samples and physical data
- Collection of radioisotope cores in the Study Area as part of the FS monitored natural recovery (MNR) assessment.

Sediment sampling results are summarized in Table 2.1-2 and presented in detail in the Round 2A Sediment SCSR (Integral 2005c); the scope of these efforts is briefly described below. Surface and subsurface sediment sampling locations during Round 2 are shown on Maps 2.1-1 and 2.1-3a–t, respectively.

2.1.3.4.1 Shorebird Foraging Areas and Human Use Beach Sediment

To support the HHRA and ERA, composite shoreline sediment samples were collected from July 26-30 and on November 5, 2004, at 21 shorebird foraging areas from RM 2 to 10, and 4 collocated shorebird foraging areas and potential human use beaches between RM 2 and 3 (see Map 2.1-1). Shorebird foraging and human use shoreline areas up to 500 m in length were selected for sampling. A total of 28 composite beach sediment samples (including two field replicate samples and one homogenate split sample) were collected and chemically tested.

2.1.3.4.2 Surface Riverbed Sediment and Toxicity Testing

Surface sediment grab samples (0-30 cm) were collected from July 19 through November 5, 2004, at a total of 523 target locations (see Map 2.1-1). Most of the stations were concentrated in the Study Area from RM 2 to 11; six upstream stations

(between RM 16 and 25) and three downstream stations (between RM 1 and 2) were also sampled. These data were collected to characterize the nature and extent of chemical distributions in LWR surface sediments. Including field replicates and homogenate splits, a total of 576 surface sediment grab samples from 523 stations were chemically tested for a full range of chemical conventional (e.g., grain size) and contaminant analytes.

Surface sediments from 222 of the 523 surface sediment stations, including the six upstream stations, were also submitted to the bioassay laboratory for toxicity testing. Toxicity testing of Round 2 sediment samples was performed to support the development of a predictive model(s) characterizing the relationship between sediment chemistry and benthic invertebrate toxicity in the Study Area. Two toxicity testing protocols were employed. The 10-day *Chironomus tentans* and the 28-day *Hyalella azteca* sediment toxicity tests were conducted on 215 sediment samples collected between RM 2 and 10, and 18 sediment samples collected at stations upstream of Ross Island (~ RM 16). Test methods and results are described in the *Portland Harbor RI/FS Round 2A Data Report, Sediment Toxicity Testing* (Windward 2005c).

2.1.3.4.3 Subsurface Riverbed Sediment

Subsurface riverbed sediment cores were collected at 200 locations between RM 2 and RM 10 from September 20 to October 8 and from October 18 to November 11, 2004, to characterize the nature and extent of chemicals in subsurface sediments for the RI/FS (see Maps 2.1-3a–t). A total of 218 subsurface sediment cores were collected from the 200 stations, with 717 sediment samples from the cores submitted for chemical and/or physical analyses, including 30 replicate core samples and 19 homogenate split samples.

Of the total 717 core samples, 60 were collected from four sedimentation cores and submitted for ^{210}Pb and bulk metals analyses. An additional 72 sedimentation core samples were analyzed exclusively for radioisotopes ^{7}Be and ^{137}Cs. Twelve samples were submitted for conventional parameter and organic compound analyses in ancillary cores taken immediately adjacent to the sedimentation core at each station. The results of the sedimentation core analyses are included in the data sets compiled in this report, but the MNR evaluation of the data is presented in Anchor (2005).

2.1.3.4.4 Archived Round 2 Surface and Subsurface Sediment Analyses

PCB Congeners in Round 2A Surface Sediments

Based on the total Aroclor data for Round 2A surface samples, a subset of the samples was selected for PCB congener analyses to evaluate the relationship between PCB totals based on the sum of PCB Aroclors versus the sum of PCB congeners. The samples analyzed were frozen archived aliquots from the Round 2A surface samples, and so the two data types were generated from the same composite sample. Kennedy/Jenks and Integral (2005) selected the samples for analysis to capture a full range of PCB concentrations and spatial coverage across the Study Area. Results of the PCB congener analyses are provided in Integral (2006k).

Archived Round 2A Subsurface Sediment Analysis
During Round 2A core processing, 128 subsurface core segments were archived without analysis. Because the core processing sampling plan (Integral et al. 2004a) defaulted to the analysis of the top two core segments below the surface segment (i.e., core segments B and C), the archived segments were most often the subsurface segments D, E, F, etc. These deeper segments typically occurred more than 5 ft below mudline (bml). Also, because the collocated surface grab sample (0-30 cm) was analyzed to characterize the sediment surface layer for each location, the top 30 cm of the core, the A segment, was also typically archived. Consequently, in addition to the 128 subsurface core segments, approximately 200 A-segment core samples were also archived (Integral 2005c).

A review of the spatial vertical trends of the Round 2A analytical results identified spatial gaps for several "indicator chemicals" in the data set. Therefore, archived surface and subsurface sediment samples were selected for a suite of analyses to supplement the Round 2 data set. Selected archived core samples were analyzed for a suite of chemicals, including metals, semivolatile organic compounds (SVOCs), PAHs, tributyltin (TBT), PCB Aroclors and congeners, and dioxins/furans. The results of the Round 2A archived core sample analyses are documented in Integral (2006j).

Archived Round 2B Subsurface Sediment Analysis
As with Round 2A, a subset of archived Round 2B core segments was selected for analysis of target chemicals based on a review of the Round 2A/2B nature and extent data set for indicator chemicals. An FSP identifying archived Round 2B samples for analysis was submitted to EPA in July 2006 (Integral 2006m). Sample analyses are pending validation and are not available for inclusion in this report.

2.1.3.5 Groundwater/ Transition Zone Water
As indicated in Integral et al. (2004b), the overall objective of the TZW groundwater sampling program is to determine whether discharges of groundwater-related chemicals of interest (COIs) to the biologically active sediments in the groundwater/surface water transition zone or to seep areas pose or contribute to unacceptable risks to human health or ecological receptors.

To meet this objective, the Round 2 Groundwater Pathway Assessment (GWPA) included the following technical elements (Integral et al. 2005):

- Development and implementation of a pilot study to identify appropriate technical methods and procedures for conducting in-water TZW characterization work, including the identification of probable locations of groundwater discharge to the river and collection of TZW samples
- Identification of upland sites where there is a confirmed or reasonable likelihood of a complete transport pathway for groundwater constituents to reach the Willamette River
- In-river mapping of groundwater discharge areas to identify appropriate TZW sampling locations at the selected sites

- Collection and analysis of TZW samples to estimate exposure-point concentrations (EPCs) at the selected sites to support risk calculations.

2.1.3.5.1 2004/2005 Pilot Study

From late 2004 to early 2005, the LWG performed a pilot study designed to evaluate groundwater discharge mapping tools and TZW sampling methods for possible use in the Round 2 GWPA. The mapping tools and sampling methods were tested at two sites within the Portland Harbor ISA: ARCO Terminal 22T and Arkema. The technical approach and scope of work for the pilot study was presented in the Groundwater Pathway Assessment Pilot Study FSP (Integral 2004a). The pilot study results (Integral 2005g), in conjunction with guidance available from technical literature sources, formed the basis for the identification of methods presented in the discharge mapping FSP (Integral 2005b) and TZW FSP (Integral 2006c).

For groundwater discharge mapping in the LWR Study Area, a combined application of two methods was recommended based on the pilot study results— temperature difference mapping using the Trident probe plus direct seepage measurements using the UltraSeep system. For TZW sampling, two of the evaluated sampling methods were recommended—push-point sampling using the Trident probe and diffusion-based sampling using small-volume peepers.

2.1.3.5.2 TZW Study Site Selection

During the planning phase of the Round 2 GWPA, 113 upland sites located between RM 2 and 11 were identified and categorized according to their potential to represent a source of COIs to Portland Harbor via the groundwater transport pathway (GSI 2003a). Of these, 21 sites were initially identified as "Category A," defined as those sites with a confirmed or reasonable likelihood for discharge of upland groundwater COIs to Portland Harbor. From this list, EPA, DEQ, and LWG ultimately identified the following nine high-priority Category A sites for inclusion in the Round 2 GWPA field program: Kinder Morgan Linnton Terminal, ARCO Terminal 22T, ExxonMobil Oil Terminal, Gasco, Siltronic, Rhone Poulenc, Arkema (Acid Plant and Chlorate Plant Areas), Willbridge Bulk Fuels Terminal, and Gunderson (Map 2.1-4).

2.1.3.5.3 2005 Discharge Mapping

The groundwater discharge mapping program was completed from August 1 to September 9, 2005 at the nine study sites (see Map 2.1-4). The discharge mapping activities focused on suspected areas of groundwater discharge identified based on site summary information. The discharge mapping approach for the Round 2 GWPA relied on multiple lines of evidence to provide information on the stratigraphic, hydrologic, chemical, and physical conditions that are indicative of groundwater discharges. This information, in turn, was used to identify appropriate sampling locations for the TZW sampling component of the Round 2 GWPA. The Round 2 groundwater discharge mapping field program consisted of the following elements:

- Drilling 24 offshore stratigraphic borings in selected locations to refine the understanding of subsurface stratigraphy in potential groundwater plume discharge areas in the river
- Collecting 344 transect-based measurements of shallow TZW temperature and conductivity, which can be indicators of differential groundwater discharge conditions
- Qualitative, transect-based mapping of surface sediment texture
- Field screening of 25 TZW samples at selected sites for semiquantitative identification of distinct chemical indicators of groundwater plume discharge (where applicable)
- Recording 67 continuous 24-hr seepage measurements in nearshore areas using ultrasonic seepage meters.

Complete results of the discharge mapping program are presented and discussed in Addenda 1 and 2 of the TZW FSP (Integral 2006a,b).

2.1.3.5.4 2005 TZW Sampling

TZW sampling activities were performed between October 3 and December 2, 2005. The findings of the discharge mapping effort were considered in conjunction with available site data (e.g., hydrogeology, surface sediment texture delineation, distribution of COIs in upland groundwater and sediments) to identify zones of possible groundwater discharge. The TZW sampling locations selected for each site focused primarily on these zones. Additional sampling locations were specified to provide comparative data for TZW quality outside of the potential discharge zones.

A total of 117 TZW samples (including replicates) were collected at depths of 0-30 cm below the sediment-water interface. An additional 38 TZW samples were collected from depths ranging from 90 to 150 cm below the sediment-water interface. Bulk sediment samples were collected at 34 of the TZW sampling locations to supplement available sediment chemistry data.

The TZW sampling activities are summarized in the TZW FSR (Integral 2006f) and in Table 2.1-5. Results are discussed in detail in the Round 2 GWPA TZW SCSR (Integral 2006g), including findings of the discharge mapping and TZW sampling activities, identification of probable groundwater discharge areas, and descriptions of patterns and trends in the TZW and bulk sediment chemistry within the Study Area.

2.1.3.6 Surface Water

Three surface water sampling events took place during Round 2A. The first sampling event occurred during the early rainy season, in late fall of 2004 (Integral 2005e). The second sampling event occurred during late winter of 2005 (Integral 2005f) to coincide with amphibian egg releases. The third sampling event in July 2005 (Integral 2005d) occurred during a low-flow period. The specific objectives of the Round 2A sampling program identified in the Surface Water FSP (Integral 2004d) included collection of:

- Surface water chemistry to characterize the nature and extent of contamination, including contaminant distribution and identification of potential sources to the river
- Surface water chemistry adjacent to amphibian habitats to support the ERA
- Surface water chemistry in generally quiescent areas adjacent to beaches that are used by swimmers to support the HHRA
- Surface water chemistry and conventional water quality parameters to support the FS.

Analytical results for all three surface sampling events were reported in the Surface Water Site Characterization Data Report (Integral 2006l) and are summarized in Table 2.1-6. Surface water sampling locations are shown on Map 2.1-5.

2.1.3.6.1 Sample Station Reconnaissance

On October 29, 2004, prior to initiation of the Round 2 surface water sampling program, the LWG performed a surface water reconnaissance survey. The survey was conducted to verify sampling locations, to determine the accessibility of each sampling station, and to confer with agency personnel on the selection of sample locations. The reconnaissance survey and the fall 2004 surface water sampling event were reported in Integral (2005e).

2.1.3.6.2 Fall 2004 Surface Water Sampling

Using a peristaltic pump, surface water samples were collected from November 8 through December 2, 2004 at 23 target locations from RM 2 to 11. This sampling period was targeted to coincide with the early fall rainy season. The stations sampled included 14 amphibian habitat stations, 3 cross-sectional river transects, 3 human-use contact areas, and 3 source area stations. Surface water samples from all 23 target stations were submitted to analytical laboratories for a full suite of chemical testing. High-volume surface water sampling using an Infiltrex™ 300 system connected to XAD-2 resin columns was also conducted to collect hydrophobic organic compounds for analysis by ultra-low analytical methods. Sample volumes of approximately 1,000 L were collected at seven target locations in the Willamette River from November 8 through November 30, 2004.

2.1.3.6.3 Winter 2005 Surface Water Sampling

From March 1 to 17, 2005, a second round of surface water samples was collected at the reoccupied stations from the fall 2004 sampling event. All 23 target stations were sampled using the peristaltic pump method. High-volume samples were also obtained from the seven target locations sampled during the first round. Results from the winter 2005 sampling event are documented in Integral (2005f).

2.1.3.6.4 Summer 2005 Surface Water Sampling

The final round of surface water samples was collected from July 5 to 20, 2005 at the same peristaltic pump and high-volume target locations. Results from the summer 2005 surface water sampling event are found in Integral (2005d).

2.1.3.7 Biota

To further support the ERA and HHRA, additional biota sampling, including juvenile Chinook salmon, epifaunal invertebrates, and infaunal invertebrates (specifically clams), was conducted in Round 2 to supplement the extensive tissue data set collected during Round 1. Tissue data from these sampling efforts are being used to determine whether chemicals in biota (and collocated sediment) could pose risks to ecological receptors. Sediments were collected at these same locations for use in laboratory bioaccumulations tests using clams and worms (see below for further discussion). A summary of biota sampling performed during Round 1 is included in Table 2.1-3. Biota sampling locations are shown on Maps 2.1-2a–d.

2.1.3.7.1 Subyearling Chinook Salmon

This sampling effort was intended to supplement ERA data related to potential exposure of juvenile Chinook salmon (*Oncorhynchus tshawytscha*) to site-related contaminants. The objectives of this study were to:

- Determine the extent to which subyearling Chinook salmon in the Portland Harbor area may accumulate COIs
- Estimate exposure of subyearling Chinook by characterizing COI concentrations in stomach contents.

Two site reconnaissance surveys were undertaken on April 11 and May 9, 2005, prior to initiation of the Round 2 subyearling Chinook tissue collection. While the results of the first reconnaissance trip determined that the subyearling salmon collected would not meet the minimum size requirements, the second reconnaissance trip confirmed the presence of fish that met the target size requirements, and sampling was initiated the following day. Subyearling Chinook tissue samples were collected at four target locations from May 10 to 12, 2005, including three stations within the ISA and one station up-river, along with one field replicate.

The standard chemical suite for whole-body fish tissue included percent lipids, percent moisture, total metals, butyltin compounds, organochlorine pesticides, PAHs, SVOCs, dioxins and furans, and PCB congeners (full list of 209 congeners). The stomach (gut) contents of five to eight individuals from each fish composite were separated for identification and enumeration of prey species. The remaining stomach contents were analyzed for PAHs, PCB congeners (full list of 209 congeners), and organochlorine pesticides. Results are documented in the Chinook tissue data report (Integral and Windward 2006).

2.1.3.7.2 Benthic Invertebrates

During Round 1, crayfish and a limited number of clam samples were collected for tissue chemistry analyses. To supplement these data for the baseline ERA, additional invertebrate chemistry tissue data were collected during Round 2. The specific objectives of the Portland Harbor invertebrate sampling were to:

- Measure constituents in invertebrate tissue samples that represent benthic invertebrate prey organisms within the Study Area for use in the ERA fish, bird, and mammalian dietary exposure models
- Measure constituents in invertebrate tissue samples that represent benthic organisms within the Study Area for use in the tissue-residue line-of-evidence for benthic risk in the ERA
- Measure constituents in invertebrate tissue samples that represent benthic organisms within the Study Area for use in calibrating the food web model
- Use information from both field collected and laboratory bioaccumulation tests to calculate a site-specific biota-sediment accumulation factor.

Two data needs were identified: 1) determining tissue residue concentrations in epifaunal invertebrates that are predominantly exposed through surface water, and 2) determining tissue residue concentrations in infaunal invertebrates that are predominantly exposed through sediment. Data collection efforts for both of these data needs were performed separately, and are summarized in Table 2.1-3.

Multiplate Sampling

Using multiplate samplers, epifaunal invertebrates were collected in the spring/summer of 2005 (Windward and Integral 2005; Integral 2006i) to provide information on invertebrate exposures in the water column. Invertebrates were collected at six surface water sampling locations distributed throughout the Study Area. Five of these stations were located along the shore of the main channel and one station was in Swan Island Lagoon. The multiplate samplers were located in a variety of habitats adjacent to riprap, on sandy beaches, and in soft-bottom quiescent areas.

Benthic Sledge Sampling

To provide information on sediment exposure to infaunal invertebrates, samples were collected during the winter of 2005 using two types of gear: a benthic sledge to collect clam (*Corbicula* sp.) and lamprey ammocoete samples for tissue residue analysis, and a sediment grab sampler to collect sediment for use in the laboratory bioaccumulation tests and for chemical analysis (Integral 2006i). This sampling program addressed infaunal invertebrate body burdens throughout the Portland Harbor Study Area, focusing primarily in the following areas: 1) near sandpiper feeding areas, 2) in both quiescent and high-flow areas, 3) in areas with elevated chemical sediment concentrations, and 4) in areas of particular interest to EPA risk assessors.

Clams and sediment for bioaccumulation testing were collected at 33 locations distributed throughout the Study Area from RM 2 to about RM 10 (see Maps 2.1-2a–d). Of these 33 locations, 20 were located along the shoreline of the main LWR channel and 12 were located in off-channel slips or embayments. The remaining station was located in Multnomah Channel. Twenty-three of the sampling locations were also within sandpiper feeding habitat. All sampling locations were in areas where elevated

concentrations of at least one chemical were measured in the Round 2 surface sediment sampling effort.

Sufficient amounts of tissue were collected for a full suite of chemical analyses, including percent lipids, PCB congeners, PAHs, organochlorine pesticides, butyltin compounds, phthalates, SVOCs, metals, and dioxins and furans.

Laboratory bioaccumulation testing was conducted with the sediments using freshwater oligochaetes (*Lumbriculus variegatus*) to estimate tissue concentrations for other common sediment-exposed benthic invertebrates. Bioaccumulation testing was also conducted using *Corbicula fluminea* to allow evaluation of the two different exposure regimes (field-collected and laboratory-exposed) and the subsequent tissue concentrations.

Seven lamprey ammocoetes were collected in the 470 tows that were taken through the entire sampling effort (Windward and Integral 2006). As part of the same sampling effort, sediment grabs were taken from six to seven locations within each of the 33 stations. Three ammocoetes were collected from among all the sediment grabs that were collected. Two of the ammocoetes came from the upstream end of the Portland Shipyard near RM 9 and the third came from a grab taken at the Oregon Steel Mills (OSM) site at RM 2. Ammocoetes were not collected in any of the benthic sledge tows at either of these stations. Insufficient lamprey tissue volume was collected; therefore, no tissue chemical analyses were conducted on this species at that time. Additional lamprey collections took place in the fall of 2006 as part of Round 3, but these findings are not discussed herein.

2.1.3.8 Cultural Resources Survey

According to the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) and its implementing regulations, EPA is required to comply with federal statutes that provide protection for archaeological and historical resources, including Native American burials and places of traditional religious and cultural significance. In 2001, EPA and DEQ signed an MOU with six tribal governments and three federal and state agencies that identified cultural resources as an area of special concern to the signatory tribes. Also in 2001, EPA signed an AOC with the LWG to perform a cultural resource survey as part of the RI/FS. The survey included the in-water portion of the Site from the confluence of the Willamette and Columbia rivers to Willamette Falls, including upland areas adjacent to this stretch of the river. Results of the survey are documented in *Cultural Resource Analysis Report for the Portland Harbor Superfund Site, Portland, Oregon* (AINW 2005). A comprehensive cultural resource analysis, including procedures for protecting and addressing cultural resources before, during, and after the RI/FS and remedial design is complete, will be provided in consultation with the tribes at a later date.

2.2 EXISTING HISTORICAL AND CONCURRENT STUDIES

This section presents existing data and information used in the development of this Comprehensive Round 2 Data Report. Since the completion of the Programmatic Work Plan (Integral et al. 2004b), numerous documents and data sets relating to the LWR have been compiled to support the preparation of FSPs, preliminary risk evaluations, and the initial conceptual site model (CSM). This section focuses on existing historical and concurrent chemical and biological data that augment data collected by the LWG. Together, LWG and non-LWG data are used to map in-river chemical distributions, identify sources, evaluate risk, and identify data gaps. A summary of non-LWG data is provided in Table 2.1-6.

Existing chemical and biological data were obtained primarily from LWG members, EPA, DEQ, USGS, and the U.S. Army Corps of Engineers (USACE). Data types included sediment, TZW, surface water, and tissue chemistry. Other existing information pertaining to regional or site-specific investigations are referenced in Section 11 (Conceptual Site Model), Appendix F (Round 2 Human Health Risk Evaluation), Appendix G (Round 2 Ecological Risk Evaluation), and Appendix J (list of CSM Site Summaries and Addenda). It is important to note that the information used to prepare upland site summaries (in the Conceptual Site Model Update) and addenda (Integral 2007) did not receive an independent review of data quality. The LWG relied entirely upon DEQ and the upland property owners for the extent to which those data accurately represent conditions at those sites.

2.2.1 Data Quality

A detailed review of the quality of each chemical and biological data set was performed prior to entering the historical data into the project database. Methods for performing the data quality review are described in the Programmatic Work Plan (Section 4 and Appendix F; see Integral et al. 2004b). The purpose of the data quality reviews was to fully evaluate each data set and categorize the quality of the data in the database, ensuring that these data were appropriate for use in the RI/FS. The two categories of data are as follows:

- **Category 1.** Category 1 data are of known quality and are considered acceptable for use in decision making for the Site. There is sufficient information on these data sets to confidently verify that the data, along with associated data qualifiers, accurately represent chemical concentrations present at the time of sampling.
- **Category 2.** Category 2 data are of generally unknown or suspect quality. The quality assurance and quality control (QA/QC) information shows that data quality is poor or suspect, or essential QA/QC data (e.g., surrogate recoveries, matrix spike/matrix spike duplicates) are either incomplete or lacking.

The evaluation of data quality was conducted at the finest level of detail available for each data set. For chemistry data, Category 1 and 2 designations were entered into the

project database for each sample and analyte. All Category 1 and Category 2 data are summarized in Table 2.1-7.

Analyses upon which project decisions will be based will utilize Category 1 data. Only Category 1 data that have had an EPA-approved level of data validation, comparable to Washington State Department of Ecology's "QA2" evaluation, are used for human health or ecological risk assessments. Data presented in Section 6 are also Category 1 data but have received either a "QA2" level of review or an abbreviated level of review, termed "QA1." Category 1 QA1 or QA2 data may be used to identify initial Areas of Potential Concern (iAOPCs).

Category 2 data are used for project scoping. For example, Category 2 tissue data were used to help identify COIs, and Category 2 sediment data were used in the initial assessment of trends in chemical concentrations, which was useful for developing sampling programs.

2.2.2 Chemical Data Review Criteria

Criteria for placing data sets into categories were developed during the compilation of existing information to identify basic data qualities and not to limit data to specific program uses. Chemical data quality was assessed by evaluating the following factors:

1. Traceability
2. Comparability
3. Sample integrity
4. Potential measurement bias
   - Accuracy
   - Precision.

All of these factors were known or supported by existing QA/QC information (analytical methods, chain-of-custody, sample holding time, method blanks, matrix spike/matrix spike duplicates, laboratory control samples, replicates, surrogates) for Category 1 data. If supporting documentation for each factor was not available or was not reinforced by the availability of other high quality QA/QC information, data were assigned a Category 2 designation. If the acceptance criteria for any of the above factors were not satisfied for either the entire data set or a specific analyte group, data for that data set or group were generally qualified and were determined to have limited usefulness. The chemical data were reviewed by analyte group (e.g., metals, SVOCs). As a result, a data set may contain all Category 1 data, all Category 2 data, or both Category 1 and Category 2.

2.2.3 Biological Data Review Criteria

Bioassay data quality was evaluated based on validation guidelines and performance criteria from the Puget Sound Estuary Program (PTI 1989). Bioassay validation

guidelines include checks of completeness, holding conditions, standard reporting methods, and QA/QC results for negative control, reference sediment, positive control (reference toxicant), and measured water quality parameters according to standard testing methods.

2.2.4 Site Characterization and Risk Assessment (SCRA) Database

Integral's LWG project database contains all of the data reported by the analytical laboratories. This includes field and lab replicates, lab dilutions, results for the same analyte from multiple analytical methods (SW8270 and SW8270-SIM, for example), and laboratory QA samples such as matrix spikes, surrogates, and method blanks. The data handling rules described in *Guidelines for Data Averaging and Treatment of Non-detected Values for the Round 1 Database* (Kennedy/Jenks et al. 2004) were used to create a data set for the SCRA data users that was simpler: the data set contained only one result per analyte per sample and excluded all of the laboratory QA results. This involved creating an SCRA database that excluded lab QA results, contained only the most appropriate dilution result and analytical method for each analyte, and contained the average of laboratory replicates.

Excluding the lab QA results was a simple database query step. The most appropriate dilution was selected by either the reporting laboratory or the data validator. Selection of the most appropriate analytical method was described in the guidelines document and was accomplished by flagging the appropriate method in the project database. Rules for averaging data and carrying qualifiers were also described in the guidelines document. Because averaging required significant data manipulation, a series of additional checks were performed on the SCRA database before distribution. Data were divided into subgroups and approximately 40 percent of each subgroup was verified. If any problems were found with the averaging, then 100 percent of the subgroup was verified and problems were corrected. The preliminary SCRA database was compiled into a series of database-compatible Excel® tables and distributed to the SCRA data users.

For purposes of reporting, both LWG and non-LWG data were combined into one SCRA database. Guidelines provided in Kennedy/Jenks et al. (2004) were consistently applied to all data sets. Data management rules used to reduce and refine the SCRA data used in nature and extent discussions are provided in Appendix A. Those used in risk assessment are provided in the Round 2 HHRA (Appendix F) and ERA (Appendix G). It is important to note that calculated totals were developed using different methods. For nature and extent discussions, calculated totals are the sum of all detected concentrations. Non-detects are handled as zero. For risk assessment, non-detects for analytes detected at least once in the data sets were included in the total using one-half the reporting limit (RL). For both nature and extent and risk assessment, if all analytes were not detected, then the highest RL was the selected value for the calculated total.

2.2.5 Existing Chemical and Biological Data

Between 2004 and 2006, there were five updates of the existing database (i.e., non-LWG data). Multiple studies were included in each update. Data types included sediment, tissue, surface water, seep, and TZW chemical data as well as bioassay and bioaccumulation testing data. As noted above, data quality reviews were performed for all data according to guidelines provided in the Programmatic Work Plan (Integral et al. 2004b), and an aggregate (LWG and non-LWG) SCRA database was developed for purposes of data evaluation and reporting.

Once the aggregate SCRA database was complete, data sets were selected using the following criteria.

- For both the nature and extent discussions (Section 6) and risk evaluation (Section 8 and 9), the aggregate SCRA database includes data collected since May 1997 (see Section 2.3).
- Human health and ecological risk assessment teams restricted their evaluation to include data with the highest level of quality (Category 1 QA2) located between RM 2 and 11. Samples collected from locations that have been dredged or capped since collection were removed[1]. The teams also selected sediment samples that were collected within 30.5 cm of the mudline.
- Chemical data presented in Section 6 (*In-River Chemical Distributions*) are Category 1 QA1 or Category 1 QA2 data and represent samples collected from the mouth of the Willamette River (RM 0) to Willamette Falls (RM 26.5).

Data sets matching the criteria set above are summarized in Table 2.0-1. No non-LWG bioassay data were included in the aggregate SCRA database. Brief descriptions of non-LWG environmental investigations with data included in the aggregate database are provided in Appendix A.

2.2.5.1 Riparian Data

During the summer of 2006, EPA provided the LWG with an inventory of Portland Harbor upland sites with actual or representative riparian soil data. The inventory also included a status of riverbank source control activities and a summary of riverbank habitat conditions. The review was conducted by DEQ Site Cleanup managers as part of an EPA questionnaire. DEQ managers defined the riverbank between +13 ft and +22 ft NAVD as the riparian zone. However, soil samples collected outside of this zone near the riverbank were considered "representative" of riparian soil, assuming material just above the top of the bank (~+20 ft) could slough onto the riverbank, and material

[1] LWG and non-LWG sediment samples were flagged as dredged or capped in the geographic information system (GIS) using the following process. Samples were plotted relative to dredge prism and cap boundaries. Dates of sample collection were compared to dates of dredging and capping. Samples collected prior to dredging and capping and intersected dredge prism and cap boundaries were flagged. The project database was updated accordingly.

just below +13 ft could have originated within the riparian zone. Based on these guidelines, DEQ project managers identified 13 sites with riparian data (Table 2.2-1). The locations of the riparian zone samples are shown in Maps 2.2-1a–d.

The LWG compiled these data in a draft riparian SCRA database. A separate data quality review of these data is pending; however, it appears that approximately half the data will be Category 2. The exceptions include those bank samples collected by LWG members. Potential riparian zone data needs relative to iAOPC-specific FS or source identification questions are discussed in Section 12.3.

2.3 DATA USABILITY

Combining historical and current data with the LWG data requires an assessment of data usability. The principal issues related to the usability of historical and current data include data quality, sediment stability, and the intended use of the data. All of these factors must be acceptable for data to be considered usable.

2.3.1 Data Quality

The quality of the existing data has been evaluated and data have been categorized as Category 1 (data of known quality) or Category 2 (data of generally unknown or suspect quality). This evaluation focused on individual analyte groups within each survey when possible, and so any given survey may contain all Category 1 data, all Category 2 data, or a combination of Category 1 and 2 data. In addition, data that received a QA1 or QA2 level of validation were flagged as such, providing a combined data quality category (e.g. Category 1 QA2). The Programmatic Work Plan (Integral et al. 2004b) clearly states that only Category 1 data that have undergone a QA2 validation process may be used to support the human health and ecological risk assessments. Category 1 QA1 data may be used to estimate the nature and extent of contamination and delineate AOPCs.

2.3.2 Sediment Stability

The evaluation of sediment stability determines whether existing chemical concentrations continue to represent conditions at the locations where sampling occurred. Investigations of sediment stability are underway, but several lines of evidence (STA®, Sediment Profile Imagery [SPI], bathymetry studies, Sedflume studies, and hydrodynamic modeling) are indicating that significant sediment bed movement or resuspension does not occur under typical flow conditions in the LWR (see Section 4.4). Based on preliminary Sedflume and hydrodynamic modeling results, there is potential, however, for significant sediment bed movement in the high-energy portions of the LWR during rare high-flow events. High-flow events occurred back-to-back in 1996 and 1997. Selection of existing sediment chemical data collected after May 1997 increases the likelihood that the chemical concentrations represent "current" conditions at the locations where sampling occurred. The maximum net bathymetric

change over the 25-month period between the January 2002 and February 2004 surveys was less than 1 ft over 90 percent of the ISA (see Section 4.4.1).

Temporal changes in chemical concentrations are evaluated in Section 6.1.2 (*Time-trends of COIs in Sediment*). Chemical concentration changes are anticipated due to analytical variability and intra-station variability. However, individual chemical concentration comparisons suggest chemical concentrations among approximate sampling locations (at similar sampling depths) remain relatively consistent. Hydrodynamic and sediment transport modeling currently underway will provide important insights into the relative stability of sediment throughout Portland Harbor, including areas that may be expected to either erode or accrete under hydrodynamic conditions that have occurred since 1997.

2.3.3 Data Use

The final consideration for determining data usability is evaluating the intended use of the data. For example, the historical database contains some samples with undetected concentrations of PCBs at high detection limits. From an analytical perspective, these data are Category 1 and acceptable for use. From a sampling design perspective, these data are not useful because of the uncertainty associated with concentrations below the high detection limits and additional sampling and analysis may be necessary. From a risk assessment perspective, these data are also likely not useful because of the uncertainty associated with concentrations below the high detection limits, and therefore the risk associated with these concentrations cannot be defined (see Section 8 and 9 for data selection). As another example, chemical data from areas that have been dredged are useful for assessing potential historical sources but are not useful for assessing current conditions, background conditions, or risk.

Data that have been qualified "N" present another situation that requires evaluation in the context of data use. The N qualifier indicates that the identity of the analyte is not definitive, generally as a result of the presence in the sample of an analytical interference such as hydrocarbons or, in the case of pesticides, PCBs. Pesticide data and SVOCs analyzed by EPA Method 8081A were most commonly N-qualified as a result of analytical interference. PCB Aroclors were also N-qualified when identifications were based on PCB congener data because the identification of the Aroclor was not definitive. Details are provided in the data and site characterization reports for the various sampling tasks (Integral 2004b). The usability of N-qualified data must be determined on a case-by-case basis.

Specific data use restrictions are provided in the risk evaluation appendices (Appendices F and G).

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3.0 CONCEPTUAL SITE MODEL SUMMARY

A summary of the CSM for the Study Area is presented in this section. This CSM portrays the general relationship among sources, chemicals, transport mechanisms, and in-water receptors. Specific references and supporting information for the conclusions presented in this CSM summary are provided in the following sections and appendices of this report. Detailed CSMs for each iAOPC, including a site-wide iAOPC, are presented in Section 11. This report presents an interim CSM that integrates all Study Area data and information available through completion of Round 2. A preliminary CSM for the ISA was provided in the Programmatic Work Plan (Integral et al. 2004b), and an updated CSM, which focused on groundwater sources and pathways, was submitted later in 2004 (Integral and GSI 2004). The final CSM for the Study Area will be presented in the RI report based on the complete data set for the RI and final baseline risk assessments. Therefore, it is important to recognize this CSM is interim and subject to modification in the final RI report.

The CSM and its future updates support the RI/FS process in the following ways:

- Identifies overwater activities that may have released contaminants to the Willamette River sediments.
- Provides a better understanding of potential contaminant impacts from upland sources (including direct discharge, overland transport, groundwater, and bank erosion) and the relative importance of the various transport mechanisms at different iAOPCs along the river.
- Identifies locations that may be continuing sources of contamination and pathways to the river based on historical and current site use information and analytical data.
- Identifies areas of the river where recontamination of sediments by upland and other sources is a concern.
- Identifies pathways and locations that may be continuing sources of contamination to the river based on historical and current site use information and analytical data.
- Assists DEQ in identifying upland sites where additional work must be done by responsible parties and DEQ (Integral et al. 2004b).
- Focuses sampling and helps support the selection of sampling points in Round 3B to fill data gaps relating to impacts from upland sources and the nature and extent of chemicals in river sediments.

Simplified CSMs for human and ecological receptors in the Study Area are depicted in Figures 3.0-1 and 3.0-2, respectively. The following discussion summarizes the CSM for the Study Area, including in-river physical environments, ecological functions, potential sources and pathways, chemical distribution and exposure media, fate and transport, and human and ecological receptors.

3.1 IN-RIVER PHYSICAL SYSTEM ENVIRONMENT

The Portland Harbor RI/FS Study Area (approximately RM 2 to 11 of the Willamette River) is located at the downstream end of the Willamette River watershed. Originally a relatively shallow, meandering portion of the LWR surrounded by forested wetlands and floodplains, it has been redirected, straightened, filled, and deepened by decades of urban development and industrialization. A -40 ft federally maintained navigation channel, twice as deep as the original river here, runs the length of the Study Area, extending nearly bank to bank in some areas and drastically altering the river's cross section. Much of the riverbank has been filled, stabilized, and/or engineered for industrial or port operations with riprap, bulkheads, and overwater piers and docks. Shallow-profile beaches and nearshore benches and submerged or overwater vegetation are rare. This dramatic physical alteration and the associated anthropogenic activities (e.g., industry, ship and boat traffic) have resulted in a river reach that little resembles its pre-industrialized character in terms of hydrodynamics, sediment transport, and ecological habitat and function.

The Willamette River is the thirteenth-largest river in the contiguous United States in terms of discharge, averaging about 40,000 cubic feet per second (cfs). Flows are highly variable, however, both seasonally and year-to-year as a function of rain and snowpack levels in the region. Discharge typically varies by a factor of 10 seasonally with late-summer dry-season levels at or below 10,000 cfs and rainy season December/January averages that approach 100,000 cfs. Thirteen federal reservoirs on the upper Willamette River and its tributaries are used to stabilize river flow somewhat by storing water in the winter months and releasing it in the summer. Nonetheless, discharge events approaching 200,000 cfs occur every few years and exceptionally large precipitation events can still result in major floods. The February 1996 event nearly flooded downtown Portland and discharge exceeded 400,000 cfs (40-50 times greater than the low-flow levels). These rare, extreme flow events have the greatest potential for significant sediment transport.

The LWR upstream of the Study Area (RM 11 to Willamette Falls at RM 26) is markedly narrower, more confined by bedrock outcrops, and faster flowing than in Portland Harbor. The reach immediately downstream of the Study Area (RM 2 to the Columbia River) is also narrower than the Study Area as the river turns toward north and converges with the Columbia. The much larger Columbia River sometimes acts as a dam, backing up the Willamette, especially during spring snowmelt freshets when the Columbia is high. At RM 3 in the lower Study Area, Multnomah Channel diverges west from the Willamette, seasonally carrying more than half of the Willamette River discharge via this alternate path. During low-flow periods on the LWR, a moderate tidal influence produces periodic upstream flows throughout the Study Area, but particularly between the Columbia River and Multnomah Channel. These complex physical setting and hydrodynamic interactions generally create a trap for suspended and bed-load sediments that enter the Study Area, a regional sediment repository for the overall LWR (RM 0 to 26).

Portions of the Study Area vary in hydrodynamic and sediment transport characteristics as a function of the cross-sectional area, navigation channel width, location with respect to Multnomah Channel, and off-channel features such as coves and slips. The LWR progressively widens downstream from RM 11 and the river transitions from its more dynamic upriver character to a predominantly depositional setting from RM 10 to RM 7, dominated by fine-grained sediments. Extensive shoaling occurs in dredged depressions as well as in much of the main channel, and the navigation channel from RM 10 to 8 has historically required regular maintenance dredging. The Study Area cross-section narrows from RM 7 to 5 and the channel becomes non-depositional and predominantly sandy. Sediments reaching the channel in this reach likely move downstream. From RM 5 downstream to RM 2, the Study Area progressively widens again, returning to the predominantly depositional or stable character noted above RM 7. Multnomah Channel exits the Study Area at RM 3, taking a significant fraction of the flow with it as the LWR continues to widen. This results in a second area of extensive shoaling in the channel from RM 3 to RM 2. Finally, throughout the Study Area, sheltered off-channel areas, such Swan Island Lagoon and Willamette Cove, are largely protected from natural disturbances but localized anthropogenic disturbances (e.g. propwash) can be widespread.

Time-series bathymetry data and sediment-profile images throughout the Study Area reveal a relatively active mixed surface sediment layer. Small-scale (i.e., less than 30 cm) scour and deposition is widespread, and steep gradients in sediment texture are evident both laterally and sometimes vertically in the sediment column along the river edges as a function of localized shoreline morphology and riverbank treatments. Offshore channel environments are more texturally homogeneous over large areas, reflecting the large-scale hydrodynamics of the river.

As noted above, some large contiguous areas of deposition or active transport are apparent. The forces that produce this dynamic surface sediment layer include both natural (e.g., river flows) and anthropogenic (e.g., propwash) disturbance factors. The surface sediment layer was defined as 30 cm for the RI/FS. Sediment quality over this interval is both temporally and spatially persistent as it accounts for the potential effects of small-scale mixing. Below 30 cm, the sediment column is relatively stable, particularly in nearshore and off-channel areas, under typical or non-extreme hydrodynamic and anthropogenic forces.

In summary, the Study Area is a relatively low-energy reach of the LWR that, without active anthropogenic removal or disturbance, accumulates sediments over time. Most of the channel and all off-channel areas have the potential to be long-term sediment repositories. On rare occasions, high-energy events may scour or remove some accumulated materials, but the long-term pattern is one of sediment buildup. Superimposed on this large-scale sediment stability is widespread small-scale surface sediment mixing that reflects small-scale natural and anthropogenic disturbance factors typical of riverine environments and working industrial harbors.

3.2 ECOLOGICAL FUNCTIONS

While the ecological function of the LWR has been greatly modified by development, a number of species of invertebrates, fishes, birds, mammals, and amphibians, including some protected by the Endangered Species Act (ESA), use habitats that occur within and along the river. As described above, the majority of the LWR habitat is industrialized, with modified shoreline and nearshore areas; wharves and piers extend out toward the channel, bulkheads and riprap revetments armor the riverbank, and active dredging has produced a uniform channel with little habitat diversity. However, some segments of the LWR are more complex, with small embayments, shallow water areas, and less shoreline development, providing habitat for a suite of local fauna. The following subsection presents an overview of the ecological functions provided by the LWR to various ecological groups (i.e., benthic invertebrates, fish, birds and mammals, amphibians and reptiles, and plants).

The benthic invertebrate community in the LWR is similar to benthic invertebrate communities typical of a deep, urbanized river system; it is dominated by the feeding group known as collectors. Collectors are composed of both gatherers, organisms that forage for organic matter in the sediments, and filterers, organisms that filter organic matter out of the water column. Oligochaetes (segmented worms) and chironomids (midge larvae) are the dominating taxa in the LWR. Oligochaetes are gatherers and chironomids can be collectors/ gatherers, herbivores, detritus shredders, or engulfing predators. LWR benthic invertebrates serve as the principal food resource for higher-trophic-level consumers (e.g., fish and wildlife) and play a vital role in nutrient cycling. The benthic community acts as the link between detrital material deposited on the riverbed and the higher trophic levels. Large benthic invertebrates in the LWR, such as shellfish and crayfish, also provide a valuable food resource for specific fish and avian species. Chemicals within the ecosystem can directly influence the benthic community and can also be transferred through the food web through prey consumption by higher-trophic-level aquatic fauna.

The fish species utilizing habitat within the LWR are numerous and diverse. The LWR is an important pathway for migration of anadromous fish such as salmon and lamprey and provides habitat for numerous resident fish species. Various recreational fisheries, including salmon, bass, sturgeon, and others, use the LWR. Fish in the LWR represent important pathways of nutrients and energy throughout the food chain and the ecosystem. Piscivorous bird and aquatic mammals rely on fish for food. Fish of all feeding guilds maintain the nutrient and energy cycles between aquatic primary producers and higher levels in the food chain, both aquatic and terrestrial. Specific LWR fish, including juvenile Chinook salmon and bass, have been identified as LWR pelagic-dominant feeders and consume their prey primarily through the water column. Chemicals within the system can directly affect fish species and adversely affect fish populations, and can also be transferred through the food web through prey consumption by higher-trophic-level aquatic fauna.

A diverse group of birds and some aquatic or semi-aquatic mammals are known to utilize habitat areas in the LWR. Birds utilizing the LWR are from various feeding guilds, each filling a distinct ecological role in the ecosystem. Mammals utilizing the LWR are predominately piscivorous; however, their diet may include amphibians and aquatic invertebrates. Birds and mammals provide a pathway for energy and nutrients to be transferred from the aquatic to the terrestrial ecosystem and may serve as prey for other predators. Piscivorous birds and mammals are relatively high on the food chain and may be exposed to greater levels of chemicals due to biomagnification of chemicals up the food chain. Chemicals present in the food chain may adversely affect their populations.

Conditions within the LWR provide a limited amount of suitable habitat for amphibians and reptiles. Amphibians and reptiles require off-channel, low-flow aquatic habitat with a substantial presence of riparian vegetation and emergent vegetation during the breeding season for ovipositing of eggs. Amphibians and reptiles that occur in the LWR feed on aquatic invertebrates and small fish, and are themselves prey items for birds, mammals, and fish. Amphibians and reptiles also provide an important pathway by which nutrients and energy are transferred between the aquatic and terrestrial ecosystems. Amphibian and reptilian populations can be adversely affected by chemicals in the aquatic ecosystem.

The current conditions of the LWR prevent the successful establishment of a dense, submerged and emergent plant community along the riverbanks due to high turbidity and the presence of riprap and other bank stabilization efforts. Aquatic plant communities that exist in the LWR are utilized by other ecological receptors for nesting habitat, breeding habitat, and refuge. Aquatic plant communities provide food for herbivores and play a role in the cycling of nutrients. Chemicals in the ecosystem may affect plant species and may adversely affect plant communities and/or be transferred from plants through the food web through consumption by higher-trophic-level species.

3.3 POTENTIAL SOURCES AND PATHWAYS

Consistent with DEQ's JSCS (DEQ 2006c), sources to the river are defined in this report as the migration pathway through which chemicals enter the river. These include upstream loading, direct discharges including stormwater/waste water/overland transport, groundwater, atmospheric deposition, riverbank erosion, and historical sources. Sediment resuspension and movement also is discussed here as an in-river source pathway.

The pathways and the relative contributions of current and historical sources are described below:

Upstream Loading—The Study Area is at the downstream end of a large (11,460 square miles) basin with a long history of agricultural, industrial, commercial, and municipal operations and activities. Sediment transport from these upstream areas over

the last century reflects not only proximal upstream municipal and industrial discharges to the river, but also stormwater drainage for the entire Willamette River Basin. Upstream loading is expected to be a significant contributor to contaminants observed in the Study Area, and in large part upstream conditions could define background conditions within the Study Area.

Direct Discharges—Pollutants from commercial, industrial, private, or municipal outfalls are being discharged directly to the Study Area. Many of these discharges are permitted under the Clean Water Act National Pollutant Discharge Elimination System (NPDES). Permitted discharges include treated industrial wastes, stormwater runoff, and combined sewer overflows (CSOs). Direct discharge also includes historical discharges of process wastes and wastewaters. The horizontal and vertical distribution of contaminants in sediments may reflect historical direct discharges of process waste and wastewater in many areas. In addition, current and historical stormwater discharges have the effect of concentrating contaminants from upland sources and aerial deposition at outfall locations.

Groundwater—Contaminated groundwater may enter the river directly via discharge through sediments or bank seeps, or it may infiltrate into storm drains/pipes, ditches or creeks that discharge to the river. Contaminant migration may occur as nonaqueous phase liquids (NAPLs) or as chemicals dissolved in the groundwater itself. Significant contaminant migration via the groundwater pathway is limited to discharges from a small number of upland sites within the Study Area. At a limited subset of these sites, the upland groundwater may load significant amounts of upland chemicals to the local transition zone, including sediment and porewater. In general, however, loading of chemicals from upland groundwater to surface water is not considered a significant pathway, given the small volume of groundwater discharging to the river.

Bank Erosion/Leaching—Riverbank materials may release contaminants directly to the river through erosion by the river or hillslope transport processes. Erosion of riverbank soils is likely to have been a significant historical contributor to in-water contamination due to the extensive filling along the riverfront. The sources of fill include dredge materials as well as imported materials that may have contained contaminated sediments and soils. Though not well-characterized, it is reasonable to expect (and in some cases documented) that some historical dredge material included contaminants introduced by other processes (e.g., direct discharge, bilge water discharges from vessels). Riverbank stabilization (seawalls, riprap) is currently present along approximately half the riverbanks in the Study Area; however, the effectiveness of the riprap for preventing releases of contaminants is not well defined. Locations currently susceptible to riverbank erosion are generally not well characterized.

Overwater Activities—Contaminants from overwater activities (e.g., sandblasting, painting, unloading, maintenance, repair, and operations) at riverside docks, wharves, or piers; discharges from vessels (e.g., gray, bilge, and ballast waters); full releases; and spills may affect the river. Overwater releases are important contributors to in-water

contamination at a limited number of sites that have long histories of overwater operations (e.g., ship building and repair) and product transfers. Occasional large spills at other sites are also expected to contribute to in-water contamination, but historical documentation (prior to about 1980) is generally not available.

Historical inputs from these pathways described above provide the most significant contributions to observed sediment contamination in the Study Area. Many of the activities that contributed to affected sediments have either been discontinued (e.g., direct discharge of process wastes) or reduced by regulatory actions over the years (e.g., stormwater discharges), are currently undergoing source control actions (e.g., groundwater and stormwater), or are no longer sources (e.g., redirection of many CSOs)

Sediment Resuspension—The redistribution of historical contamination in sediments with typical winter and extreme storm events contributes to the distribution of contamination observed the Study Area. Initial evaluations indicate that contaminants are transported in the downstream direction and, to a much lesser extent, upstream with tidal changes. This is most easily observed in the distribution of pesticides, PAHs, and petroleum hydrocarbons downstream of in-water contaminated sources on the west side of the river.

3.4 CHEMICAL DISTRIBUTION AND POTENTIAL EXPOSURE MEDIA

3.4.1 Sediment

The concentrations of iCOCs in sediment are generally relatively low in most parts of the navigation channel and slightly or significantly higher in localized areas near the east and west riverbanks. In-river transport processes may disperse sediment and associated contaminants from areas of high concentrations, although the extent of this process appears to be limited based on the distinct and localized PCB, dioxin/furan, and PAH patterns seen in the sediment. Chemical concentrations are often higher in subsurface sediment than in surface sediment, with notable exceptions in some areas. This pattern is consistent with the predominantly depositional nature of the Study Area and the relative historical magnitude of sources as noted above.

Based on initial risk screening, PCBs, dioxins/furans, and dichloro-diphenyl-trichloroethane (DDT) compounds are preliminarily identified as primary risk drivers at theStudy Area, with PCBs accounting for the largest contributions overall to human health and ecological risk. Additional iCOCs and potential iCOCs for human and ecological risk include metals, pesticides in addition to DDT, individual and total PAHs, phthalates, TPH, and several other SVOCs.

PCBs were manufactured in the United States from 1929 until 1977, primarily for use as dielectric fluids in transformers and capacitors. PCBs were additionally used in cutting oils, hydraulic oils, and heat transfer fluids; as plasticizers; and as additives to pesticides, paints, copy paper, adhesives, and sealants.

PCB concentrations in surface and subsurface sediment vary widely throughout the Study Area, reflecting contributions from numerous sources. Overall, PCB concentrations are fairly low (i.e., undetected or detected at levels that are fairly similar to preliminary background concentrations) in the navigation channel throughout the Study Area, in surface as well as subsurface sediment. PCB concentrations are generally higher in the nearshore zones, with a number of areas with substantially elevated PCB levels. The highest PCB concentrations exceed 10,000 µg/kg in only a few areas. Approximately seven additional locations have PCB concentrations in surface and/or subsurface sediment above 1,000 µg/kg. PCB concentrations are higher overall in subsurface sediment than in surface sediment in the nearshore zones over much of the Study Area.

Aroclors 1248, 1254, and 1260 were common throughout the Site in varying proportions, and Aroclors 1242 and 1268 were reported in isolated areas. Generally, in areas with the lowest concentrations, Aroclors 1254 and 1260 are most common. Distinct Aroclors patterns are evident in some areas of greater PCB contamination and may reflect different sources from background. However, quantifying specific Aroclor concentrations in environmentally complex mixtures of PCBs from various sources, some of which may have been subject to degradation, is somewhat subjective. Dioxin/furan toxic equivalent concentrations (TEQs) exhibit a wide range in sediment, from values that are similar to preliminary background to an overall maximum of 16,600 pg/g. In general, values are higher in the western nearshore zone than in the eastern nearshore and navigation channel zones.

Areas of relatively elevated concentrations of total DDx compounds (which include 2,4'- and 4,4'-DDT and its primary breakdown products, 2,4'- and 4,4'-dichloro-diphenyl-dichloroethane [DDD] and 2,4'- and 4,4'-dichloro-diphenyl-trichloroethene [DDE]) occur at several locations along the nearshore zones and channel margins. The most prominent of these areas occurs near the Arkema facility at RM 7.5 and extends downstream along this side of the river to approximately RM 6. Overall, DDx concentrations are somewhat higher in subsurface sediment than in surface sediment in the nearshore zones and in some areas of the navigation channel.

The individual DDx components show generally similar patterns of distribution. However, the relative abundance of the DDx isomers is highly variable between locations across most of the Study Area in both surface and subsurface sediment samples.

3.4.2 Transition Zone Water

The TZW sampling effort was not a harbor-wide study of TZW, but instead a focused investigation offshore of nine Round 2 study sites that were selected based on confirmed or reasonable likelihood for discharge of upland groundwater COIs to the Study Area. Based on the approach taken for site selection, this study is expected to have delineated the majority of TZW contamination in the Study Area originating from upland groundwater.

TZW analyte lists were based on site-specific upland groundwater COIs for the adjacent upland sites; therefore, analyte lists varied by study site. iCOCs and potential iCOCs identified in TZW include cyanide, perchlorate, metals, pesticides, PAHs, and volatile organic compounds (VOCs). Chemical concentrations generally varied widely between study sites, reflecting variability in upland groundwater source concentrations, in-river sediment concentrations, and completeness of the groundwater pathway at each site. For the hydrophobic iCOCs (such as high-molecular-weight polycyclic aromatic hydrocarbons, or HPAHs, and pesticides), analyte concentrations were generally lower in filtered samples than unfiltered samples, likely reflecting the expected inclusion of small amounts of sediment in unfiltered samples.

3.4.3 Surface Water

Round 2 surface water samples were collected during three sampling events in 2004 and 2005. Contrary to expectations based on historical weather patterns and river stages, low flow conditions prevailed during all of these sampling events. Individual samples may have been affected by storm water discharges from isolated rainfall events that occurred while sampling operations were in progress.

Concentrations of many organic iCOCs, including the risk drivers PCBs, dioxins/furans, and DDx, were somewhat higher at river transect sampling locations within the Study Area than at the upstream transect at RM 11. This implies that although these iCOCs are entering the Study Area from upstream sources, sources within the Study Area also contribute iCOCs to the water column.

Concentrations of iCOCs were generally higher at one or more of the near-bottom sampling locations than at the transect stations, reflecting input from local sources. PCB patterns in near-bottom suspended solids generally reflected patterns found in nearby surface sediment, suggesting that bottom sediment may become entrained in the water column at these locations.

Temporal trends varied widely between iCOCs and between sampling locations for a given iCOC. Pesticide concentrations were generally lowest in November 2004, intermediate in March 2005, and highest in July 2005. However, DDx and several additional pesticides did not conform to this concentration trend at the locations with the highest concentrations. No consistent temporal trends were evident for PCBs and dioxins/furans.

3.4.4 Tissue Samples

Data for a variety of tissue samples were collected to support the human health and ecological risk evaluations, including fishes (whole body and fillets), benthic invertebrates, epibenthic communities, and stomach contents of juvenile Chinook salmon. Nine fish species were included. Both field and laboratory exposures were considered for clam samples. Worm samples represented laboratory exposures.

Among invertebrates, chemical concentrations were highest overall in lab-exposed worms (*Lumbriculus variegates*) and in field-collected clams. Among fishes, chemical concentrations were highest overall in carp (whole body), sculpin (whole body), and smallmouth bass (whole body). Maximum concentrations for individual iCOCs varied among species and sampling locations.

PCBs were elevated (>500 mg/kg) in a number of fish and invertebrate species. PCBs were elevated in site-specific tissues (i.e., invertebrates and/or sculpin) in several nearshore locations; these areas all have elevated PCB levels in surface sediment and, where tested, also in surface water (i.e., with respect to transect locations). PCBs were elevated in a variety fish species collected from broader areas of the river with no obvious pattern.

DDx concentrations were elevated in fish from numerous locations and were generally lower in invertebrates than in fish. Average and median DDx concentrations were below 300 µg/kg for most fish species and below 100 µg/kg for most benthic invertebrate tissues.

Dioxin/furan TEQ values were generally higher in invertebrates than in fish, with mean and median values below 5 pg/g for most benthic invertebrate tissues and all fish species. TEQ values were elevated (>100 pg/g) in lab-exposed worms and field-collected clam samples from numerous locations.

3.5 FATE AND TRANSPORT

The current understanding of the important physical, chemical, and biological processes that govern the loading, fate, and transport of iCOCs to the Study Area was developed based on sampling of biotic and abiotic media, FWM results, estimated loading rates, and a scientific understanding of the properties and expected behavior of each chemical. Additional information to develop improved estimates of loading and transport will be obtained from Round 3 upstream sediment and surface water sampling, Round 3 and/or DEQ-led stormwater evaluations, DEQ-led bank erosion studies, and ongoing modeling efforts (hydrodynamic model and the Fate and Transport Model).

For the three primary risk drivers at the Study Area (dioxins, PCBs, and DDx pesticides), the conceptualization of loading, fate, and transport is similar. All are chlorinated organic chemicals that tend to persist in the environment, exhibiting very low degradation/transformation rates. Dioxins, PCBs, and DDx pesticides are also highly hydrophobic, exhibiting a strong tendency to be associated with particulate matter, especially organic matter or particulate matter coated with organic matter. As such, the vast majority of these chemicals at the Site are associated with sediment and suspended solids. Therefore, transport within the Study Area is largely defined by solids transport, including suspended sediment transport in surface water and sediment erosion/resuspension and deposition processes.

Given their resistance to degradation, dioxins, PCBs, and DDx pesticides bioaccumulate within Willamette River food webs. The primary external loading terms for dioxins, PCBs, and DDx pesticides are expected to be upstream surface water loading, upstream sediment loading, and historical releases. Air deposition and bank erosion may also provide relatively small loads, though these terms are highly uncertain. Finally, upland groundwater plumes and permitted industrial discharges are not expected to be relevant loading terms for dioxins, PCBs, and DDx pesticides.

The remaining iCOCs exhibit a wide range of chemical properties, including but not limited to high solubility (cyanide and arsenic), high volatility (VOCs), and redox sensitivity (arsenic), which affect conceptualization of their loading, fate, and transport. As is the case with dioxins, PCBs, and DDx pesticides, many of the other iCOCs and potential iCOCs (e.g., non-DDx pesticides, PAHs, phthalate esters, TBT, and the SVOCs) tend to sorb strongly to sediments, and are therefore subject to sediment and surface-water-associated suspended solids transport processes. Uptake into biota, resulting in bioaccumulation, is a relevant process for all iCOCs in the Study Area except pentachlorophenol (PCP), cyanide, and VOCs, which were either not observed in tissue or not sampled because they are not expected to bioaccumulate. Several iCOCs are subject to potentially significant rates of degradation/transformation and/or metabolization, including PAHs, phthalate esters, cyanide, TBT, VOCs, and PCP.

Based on our current understanding of the Study Area, historical releases associated with heavy industrial and shipping activities in the Harbor comprise most of the contamination observed during the sampling completed to date. Upstream surface water loading, upstream sediment loading, and stormwater runoff are expected to be the primary current loading terms for most iCOCs. Stormwater loading will be evaluated in the next round of sampling. Preliminary estimates, based on food web modeling, are that surface water exposure is responsible for approximately 5 to 20 percent of benthic invertebrate and fish tissue concentrations of PCBs, the chemicals associated with the preponderance of potential risks. The proportional contribution of surface water exposure to tissue burdens should be expected to increase as sediments are remediated (because the upstream and stormwater contributions would remain constant while the sediment contribution declined). The Round 3 sampling program will improve understanding of how much stormwater and upstream sources could be contributing to tissue burdens. The current loading contribution of riverbank erosion is highly uncertain because of the absence of data. However, it is expected to be mitigated by armoring of the bank at most of the industrial sites where contaminated fill may occur. Similarly, the current loading rate of iCOCs from permitted wastewater discharges, although uncertain, is expected to be relatively small considering the regulation and monitoring of these outfalls. Upland groundwater plume discharge is expected to be relevant for cyanide and VOCs. Atmospheric deposition may provide a small fraction of the load of PAHs, phthalate esters, and mercury; however, these contributions are highly uncertain.

3.6 RECEPTORS

3.6.1 Human

The following is a summary of the human receptor populations and corresponding exposure pathways evaluated in the Round 2 HHRA (Appendix F):

- **Dockside Worker—Direct contact with beach sediment.** Dockside workers include industrial and commercial workers at facilities adjacent to the river who conduct specific activities within natural river beach areas, such as unloading ships or barges from the beach itself or conducting occasional maintenance activities from the water's edge. Although exposure is anticipated to be infrequent to nonexistent, dockside workers may be exposed to beach sediment within riverfront industrial and commercial sites in the Study Area.

- **In-water Worker—Direct contact with in-water sediment.** In-water workers are those workers who conduct overwater activities such as maintenance dredging and repair of in-water structures. Although most of these activities are unlikely to result in significant sediment contact, in-water workers may be exposed to in-water sediment from activities performed on the water throughout the Study Area, but most likely in shallower, nearshore locations.

- **Adult and Child Recreational Beach User—Direct contact with beach sediment and surface water.** Both adults and children participate in recreational activities in beach areas within the Study Area. Adult and child recreational beach users may be exposed to beach sediment at riverfront beaches where recreational use occurs. Adult and child recreational beach users may also be exposed to surface water from activities such as boating and swimming.

- **Transient—Direct contact with beach sediment, surface water, and groundwater seeps.** Tents and makeshift dwellings have been observed as evidence that individuals were occupying some riverbank areas. While the tents and makeshift dwellings were typically observed above the actual beach areas, transients may be exposed to beach sediment at riverfront beaches where transient use occurs. Transients may also be exposed to surface water at some riverfront beaches from activities such as swimming, bathing, or the washing of clothing or equipment or through use of river water as a drinking water source; however, there is no evidence that this actually occurs. Transients may be unintentionally exposed to groundwater at human use beaches where groundwater comes to the surface (i.e., seeps) on the beach above the water line.

- **Native American Angler—Direct contact with beach sediment or in-water sediment and ingestion of fish.** Six Native American Tribes (Yakama, Grande Ronde, Siletz, Umatilla, Nez Perce, and Warm Springs) assert treaty-fishing rights to fish in the Willamette River within the Study Area. The extent to

which Native Americans fish within the Study Area and the amount of fish consumed from within the Study Area are unknown. Native American anglers who fish from the water's edge within natural river beach areas could have direct exposure to beach sediment. Native American anglers who fish from boats or piers could be exposed to in-water sediment on anchors or hooks. Both adults and children may consume fish that are caught from the Study Area.

- **Non-tribal Angler—Direct contact with beach sediment or in-water sediment and ingestion of fish and shellfish.** A year-round recreational fishery exists within the Study Area. In addition to recreational fishing, immigrants from Eastern Europe and Asia, African-Americans, and Hispanics may be catching and eating fish from the lower Willamette. Non-tribal anglers who fish from the water's edge within natural river beach areas could be directly exposed to beach sediment. Non-tribal anglers who fish from boats or piers could be exposed to in-water sediment on anchors, hooks, or crayfish pots. Both adults and children may consume fish that are caught from the Study Area. Although there is little evidence supporting shellfish consumption within the Study Area, adults may consume clams and crayfish caught from the Study Area.

3.6.2 Ecological

The following is a summary of the ecological receptors and corresponding exposure pathways evaluated in the Round 2 ERA (Appendix G):

- **Ingestion of Biota and Sediment.** The ingestion of biota (i.e., fish or invertebrate prey) and incidental ingestion of sediment are considered complete pathways for all benthic invertebrates (infauna and epifauna species), fish receptors, wildlife receptors, and amphibians[2]. Invertebrate and/or fish biota comprise the diets of these receptors and these receptors are known to incidentally ingest sediment while foraging for prey.

- **Direct contact with Surface Sediment.** Direct contact with sediment is considered a complete and major pathway for benthic invertebrates (including infauna and epifauna) and benthic fish (i.e., largescale sucker, carp, white sturgeon, sculpin, and lamprey ammocoetes), as these receptors live in close association with surface sediment. Because aquatic plants actively and passively transfer chemicals from sediments, this pathway is also considered complete and major for aquatic plants. Direct contact with sediment is considered complete and uncertain for spotted sandpipers and amphibians; however, shorebird (i.e., spotted sandpiper) risks from sediment contact are considered insignificant relative to those from ingestion (EPA 2000c). Direct contact with sediment is a complete and minor pathway for fish that are known to be pelagic feeders and not frequently in contact with sediments (e.g.,

[2] Amphibians were evaluated as a protected surrogate receptor group for reptiles (see Appendix G).

peamouth, juvenile Chinook salmon, smallmouth bass, and northern pikeminnow) and for wildlife receptors that have minimal contact with sediments (e.g., hooded mergansers, bald eagle, osprey). Direct sediment contact may contribute to total exposure through dermal absorption for mammals; however, given the protective properties of the fur of mink and other aquatic carnivorous mammals that may use the Study Area, direct contact would be limited to the paws (and possibly to the nose and/or eyes), and risks from sediment contact are considered insignificant relative to those from ingestion (EPA 2000c).

- **Ingestion of and Direct Contact with Surface Water.** All benthic invertebrates, fish, and amphibians are in direct contact with surface water and incidental ingestion of surface water likely occurs for each of these receptors; therefore, surface water ingestion and direct contact are considered complete and major pathways for these aquatic receptors. Because aquatic plants actively and passively transfer chemicals from surface water, this pathway is also considered complete and major for aquatic plants. Surface water exposure by direct contact (swimming) and ingestion (as drinking water) are considered complete and minor for all wildlife receptors because risks from water ingestion are considered insignificant relative to those from biota and/or sediment ingestion, uptake through direct (dermal) contact with water is limited because feathers (on birds) and fur (on mammals) insulate skin and limit the direct contact of skin with water, and uptake through exposure of birds and mammals to surface water is limited because of the relative insolubility of many contaminants in the Study Area.

- **Ingestion of and Direct Contact with TZW.** Benthic invertebrates may be exposed to chemicals associated with groundwater infiltration into sediments and this exposure may not be reflected in sediment concentrations of VOCs and some metals that do not partition into sediments. Therefore, exposure to benthic invertebrates via TZW (through ingestion or through direct contact) is considered complete and uncertain. TZW exposure by direct contact (while foraging for prey) and ingestion are considered incomplete pathways for all other ecological receptors; however, TZW exposure for selected fish receptors (e.g., sculpin and lamprey ammocoetes) and aquatic plants was evaluated per direction from EPA in the Round 2 ERA (Appendix G).

EXECUTIVE SUMMARY

SECTION 4 – PHYSICAL SETTING

Abstract

The physical setting of the Portland Harbor Study Area is detailed in Section 4. Physical studies conducted by the LWG have focused on the detailed conditions of the riverbed, the flow characteristics of the river, and the locations of groundwater plume discharge areas on the river bottom. It is important to understand these physical processes and conditions in order to further understand the CSM, and support the fate and transport modeling and the Feasibility Study.

Over the past 150 years, the Portland Harbor area of the LWR has been redirected, straightened, filled, and deepened by dredging. Most of the riverbank has been filled, stabilized, and/or engineered for industrial or port operations with riprap, bulkheads, and overwater piers and docks. The river flow varies dramatically with the seasons, with low late-summer dry-season levels and high rainy season and spring snow melt levels; periodic flow reversals within Portland Harbor also occur due to tidal effects. The Willamette River flows into both the Columbia River and Multnomah Channel and under certain conditions more than half the river flow is directed into Multnomah Channel. The width and depth of the river affect the flow velocities and determine in part where sediment is eroded and deposited.

The data set utilized to assess the physical conditions and processes of the Study Area will meet the goals of the RI/FS, with the following additions: limited bathymetric data within Multnomah Channel, further physical and chemical sediment characterization within the Study Area and upstream areas to address completion of the physical CSM, characterization of background, upstream contaminant loading estimates, and Feasibility Study data needs.

Work Plan and Field Sampling Plan Directives

The Programmatic Work Plan (April 2004) established the overall framework and objectives for the characterization of the physical system for the RI/FS that built upon the extensive amount of existing data collected by members of the LWG and others within the harbor. Numerous media-specific field sampling and quality assurance project plans that detailed sampling design and rationale, data use objectives, field and laboratory sampling and analysis methods, and data management and reporting requirements were developed with and approved by EPA and its partners.

Data Collection Activities

Collection of data to support characterization of the physical system for the Study Area began before the AOC was signed and has continued through Round 2. Physical system investigations conducted by the LWG included collection of the following types of data:

- Multibeam acoustic bathymetry surveys from RM 0 to Ross Island conducted in January and July-September 2002, May 2003, and February 2004

- Integration of a sediment trend analysis and an evaluation of historical bathymetry
- Sediment-profile imaging field study
- Time-series sediment stake measurements to document nearshore bank elevation changes
- Three acoustic Doppler current profiler (ADCP) surveys to provide river flow measurements during specific hydrological conditions
- Physical system data to calibrate the hydrodynamic sedimentation model: total suspended solids (TSS) concentration sampling, cohesive suspended sediment settling velocities measurements, and measurement of erosion rates and critical erosion velocities in a laboratory sediment flume
- Preliminary natural attenuation sampling (e.g., radioisotope cores) targeted for areas that may have potential natural processes to support this alternative.

Preliminary Assessment of Findings

Historically, the Portland Harbor area was a relatively shallow, meandering portion of the LWR surrounded by forested wetlands and floodplains; decades of urban development and industrialization resulted in a river that has been redirected, straightened, filled, and deepened. A -40 ft federally maintained (i.e., dredged) navigation channel, twice as deep as the original river, runs the length of the Study Area. Much of the riverbank has been progressively filled, stabilized, and/or engineered for industrial or port operations with riprap, bulkheads, and overwater piers and docks.

The river flow typically varies seasonally from 10,000 cubic foot per second or cfs (late summer) to about 100,000 cfs (rainy season), with an annual average of about 40,000 cfs. The LWR upstream of the Study Area (RM 11 to Willamette Falls at RM 26) is markedly narrower, more confined by bedrock outcrops, and faster flowing than in Portland Harbor. The reach immediately downstream of the Study Area (RM 2 to the Columbia River) is also narrower as the river turns northward and converges with the Columbia. The much larger Columbia River sometimes acts as a dam, backing up the Willamette, especially during spring snowmelt when the Columbia is high. At RM 3, the Multnomah Channel diverges west from the Willamette, seasonally carrying more than half of the Willamette River discharge. During low-flow periods on the LWR, Columbia River tidal fluctuations extend into the Study Area, producing periodic upstream flows.

Portions of the Study Area vary in hydrodynamic and sediment transport characteristics as a function of the cross-sectional area, navigation channel width, and off-channel features. The river transitions from its more dynamic upriver character to a predominantly depositional setting from RM 10 to RM 7 and is dominated by fine-grained sediments. Extensive shoaling occurs in this reach, requiring regular maintenance dredging in the navigation channel between RM 8 and 10. The Study Area becomes predominantly sandy between RM 5 and RM 7, where the river narrows. Sediments that arrive in the channel in this reach likely move downstream. As the river widens from RM 5 downstream to RM 2, it again becomes predominantly

depositional or stable in character. Division of the river flows by the Multnomah Channel at RM 3 results in a second area of extensive shoaling in the channel from RM 3 to RM 2. Finally, throughout the Study Area, sheltered off-channel areas, such as Swan Island Lagoon and Willamette Cove, are largely protected from natural disturbances but localized anthropogenic disturbances (e.g., propwash) can be widespread.

Time-series bathymetry data and sediment-profile images throughout the Study Area reveal a relatively active mixed surface sediment layer that would be expected from the hydrodynamics and sediment transport characteristics observed in the river. Small-scale (i.e., less than 30 cm) scour and deposition is widespread, and rapid changes in sediment texture are evident both laterally and sometimes vertically in the sediment column along the river edges as a function of localized shoreline morphology and riverbank modifications, including in-water structures such as piers or docks. Offshore channel environments are more texturally similar over large areas, reflecting the large-scale hydrodynamics of the river.

Some large contiguous areas of deposition or active transport are apparent within the Study Area. The forces that produce this dynamic surface sediment layer include both natural (e.g., river flows) and anthropogenic (e.g., propwash) disturbance factors. Sediment quality in the surface sediment layer (30 cm) is both temporally and spatially persistent, reflecting the effects of small-scale mixing. Below 30 cm, the sediment column is stable, particularly in nearshore and off-channel areas, under typical hydrodynamic and anthropogenic forces.

Additional Data/Next Steps

Sediments

Some additional sediment radioisotope and chemistry data will be collected as part of Round 3 for the following data needs:

- Upstream subsurface sediment core samples will be collected in Round 3A to inform the definition of background, and support evaluation of contaminant loading to the Study Area from upstream
- Representative engineering properties of sediments in iAOPCs will be determined to support the FS.

Bathymetric Surveys

An additional bathymetric survey of the upper portion of Multnomah Channel will be conducted in Round 3A to support an assessment of the downstream transport of contaminants from the Study Area into Multnomah Channel.

All additional physical characterization data collected in Round 3 or compiled from non-LWG sources will be evaluated as part of the final physical setting discussion presented in the RI/FS report.

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4.0 PHYSICAL SETTING

This section describes the natural and human-altered physical setting of the Portland Harbor Superfund Site, including historical and current land use, regional geology and hydrogeology, surface water hydrology, the physical system (which includes bathymetry, physical sediment characteristics, and hydrodynamics and sediment transport), habitat, and human access and use. These factors have all been considered in the development of the physical and risk assessment conceptual site models to plan the RI/FS sampling completed through Round 2. Each will be refined based on the comprehensive data evaluation presented in this report and parallel RI efforts (e.g., hydrodynamic modeling), and will be used as warranted to plan future sampling efforts and design remedial alternatives.

Section 4 focuses primarily on the physical setting of the Study Area. However, the LWR and physical features of the Willamette River and basin from Willamette Falls (RM 26) to the Columbia River (RM 0), as well as the upstream portion of Multnomah Channel, are discussed as needed to place the Study Area's physical characteristics into a regional context.

The Willamette River drains the Willamette basin from the Cascade Range to the Coast Range. The portion of the river from Willamette Falls to the Columbia River is considered the LWR (Map 1.1-1). Multnomah Channel is a distributary of the LWR that begins at RM 3.1 and flows approximately 21 miles to its confluence with the Columbia River.

The upstream reaches of the Willamette River above Willamette Falls constitute a meandering and, in some cases, braided river channel. Upstream flooding is largely controlled by 13 major tributary reservoirs (Uhrich and Wentz 1999). In the LWR, especially near and around Portland, the channel banks have been stabilized (by placement of riprap, construction of bulkheads, etc.), and the channel itself has been deepened to an authorized depth of -40 ft (Columbia River Datum; CRD, see Section 4.3.1). These measures have created a stable channel in the LWR. The federally maintained navigation channel defines Portland Harbor and extends upstream from the Columbia River to RM 11.7 (Broadway Bridge) (Map 1-1). From 1973 through 2000, average annual mean flow in the Willamette River was approximately 33,800 cfs at the Morrison Bridge in Portland.[3]

4.1 LAND USE

This section provides an overview of Portland Harbor's waterfront development, including historical shoreline modifications and current land use. Portland Harbor, in this section, generally refers to the area between RM 0 and RM 11.7, the extent of the

[3] Data obtained from the U.S. Geological Survey Water Resources web site (http://waterdata.usgs.gov/or/nwis/sw).

navigation channel. The long history of settlement and urbanization in Portland Harbor has resulted in major physical landscape alterations and contributed to chemical contamination of surface water and sediments in the LWR. Other influences include industrial and shipping activities in Portland Harbor, as well as agricultural, industrial, and municipal activities upstream of the harbor. Potential sources of chemical releases to the river are described in Section 5. The historical background information presented in this section supports further discussions of the physical system, potential sources of contamination, the distribution of in-river chemicals, and the effects of such chemicals on the environment in the LWR.

4.1.1 Portland Harbor Overview

Portland Harbor remained largely undeveloped through the late 1800s. Early industrial and commercial development along the river began in scattered areas such as downtown Portland, St. John's, Linnton, and Macadam. At the beginning of the 20th century, businesses began to relocate to the current industrial area of the harbor as crowding in the downtown area prevented further industrial development.

Commercial and industrial development in Portland Harbor accelerated in the 1920s and again during World War II, which reinvigorated industry following the Great Depression. During the war years, a considerable number of Liberty ships, minesweepers, and T-2 tankers were built at military shipyards located in Portland Harbor. A number of these shipyards were also involved in ship repair. Following the war, some of the shipbuilding facilities closed, but a few remained and were repurposed for scrapping the military's surplus and obsolete vessels. The years following the war also saw an increase in industrial development, which continued to spread throughout the Study Area. In addition to shipbuilding and repair, land uses in Portland Harbor have included lumber and steel mills, fuel facilities, rail yards, and manufacturing facilities, as presented previously (Integral et al. 2004b; Integral and GSI 2004).

Significant physical modifications to the river coincided with the rapid development and industrialization of the harbor. Modifications included redirection and channelization of the main river, draining of seasonal and permanent wetlands in the lower floodplain, and relatively frequent dredging to maintain the navigation channel. Overwater structures such as wharfs, piers, floating docks, and pilings were and remain common. Man-made structures are clearly visible in the aerial photos provided in Maps 4.1-1a–r. These structures were built largely to accommodate or support shipping traffic within the river and to stabilize the riverbanks for urban development.

Riprap was the most common bank-stabilization measure. However, upland bulkheads and rubble piles were also used. Seawalls were constructed to control periodic flooding, whose effects became more pronounced with the filling of riparian wetlands in the harbor. Numerous public and private outfalls, including storm drains and CSOs, enter both shores of Portland Harbor.

Portland Harbor is heavily industrialized and is located within a broader region characterized by commercial, residential, recreational, and agricultural uses. Land use along the LWR in the harbor includes marine terminals, manufacturing, and commercial operations as well as public facilities, parks, and open spaces. Map 4.1-2 illustrates current land use zoning within the LWR. Sites located within Study Area drainage basins and inventoried in DEQ's Environmental Cleanup Site Inventory (ECSI) database are identified. Waterfront properties are also labeled. Current and previous facility names for these sites are listed in Table 4.1-1.

The remainder of Section 4.1 presents a history of the authorized dredging channel, recent dredge and sediment cap projects within the Study Area, stormwater systems, a general description of land use changes in Portland Harbor since the 1930s, and a more detailed history of shoreline modifications due to dredge and fill activities and overwater operations.

4.1.2 Navigational Channel Authorization History

Congress authorized the LWR federal navigation project through the Rivers and Harbors Act in June 1878. Its purpose was to deepen and maintain parts of the Columbia and Willamette rivers to a 20-ft minimum depth. The channel for both rivers has been deepened at various intervals since that time. Most significantly, the authorizations affecting the LWR depth occurred as follows: 25 ft in 1899, 30 ft in 1912, 35 ft between 1930 and 1935, and, finally, 40 ft in 1962.

The current project authorization, as modified by Congress in 1962, encompasses 11.6 miles of the Willamette River below Portland and 103.5 miles of the Columbia River below Vancouver, Washington. Work on the authorized 40-ft-deep channel from Portland and Vancouver to the Pacific was completed in 1976. The Willamette River channel from the Broadway Bridge (RM 11.7) to the mouth (RM 0) varies in width from 600 to 1,900 ft.

4.1.3 Dredging and Capping Activities

In certain areas of Portland Harbor, periodic dredging is necessary to maintain the authorized depth of the navigation channel, as well as to maintain operational depths at docks and wharfs. The navigation channel has not been dredged since January 1997, although dredging at various docking facilities has occurred on an as-needed basis. This section presents Portland Harbor dredging and capping activities since 1997. This date corresponds to the oldest data used in the presentation and evaluation of analytical data presented in this report.

Dredging projects undertaken since 1997 by the Port of Portland, USACE, the City of Portland, and private parties are listed in Table 4.1-2. This table is an update of a similar compilation provided in the Programmatic Work Plan (Integral et al. 2004b). Map 4.1-3 shows the locations of these dredging and capping operations between RM 2

and RM 11.7 since the most recent USACE-sponsored dredging of the federal navigation channel in January 1997.

Since 1997, the Port of Portland has performed maintenance dredging at its marine Terminals 2, 4, and 5 (see Table 4.1-2). Maintenance dredging has also been performed by Schnitzer Steel Industries, Inc. (Schnitzer) (International Terminal Slip RM 4), Chevron (Willbridge Terminal, RM 7.5), the City of Portland (Portland Fire Bureau Station 6 Dock, RM 9.7), the former Goldendale Aluminum Company (Goldendale Aluminum facility dock, RM 10), and Cargill (Irving Elevator Terminal, RM 11.6). The City of Portland project also included cap placement, as noted below. Brief descriptions of these dredging projects are described below.

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

In addition, two in-river sediment capping projects related to cleanup actions (McCormick & Baxter Creosoting Company and Gasco) took place in the past 2 years.

- Sediment cap construction activities at the McCormick & Baxter Creosoting Company, a former wood treating facility, were completed in 2004. The cap's shoreward boundary extends from the south end of the property north into

Willamette Cove (RM 6.8). Its offshore boundary extends to -46 ft CRD at its deepest location outside the navigation channel. In Willamette Cove, the cap extends offshore to -16 ft CRD. Approximately 23 acres of contaminated sediments were capped with 2 ft of sand. More highly contaminated areas were capped with 5 ft of sand. In addition, areas of the cap influenced by seeps were capped with 600 tons of organoclay, a bentonite or hectorite clay altered to be hydrophobic. The cap design incorporated different types of armoring (i.e., articulating concrete block mats and rock) to prevent erosion in the nearshore areas (DEQ 2005c).

- Approximately 15,300 yd^3 of tar and tar-contaminated sediment (a "tar body") were removed from the riverbank and nearshore area adjacent to the Gasco facility and disposed of at the Chemical Waste Management landfill at Arlington, Oregon. After the removal action, an organoclay mat was placed along a small upper-elevation band of the shoreline dredge-cut. This mat was secured with placement of cap sand and quarry spalls over the clay mat. The remainder of the removal area (0.4 acres) received 1 ft of cap sand and 0.5 ft of erosion protection gravel. In addition, 2.3 acres of the area surrounding the removal area received 0.5 ft of "fringe cap" sand material. The removal action also created a depression into which potential seepage could be captured and localized for future response. Construction activities took place between August and October 2005 (Parametrix 2006).

4.1.4 Stormwater Systems

Information presented in this section is primarily from the Portland Harbor Programmatic Work Plan (Integral et al. 2004b) and the *Programmatic Source Control Remedial Investigation Work Plan for the City of Portland Outfalls Project* (CH2M Hill 2004b), as well as additional LWG analysis. This section describes the physical structures of the stormwater systems; section 5 addresses stormwater as a pathway for contaminants.

Stormwater enters the river via stormwater conveyances, overland flow, and infiltration to groundwater. Figure 4.1-1 shows the approximate overall area draining to the Study Area. The delineation of the overall drainage basin area between RM 2 and 11 was provided by the City of Portland.

Stormwater runoff to the Study Area is discharged mostly via stormwater outfalls that are connected to stormwater conveyance systems. These systems have been installed within the Study Area by a variety of entities, including private landowners, the Port of Portland, the State of Oregon, and the City of Portland. Stormwater conveyance systems located in the drainage area typically consist of storm drains, inlets, and catch basins connected to pipes that discharge to the river via outfalls. In some locations, stormwater is captured in combined stormwater/sewerage systems and is routed to the Columbia Boulevard Wastewater Treatment Plant (CBWTP). The relationship between stormwater and sewerage overflows is discussed further below.

Overland flow of stormwater to the river occurs at some locations immediately adjacent to the river. In many of these areas, the extent to which rainwater falling on pervious ground near the river shoreline may run off versus infiltrate into the ground is unknown. In some impervious shoreline areas, stormwater appears to be transported to the river via overland flow, with little chance for infiltration into the ground. Based on a preliminary assessment of outfall drainage basins, the area drained by overland flow appears to be smaller relative to the area discharged via outfalls, although this conclusion is somewhat uncertain given that considerable areas were not characterized into either category.

Stormwater can also enter the river via infiltration into pervious ground (or through dry wells, sumps, and other infiltration facilities), where it is then discharged as groundwater entering the river. Groundwater discharges are discussed in Section 5.

Most of the stormwater flow from the west side of the river comes from Forest Park stream drainage, which consists mostly of undeveloped park. In general, Forest Park streams enter underground pipes at the base of the West Hills, near State Highway 30. The highway stormwater drainage enters a series of conveyance systems along this shoreline of the Study Area. The one exception is Saltzman's Creek, which is a predominantly open channel except for approximately 1,400 ft of culvert close to the river. In contrast, there are few open channel drainages on the east side of the river and most of the stormwater is discharged via conveyance systems. On both sides of the river, most properties adjacent to the river do not discharge through large conveyance systems but have direct discharge to the river via their own stormwater conveyance systems and outfalls or via overland flow.

The City of Portland has identified approximately 322 outfalls along both shores of the Study Area (City of Portland 2006a,b). The LWG was able to independently verify approximately 158 of them, based on site-specific information, in a preliminary assessment, which is ongoing. Drainage basins, outfalls, and land use zoning are shown on Map 4.1-4a–c.

Some discharges via outfalls are regulated via NPDES stormwater and other permits. These include the City of Portland and Port of Portland Municipal Separated Storm Sewer System (MS4) permit, one site specific individual stormwater permits, and multiple general industrial stormwater permits. The Oregon Department of Transportation (ODOT) also has its own MS4 permit.

Stormwater quality is affected by land use and the associated activities that occur within that land use. Preliminary estimates of the predominant land use zoning classifications for the overall Study Area drainage basin per Table 4.1-3 are:

- Rural/open space—approximately 41.1 percent of total site drainage
- Industrial—approximately 31.5 percent
- Single family residential—approximately 19.2 percent

- Multifamily residential—approximately 4.6 percent
- Mixed use—approximately 2.9 percent
- Commercial—approximately 0.7 percent.

It should be noted that the land use percentages are based on Metro zoning layers (see Map 4.1-2). Zoning is known to differ from actual land uses in a number of areas. Most notable is that some areas of existing undeveloped rural open space are zoned for residential use though they are not currently developed for this use. Consequently, the above percentages overestimate the residential land use as it currently exists.

Major transportation (e.g., highways and freeways) is an additional land use category identified from national and local stormwater studies as having unique effects on stormwater. Some refinement of the zoning-based land use maps presented in this report will be necessary to more accurately define major transportation land use areas. This effort will be conducted for the RI.

Areas adjacent to the river are dominated by industrial land uses, with the following exceptions:

- A large percentage of the areas adjacent to the river on its east shore between RM 5.5 and RM 7 consist of parks and open space. There are few identified active outfalls in these areas.
- An area adjacent to the east shore of the river between RM 7 and RM 8 is classified as multifamily. This 80-acre area is the University of Portland campus, and, based on plumbing records, it appears that this area does not discharge to the river.

4.1.4.1 Combined Sewer Overflows

Historically, sanitary and industrial wastewater discharged directly to the river through both public and private outfalls. When sanitary sewer interceptors were constructed in the 1950s through 1970s, most of the Portland Harbor Study Area was required to connect to the sanitary sewer. This, combined with NPDES requirements for direct industrial discharges, improved Willamette River water quality through that period (EPA 2000d).

After construction of the sanitary interceptors, some combined systems still existed within the harbor area. The system was designed to handle the total sanitary load, but during heavy storm events a large portion of the storm load would be bypassed through the outfall in a CSO. (A CSO occurs when sanitary wastewater and stormwater overflow to the river when system storage and conveyance capacity are exceeded during wet weather events.) When CSOs occurred from these systems, they typically consisted of approximately 80 percent stormwater and 20 percent untreated sewage. The City of Portland is now 15 years into a 20-year CSO abatement program. All but two CSO systems (City of Portland Outfalls 17 and 46) between RM 2 and 11) were fully abated

by 2006 (Adderley 2006, pers. comm.). Abatement is defined as including both full and partial separation techniques. A previously combined system that has been fully separated sends sanitary wastewater to the publicly owned treatment works (POTW) and stormwater to a receiving stream through separate conveyance systems. A partially separated CSO system conveys the combined sanitary wastewater and significantly reduced stormwater to the POTW except during extreme wet weather events when a portion of the combined flow overflows due to capacity limitations.

4.1.5 General Land Use History

As part of the Conceptual Site Model Update (Integral and GSI 2004), historical aerial photos were reviewed to evaluate general trends in land use along the Willamette River waterfront. A general description of the development of Portland Harbor was presented in that document and it is repeated here to provide context for the source discussions that follow later in this report.

For most years, aerial photo images were available for the entire river waterfront from the Columbia River to Ross Island. Mosaic TIFF (tagged image file format) images created from scanned aerial photos of the river and waterfront were also reviewed (see Maps 4.1-5a–d). Historical image mosaics were developed by the Port of Portland. The oldest historical aerial photos available for this harbor-wide review were taken in 1936. Based on the pace of land development observed during the preliminary review of all of the aerial photo mosaics, five of the photo mosaics (1936, 1948, 1961, 1974, 2000) were selected for broader-scale depiction of changes in land usage.

In general, industrial and commercial development was initially concentrated along the river in downtown Portland, St. John's, Linnton, and Macadam. Development fanned outward from those areas over the past century to form the present, near-continuous strip of waterfront development along the river. Construction in many of these areas was preceded by placement of hydraulic fill.

Several shipyards were present during and immediately following World War II. The Burgard Industrial Park was the location of a large shipyard owned by the Oregon Shipbuilding Corporation. The deep-draft International Terminal Slip was created during this period, and portions of the marshy, low-lying areas on the site were filled. Over 450 ships were built on this property from 1941 to late 1945. The MarCom facility, which ceased operations in 2004, was situated on land that had been used for ship building and vessel repair since approximately 1905. The central portion of Willamette Cove was also used for ship repair and related ship maintenance between 1903 and the late 1940s. Upland shops and structures and in-water dry docks were used by independent contractors working for respective vessel owners. During wartime, U.S. Government contractors operated the dry docks for military shipbuilding and repair. The Swan Island area was occupied by a 250-acre shipyard owned by the Port of Portland and leased to the U.S. Maritime Commission. The Kaiser Company built, converted, and repaired oil tankers for the U.S. Navy. The Willamette Iron and Steel Company (WISCO) used Terminal 2 and the Sulzer Pumps property for shipyard

activities for an unknown period ending in 1949. The WISCO shipyard was used throughout the war for conversion, maintenance, and repair of government ships. WISCO constructed minesweepers, minelayers, escort vessels, and patrol vessels, and repaired various operating vessels.

Development changes noted in the five photo mosaics are described below:

- **1936.** In 1936, large areas of the waterfront were undeveloped or showed evidence of only minor development of indeterminate nature (Map 4.1-6). Hydraulic fill appeared to have been placed recently along the east side of the river from RM 1 to 4. Industrial facilities consisted primarily of lumber mills (many areas along the riverbank were used for log storage), along with a dry dock at Willamette Cove (RM 6.8) and a few steel mills. Several tank farms populated the south side of the river from RM 4 to 8. In downtown Portland, development on both sides of the river consisted mostly of warehouses and docks. The large rail yards (see Map 4.1-2) were already present on both sides of the river between RM 10 and 12. Swan Island was an airport, with mostly open space between the runways.
- **1948.** By 1948, undeveloped areas had decreased in size and were more fragmented, although large open areas remained downstream of Multnomah Channel (Map 4.1-7). Industrial facilities consisted primarily of lumber mills (with log storage along the riverbanks), although several WWII shipyards and manufacturing plants were present. The tank farms along the west side of the river from RM 4 to 8 were intact, and both sides of the river in downtown Portland remained largely industrial. The large rail yards between RM 10 and 12 were more fully developed. Waste detention ponds had been constructed on the Gasco property in the 1940s. The airport observed in the 1936 aerial photo was no longer present, and a shipyard occupied the northwest portion of Swan Island.
- **1961.** Industrial development had expanded on both sides of the river within the Study Area (Map 4.1-8). Several of the shipyards were gone, and several of the tank farms had expanded. The federal housing areas had been converted to industrial uses. Industrial development in Mock's Bottom (east of Swan Island Lagoon) had also expanded. Log storage areas were present along the riverbanks.
- **1974.** By 1974, development had expanded along the east bank from St. John's bridge (RM 5.8) toward the mouth of the Willamette River (Map 4.1-9). Cargo handling operations had expanded considerably throughout the river, and a steel mill was constructed on the east bank at RM 2.2. The Siltronic property was substantially filled by the 1970s. Construction of I-5 and I-405 was complete (see Map 4.1-5a–e).
- **2000.** Relatively few land use changes had occurred between 1974 and 2000(Map 4.1-10). Several parcels with previous industrial operations were

vacant by 2001. Some previously industrial land had been converted to commercial and residential uses, and public access areas along the river, such as Cathedral Park (RM 6), had increased substantially.

4.1.6 Historical Shoreline and Fill Placement

This section presents additional specific information related to shoreline modifications and fill placement.

The shoreline of the Study Area has undergone significant change in the last 100 years as industrial operations were developed. Maps of shoreline changes are presented by decade in Maps 4.1-11a–d. The maps represent 1 year from each decade starting in 1936, the earliest date of available aerial photography. Specifically, the maps cover 1936, 1948, 1957, 1966, 1975, 1985, 1995, and 2000.

Detailed information on the fill placement activities can be found in Table 4.1-4. Information used to construct this table was obtained from the aerial photographs, site summaries[4], and the City of Portland. The descriptions of subsurface soils in site investigation reports suggest that much of the fill placed in these areas consists of river dredge material (from either the Willamette or Columbia River). The source of the fill, if known, is identified in Table 4.1-4. The most notable changes for the major reaches in the Study Area are described in the following subsections. Physical and hydrodynamic characteristics of the Study Area reaches are described in Section 4.5.2

4.1.6.1 Upper Study Area

The Upper Study Area extends from RM 9.2 to RM 11. The area with the most change is Mock's Bottom and Swan Island. Swan Island was separated by two channels of the Willamette River. Prior to 1920, the eastern channel was the river's main channel. The eastern channel was deeper than the western channel, which was wide and shallow with a shoal that hindered boat passage. In the late 1920s, the main channel of the river was relocated from the east side to the west side of the island through the construction of a causeway at the island's upstream end (thus creating a lagoon on the east side). From the late 1940s into the 1950s, the southwestern and southeastern ends of Swan Island were filled using material dredged from the river. Mock's Bottom, once a swampy slough, was filled to build roads and facilitate industrial development. On the eastern banks of the Willamette from approximately RM 9.5 to 10, the original shoreline formed a cove. In the 1970s this area was filled (corresponding with filling in the lagoon). Significant changes also occurred along the west bank with the creation of the

[4] Site summaries describe general site information (location, physical description); owner history; current and historical site uses; potential sources (overwater activities, recent and historical spills); the nature and extent of chemicals in soil, groundwater, surface water, and sediment; stormwater and wastewater permit information; and a summary of cleanup actions. Sediment transport mechanisms for waterfront properties are also described (see Section 5.1.1). Site summaries were presented in the draft Conceptual Site Model Updates (Integral and GSI 2004, Integral and GSI 2005a,b,c) and updated addenda contained herein.

Albina Ferry slip (Slip No. 1) at Port of Portland Terminal 1 in 1914 and Slip No. 2 in 1923; dredging of a slip at the WISCO shipyard (now Port of Portland Terminal 2) in the mid-1940s (RM 10, 10.6, and 10.9); filling of the western shoreline downstream of Terminal 2 in the 1950s and 1960s; filling of the Terminal 1 South slip in the early 1900s; and filling of the Terminal 2 upstream slip by 1987.

4.1.6.2 Upper ISA

The Upper ISA extends from RM 6.9 to RM 9.2. The eastern bank remained relatively unchanged until the 1970s, when the downstream end of property—presently known as Triangle Park LLC (RM 7.4)—was filled to create a dock and berth area. On the downstream end of Swan Island Lagoon (present-day Cascade General Ship Repair Yard, RM 8.4), shipways were constructed in the early 1940s and removed in the late 1940s through 1957 for the addition of dry docks. Filling occurred in the northwestern portion of the yard area in the 1970s. On the west side of the river, fill was placed along the shoreline beginning in the 1950s. In the 1960s, filling of the present-day McCall Oil facility (RM 8.2) occurred, modifying the shoreline south of the Willbridge Terminal (RM 8.6/8.8).

4.1.6.3 Middle ISA

The Middle ISA extends from RM 5 to RM 6.9. Most of the shoreline change in this reach occurred on the west side of the river from the 1940s to the 1960s. Fill was placed along the eastern shoreline of RM 5 to RM 5.7 from the 1950s through the 1970s. Until 1975, fill was also placed along the western shoreline and a larger low-lying area at what is present-day Siltronic and Gasco property (RM 6). Fill materials for both sides of the river included quarry discards and dredge spoils. At the Gasco and Siltronic properties, MGP materials were also included in the fill.

4.1.6.4 Lower ISA

The Lower ISA extends from RM 3 to RM 5. The most important shoreline changes in the Lower ISA occurred along the eastern shoreline. In the late 1910s and early 1920s, the mouth of Gatton Slough was filled, and two slips were dredged forming the Port of Portland Terminal 4 area (present-day Slips 1 and 3). In the mid 1940s, material was excavated to create a slip at the present-day Schnitzer International Slip (RM 3.7). In the 1950s, the middle slip at Terminal 4 (which was never completed) was backfilled and Slip 3 was widened.

4.1.6.5 Lower Study Area

The Lower Study Area extends from RM 2 to RM 3, just downstream of the head of Multnomah Channel. Fill materials were placed at the present-day OSM site from the 1940s to the 1960s; additional filling of the riverbank occurred in the 1970s using OSM slag materials. A dredge fill map compiled from USACE data shows dredge spoils from the Post Office Bar and the mouth of the Willamette being placed in the Rivergate Industrial area in the 1950s through 1970s (USACE 1973; Port of Portland 1981).

4.1.7 Historical Overwater Operations

Overwater operations in the Study Area include docks, pipelines, material storage and transfers, mooring facilities, shipbuilding and repair, and ship dismantling. Overwater features on the maps were obtained from aerial photographs dated as early as 1936. Historical overwater operations are presented in Maps 4.1-12a–f. The dominant overwater features are described in the following paragraphs, with more detailed information provided in Table 4.1-4.

4.1.7.1 Upper Study Area

Primary overwater features in the Upper Study Area include the docks along the western shoreline at Port of Portland Terminals 1 and 2 (RM 10, 10.6, and 10.9) and an oil transfer pipeline (south of present-day Sulzer Pumps) at RM 10.4. The oil transfer pipeline was used by Pacific Power & Light for transferring Bunker C oil from vessels to tanks at a nearby substation. Some of these docks remain in place but are no longer in use. Most overwater activity associated with the docks in this area appears to have occurred in the 1940s and 1950s, when the docks were used for loading lumber, paper products, steel, grain, gravel, and coal.

4.1.7.2 Upper ISA

The dominant overwater features in the Upper ISA were associated with the Portland Shipyard (present-day Cascade General Ship Repair Yard, RM 8.4) on the east, and present-day Gunderson (RM 8.8), Willbridge Terminal and McCall Oil (RM 7.5), and present-day Arkema (RM 7.3) on the west. Prior to the 1940s, Swan Island was operated as a municipal airport. In the early 1940s, the airport was demolished to make way for a WWII military shipyard where T-2 tankers were constructed. Following the war, a military contractor used the facility for ship scrapping.

On the west bank, similar activities occurred at what is the present-day Gunderson site, where operations began in the 1940s. Starting at about the same time and continuing to the present, barges and rail cars were manufactured at the Gunderson site. During the 1960s and 1970s, a portion of the Gunderson facility was used by American Ship Dismantlers for ship scrapping. Overwater activities occurred at the barge launchways in Area 2 and the outfitting dock in Area 3.

Petroleum products have been loaded and unloaded at the Willbridge Terminal since the early 1900s. Aerial photography indicates that the current Willbridge docks were added in the 1930s. A dock and transfer pipeline were historically located at the McCall Oil site prior to filling in the late 1960s.

Present-day Arkema also began operations in the 1940s. Arkema maintained two dock structures for receipt of sodium chloride and shipping of inorganic chemicals produced onsite. Operations ceased in 2001, but the dock structures remain.

4.1.7.3 Middle ISA

Dominant historical overwater features along both sides of the Middle ISA include docks associated with ship repair, lumber mills, petroleum product distribution,

moorage, and cargo unloading. Several dry docks associated with shipbuilding and repair have been removed from this stretch of the river. Dock structures of the former McCormick and Baxter facility were removed during the recent Superfund cleanup of this site.

4.1.7.4 Lower ISA

Dominant historical overwater features in the Lower ISA include docks associated with lumber mills, petroleum product distribution, moorage, and cargo unloading. Port of Portland facilities that handle soda ash, ore, metals, grain, and liquid bulk materials from their docks are located on the eastern shoreline. Metal scrap delivery occurs at docks in the International Terminal Slip. Along the western shoreline, there are bulk petroleum distribution docks (ARCO) and sand and gravel unloading/loading overwater activities (Linnton Plywood).

4.1.7.5 Lower Study Area

The primary overwater features along the eastern shore of the Lower Study Area are docks for distribution of chemicals and petroleum products. The only industrial feature on the western bank of the river in this area is Alder Creek Lumber Company (RM 2.9). Since 1959, floating logs have been delivered to the dock area at the site.

4.2 HYDROGEOLOGY

An overview of the hydrogeology of the Portland Harbor region has been presented in the Programmatic Work Plan (Integral et al. 2004b) and is not repeated here. The discussion in the Programmatic Work Plan includes a general description of the geologic setting, the hydrogeologic units, groundwater occurrence and flow, major physical processes governing discharge of groundwater to the site, and the definition of the groundwater/surface water transition zone. Data collection activities performed for the Round 2 GWPA are summarized in Section 2.1.3.3, and results are presented in Section 6.2. A detailed analysis of Round 2 GWPA results is presented in the Round 2 GWPA TZW SCSR (Integral 2006g).

4.3 HYDROLOGY

The complex interactions between flows in the Willamette River, the Columbia River, and Multnomah Channel are controlled by relative discharges, river stages, tidal stages, and topography among these three waterways. These interactions were described qualitatively in the Programmatic Work Plan. That discussion is not repeated here; instead, new data compiled since that time as part of the RI/FS are presented.

River stage refers to the height of the river measured relative to a specific elevation or "datum." A variety of vertical datums are used in the Portland Harbor region, and are reviewed below.

4.3.1 Regional Datums

Current or historical bathymetric and topographic data may be referenced to a variety of vertical datums in Portland Harbor. Three datums, the North American Vertical Datum of 1988 (NAVD88), the National Geodetic Vertical Datum of 1929 through the Pacific Northwest Supplemental Adjustment of 1947 (NGVD29/47), and the Columbia River Datum (CRD), are the major reference elevations used on maps and charts of Portland Harbor. These datums and the relationships or conversion factors between them were described in the Programmatic Work Plan (Integral et al. 2004b). In brief, water levels (river stage) measured by the Morrison Bridge gauge (at RM 12.8) are recorded based on the Portland River Datum (PRD), which is 1.55 ft above NGVD29/47. CRD is 1.85 ft above NGVD29/47 at RM 12.8 (USACE 1991; Integral et al. 2004b).

4.3.2 Willamette River Seasonal Stages and Flows

The seasonal trends of river stage and flows on the LWR were discussed in the Programmatic Work Plan. This section presents an update of those data and places into historical context the hydrologic conditions that have occurred in the LWR during the RI/FS (since 2001).

Figure 4.3-1 shows a plot of the mean daily river stage data (reported in ft PRD) measured by USGS gauge (#14211720) on the Morrison Bridge in Portland near RM 12.8 from October 1, 1972 through June 30 2006[5]. Similarly, Figure 4.3-2 plots historical daily mean discharge (cfs) at the USGS Morrison Street Bridge gauge (#14211720), and Figure 4.3-3 presents the mean daily discharges, averaged by year, over the period of record. Flow data from October 1972 to September 1994 were computed by the USGS using velocity measurements from an acoustic velocity meter (Lee 2002, pers. comm.). Most data after September 1994 are USGS estimates based on measurements from regional stations (Miller 2006, pers. comm.). Figure 4.3-4 presents the frequency distribution of daily mean discharge values from the October 1, 1972 through June 30 2006 data set. Note that the two highest peaks in the daily mean discharge record (Figure 4.3-2) occurred in the winters of 1996 and 1997, when peak flows reached 420,000 cfs on February 9, 1996 and 293,000 cfs on January 2, 1997. As bottom shear forces are proportional to the square of the current velocity, it is evident that these two discharge events represent, by far, the most significant potential sediment transport events during the period of record.

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[5] Data obtained from Regulation and Water Quality Section web site (http://www.nwd-wc.usace.army.mil/perl/dataquery.pl?k=id:PRTO+record://PRTO/HG//1DAY/MEAN/) and the USGS National Water Information System web site (http://waterdata.usgs.gov/or/nwis/uv?14211720). Where USGS data are available, they replaced USACE data for compiling the graphs shown in this section. The USACE site notes that these "data have not been verified and may contain bad and/or missing data and are only provisional and subject to revision and significant change." The data are used here only to illustrate long-term relative trends in the Willamette River stage at Portland. No data are available for 1991 and 1992.

Figures 4.3-5a–f show river stage data through each of the RI water years[6], i.e., 2001-June 30, 2006. For comparison, the graphs also include a plot of average annual river stage values based on the entire period of record, and plots of the values within one and two standard deviations from the average (representing approximately 68 percent and 95 percent of the recorded values, respectively). Note that LWR flood stage is +18 ft CRD (18.3 ft PRD), and the ordinary high-water mark in the LWR is approximately +15 ft CRD (15.3 ft PRD).

The average seasonal water level trend line in these plots illustrates the typical cycle of water levels on the Willamette. The annual low water levels occur during the regional dry season from August to November. Winter (November to March) river stage is relatively high but variable due to short-term changes in precipitation levels in the Willamette basin. Finally, a distinct and persistent period of relatively high water levels occurs from late May through June when Willamette River flow into the Columbia is slowed by high-water stage in the Columbia River during the spring freshet in the much larger Columbia River basin. The river stages recorded during the 2001 through 2006 water years indicate that water levels throughout the RI study period have been within the range of typical values over the period of record.

Figures 4.3-6a–f present plots of river discharge data through each of the RI water years (2001 to June 30, 2006), with plots of the average daily discharge (October 1, 1972 through June 30, 2006) and values within one and two standard deviations from the average shown for comparison. LWR discharge rates follow a typical seasonal pattern. Winter (November to March) high-discharge events occur as a function of watershed precipitation from November through April and vary in frequency and duration from year to year. From May to July, discharge levels gradually drop and then stabilize during the regional dry season from August to November. The river discharge rates during the RI study period have followed this annual pattern and, as with river stage levels, have generally been well within the range of typical discharges on record.

4.3.3 Hydrodynamics

Recent investigations of the hydrodynamics of the Study Area and Multnomah Channel are summarized in this section.

4.3.3.1 Flow in the Study Area

The hydrodynamic model developed for the Portland Harbor RI/FS (WEST Consultants and Integral 2005) was used to develop vector plots of current velocities throughout the Study Area during both maximum flood and maximum ebb tides for both low and high river flow periods (Figures 4.3-7 to 4.3-10). The model output shows that currents generally flow downstream during three of the four flow-tide conditions. At the maximum flood tide during the low-flow period, reversed flows extend upstream

[6] A water year extends from October 1 to September 30 (e.g., October 1, 1972 to September 30, 1973 comprises the 1973 water year).

beyond RM 11.5 (Figure 4.3-10c). Flow in many of the relatively shallow nearshore embayments and slips is characterized by eddies and/or inshore flow except on ebbing tides during low-flow periods, when downstream or offshore flow directions are dominant. Flow in Multnomah Channel is in a downstream direction under all flow/tide combinations modeled. As expected, higher current speeds occur in the deeper portions of the river channel and lower speeds occur in the shallow nearshore areas, regardless of flow direction.

4.3.3.2 Flows to Multnomah Channel

Flow data collected by ADCP surveys in April 2002, May 2003, and January 2004, and summarized in the Round 1 SCSR (Integral 2004b) suggest that LWR discharge through Multnomah Channel can be significant, ranging from 25 to 50 percent of the discharge volume in the Willamette during the "snap-shot" ADCP measurement periods. The percentage of flow from the Willamette to Multnomah Channel is a function of the relative flow regimes in the Willamette and Columbia rivers, as well as tidal stage.

To investigate Multnomah Channel flows on a more continuous basis, the CE-QUAL-W2 hydrodynamic model of the Columbia River/Willamette River System developed by Portland State University was used to model daily average flows in the system over a nearly 4-year period from January 1999 through December 2002. The results of this study were discussed in the Round 3A Upstream & Downstream Sediment FSP (Integral 2006d), and are briefly summarized here.

The modeling effort identified three distinct river flow combinations and evaluated the proportion of discharge carried by Multnomah Channel:

1. Low flows in both the Columbia River and Willamette rivers: when flows are relatively low in both the Willamette and Columbia rivers, about 50 to 60 percent of the Willamette flow goes down Multnomah Channel.
2. Low flow in the Columbia River and high flow in the Willamette River: when flows in the Willamette River are relatively high concurrent with relatively low flows in the Columbia, the proportion of Willamette River flow carried by Multnomah Channel decreases to about 25 to 30 percent of the total Willamette River flow.
3. High flow in the Columbia River and low flow in the Willamette River: when Columbia River flows are high and Willamette River flows are low, the increased river stage at the Columbia/Willamette confluence forces much of the Willamette River flow down Multnomah Channel. At certain low-flow Willamette periods (summer/early fall), all of the Willamette River flow, in terms of daily average volumes, plus some flow from the Columbia River, goes down Multnomah Channel. This last condition occurs about 25 percent of the time.

No clear periods of concurrent high flows in both the Willamette River and Multnomah Channel were identified within the nearly 4-year model simulation period. Averaged

over the study period, flows in Multnomah Channel represent about 60 percent of the Willamette River flow upstream of Multnomah Channel. It should be kept in mind that some of the Multnomah Channel flow is Columbia River water, but the relative volumes of Willamette River versus Columbia River water flowing down Multnomah Channel cannot be determined from these modeling results.

4.4 RIVERBED CHARACTERISTICS AND SEDIMENT DYNAMICS

Several investigations have been conducted to characterize the nature and dynamics of the LWR bed sediment. The findings of the time-series bathymetric change investigations, sediment sample texture and total organic carbon (TOC) distributions, and recent investigations of potential sediment resuspension and suspended sediment concentrations are summarized in this section.

4.4.1 Bed Bathymetry and Time-series Change Data

Multibeam bathymetric surveys have been conducted to measure LWR riverbed elevation for the RI/FS in January 2002, July-September 2002, May 2003, and February 2004. For each survey, the vertical accuracy of the water depth measurements was specified at less than or equal to 0.5 ft (approximately 15 cm; NAVD88), and the horizontal accuracy was set at less than or equal to 1 meter. The data were processed using a 1-meter grid size to generate a digital terrain model, and the survey results were plotted in both 3-D color-graded (i.e., "hillshade") and contour formats. The results of each survey were compared to those from preceding surveys to analyze net bed elevation changes and change trends over time. The results of these surveys and the time-series change analyses have been reported previously (Integral et al. 2004b; Integral 2004b).

Map 4.4-1 shows the most recent (February 2004) LWR riverbed bathymetry data. This bathymetric survey was conducted within a month of a relatively high-flow event from January 31 to February 1 when flows had peaked at approximately 130,000 cfs.

Map 4.4-2 shows the net bathymetric change over the 25-month period between the first (January 2002) survey and the fourth (February 2004) survey. The elevation change maps were created by overlaying the 1-m cells from each survey and subtracting the January 2002 data from the February 2004 data to generate a direction and magnitude of change for each cell. The vertical resolution of the multibeam survey overlay was ±0.25 ft (approximately 7.6 cm), so cell comparisons that show positive or negative changes less than or equal to 0.25 ft represent no discernable change in riverbed elevation.[7] Because the January 2002 data were subtracted from the February 2004 data, negative elevation changes (shallower in 2004 compared to 2002) indicate

[7] The survey vertical accuracy specification of ≤0.5 ft was exceeded for both individual surveys (DEA 2002a, 2004a). An analysis of bathymetric change data indicated that the vertical resolution of the survey overlay was ± 0.25 ft for approximately 80 percent of the channel data. Therefore, this interval was used as the no-change category (Integral and DEA 2004).

shoaling, and positive elevation changes (deeper in 2004 compared to 2002) indicate deepening. In Map 4.4-2, the no-change areas are shaded gray, while shoaling areas (negative change) are shown in yellow to orange shades, and areas that deepened (positive change) are shown in blue shades.

The bathymetric change analyses show generally consistent results throughout each time period, and support the early evaluations of the LWR physical system discussed in the Programmatic Work Plan (Integral et al. 2004b, Integral 2006h):

- Most net bathymetric changes are small-scale (±1 ft), and occur more commonly in the shallower nearshore areas than in the main channel
- Reaches between RM 5 and 7 and RM 10 and 11, where the river is relatively narrow, are dominated by areas of small-scale net deepening
- Wide areas of deposition occur in the channel and along channel margins in the broader sections of the river (RM 2 and RM 8 to 10) that are known to be sediment accumulation areas based on historical dredging records
- Signs of in-filling are apparent in formerly dredged borrow areas (e.g., RM 5.2 and RM 10 to11)
- Nearshore deepening occurs along the west side of the river in an extensive stretch between RM 0 and 3, likely the result of natural river processes
- Bridge footings create localized areas of deep scour and accretion (e.g., the Railroad Bridge at RM 7)
- Many deepening areas are closely associated with berthing areas, slips, and pier structures (e.g., Terminal 4, Portland Shipyard, Willbridge Terminals), likely the result of anthropogenic factors (propwash from ships, dredging).

Data from the 2004 post-high-flow bathymetric survey event showed that the February 2004 flood event had little net effect on the Study Area: less than 3 percent of the nearshore and less than 1 percent of the channel areas showed changes greater than 1 ft in magnitude. The channel zone of RM 9 to10, which consistently displays a large area of accretion throughout the study period, was the only river mile segment where the majority of the area displays changes of more than 1 ft.

4.4.2 Physical Characteristics of Sediments

Bed sediment texture, bed stability, and suspended sediment data are discussed in this section.

4.4.2.1 Sediment Texture

In general, the physical characteristics of bed sediment are indicators of energy regime of the riverbed at that location. Typically, fine-grained sediments (silts, clays) are found in relatively low-energy environments where current velocities are low enough to allow fine particles to settle out of the water column, whereas coarse sediments (sands, gravels) are indicative of higher-energy environments where fines are kept in

suspension in the water column and/or winnowed out of previously deposited material and transported away during transitory high-energy events (e.g., floods or anthropogenic disturbances, such as propwash, dredging, etc.). The grain-size data measured in 1,642 surface sediment samples in the Nature and Extent database are presented as contour maps of surface sediment texture (as percent fines) and TOC (percent) in Maps 4.4-3 and 4.4-4.

Coarse surface deposits (i.e., containing low percentages of fines) are present in the LWR in the relatively narrow reaches of the river, near bridge footings, and in dredged industrial slips (Map 4.4-3). The finer-grained deposits are generally located in the lower-energy nearshore areas and in the relatively wider sections of the channel. TOC content roughly mimics the sediment texture distribution, with higher TOC content occurring in the finer-grained deposits, and lower TOC content occurring in the coarser-grained deposits (Map 4.4-4).

The grain-size data from subsurface core samples are shown in Maps 4.4-5a–4.4-5c. Differences in vertical grain-size profiles may be seen by comparing cores from high- and low-energy reaches. An examination of cores across the river between RM 5 and 7 and those near RM 8 reveals that thick coarse-grained deposits (low fines) are more prevalent in the narrow, higher-energy reach (RM 5 to 7) than in the broader, lower-energy reach (RM 8), particularly in the main navigation channel.

4.4.2.2 Sediment Stability

Sediment erosion rates and critical erosion shear stress values for LWR sediment were measured directly as part of the hydrodynamic data collected in the spring of 2006 (Integral 2006h). This study involved the collection of 17 cores from locations throughout the Study Area (Map 4.4-6).

The cores were subjected to various flows using a Sedflume system to produce a range of shear stresses (from 0.1 Newtons (N)/m^2 to 10 N/m^2) on the sediment surface, and erosion rates were measured to depths of approximately 25 cm. Physical properties of bulk density and grain size distributions were analyzed at approximately 5-cm intervals. Erosion rates per shear stress applied varied depending on sediment grain size, bulk density, and sediment depth. A summary of the number of applications per shear stress value and range of observed erosion rates on all Sedflume cores is presented in the following table.

Shear Stress	Measurements	Erosion Rate (cm/s)	
(N/m^2)	Count	Min	Max
0.1	16	0	0.0003
0.2	23	0	0.0003
0.4	55	0	0.001
0.8	74	0	0.04
1.6	76	0.0002	0.1
3.2	76	0.0003	0.3
6.4	60	0.007	0.4
10	2	0.02	0.04

Critical erosion velocity shear stress values (defined in the Sedflume method as the shear stress at which erosion occurs at 10^{-4} cm/s; Sea Engineering 2006) were calculated at approximately 5-cm intervals. Median grain-size (D50) values for the sediment intervals ranged from 9.7 µm (medium silt) to 401 µm (medium sand), and critical shear stresses (T_{cr}) were calculated to range from 0.06 N/m^2 to 1.28 N/m^2. These data summarized by core depth interval are tabulated below.

Sample Depth Category	D50 (µm)		T_{cr} (N/m^2)	
	Min	Max	Min	Max
0-5 cm	9.7	401	0.06	0.64
5-10 cm	12	367	0.32	1.28
10-15 cm	10	378	0.22	1.28
15-20 cm	7.8	384	0.26	1.28
20-25 cm	10.9	357	0.24	1.28

The hydrodynamic model (WEST Consultants and Integral 2005) was used to predict bed shear stresses that would occur in the LWR under typical low-flow (e.g., 40,000 cfs) and relatively rare high-flow (e.g., 160,000 cfs) conditions (Map 4.4-7).[8] Under the low-flow conditions, bed shear values are predicted to remain below 0.4 N/m^2 throughout most of the channel and below 0.1 N/m^2 in the nearshore areas. Slightly higher shear stresses (up to 0.7 N/m^2) are predicted for the channel near RM 11 and for the head of Multnomah Channel. As a first-order approximation, these data indicate that significant sediment bed movement or resuspension does not occur under typical flow conditions (i.e., less than 50,000 cfs) in the LWR.

Under the relatively rare high-flow conditions, the predicted bed shear values remain low in most nearshore areas and industrial slips but are much higher, as well as more variable, in the channel. The predicted bed shear values in the main channel range from 0.614 N/m^2 between RM 2 and 2.3 to the maximum value of 19.7 N/m^2, which occurs in the channel at approximately RM 10.3. The highest values (>5.0 N/m^2) occur in both the nearshore and channel areas in the more constricted reaches (e.g., between RM 10 and 11, and again between RM 5 and 7; Map 4.4-7), which is consistent with the working physical conceptual model for the LWR system. The predicted high-flow bed shear values in the channel approach or exceed the highest critical shear stress calculated from the Sedflume study (1.28 N/m^2) throughout much of the Study Area.

[8]Mean daily flows of approximately 160,000 cfs or more were recorded on 125 days (1 percent) over the 30 year period of record and on 16 days (0.8 percent) over the RI water years 2001-June 30, 2006. Mean daily flows of 40,000 cfs or less were recorded on 8,909 days (75 percent) over the period of record and on 1,678 days (80 percent) over the RI water years 2001 through June 30, 2006.

4.4.2.3 Suspended Sediment

Suspended sediment loads and dynamics are potentially an important component of the LWR physical system, and TSS data have been collected as part of the surface water and hydrodynamic model data collection efforts. Suspended solids data were collected in November 2004, March 2005, and July 2005 as part of the Round 2A surface water characterization effort, and during sampling conducted from November 2005 to April 2006 to directly support the hydrodynamic modeling effort. The Round 2A surface water data, collected during the fall of 2004, winter of 2005, and summer of 2005, were reported previously in the Round 2A Surface Water Site Characterization Summary Report (Integral 2006l). The results of conventional parameter analyses (TSS and TOC) from the November 2005 to April 2006 surface water sampling efforts (summarized in Table 4.4-1), and recently provided TSS data from the City of Portland, are presented in this section.

4.4.2.3.1 November 2005-April 2006 LWG Sampling

Suspended solids concentrations were analyzed in a time series (November 2005 to April 2006) of vertically and horizontally integrated composite water samples from upstream of the Study Area, which were collected to verify the hydrodynamic model's suspended sediment inflow-river flow rating curve, and from samples collected in April 2006 from points downstream of RM 11 and in Multnomah Channel to support hydrodynamic model calibration (Integral 2006h).

The data from the sampling events are presented in Tables 4.4-2 and 4.4-3. TSS concentrations at the upstream stations ranged from 7 mg/L to 50 mg/L over the measurement period. Although the data set is relatively small, a plot of the upstream TSS data against the discharge hydrograph shows the expected pattern of higher concentrations on the rising limb of the hydrograph peak (i.e., 50 mg/L on December 22, 2005 at a discharge rate of 67,700 cfs) compared with the falling limb (i.e., 49 mg/L on January 19, 2006 at a discharge rate of 169,000 cfs, 39mg/L on February 3, 2006 at 139,000 cfs, and 25 mg/L on February 7, 2006 at 108,000 cfs; Figure 4.4-1).

Available upstream TOC data (from March 3 and April 4, 2006 samples) show organic fractions of total solids in the water column remaining relatively consistent, ranging from 2.2 to 2.4 mg/L. In the same samples, TSS concentrations drop from 21 to 22 mg/L at a flow of 41,500 cfs in March to 9 mg/L at a flow of 28,000 cfs in April, suggesting a higher inorganic suspended solids fraction with increased discharge.

Samples were collected twice per day at stations downstream of RM 11 and in Multnomah Channel, once on the rising tide and once on the falling tide. TSS concentrations in these samples ranged from 7 to 12 mg/L, and TOC concentrations ranged from 1.8 to 2.4 mg/L (Table 4.4-2). Due to the low variability of the results and limited number of data points, there is no clear pattern for the concentrations based on location or tidal phase; however, TOC values were generally slightly higher at the RM 11 and RM 6.3 stations than at the RM 2 and Multnomah Channel stations. The downstream concentrations were consistent with the upstream concentrations measured in April 2006 (i.e., 9 mg/L TSS and 2.4 mg/L TOC).

In situ suspended particle sizes were measured at HMV01 through HMV05 (RM 2, 6.3, 11, and 18) in early April 2006 using a laser *in situ* scattering and transmissometry (LISST) instrument as part of the hydrodynamic model data needs collection (Integral 2006h). Particle size was measured in 0.5-m increments through the water column. The median grain-size measurements with depth at each station are plotted in Figure 4.4-2, and a summary of the grain-size ranges measured is tabulated below. As indicated by the data, particles primarily in the silt and fine to medium sand size ranges were in suspension, under a flow of approximately 30,000 cfs. The coarsest median grain-sizes were found upstream of the harbor at station HMV05 (RM 18) where the river is relatively narrow.

		Maximum Grain Sizes Per Station		
Location	**Station**	**d10(µm)**	**d50(µm)**	**d90(µm)**
RM 2 West Side	HMV01	4.28	25.76	204.36
RM 6.3 East Side	HMV02	4.1	40.66	274.53
RM 11 West Side	HMV03	3.32	35.28	242.34
RM 11 Mid-Channel	HMV04	2.98	32.11	242.91
RM 18 Mid-Channel	HMV05	3.78	79.3	383.11

Note:
d10, d50, d90 – diameter of the 10th, 50th, and 90th percentiles of the grain-size distribution.

4.4.2.3.2 Long-Term City Data

The City of Portland has provided TSS data collected from the Willamette River at locations between RM 1.1 and RM 20 from February 1992 to March 2006. Data from the RI years (2001 to June 30, 2006) within the Study Area are available only from the City's RM 6.8 sampling location. These data are presented against the USGS discharge data for the 2001 through 2006 water years in Figures 4.4-3a–f. In general, these data support a consistent and predictable pattern between discharge rate and total suspended sediment loads in the system.

4.5 SEDIMENT TRANSPORT REGIMES

The movement of sediment through the LWR channel appears to be controlled in large part by the physical shape of the river, both the cross-sectional area and anthropogenic alterations such as borrow pits, dredged areas, and structures (e.g., bridge footings). In off-channel, nearshore areas, the sediment dynamics are potentially complicated by local riverbank morphology, changing water levels, bank treatments, and other anthropogenic factors such as propwash.

Data collected during Round 2 investigations to characterize the physical aspects of the LWR system, presented in the preceding sections, are consistent with early site characterization activities and the sediment transport conceptual site model presented in the Programmatic Work Plan. These data indicate that the hydrodynamic character and sediment transport regimes of the LWR may be broadly described in terms of nine segments, shown in and discussed in the following sections.

4.5.1 Upstream of the Study Area

The "Upriver" segment includes the stretch of the river from Willamette Falls to the upstream end of Ross Island (approximately RM 26 to RM 15.3). Here the river is relatively narrow and flows through suburban areas under largely natural conditions. Much of the river bottom consists of exposed basalt bedrock (GeoSea Consulting 2001). Bed shear stresses through this area are generally high (averaging 5.8 N/m^2), with the highest shear stresses occurring in the bend between RM 24 and 25. Sustained current speeds in this reach appear to prevent all but the coarsest material from being deposited for the long term in the main stem of the river. Some low to moderate shear stresses occur in the smaller bifurcation channels, embayments, and nearshore areas (Map 4.5-1).

The downtown corridor segment of the LWR extends from the upstream end of Ross Island (RM 15.3) to the upstream end of the Study Area at RM 11. This is also a high-energy segment, where the main channel of the river is narrow (average cross-sectional area estimated at 34,000 ft^2) with steep channel margins that are largely constrained by upland bulkheads along both riverbanks. An example cross-sectional profile of the channel is shown in Map 4.5-2. The deepest areas of the channel are found on the outer edges of bends in the river below Ross Island, and in the dominant bifurcation channel west of Ross Island (Map 4.4-1). Relatively high bed shear stresses (averaging 3.4 N/m^2) occur in the main portions of the channel, while shear stresses in the smaller channel east of Ross Island and in shallower nearshore areas remain moderate to low (Map 4.5-1).

The high-energy environment of the main channel is evidenced by the observed bed sediment, which consists primarily of gravels and sands (SEA 2002b), and by the net deepening that has occurred throughout the majority of this segment over the study period (Map 4.4-2). The magnitude of the observed deepening during this period is typically about 1 ft (Integral 2004b). Localized areas of exposed bedrock occur, particularly near bridges where scouring appears related to footing structures (Map 4.4-1; GeoSea Consulting 2001). Fine-grained deposits are observed in the nearshore areas and in dredged areas removed from the main flow of the river (SEA 2002b). The bathymetric change data reveal limited sediment accretion throughout this reach; areas showing no change and small-scale deepening ($\leq$ 1 ft) are most dominant (Integral 2004b). Sand waves are evident migrating along the western portion of the channel between RM 11 and 11.7 (Map 4.4-2). The authorized -40 ft federal navigation channel begins in the downstream portion of this reach at RM 11.7 (e.g., see Map 4.4-1); it extends from this point downstream to the Columbia River at RM 0.

4.5.2 RI Study Area

The Study Area extends from RM 1.9 to RM 11. The varying physical/hydrodynamic characteristics along this length of the river support its classification into six separate segments:

- Upper Study Area 1
- Upper Study Area 2

- Upper ISA
- Middle ISA
- Lower ISA
- Lower Study Area.

4.5.2.1 Upper Study Area

The upper Study Area extends from RM 9.2 to the upper boundary of the Study Area (RM 11). This stretch of the LWR can be further divided into two segments hydrodynamically, the first extending from RM 9.2 to approximately RM 10 (mapped as Upper Study Area 1 in Map 4.5-1) and the second extending from approximately RM 10 to RM 11(mapped as Upper Study Area 2).

4.5.2.1.1 Upper Study Area 2, RM 11 to RM 10

The cross-sectional area of the river begins to increase in this segment as the river broadens in a downstream direction, but the hydrodynamic energy of this segment of the Study Area remains relatively high (Maps 4.5-1 and 4.5-2). This is evidenced by the high potential bed shear stresses, particularly in the eastern portion of the main channel where the channel bank is steep (Maps 4.4-1 and 4.5-1), and by the observed bed sediment texture, which is dominated by coarse-grained deposits (i.e., sands). The lower bed shear stresses predicted to occur along the channel flank at RM 11.5 at the Goldendale Aluminum facility (Map 4.5-1) is supported by the historical dredging that has been required to maintain that facility's docking berth (CH2M Hill 2001b).

The nearshore areas of this reach are narrow, and show a nearly equal proportion of small-scale deepening, shoaling, and no-change areas (Integral 2004b). The channel through this reach has generally undergone minor net deepening over the study period (on the order of 1 ft or less), though small areas have deepened more substantially. Deposition on the order of several feet has occurred in the deep areas of previous dredged holes (borrow pits) on the western side of the channel (Map 4.4-2). These are the farthest-upstream areas of significant net deposition in the LWR surveyed bathymetrically (i.e., from the Columbia River to the upper end of Ross Island) as part of the Portland Harbor RI/FS.

4.5.2.1.2 Upper Study Area 1 (RM 10-9.2)

The river becomes depositional as it widens significantly at approximately RM 10. The resulting increase in cross-sectional area (to an estimated average of 63,000 ft^2) reduces flow velocities as reflected by the lower predicted bed shear stresses, particularly along the broad western flank of the channel (Maps 4.4-1 and 4.5-1). These changes in turn allow part of the river's suspended sediment load to be deposited (Map 4.4-2). Shoaling on the order of 2 ft was measured along the broad western flank of the channel. Observed bed sediment textures reflect the cross-channel energy differences, with coarser-grained deposits dominating the eastern portion of the riverbed, and finer-grained deposits occurring along the western portion (Map 4.4-3).

4.5.2.2 Upper ISA

The Upper ISA, which extends from RM 6.9 to RM 9.2, includes Swan Island Lagoon. The main stem of this section is also characterized by a relatively wide cross-sectional area, estimated at an average of 68,000 ft^2, and moderate to low bottom shear stresses (Map 4.5-1). Approximately 40 percent of the surface sediment (outside Swan Island Lagoon) consists of deposits containing over 50 percent fines (Map 4.4-3). The depositional nature of the upper portion of this reach is seen in the areas of shoaling observed in the channel between RM 8 and 9 over the study period (Map 4.4-2) and by the maintenance dredging required historically along the western shoreline.

Swan Island Lagoon is characterized by low bed shear, but deposition in the lagoon is limited. Observed areas of deepening in the lagoon are likely the result of anthropogenic factors such as propwash and/or dredging.

4.5.2.3 Middle ISA

The Middle ISA extends from RM 5 to RM 6.9, where the river narrows to an average cross-sectional area of approximately 57,000 ft^2 (Map 4.5-2). This stretch of river is a relatively high-energy sediment transport zone. Suspended sediments are likely transported through this reach, but the degree of bedload sediment deposition and transport is likely a function of temporally varying hydrology. Predicted maximum bed shear stresses are moderate to high (Map 4.5-1).

The high-energy nature of this segment of the river is evident in the predominantly coarse-grained texture of the bed sediment (Map 4.4-3) and the observed net deepening that has occurred in majority of both the channel and nearshore areas (primarily on the order of 1 ft or less) over the RI study period (Map 4.4-2). Localized areas of exposed bedrock have been noted, particularly on the west side of the river near the St. Johns Bridge. Sand wave migration is evident along the central portion of the channel between RM 5 and 6. Minor shoaling has also occurred, associated primarily with deeper, more energy-isolated dredged areas.

4.5.2.4 Lower ISA

The Lower ISA is a depositional area extending from RM 3 to RM 5, where the river widens once again (to an average cross-sectional area of 65,000 ft^2; Map 4.5-2). The bathymetry is dominated by a deep (up to -70 ft) dredged area on the eastern half of the channel between RM 4 and 5, which gradually shoals to the typical -40 ft depth downstream of the International Terminal Slip. The time-series bathymetry indicates that the majority of the riverbed in the main channel undergoes no net change, though net shoaling (1 ft or less) is evident along the channel margins (Map 4.4-2). The majority of observed deepening that dominates the nearshore areas is likely due to anthropogenic factors. The hydrodynamic model predicts low to moderate bed shear stresses, with relatively lower bed shear in the deeper upstream portion of this river segment and along the channel margins (Map 4.5-1).

Surface sediment grain sizes appear to be largely controlled by maintenance dredging of the industrial slips and berths operating on the eastern shoreline of this stretch of the river (Map 4.4-3). Overall, approximately 25 percent of surface consists of bed sediment containing fine-grained fractions of 50 percent orgreater.

4.5.2.5 Lower Study Area

The Lower Study Area is a depositional area extending from RM 1.9 to RM 3. The Multnomah Channel branching defines the upstream boundary of this reach and the hydrodynamic interactions between the LWR and the channel are discussed in Section 4.3.3. The reduced LWR discharge volume downstream of Multnomah Channel results in markedly reduced bottom shear estimates (Map 4.5-1). In addition, the main stem of the LWR continues to widen in this reach as it bends to the northeast, to an average cross-sectional area of approximately 67,000 ft^2 (Map 4.5-2). Maximum bed shear values are very low, particularly on the inside curve of the bend (Map 4.5-1). This is reflected in the observed surface sediment texture, which is predominantly (approximately 73 percent of the surface area) fine-grained, and in the net shoaling observed in the channel (mainly 1 ft or less). Net deepening (5 ft or less), apparently from natural river migration processes, is observed along the western shoreline (Map 4.4-2).

4.5.3 Downstream of the Study Area

The 2-mile river segment downstream of the Study Area extends to the Willamette's confluence with the Columbia River. Bed shear stresses are low to moderate, increasing slightly in a downstream direction as the river narrows and becomes more dynamic as it reaches the Columbia (Map 4.5-1). Net shoaling (2 ft or less) has been measured along the eastern portion of this broad, depositional channel, which continues to around RM 1.5; the furthest downstream extent of significant sediment deposition in the LWR channel. Net deepening (generally 2 ft or less) has occurred in a narrow strip along the western shoreline, particularly in the final 1-mile reach, possibly representing natural channel migration as the river flow seeks the shortest, most efficient downgradient flow path.

4.6 HABITAT

The majority of the Study Area is industrialized, with modified shoreline and nearshore areas. Wharves and piers extend out toward the channel, and bulkheads and riprap revetments armor the riverbank. Active dredging has produced a uniform channel with little habitat diversity. However, some segments of the Study Area are more complex, with small embayments, shallow water areas, and less shoreline development, providing habitat for a suite of local fauna. This section describes the general types of habitat available to ecological species in the LWR. The habitats for each ecological receptor group are described in greater detail in the ecological risk assessment (Appendix G).

4.6.1 Open-Water Habitat

The LWR is characterized by a developed navigation channel and shoreline. Most open-water habitat in the Study Area is in the main river channel, but also includes several shallower backwater sites (e.g., Willamette Cove, Swan Island Lagoon, slips). The deep open water provides foraging habitat for fish and wildlife that feed in the water column. Shallow-water habitats provide refuge for juvenile salmonids as well as greater foraging opportunities for birds and mammals. Aside from Willamette Cove and Swan Island Lagoon, shallow-water habitats are largely limited to the narrow strip between the shoreline and the navigation channel.

There are three types of benthic habitats in the open water of the LWR: 1) unconsolidated sediments (sands and silts) in the deeper water (greater than approximately 20 ft CRD) of the navigation channel and lower channel slopes; 2) unconsolidated sediments (sands and silts) in water depths less than 20 ft CRD in gently sloping nearshore areas (e.g., beaches and benches) and on the upper channel slopes; and 3) developed shoreline (e.g., rock riprap, sheet pile, bulkheads). The navigation channel habitat is subject to variable (seasonal and annual) hydrodynamic forces, the impacts of navigation, natural sediment deposition, erosion, bed load transport, and periodic navigational dredging. These forces vary spatially through the system, largely as a function of the channel cross-sectional area, resulting in both relatively stable and unstable sedimentary environments that likely support heterogeneous infaunal communities controlled by the local physical regime. In the relatively shallow, nearshore areas, natural hydrodynamic forces are likely less temporally variable. The physical sedimentary regimes are a function of the local riverbank morphologies, and sheltered areas away from anthropogenic disturbance factors should support well-developed infaunal invertebrate communities. Conversely, exposed nearshore areas, particularly around berths, docks, and boat ramps, likely have limited benthic communities controlled by physical disturbance factors. The hard surfaces of the developed shoreline provide habitat for an epibenthic community.

4.6.2 Bank and Riparian Habitat

The most common bank types occurring in the Study Area are riprap, sandy and rocky beach (with and without emergent vegetation), unclassified fill, and seawall. Riprap and unclassified fill combine to make up about half of the shoreline in the 15-mile stretch of the LWR from the Columbia through downtown Portland (City of Portland 2001c) (Map 4.6-1). The riprap or rocky bank type is usually located on fairly steep banks with no or very narrow shallow water habitat present. These areas are usually exposed to heavy wave action and strong currents. The sandy bank type with no emergent vegetation is gently to steeply sloped beaches, often adjacent to steep riprapped shorelines or developed uplands. This bank type is frequently located in areas exposed to heavy wave action and faster moving water. The rocky or sandy bank types with emergent vegetation are common within the Study Area. These bank types are gently to steeply sloped beaches and, similar to the sandy bank type without vegetation, are often adjacent to steep uplands, although the uplands are either of sandy or rocky

substrate. The rocky or sandy bank types are located in more protected areas in the Study Area, such as at the end of slips or in Swan Island Lagoon.

The type of riverbank present is expected to influence the species of fish utilizing a given area. A common factor associated with beneficial habitat for juvenile salmonids is the presence of large woody debris along riverbanks, which generates small shallow pools and provides cover (Bjornn and Reiser 1991; Sedell and Froggatt 1984). Sculpins prefer shallow water habitats and, in the LWR, have been observed mostly in riprapped areas (SEA et al. 2003). Juvenile largescale suckers (yearling and subyearling) are most abundant in shallow backwater pools, whereas adult largescale suckers can be found in the deeper, more open waters (Windward 2004a).

Numerous aquatic and shorebird species such as cormorants and spotted sandpipers use the habitats in the LWR. The upland environment near the LWR is primarily urban, with fragmented areas of riparian forest, wetlands, and associated upland forests. Historical development and filling of channels and wetlands has left only small strips or isolated pockets of riparian wildlife habitat. Therefore, isolated wildlife habitat areas along the LWR corridor exist, but linkages to the larger landscape are limited.

The City of Portland's natural resource inventory of the Willamette River corridor classified habitat based on characteristics such as connectivity to other areas, access to water, and other factors in order to determine their overall habitat value (Adolfson et al. 2000). Ten distinct habitat classes were identified along the 16-mile stretch of the Willamette River from Sellwood to the Columbia River, including bottomland forest, foothill savanna, conifer forest, scrub/shrub, meadow, emergent wetland, beach, rock outcrop, open water, and unvegetated/disturbed habitats. Fifteen sites of significant habitat value were designated as "habitat sites" for fish and wildlife. The habitat sites identified in the Study Area were the South Rivergate corridor at the north end of the Study Area, the Harborton forest and wetlands, Willamette Cove, the railroad corridor, and the Swan Island beaches and lagoon on the southern end (Adolfson et al. 2000). The available wildlife habitat in the Study Area is shown on Map 4.6-2 . Other important habitat sites identified in the general area were Kelley Point at the confluence of the Willamette and the Columbia rivers, and the Ross Island and Oaks Bottom Complex around RM 16. The habitat sites listed are known to be utilized by numerous aquatic birds and aquatic and semi-aquatic mammals (Adolfson et al. 2000).

4.7 HUMAN ACCESS AND USE

This section describes the current understanding of the physical and biological setting of the Study Area as it pertains to potential human uses, including specialized groups that may use the river for various activities. Most of the demographic information relating to the Study Area is based on historical background and documented human uses. This information is used to determine potential receptor populations and to develop the general CSM.

Portland Harbor and the Willamette River have served as a major industrial water corridor for more than a century. Industrial use of the Study Area and adjacent areas has been extensive. The majority of the Study Area is currently zoned for industrial land use and is designated as an "Industrial Sanctuary" on the Portland Comprehensive Plan Map (City of Portland 2001a). The Portland industrial sanctuary policy is designed to encourage the growth of industrial activities in the city by preserving some industrial land primarily for manufacturing purposes. The Guild's Lake Industrial Sanctuary Plan (GLISP) is intended to preserve and enhance industrial land in the Guild's Lake area generally bounded by Vaughn Street on the south, the St. Johns Bridge on the north, Highway 30 on the west, and the Willamette River on the east (City of Portland 2001a). Over many decades, public and private investments in infrastructure, such as marine, rail and highway facilities, as well as investments in industrial physical plants, have made the Guild's Lake Industrial Sanctuary one of the premier heavy industrial districts in the Pacific Northwest. The purpose of the GLISP is to maintain and protect this area as a dedicated place for heavy and general industrial uses. The plan's objectives were adopted as part of Portland's Comprehensive Plan to ensure preservation of this land use over the next 20 years.

Much of the shoreline in the Study Area includes steeply sloped banks covered with riprap or constructed bulkheads, with human-made structures such as piers and wharves over the water in various locations. A comprehensive update of Portland's Willamette Greenway Plan and related land use policies and zoning (The River Plan) is underway, addressing all of the Willamette riverfront in Portland (City of Portland 2001b). The plan update may affect land use practices in Portland Harbor, but it will not affect the "Industrial Sanctuary" designation.

People interact with the riverine environments in a number of ways. Worker activities that may include contact with sediments and surface water at industrial and commercial facilities in the Study Area are limited in the shoreline areas due to the sparse beach areas and high docks associated with most of the facilities.

In addition, the LWR provides many natural areas and recreational opportunities, both within the river itself and along the riverbanks. Within the Study Area, Cathedral Park, located under the St. Johns Bridge, includes a sandy beach area and public boat ramp and is used for water skiing, occasional swimming, and waterfront recreation. Recreational beach use also may occur within Willamette Cove, which is a riverfront natural area, in Swan Island Lagoon, and on the southern end of Sauvie Island, which is within the Study Area. Swan Island Lagoon includes a public boat ramp. Additional LWR recreational beach areas exist on the northern end of Sauvie Island and in Kelley Point Park, both of which are outside of the Study Area. Potential recreational beach use areas in the Study Area are shown in Map 4.7-1a–c.

The St. Johns Town Center is a mixed-use district that extends to the waterfront on the east side of the Willamette River at the St. Johns Bridge. A proposal emerging in the recent St. Johns-Lombard Plan project includes redevelopment of this area near the

Willamette River. This area is a potential example of the "vibrant waterfront districts and neighborhoods" theme in the River Renaissance Vision developed by the City of Portland.

The exact extent to which commercial fishing occurs within the Study Area is currently not known. No reports of commercial fisheries for anadromous salmonids on the Willamette River have been found. A limited commercial crayfish fishery exists in the Lower Willamette River. However, non-commercial fishing is conducted throughout the LWR basin and within the Study Area, both by boaters and from locations along the banks. A news story by The Oregonian and the limited interviews by ATSDR suggest that the groups most likely to be catching and eating fish from the LWR are immigrants from Eastern Europe and Asia, African-Americans, and Hispanics. These same sources also suggest that the most consumed species are carp, brown bullhead (a catfish), crappie, and smallmouth bass (ATSDR 2002). Other sources (CRITFC 1994) suggest that Native Americans fish in the Willamette River. The LWR provides a ceremonial and subsistence fishery for Pacific lamprey (particularly at Willamette Falls) and spring Chinook salmon for Native American tribes. Many areas in the LWR are also important currently for cultural and spiritual uses by local Native Americans.

Transients have been observed along the LWR, including some locations within the Study Area. The observation of tents and makeshift dwellings during RI sampling events confirms that transients were living along some riverbank areas. Transients are expected to continue to utilize this area in the future.

EXECUTIVE SUMMARY

SECTION 5 – POTENTIAL SOURCES

Abstract

Section 5 presents, to the extent practicable, the potential current and historical sources and pathways of contamination to in-water media in the Study Area. This section evaluates available upland source information and the likelihood that chemicals associated with facility operations may have migrated or been released to the river via one or more pathways. Additionally, potential sources outside the Study Area from other reaches of the LWR are identified.

This evaluation of potential sources concludes:

- There were likely numerous historical sources that contributed contamination to the river via all pathways (surface water, sediment transport, groundwater, stormwater and process wastewater discharge, overland flow, bank erosion, overwater activities/spills, and atmospheric deposition)
- Most historical sources are no longer active or have been significantly diminished
- Upstream surface water, sediment transport, and stormwater from within and upstream of the Study Area remain the most likely current significant pathways.

This information was used to refine the CSM for the Portland Harbor (see Sections 3 and 11), and to guide planning for Round 3 sampling efforts to fill data gaps necessary to complete the RI/FS. A final assessment of potential sources and pathways of contaminants to the in-water system will be further updated, evaluated, and presented in the RI. Some of these sources may require additional evaluation or investigation as part of Oregon Department of Environmental Quality's (DEQ) source control program.

Although potential source and pathway information will be updated in the final RI, the quantity and quality of information presented in this section, along with the CSMs developed and presented in Sections 3 and 11, is adequate to support the Round 3 data gap and data needs analysis.

Work Plan and Field Sampling Plan Directives

The Round 2 Report updates the CSM initially developed in the Programmatic Work Plan (2004) and refined in a later document by integrating information on sources and pathways available through completion of Round 2.

A summary of the current harbor-wide CSM is presented in Section 3, including a general discussion of the types of potential sources of contaminants and pathways that could adversely impact the river. Section 5 provides more details about specific potential sources and pathways within and upstream of the Study Area. This information is then utilized in Section 11 to

develop CSMs for each iAOPC, drawing relationships between specific potential sources and pathways and their potential impact on in-water media, where possible.

Data Collection Activities

The primary evidence regarding potential upland sources and releases to the river are the site summaries assembled from currently available information provided by DEQ and the LWG for facilities proximal to the river. Most site summaries were submitted to EPA in 2005 and 2006. The remaining site summaries, as well as updates for some previously submitted, were submitted in a separate deliverable in February 2007. A list of all site summaries is contained in Appendix J.

Originally, the site summaries were prepared based on reviews of the DEQ Environmental Cleanup Site Inventory (ECSI) database and Strategy Recommendations prepared by DEQ that provided information on facility operations, possible chemicals of concern associated with the industrial processes at a facility, and pathways to the river. (Note that the amount of available information varies by facility, and not all facilities adjacent to Portland Harbor are included in DEQ's ECSI database.) Site summaries have been periodically updated based on new information added to the ECSI database and other site information as it is made available to the LWG, including reports documenting the results of site investigations, source control activities or status, monitoring data, permit applications, or spill records.

Preliminary Assessment of Findings

Groundwater seepage, direct discharges (spills, waste disposal practices, stormwater and wastewater discharges), riverbank erosion, atmospheric deposition, and overwater activities were assessed as potential pathways for transporting contaminants to the river from potential sources at 79 upland sites bordering the Study Area. Pathways were characterized as either historical or current and whether they were complete, likely complete, incomplete, or indeterminate. Sources to the harbor from outside the Study Area are also briefly characterized.

Groundwater

The Round 2 assessment of the groundwater pathway updates an earlier assessment made by DEQ (2006), and includes an evaluation of transition zone water sampled by the LWG at nine facilities within the Study Area. Overall, there is evidence that groundwater from 14 facilities or properties may currently transport upland site-related contaminants to the river. Groundwater at the remainder of the upland parcels is either not a current pathway to the river or deemed to pose an insignificant risk to the in-water system. Groundwater was likely a more significant pathway to the river historically, when upland sources and onsite disposal practices were uncontrolled.

Direct Discharge

Most stormwater and wastewater discharges entering the river require a permit under the National Pollutant Discharge Elimination System (NPDES). Nearly all the industrial permittees

within the Study Area have general permits (96 for the discharge of stormwater, 16 for other types of discharges, including cooling water, blowdown, and treated groundwater), which are used for minor discharges from similar operations and wastes. Based on available information, there are only eight individual wastewater permits issued for facilities with unique industrial processes that merit customized monitoring programs and three individual permits for municipal-separated stormwater discharges. There are no municipal sewage treatment plant discharges in the Study Area; combined sewage overflows, although significantly reduced in volume and frequency today, occurred for decades.

Extensive efforts were made to characterize current stormwater drainage basins adjacent to the river. About 60 percent of the total area represented by these basins contributes stormwater to the Study Area; about 22 percent of the watershed draining to the river is largely uncharacterized.

The potential for either stormwater or wastewater to act as potential pathways to the river was evaluated at 311 outfalls within the Study Area (the exact number of outfalls within the Study Area is continuing to be evaluated). Sediment chemistry in the vicinity of a subset of the outfalls associated with sites actively under investigation by DEQ was compared to adjacent upland site information to assess whether an outfall may have transported upland contaminants to the river. Sediment in the vicinity of 145 of these outfalls had contaminants similar to those in media from adjacent upland facilities; however, almost all of these locations had facilities upstream with similar contaminants detected in upland site media as well, suggesting that sediment transport might also have affected sediment quality in the vicinity of those outfalls. About half of those outfalls potentially linked to in-river contamination are classified as active; the status of the remainder has not been evaluated. The presence and significance of ongoing stormwater and wastewater discharges may require additional evaluation or investigation as part of DEQ's source control program; however, current wastewater discharges are probably a negligible pathway to the river due to regulatory controls. Historically, stormwater and process wastewater discharges were likely significant pathways to the river. Stormwater likely continues to be a source but at rates significantly less than historical contributions.

Bank Erosion

Various engineered structures or materials, including seawalls, riprap, and engineered soil, cover about half of the Study Area riverbanks. Unarmored shorelines may be eroded from in-river processes and localized human activities. Although relatively little riverbank soil data are available, contaminants potentially associated with upland site activities have been detected at approximately 19 sites. Riverbank erosion is not anticipated to be a major ongoing release mechanism harbor-wide, although it may be significant on a site- or iAOPC-specific basis. Bank erosion may have been more significant historically, as upland and in-water facilities were constructed and the shoreline was developed.

Atmospheric Deposition

Atmospheric deposition is known to be a source of contamination globally. A literature-based evaluation of atmospheric deposition to surface water in the Study Area is presented in

Section 7. Atmospheric deposition in the entire drainage basin, which could then enter the Study Area through stormwater, could be more significant. This will be accounted for in the Round 3A stormwater evaluations.

Overwater Activities

The overwater activities most commonly associated with release of materials to the river are product handling, refueling, overwater construction, repair or maintenance (e.g., ships, piers, pipes, etc.), and leaks or direct discharges from vessels (diesel fuel, gasoline, hydraulic oil, lubricating oil, waste oil, bilge and ballast water). Historical records of these unpermitted discharges are limited to the last several decades, and information tends to be general, especially for the earliest records. Few spill reports are available, and those reported ranged in volume from less than a gallon to over a thousand gallons. Historical overwater activities were likely significant sources to the river; current activities are subject to improved technologies and best management practices that limit the occurrence or extent of spills.

External Sources to the Study Area

Sources in the LWR, both downstream and upstream of the Study Area, may contribute to chemical deposition in the Study Area. Potential sources immediately upstream of the Study Area include aluminum storage facilities, rail yard maintenance operations, cement manufacturing, marinas, and numerous (hundreds) private and public outfalls. Johnson Creek, a tributary that enters at RM 18, is a known source of contaminants such as PCBs, PAHs, DDT, and dieldrin.

Under certain river stage, flow, and tidal conditions, the tidal influence of the Columbia River estuary causes seasonal flow reversals that could transport sediment-bound chemicals from downstream reaches of the Columbia River into the Study Area.

More than 750 permitted discharges enter the Willamette River upstream of Willamette Falls, including municipal sewage treatment and stormwater discharges. Unregulated runoff from residential, industrial, and commercial areas in the upper river is a potential source of pesticides, PAHs, and metals. Most of the agricultural and forested lands in the Willamette River basin are considered non-point sources of sediments, nutrients, fertilizers, pesticides, and herbicides. Runoff from natural volcanic sources, past mining activities, and atmospheric deposition in the upstream reaches of the Willamette River basin has contributed to high levels of mercury in fish throughout the entire main stem of the Willamette River, resulting in fish consumption advisory.

Next Steps

Information regarding upland sources and potential ongoing releases to the river will be presented in the RI Report as part of finalizing the CSM. Recommendations regarding the potential need for investigation or source control will be prepared for agency use as potential ongoing sources are identified.

5.0 IDENTIFICATION OF SOURCES

One objective of the Portland Harbor RI/FS is to identify sources that are contributing to contamination of the in-water portion of the Study Area. The SOW (EPA 2001a and amendments, Section 7) states:

> Although DEQ is primarily responsible for the control of upland contaminant sources to the Site, as part of the RI/FS, Respondents shall evaluate the distributions of sediment contaminants and, if appropriate (e.g., if the sediment data suggests the presence of an ongoing source), make recommendations to EPA and DEQ if the need for further investigation or control of sources is identified. EPA and DEQ will utilize this information in making source control adequacy determinations. Because upland sites represent many of the known contaminant sources, coordination with upland investigations and DEQ source control efforts will be required.

This section summarizes the general types of sources of contamination to in-water media in the Study Area (i.e., between RM 2 and RM 11). Potential sources outside the Study Area from other reaches of the Lower Willamette River are also identified. Although the section provides some information on historical sources of contamination associated with upland sites and some sources within DEQ's cleanup program, the focus of the subsection on stormwater and waste water is on the identification of potential ongoing sources.

Sources are one component of the CSM for the Portland Harbor. Other components of the CSM are presented elsewhere in this document:

- The methods and information used to evaluate fate and transport of chemicals from potential sources is evaluated in Section 7
- Human health and ecological risk evaluations are used to identify receptors potentially exposed to unacceptable risk in Sections 8 and 9
- iAOPCs are identified in Section 10
- The relationship between known upland sources and in-river areas of unacceptable risk completes the CSM in Section 11.

5.1 UPLAND SOURCES

Locations where contaminants may have been introduced, mechanisms by which they may have been released, and pathways through which they can migrate into the Study Area are described in this section. Note that in this context, the term "pathway" refers only to the physical transport of a contaminant of interest to the Study Area. It does not include identification of exposure points, receptors, or exposure routes.

The site summaries in Section 5.1.1, the groundwater pathway information in Section 5.1.2, and the stormwater and wastewater descriptions in Section 5.1.3 represent the latest refinement of analyses that have been underway for several years. Information presented in these subsections varies in detail because of differences in the level of understanding of the upland sites and various other potential sources. For example, because information on riverbank erosion, atmospheric deposition, and overwater releases is limited, these potential sources are described in general terms.

5.1.1 Site Summaries

Site summaries are the primary vehicle for assembling information on upland sources. Summaries have been prepared for sites in DEQ's ECSI database that were generally located within 0.5 miles of the Lower Willamette River between RM 2 and RM 11. Site summaries are updated periodically, primarily from information on file with DEQ. The following provides a summary of the site summary update iterations:

- In 2003, summary descriptions focused on the groundwater pathway were prepared for the ECSI sites (GSI 2003a).
- Following discussions with EPA and its partners in early 2004, updated site summaries were prepared in 2004-2005 (Integral and GSI 2004, 2005a,b,c). This iteration provided information on all pathways potentially contributing to in-river contamination.
- A second update of site summaries was prepared in 2006 (Integral 2007). At the request of the LWG, DEQ (Anderson 2006a,b, pers. comm.) provided information concerning the status of cleanup actions and regulatory decisions at sites not owned by members of the LWG (i.e., non-member sites). New or completely revised site summaries were prepared for sites that had not previously been described, for sites where EPA-requested revisions had not previously been submitted, and for sites where significant new work warranted a complete revision. Addenda to existing summaries were prepared for sites where significant additional information was provided on one or two pathways.

The site summaries and addenda are based on a review of information in the associated DEQ ECSI files and other readily available site information, including, in the case of LWG-member sites, that provided by the site owner. The site summaries focus on overland transport, riverbank erosion, groundwater, and direct discharge pathways to the river.

The status of site summaries is tabulated in Table 5.1-1. For each site listed in the table, the following information is shown:

- Whether additional information had been identified by DEQ (Anderson 2006a,b, pers. comm.)
- Where LWG submitted a site summary in 2007, whether it was a full site summary or an addendum

- The nature and source of the information generated since the original site summary
- Whether the new information was relevant to the initial site-specific conceptual model
- Notes on why an addendum was not prepared if DEQ identified additional information.

Table 5.1-2 tabulates information for the site summaries:

- Site name
- ECSI number
- Location along the riverbank
- Potential upland sources
- Potential upland and overwater COIs associated with sources
- Detected COIs for pathways.

A chemical is listed as a pathway COI if it was detected in sampled media, identified as having been released to site media, or documented to have been released directly to the river from site operations. LWG has not separately screened the results against DEQ Joint Source Control Strategy values (DEQ 2005c).

COIs for a pathway in Table 5.1-2 were assigned one of four categories (a–d) as defined below:

Category a. **Documented evidence of a complete transport pathway**—Data demonstrate that the pathway is complete; DEQ, the owner, or both concur that the pathway is complete.

Category b. **Likely a complete pathway**—Data suggest that the pathway is complete, but in the absence of confirming data (e.g., investigations are incomplete, nearshore wells are not yet installed, overwater operations are present and active), DEQ, the owner, or both have not concurred that pathway is complete. Although DEQ and owner evaluations are considered, LWG's analysis may support a different conclusion.

Category c. **Insufficient data to make determination**—A release has been documented but there has been no sampling of the potentially affected media, a release has been documented but transport pathways have not been investigated, or permitted discharges have not been sampled beyond general permit requirements. Although DEQ and owner evaluations are considered, the LWG may have, for the purposes of the RI CSM, assumed that the pathway is complete.

Category d. **Not a complete pathway**—Information indicates with reasonable certainty that either of the following is likely for both current and historical pathways:

- The relevant media for a given pathway are not affected by site-related COIs (e.g., site-related COIs are not detected in groundwater)
- A current or historical complete pathway as defined above is not present (e.g., riverbank is not present at a site away from the river, COIs were not detected in downgradient groundwater).

The overall importance and relative contribution of the pathway is not evaluated in Table 5.1-2. This assessment is deferred to Section 11, where the relationships between upland sources, pathways, and in-water media are examined for iAOPCs.

For each potential migration pathway that is known or likely to be complete (categories a and b), Table 5.1-2 also shows whether the site's impact is current (C) or historical (H). A question mark in this column indicates either that this temporal assessment could not be made or that the pathway's completeness could not be determined (Category c). The column remains blank if the migration pathway at the site is known to be incomplete (Category d).

For the groundwater pathway, Table 5.1-2 includes a column for the presence of NAPL. A "yes" is shown where the pathway is known or likely to be complete. A "no" is shown where the pathway is known to be incomplete. A question mark is shown if the presence or absence of NAPL cannot be evaluated because of insufficient data.

To help readers track the assessments tabulated in Table 5.1-2, selected information reported in DEQ's (2006c) Milestone Report (DEQ's Table 1) is reproduced here as Appendix B. The table, which was considered in the development of Table 5.1-2, provides information on the status of DEQ's source control evaluations, decisions, and measures. An important difference between DEQ's and LWG's evaluation of sources is that DEQ focused on current and potential sources of pollution to the river, where LWG also considers historical inputs where information was readily available. As a result, DEQ may identify a source as "insignificant" based on the current situation where LWG may characterize the same source as a known or potentially complete pathway because of historical conditions. LWG's evaluation may also differ where DEQ identifies a source as insignificant because there are no data (e.g., no groundwater sampling) supporting DEQ's conclusion.

5.1.2 Groundwater

Groundwater pathway information is presented in the site summaries and summarized in Table 5.1-2. Maps 5.1-1a–h provide a river-mile-scale view of the areas known to be affected by groundwater in the vicinity of the Portland Harbor. Because the quantity and quality of available data differ substantially between sites, the approach for

identifying affected groundwater (detected analytes, water quality standards, other baseline values) is not necessarily consistent from site to site. The criteria used are shown on the "plume map" figure for each site summary.

Maps 5.1-1a–h also show zones of in-river groundwater plume discharge, both interpreted and potential. These discharge zones were determined using multiple lines of evidence from results of the Round 2 TZW sampling effort (Integral 2006g):

- Trident probe temperature mapping results
- Direct measurements of flux across the sediment-water interface using seepage meters
- Upland and in-river subsurface stratigraphic information (e.g., coring logs, stratigraphic cross-sections)
- Surface sediment texture mapping
- Information on upland groundwater flow patterns (e.g., potentiometric surface maps, preferential flow paths, remediation systems, and shoreline structures)
- Nature and extent of COIs in upland groundwater
- Analysis of spatial patterns in TZW chemistry, sediment chemistry, and upland groundwater chemistry
- Major ion analysis
- Chemical partitioning analysis.

It should be noted that the in-river groundwater discharge zones presented on Maps 5.1-1a–h represent the combined observations for all relevant upland groundwater COIs for the local area, not necessarily for only the specific upland plume analyte presented on each map. Instead, the zones displayed represent areas where multiple lines of evidence suggest, to various degrees of certainty (interpreted vs. potential), that groundwater is discharging to the river and one or more upland groundwater COIs is present. For a site-by-site, analyte-specific discussion and presentation of all lines of evidence related to the groundwater pathway, refer to the GWPA TZW SCSR (Integral 2006g).

DEQ's evaluation of pathways has been reproduced in Appendix B (DEQ 2006c, Table 1). LWG's conclusions from the information in the site summaries and DEQ's analysis of the groundwater pathway are similar in evaluating the current status of the site, with a few areas of potential disagreement:

- DEQ determined that the groundwater pathway was "insignificant" at several sites based on "screening" (footnote at the end of Table 1, DEQ 2006c); however, in Table 5.1-2, sites without groundwater investigations are classified as category c (insufficient data to make determination). These sites include Alder Creek, Babcock Land Company, and Transloader International.

- DEQ determined that the groundwater pathway was "insignificant" at several sites where no groundwater investigations had been completed, investigations were incomplete, or no downgradient information was available, specifically McCall Oil, RoMar Transportation, Schnitzer Investment-Kittridge, Shaver Transportation, Trumbull Asphalt, and Union-Pacific Railroad (UPRR). These sites are classified in Table 5.1-2 as category c (insufficient data to make determination).

The groundwater pathway has been reasonably well-characterized at relatively few of the sites listed in Table 5.1-2, as summarized by category below:

- Documented evidence of a complete pathway: 11 sites
- Likely a complete pathway: 3 site
- Insufficient data to make determination: 50 sites
- Not a complete pathway: 15 sites.

In the first LWG assessment of the groundwater pathway (GSI et al. 2004), 19 sites were classified as high priority or Group A, having met the following three criteria:

- An upland source of COIs is present.
- COIs have been detected in upland groundwater.
- A groundwater pathway from the upland site to the river is complete or is reasonably likely to be complete. This criterion is met when COIs present in upland groundwater are either confirmed or, based on professional judgment believed to have a reasonable potential, to discharge to the river (via sediments, the transition zone, surface water, or a combination thereof).

Thirteen of the 14 sites from Table 5.1-2 where a complete pathway is likely or has been documented are included in the Group A sites identified by GSI et al. (2004); the remaining site—Port of Portland Terminal 4, Slip 1—was included in Table 5.1-2 as a site with documented evidence because COIs were detected in seeps. Three of the original Group A sites where the groundwater pathway was characterized as complete (Mar Com, Premier Edible Oils, and UPRR) are not listed as such in Table 5.1-2, because investigations of groundwater are incomplete. Investigations by the owners at two of the original Group A sites (Oregon Steel Mills and Marine Finance) have determined that groundwater does not provide a complete pathway to the river.

At nine Group A sites that had been identified as locations with significant potential for a complete groundwater pathway to the river, the LWG sampled TZW in 2006 (Integral 2006g). Results were used to ascertain the status of the groundwater pathway using combined lines of evidence:

- Approximate zones of groundwater discharge offshore of the sites, identified from groundwater discharge mapping (site stratigraphy, upland groundwater

contours and concentrations, sediment texture, Trident temperature data, and seepage meter results) and from analytical chemistry data for TZW and sediment

- Major ion signatures for upland groundwater, surface water, and TZW, evaluated using Piper diagrams
- Chemical concentrations in zones of groundwater discharge relative to zones of little or no groundwater discharge (concentration graphs by flow zone)
- Partitioning of hydrophobic chemicals between sediment and TZW (partitioning plots).

At the nine sites where TZW was sampled, a complete groundwater pathway was confirmed at four, migration of groundwater was found to have no significant influence on TZW and sediment chemistry at four others, and the relationship between upland groundwater and TZW could not be established at one (Integral 2006g):

- **Arkema.** The pathway for transport of upland groundwater COIs to the transition zone within the nearshore and intermediate zones is complete.
- **Gunderson.** Chlorinated solvents measured in nearshore TZW off Area 1 are likely the result of migration of upland groundwater COIs prior to installation of the remediation system extraction wells.
- **Rhone Poulenc.** A complete pathway for transport of upland groundwater COIs to the transition zone is likely to be present.
- **Siltronic.** The pathways for chlorinated volatile organic compounds (CVOCs) in the offshore zone and PAHs, benzene, toluene, ethylbenzene, and xylenes (BTEX), and TPH in the nearshore zone are complete.
- **ARCO.** Migration of chemicals in upland groundwater to the transition zone does not appear to significantly influence TZW and sediment chemistry.
- **ExxonMobil Oil Terminal.** Migration of chemicals in upland groundwater to the transition zone does not appear to significantly influence TZW and sediment chemistry.
- **Kinder Morgan Linnton Terminal (GATX).** Migration of chemicals in upland groundwater to the transition zone does not appear to significantly influence TZW and sediment chemistry.
- **Willbridge Bulk Fuel Facility.** Based on concentrations and spatial patterns in TZW, a complete groundwater transport pathway from the upland to the transition zone does not appear to be present.

- **Gasco.** The contribution of the groundwater transport pathway to COI concentrations in the TZW is indiscernible from in-water sediment chemical sources, and the TZW sampling was limited due to concurrent in-water removal actions (thus the truncation of the indeterminant symbol at the Gasco/Siltronic property line in Map 5.1-1a–h).

Risk from the groundwater pathway to human health and ecological receptors is addressed in Sections 8 and 9.

5.1.3 Direct Discharge - Stormwater and Wastewater

The discussion of stormwater and wastewater discharges in this subsection focuses on the existing discharge conditions within the Study Area. A comprehensive review of historic stormwater and wastewater discharges has not yet been completed, but where information is readily available, may be briefly discussed here.

The following sections provide a preliminary description of the stormwater basins, the types of stormwater discharges, potential sources, currently available data, and a review of the current stormwater and wastewater permits within the Study Area.

5.1.3.1 Stormwater

The LWG has mapped, to the extent practicable, the stormwater basins within the Study Area and to identify outfalls that may be contributing to in-water sediment contamination. As noted in Section 4.1, some inaccuracies with the outfall database have been identified and will need to be refined for the RI. The current information is nonetheless useful for understanding the general characteristics and locations of basins within the Study Area's overall drainage area. This section describes the development of the process and results of these initial evaluations.

5.1.3.1.1 Basin Mapping Approach

Drainage basins for City stormwater outfalls were compiled into GIS maps directly using the shape files provided by the City of Portland (2006b). The drainage basins for private and Port of Portland outfalls were developed using the maps and descriptions contained within the LWG site summaries, stormwater pollution control plans (SWPCPs) contained in NPDES permitting documents administered by DEQ and the City of Portland, and individual LWG member-provided stormwater drainage documents. This information was combined into basin maps (Maps 4.1-1a–i).

Paper maps from SWPCPs available at DEQ and from LWG members were scanned in and geo-referenced. Basins were then created by hand digitizing these maps, and checked against stormwater descriptions in the SWPCPs and CSM site summaries. Ground infiltration, sheet flow to the river, and areas where stormwater is captured in process or other water treatment systems that do not discharge to the river were also noted at this time, and compared against 2005 aerial photographs to identify pervious and impervious surfaces. Where the location of catchments and underground piping

leading to outfalls was the only information available, drainage basins were estimated from topography and aerial photography.

The private and Port of Portland basin maps were overlain with the City basin maps. Where basin delineations coincided, the City outfall basins were modified according to the individual site drawings. Although site-specific information was assumed to be correct, its accuracy relative to that of the City basin maps was not independently verified. The relative accuracy of the sources of information used to define drainage basins is an area of expected future refinement during RI development. Consequently, as noted in Section 4, the estimates of areas associated with various stormwater runoff categories and land use types should be regarded as preliminary estimates that are subject to change.

5.1.3.1.2 Drainage Basin Categories

Four categories of basins and associated outfalls have been defined for the Study Area (Table 4.1-3). City basins were categorized on the basis of conditions at the end of 2006, as indicated by City staff (Sanders 2005, pers. comm.). Private basins were categorized on the basis of the available site-specific information (and associated dates). The four categories are defined as follows:

1. **Stormwater only**—Outfalls draining these basins discharge mostly or exclusively stormwater. These basins constitute approximately 54 percent of the total basin draining to the Study Area, including Saltzman Creek, with predominantly industrial and open space land uses. Considerable areas of private stormwater drainage including substantial open space areas are known or suspected to exist but could not be characterized given the information available. Consequently, this percentage is likely to be an underestimate. Also, this category does not include areas of sheet flow and pervious surfaces along the riverbank that may flow directly to the river, which are discussed below.

2. **Uncontrolled CSO**—For this report, these basins are considered to produce stormwater and, less frequently, CSOs to the outfall (a conservative assumption because a large percentage of the stormwater flow goes to wastewater treatment plants). This category is equivalent to the "unabated" CSO definition discussed in Section 4. The characteristics and frequency of overflow are different for each basin. These basins constitute approximately 6 percent of the total basin draining to the Study Area, with predominantly residential land use (Table 4.1-3).

3. **Controlled CSO**—These basins ordinarily convey flow to wastewater treatment facilities. Only during extreme wet-weather events (designed for less than approximately 6 percent of the average pre-existing harbor-wide CSO volumes) do they discharge directly to the river. This category includes the "abated" CSO definition discussed in Section 4. These basins constitute approximately 10 percent of the total basin draining to the Study Area, with predominantly residential land use (Table 4.1-3).

4. **Discharge to Treatment**—These basins do not ever discharge directly to the river, even during large storms. This is part of the "abated" CSO definition discussed in Section 4 where these areas used to be part of combined system. In these areas, all wastewater flow is conveyed to municipal or private (e.g., onsite) treatment, usually combined with some stormwater. These basins constitute approximately 2 percent of the total basin draining to the Study Area, with predominantly residential land use.

Some outfalls or basins are noted in more than one category. For example, Outfall 17 appears in both the "stormwater only" and "uncontrolled CSO" categories. In such cases, a portion of the basin historically draining to the outfall in question has been separated from the sewer system (i.e., abated) and is now stormwater only, while other portions of this basin remain part of combined systems (i.e., not abated), or have been diverted entirely to treatment (i.e., abated).

A fifth classification is pervious surface, a condition assumed when the site information reviewed indicated the area had no paving or known stormwater drainage system. (Pervious surface is shown on the maps [e.g., Maps 4.1-1a–i] by light gray stippling and constitutes approximately 6 percent of the total basin draining to the Study Area.) The degree to which rainwater infiltrates into the ground or, alternatively, drains as sheet flow to the river, is unknown. Infiltration is more likely during drier months, with sheet flow (or localized ponding) more likely as the ground becomes saturated in wetter periods.

Areas that remain uncharacterized because of data gaps constitute the remaining 22 percent of the watershed draining to the Study Area.

Only categories 1 and 2 above substantially contribute stormwater to the river. Combined, these basins currently represent approximately 60 percent of the total draining to the Study Area (not including any of the uncharacterized areas, many of which would add to this percentage). Category 3 (controlled CSO, one type of abated CSO) contributes a negligible amount of stormwater and sewage to the river—0.03 percent of the total outfall volume. This contribution from controlled CSOs was calculated as the proportion of the approximately estimated CSO volume entering the Study Area divided by the estimated total outfall flow entering the Study Area. The total CSO volume in the entire Lower Willamette River system was estimated by the City of Portland (1998) as 1 million gallons per year after 1997. The total stormwater volume discharging from all stormwater related outfalls annually to the Study Area was estimated by the LWG using methods discussed in Section 7. The result—0.03 percent—is conservative (i.e., likely to be an overestimate) because the City's CSO volume includes both uncontrolled and controlled flow and because further separation has been achieved since the City's 1998 estimate. It should be noted that contaminant concentrations in combined sewer overflows and stormwater vary and some chemicals may be typically higher in one or the other type of discharge. Due to the variability in

both types of discharges and limited data for the Study Area, it is unclear whether many chemicals would be routinely expected to be higher in one type of flow versus the other.

Preliminary sub-basins and associated outfalls are depicted in Maps 4.1-1a–i for locations where information was available; associated basin areas and land uses are listed in Table 4.1-1. Of the otherwise uncategorized 22 percent of the total basin draining to the Study Area, two-thirds (64 percent) is open space (mostly Forest Park) and the remaining third (36 percent) is largely industrial (Table 4.1-1).

Also, note that the cutoff for drainage entering the river via Multnomah Channel is arbitrary: the extent to which stormwater entering the mouth of the channel moves into the Willamette River depends on river flow and tidal condition, and is unknown.

5.1.3.1.3 Potential Stormwater and CSO Sources

Surface sediment concentrations of selected COIs were mapped to identify outfalls that might currently function as sources of contamination. The underlying assumption behind this exercise is that some portion of particulate-associated chemicals in stormwater discharges settles out near the outfall. A pattern of increasing sediment chemical concentrations with proximity to outfalls has been observed at many contaminated sediment sites, even in environments that are hydrodynamically very active. It is also known from the literature on mixing studies that progressively finer fractions of materials (i.e., with slower settling rates) and dissolved chemicals can travel farther distances from an outfall, producing a smearing effect in the spatial distribution of chemical concentrations. Even so, the spatial distribution of sediment contaminants relative to outfalls helps to discern potential sources.

This analysis was conducted without considering the potential confounding effects of other sources (e.g., historical direct discharge), the importance of which is discussed elsewhere in Section 5. Contributions from all the various sources are integrated in the conceptual site models in Section 11 to explain sediment contamination footprints observed in the river.

Maps showing the distribution of mercury, arsenic, total PAHs, total PCBs, total DDT, and bis-2-ethylhexyl phthalate (BEHP) are provided in Appendix B. These analytes represent the general types of chemicals suspected to be driving risks in the system. Data points used to prepare the maps were derived from all LWG surface sediment samples (0-30 cm bml) as well as comparable non-LWG samples in the database.

The sediment chemistry distribution maps were examined to identify locations where concentrations of the selected COIs were elevated relative to nearby samples and the degree of elevation. Maps of drainage basin boundaries and the identity of upland properties were consulted to identify parcels that might contribute COIs to stormwater discharged through the outfall. Site summaries were reviewed to determine whether a COI found in sediment samples collected near a given outfall had been detected or could be inferred to be present at a given property on the basis of previous industrial activities or usage. Table 5.1-3 summarizes the findings. It notes the features of the

outfalls (location, owner, size, material, status, area), the COIs with elevated concentrations in nearby sediment, upland facilities in the outfall basin with matching COIs, and upriver facilities with matching COIs. Outfalls of active, inactive, and unknown status are shown. Of the 311 outfalls evaluated, 145 had contaminants similar to those in media from adjacent upland facilities; however, almost all of these locations had facilities upstream with similar contaminants detected in upland site media as well, suggesting that sediment transport might also have affected sediment quality in the vicinity of those outfalls. It should be noted that Table 5.1-3 focuses on known industrial sites and activities as potential sources within outfall basins. Ubiquitous urban pollutant sources that are difficult to identify with any particular site or activity also exist for all of these stormwater basins, including public, private, large, and small basins. Further, these ubiquitous sources could and likely do include some of the COIs identified in Table 5.1-3 near particular outfalls.

As a general rule, stormwater pollutant loading varies with land use, although the widely cited local and national studies (e.g., Woodward-Clyde 1996, 1997; EPA 1983) tend to focus on metals, nutrients, TSS, and oil and grease, and not the COIs mapped in this effort. The studies suggest that the land uses generating the highest pollutant loading rates are, in descending order, industrial, transportation, commercial, residential, and open space. Depending on the activity in adjacent land uses, the more widely studied stormwater parameters could also indicate the presence of other Portland Harbor COCs.. The available literature for other chemicals, including organic compounds, suggests that their loading-land use relationship is similar to those of metals, nutrients, TSS, and oil and grease. Studies have also found a general correlation between these chemicals and increased urbanization. These findings are particularly applicable for runoff from large urban areas, as opposed to, for example, a single catch basin. Literature findings that support this concept are discussed in Section 7 and Appendix E.

5.1.3.1.4 Stormwater and CSO Chemistry Data

Identified pollutants in Portland-area CSOs primarily include bacteria and metals (City of Portland 2001d). A study of CSO effluent from five discharge locations in Seattle, Washington detected metals and SVOCs, including some phenols, phthalates, and PAHs (Metro King County 1999). In general, pesticides and PCB detections were not detected in CSO effluents in Seattle. Although these data are not from Portland, they give a general indication of the types of organic chemicals potentially present in CSOs.

For stormwater chemistry, very limited and sporadic site-specific data are available on concentrations or loads of chemicals entering the Site via stormwater outfalls. Two primary types of chemical sampling and analysis data are most relevant to the Site RI/FS: (1) stormwater and (2) solids gathered from conveyance structures (e.g., catch basins) or by other means (e.g., in-line sediment traps). Water chemical concentrations can be used directly in loading estimates and solids chemical data can provide an indirect estimate of water concentrations, when assumptions or estimates of the TSS concentrations in the stormwater are also made. It should be noted that there are a

number of potential pitfalls associated with extrapolation from solids data to water concentrations; however, when complete water data sets are unavailable, such extrapolated data can be a valuable source of information for first-level estimates of loads. Specific available information is reviewed below and some of this information is used in loading evaluations described in Section 7.

DEQ has identified approximately 26 sites within the Site that have conducted some type of stormwater-related sampling (e.g., stormwater and catch basin sediments) either prior to or under the JSCS program (Table 7.1-3) (Tarnow 2006a,b, pers. comm.). In addition, DEQ has indicated stormwater-related sampling under the JSCS program will or could possibly take place at approximately 41 sites during the winter of 2006/2007 (Tarnow 2006a,b, pers. comm.). Of these 41 sites, 22 have not previously conducted stormwater sampling under DEQ programs (Tarnow 2006a,b, pers. comm.) (Table 7.1-3). Sampling under the JSCS program is in addition to any sampling conducted for NPDES permit compliance. JSCS sampling is generally focused on site-related chemicals, and can range widely in scope and approach, from screening-level sampling (catch basin sediments and/or stormwater grab samples) to extended stormwater monitoring programs. The scope of the sampling is negotiated between DEQ and the owner/operator on a site-specific basis. To date, no comprehensive data set or summary has been compiled by DEQ or LWG. The LWG will continue to work with DEQ to obtain a comprehensive data set for use in the RI. In addition, any data available through early fall 2007 is expected to be incorporated into the RI. Data collected after that time is expected to be too late for incorporation into the RI under the existing schedule.

The City of Portland has conducted storm water-related sampling mostly within sub-basins of outfalls, including sampling of in-line solids within basins for Outfalls M1, 18, 17, 22B, and 53A for a variety of metals and organic compounds. This information was collected for source tracing and may have little or no value for determining source loads.

Also, as part of the Portland MS4 NPDES permit, the City of Portland conducted land-use-specific stormwater sampling from 1991-1996 at ten stations representing various land uses (residential, commercial, industrial, transportation, parks and open space, and mixed land uses). Three land-use monitoring stations were located within the Site: two industrial stations and one transportation station. Industrial station I2 was located at City Outfall OFM-1, and industrial station I1 was located within a sub-basin of City Outfall 18. Transportation station T1 was located with a sub-basin of City Outfall 18 and represented runoff from Highway 30 (Woodward-Clyde 1996). Metals were extensively sampled, and between two and five storm events were sampled for pesticides, SVOCs, VOCs, phenols, and cyanide. Pesticides, SVOCs, and VOCs were mostly undetected in stormwater using standard laboratory detection limits. PAHs were also analyzed with ultra-low detection limits; detected PAH concentrations ranged from 0.1 to 30 µg/L, with the highest concentrations associated with industrial land use.

In most cases, samples collected for the private and City-related source tracing and MS4 efforts were analyzed for only a subset of chemicals in the RI/FS target analyte list. In many cases, samples were collected at specific locations within the conveyance system, and are not likely representative of overall chemical contributions across the entire basin. This makes much of this information difficult to use in a consistent manner to develop stormwater loading estimates either for these specific outfalls or the Site as a whole.

5.1.3.2 Stormwater and Wastewater Discharge Permits

Many types of stormwater and industrial wastewater permits are issued within Study Area uplands. Stormwater permits include discharges of industrial stormwater. Wastewater includes permits for process water, oil/water separator discharge, petroleum hydrocarbon cleanup wastewater (tank cleanup and groundwater treatment), vehicle and equipment washwater, boiler blowdown, filter backwash, cooling water, heat pump wastewater, log pond drainage, noncontact geothermal exchange water, and rinsewater of various types. Permitted wastewater discharges are generally required to be treated before discharge.

Stormwater and wastewater enter surface waters via pipes, culverts, ditches, catch basins, and other types of channels. In the Study Area, both stormwater and treated wastewater generally enter the river via constructed conveyance systems and outfalls. All wastewater discharges and stormwater discharges from certain types of facilities require an NPDES permit.

DEQ issues two types of NPDES permits: general and individual. General permits are issued to dischargers whose operations and type of waste are similar. Individual permits are issued to facilities whose processes or wastewater/stormwater flows merit unique monitoring requirements. There are only nine individual wastewater permits. There are no municipal wastewater treatment plant (WWTP) discharges in the Study Area. The Port of Portland, ODOT, and the City of Portland discharge stormwater under MS-4 permits.

There are approximately 76 NDPES stormwater (not including construction permits) and 33 NPDES wastewater permitted discharges to the Study Area, as listed in Table 5.1-4 (DEQ 2006c). Note that multiple permits may be associated with a single outfall. The number of NPDES-permitted discharges by type of permit is shown below:

NPDES Permit Type	Number of 2006 Permits
General Permits for cooling water/heat pumps (GEN01)	9
General Permits for boiler blowdown (GEN05)	2
General Permits for treatment of groundwater (GEN1500A)	3
General Permits for stormwater (GEN1200A,C,Z,T)	76
General Permits for oily stormwater (GEN1300)	10
Individual Permits for facilities not elsewhere classified that dispose of primary smelting/refining of metals not elsewhere classified (NPDES-IW-B08)	1
Individual Permits for facilities not elsewhere classified that dispose of process wastewater (includes remediated groundwater)	1
NPDES B014	
Individual Permits for facilities not elsewhere classified that dispose of process wastewater (NPDES-IW-B15)	5
Individual Permits for facilities not elsewhere classified that dispose of non-process wastewater (NPDES-IW-16)	3
Individual NPDES Permit	1
Municipal Separate Storm Sewer System Discharge Permit (NPDES-MS4)	1

The number and types of permits changed very little between 2004 and 2006, as shown in Table 5.1-4. New permits (listed in 2006 but not 2004) are shown in bold; expired permits (listed in 2004 but not 2006) are shown in strikethrough.

Individual permit limits may be based on either effluent concentrations or total loadings, incorporating factors such as mixing zones or available technologies. The vast majority of permitted discharges to the Study Area (by number of permits) are for industrial stormwater discharges under general permits (NPDES GEN1200Z). Instead of flow or chemical limits, these permits specify benchmark concentrations to help permittees evaluate the effectiveness of their stormwater management practices.

Monitoring parameters for NPDES GEN1200Z are limited to pH, oil and grease, TSS, copper, lead, zinc, and sometimes E. coli. The monitoring data generated under these permits are of limited value in identifying sources.

5.1.4 Riverbank Erosion

Surface soils exposed along riverbanks and the adsorbed chemical contaminants can be eroded and carried to the river in runoff from the upland areas (i.e., overland transport). They can also be eroded directly into the river (especially from unarmored or unprotected banks) by in-water forces due to fluctuations in river level, currents, floods, and propeller wash from localized ship activities. Riverbank conditions in the Study Area are shown in Map 4.6-1. Various engineered materials, including seawalls, riprap, and engineered soil, cover about half of the riverbank area.

Although relative little riverbank soil data are available, COIs have been detected at approximately 19 sites where data are available; information is presented in the site summaries. DEQ also listed sites for which riverbank data are available (Anderson 2006a,b, pers. comm.). The data compiled from site investigation reports and LWG members are described in Section 7.1.

Riverbank erosion may represent an ongoing release mechanism in the Study Area. Due to the significant amount of armored banks and lack of bank filling in recent decades, the contribution of riverbank erosion may have been more significant in the past.

5.1.5 Atmospheric Deposition

The LWG is not aware of information specific to the Study Area with which to evaluate the atmospheric deposition of chemicals. Atmospheric deposition is known to be a source of contamination globally, but its relative importance in the Study Area is not known. An evaluation based on literature is presented in Section 7.

5.1.6 Overwater Releases

Overwater spills are unpermitted releases that occur directly into the waterway. Spill records for the LWR are summarized in Table 5.1-5, based on information from DEQ, the U.S. Coast Guard (USCG), and the National Response Center's (NRC) centralized federal database of oil and chemical spills. Records for 1995 to 2006 were available from DEQ, detailed reports of spills from 1990 to present were available from the federal sources, and summary information for spills between 1982 and 1989 was obtained from the NRC online database. Releases that did not meet reporting requirements in effect at the time of occurrence may not be included in these databases. Historical and unreported spills are certain to have occurred but cannot be specifically documented in this report.

Information on spill locations, particularly in the earliest reports, is often very general (e.g., only the river mile is provided). The nature of reported spills ranges widely, from

dropped bottles to sheens of unknown origin to 500-gallon fuel spills. Since 1990, 5 of the spills reported to the USCG involved volumes greater than 5 gallons. Of these five, one exceeded 1,000 gallons; it was attributed to operator error during transfer of fuel oil from a barge.

The activities most commonly associated with spills in the Study Area are product handling, overwater activities such as refueling, and vessel leaks:

- **Product handling**. The types of facilities on the LWR and products or chemicals associated with these industries are listed in Appendix E. Many facilities are now required to maintain spill prevention plans and have instituted practices to reduce spills.
- **Overwater activities.** Overwater activities including ship repair or vessel refueling are potential sources to surface water and sediment contamination. Regulations and best management practices have reduced such contributions in recent years. Spills during refueling are the most common type of overwater spill, but incidents during transfer of other materials (e.g., paint, hydraulic fluid, coal tar pitch) have also been reported.
- **Utility Crossings.** One petroleum pipeline crosses the Willamette River within the Study Area. It is located between the Willbridge bulk fuel terminal and south end of Triangle Park (approximately RM 7.7). There is no record of spills or leaks from this crossing.
- **Vessel leaks.** On average, 20 spills from vessels directly into the LWR are reported to the USCG each year (NRC 2002), nearly all of which are diesel fuel, gasoline, hydraulic oil, lubricating oil, or waste oil. Bilge and ballast water has also been released.

5.2 SOURCES OUTSIDE THE STUDY AREA

Point and nonpoint discharges within the Willamette River basin are potential sources of contamination in sediment, surface water, and biota in the Study Area. Chemicals in discharges and runoff from diverse land uses in the basin eventually make their way to the river by the time it flows into the Study Area.

5.2.1 Non-Study Area Sources in the Lower Willamette River

Sources in the LWR, both downstream and upstream of the Study Area, may contribute to chemical deposition in the Study Area. Potential sources immediately upstream of the Study Area include aluminum storage facilities, rail yard maintenance operations, cement manufacturing, marinas, and numerous private and public outfalls. Shoreline facilities upstream of the Study Area that are included in DEQ's ECSI database are listed in Table 5.2-1, with locations shown in Map 5.2-1. Map 5.2-1 also shows outfalls upstream of the Study Area. The outfalls shown are generally limited to City of Portland outfalls; information on the perhaps hundreds of private outfalls within this

map view is not currently available. Currently available data on NPDES-permitted discharges from facilities upstream and downstream of the Study Area (Anderson 2006a,b, pers. comm.) are listed in Table 5.2-2.

Under certain river stages, flows, and tidal conditions, the influence of the Columbia River estuary causes periodic flow reversals in the Willamette River near its mouth and within Multnomah Channel. These flow reversals could transport sediment-bound chemicals from downstream reaches of the river into the Study Area.

The list of impaired waters in Oregon prepared under Section 303(d) of the federal Clean Water Act and its amendments (DEQ 2006c) includes the main stem and tributaries of the Willamette River. Most of the 303(d) listings for impaired water quality outside the Study Area in the LWR are for temperature, pH, and bacteria. Johnson Creek, a tributary that enters at RM 18, is listed for toxic chemicals, including PCBs, PAHs, DDT, and dieldrin.

5.2.2 Sources Above Willamette Falls (Upper Willamette River)

Both point sources and nonpoint sources of contamination are present above Willamette Falls. Agriculture, forestry, urban land use, and geologic features can contribute to conditions in Portland Harbor.

More than 750 permitted discharges enter the Willamette River upstream of Willamette Falls, including 10 municipal sewage treatment plants and several pulp, paper, lumber, and fiberboard manufacturers. Hundreds of facilities also have general permits for discharge of noncontact cooling water and filter backwash, gravel mining wastestreams, and tank cleaning fluids. Industrial stormwater discharge permits are held by facilities that handle paint, steel, metal plating, semiconductors, adhesives, and food products, as well as by landfills and transportation companies.

Most of the agricultural and forested land in the Willamette River basin can generate nonpoint sources of pollution. The primary nonpoint source problem associated with forestry is accelerated sediment transport, but nutrients, fertilizers, and herbicides are also found in forest runoff. Erosion from agricultural lands in the Willamette Valley is the most commonly cited nonpoint source pollutant in the upper reaches of the Willamette River basin (Tetra Tech and E&S 1993), especially fertilizers, pesticides, and herbicides. In USGS studies of pesticides in the Willamette basin (Wentz et al. 1998), the highest concentrations of organochlorine pesticides and PCBs were reported for three mostly agricultural sites.

Nonpoint pollutants from the upper Willamette basin (e.g., pesticides, PAHs, metals) also enter via runoff from residential, industrial, and commercial areas that do not require stormwater permits. Municipal stormwater permits are also held by cities in the upper Willamette Basin.

A fish advisory for mercury is in effect throughout the entire main stem of the Willamette River, due in part to runoff from natural volcanic sources, past mining activities, and atmospheric deposition in the upstream reaches of the Willamette River basin.

DEQ's (2006d) 303(d) list of impaired waters above Willamette Falls includes numerous tributaries of the Willamette River. Most of the 303(d) listings are for temperature and bacteria; other listings relate to nutrients, dissolved oxygen, and pH. Smaller creeks in the middle and upper Willamette basins are listed for dieldrin, arsenic, copper, lead, mercury, or zinc. The Molalla-Pudding sub-basin is listed for DDT, arsenic, chlordane, and dieldrin, and the Tualatin sub-basin is listed for hexavalent chromium, copper, lead, zinc, and silver.

Based on the 303(d) list, DEQ has developed total maximum daily loads (TMDLs) for 10 of the 12 Willamette River sub-basins (Table 5.2-3). TMDLs will be developed for the Yamhill and Molalla-Pudding sub-basins in 2007. Mercury TMDLs have been issued for all Willamette River sub-basins, and temperature and bacteria TMDLs have been issued for 9 of the 12. A dioxin TMDL was developed by EPA in 1991 for the Willamette and Columbia rivers.

5.3 HISTORICAL SOURCES

Historical sources within the Study Area likely contribute to the majority of the observed chemical distribution in sediments within the Study Area. This section identifies the major historical operations that contributed to sediment contamination.

Table 5.1-2 provides an assessment of whether the predominant impact for each of the pathways was historical or current. As would be expected, nearly all the pathways have a historical component and many can be attributed entirely to historical operations or releases.

The LWR has been an active industrial center for over 100 years. Direct discharge of industrial process waste or wastewater was a common and accepted practice throughout the majority of the past century. There is little specific information on the discharges and waste disposal practices associated with these varied industrial activities. For example, ship building, ship repair, and ship dismantling occurred throughout the Study Area during WWII and the decades following the war. Site-specific information is limited; however, ship building and dismantling activities in general have been associated with releases of PCBs, heavy metals, asbestos, and petroleum products, among other contaminants (EPA 1997a). In addition, stormwater discharges had very little control and monitoring until recent decades. Uncontrolled releases at upland sites resulted in impacts to groundwater and migration to the river and overland flow discharges. Source control actions in recent decades have significantly reduced these impacts to the LWR

As shown in Map 4.6-1 the shoreline in the Study Area has undergone significant modification with the placement of fill materials. Much of the fill material was obtained from nearby dredging. In cases where these sediments were contaminated prior to dredging, by uncontrolled releases from upland sites or other sources, the sediment fill can act as a source. However, many of the areas where fill was used to gain land space have armored banks to control bank erosion.

Finally, loading from sediment transport and water from upstream areas throughout the last century is expected to play a significant role in the conditions currently observed in the Study Area. The Study Area is at the downstream end of a large basin with a long history of industrial, municipal, and agricultural inputs.

Valuable insight into the magnitude of historical releases is provided by Glen D. Carter, an aquatic biologist employed between 1956 and 1988 by the Oregon State Sanitary Service Authority (OSSA), a forerunner to Oregon's DEQ. By the time he was hired in 1956, "fish kills were common in the river, massive rafts of decaying algae floated downstream, and a thick layer of bacterial slime covered much of the river bottom and shoreline. Rotting vegetation, bacterial slime, and countless dead fish produced highly unpleasant sights and odors. Large deposits of sewage sludge accumulated around sewage outfalls" (Carter 2006). Mr. Carter describes Portland Harbor as the most polluted stretch of the river: during the 1950s, as Navy ships left the Harbor after the Rose Festival, "every ship and small boat accumulated a two-foot-wide belt of heavy tar, grease, and oil at waterline." Fill placement and muddy return flows from harbor dredging "contaminated the river and far downstream and kept it highly turbid for two years" in the 1950s. Mr. Carter believed that waste products from chemical manufacturing in the 1960s resulted in chemical taste in fish caught in the nearby river. OSSA circulated an emergency bulletin to the agricultural community explaining how the practices used for weed control in the Willamette Valley endangered fish and other aquatic life and requesting that it be stopped. Finally, Mr. Carter describes blockages of fish migration due to low or nonexistent oxygen levels in the lower river due to discharges from wood and pulp mills in the late 1960s.

The effect of these historical sources has been largely abated by the implementation of regulations on hazardous waste handling, stormwater controls, and state and federal laws on environmental cleanups. Many of these regulations have been in place for over 20 years.

EXECUTIVE SUMMARY

SECTION 6 – IN-RIVER CHEMICAL DISTRIBUTION

Abstract

The distribution of chemicals in sediment, water, and biota is detailed in Section 6. The nature and extent data set includes all LWG data collected through Round 2 of the RI/FS and any other existing data collected from the Study Area between May 1997 and December 2005 and determined by EPA to be of suitable quality. The nature and extent of COPCs identified from the ecological and human health risk screening steps (see Appendices F and G of this report) is examined. Key COPCs include arsenic, mercury, PCBs, DDx, PAHs, petroleum, some phthalates, and dioxins and furans. Detailed information on the distribution of these compounds in sediment is presented graphically and on maps for the Study Area (RM 2 to RM 11). Taken as a whole, these data show that sediment concentrations tend to be fairly uniform across the Study Area except in nearshore or off-channel areas that are generally associated with known or suspected historical or current sources, where concentrations tend to be higher.

Sediment data are also available from areas outside the Study Area; these areas include upriver (RM 15.3 to RM 26), the downtown corridor (RM 11 to RM 15.3), downstream (RM 0- RM 2), the upper Multnomah Channel, and the riparian zone bordering the in-water Study Area. In general, except for arsenic and mercury, these areas show lower concentrations of COPCs than the Study Area.

Based on the quantity and quality of the chemical data sets, along with the spatial distribution and density of sampling locations:

- The information is adequate to establish the nature and extent of contamination in the harbor, conduct fate and transport modeling, support the human and ecological risk evaluations, and identify data gaps.
- Limited additional sediment and surface water chemical data collection is proposed for Round 3 in the Study Area and upstream and downstream primarily to address site boundary, background, upstream contaminant loading, and FS data needs.
- Any data collected during Round 3 will also be used to augment the nature and extent data set.

Work Plan and Field Sampling Plan Directives

The Programmatic Work Plan (April 2004) established the overall framework and objectives for the characterization of the nature and extent of contaminants in abiotic and biotic media for the RI/FS that built upon the extensive amount of existing data collected by members of the LWG and others within the Study Area. Numerous media-specific Field Sampling and Quality Assurance Project Plans that detailed sampling design and rationale, data use objectives, field

and laboratory sampling and analysis methods, and data management and reporting requirements, were developed with and approved by EPA and its partners.

Data Collection Activities

Nature and extent samples collected by the LWG through Round 2 of the RI include beach sediment, surface and subsurface riverbed sediment, TZW, surface water, groundwater seep, shellfish and other invertebrate tissue, and fish tissue. Also evaluated in this report were additional beach and riverbed sediment data, limited TZW data, conventional water quality data, and upriver fish tissue data collected by other parties. The extensive data set used in the Round 2 nature and extent evaluation includes approximately:

- 1,650 surface sediment chemistry samples (270 of these samples were subjected to amphipod and midge bioassay/clam and worm bioaccumulation testing) from the Study Area and upstream and downstream reaches
- 1,800 subsurface sediment chemistry samples (from about 660 coring locations) in the Study Area
- 225 TZW samples from 108 stations at nine sites in the Study Area
- 130 water samples from 25 point and transect stations from the Study Area
- 150 fish and invertebrate (clams, crayfish, and epibenthic invertebrates) composite samples from throughout the Study Area and upriver (generated from over 2000 individual fish and invertebrate specimens).

All media were analyzed for more than 540 target chemicals, including conventional parameters (e.g., pH, conductivity, and suspended solids), metals, PAHs, PCBs, pesticides, herbicides, petroleum, phenols, phthalates, other SVOCs, and dioxins and furans. The sediment and tissue samples span the entire Study Area but were generally focused on areas of known historical contamination along the shore. Beach sediment samples were collected in potential human and ecological exposure areas. TZW samples were collected in nine areas with upland groundwater plumes with the potential to discharge to the river. Surface water was collected along transects at the boundaries and middle of the Study Area to provide general water quality characteristics as well as at discrete locations that targeted potential sources and ecological or human health exposure pathways.

Preliminary Assessment of Findings

<u>Sediments</u>

The concentrations of COPCs in Study Area sediments are generally higher in localized nearshore and off-channel areas relative to sediments from the navigation channel, upriver and downstream areas, particularly for organic compounds. Metals concentrations tended to be similar among all areas sampled. PCBs, PAHs, DDx, dioxin and furans are found across the Study Area, but concentrations vary by orders of magnitude. In most areas, concentrations are more elevated at the surface, while a few areas show elevated levels in subsurface sediments

underlying relatively uncontaminated surface sediment. Metals generally show a much narrower concentration range and fewer and less steep horizontal and vertical gradients within the sediment column.

Transition Zone Water

TZW was sampled in nine areas along the river bed with known or likely discharge of contaminated groundwater. Multiple lines of evidence, including upland groundwater chemistry and potentiometric observations, upland and in-river stratigraphy, sediment texture mapping, and in-river discharge mapping were used to interpret whether and where upland groundwater plumes were discharging to the river at the nine study sites. TZW analyses reflected site-specific groundwater information from adjacent upland facilities and included conventional analytes, cyanide, perchlorate, metals, pesticides, herbicides, PAHs, TPH, SVOCs, and VOCs. Concentrations varied between study sites, reflecting variability in upland groundwater source concentrations, in-river sediment concentrations, and completeness of the groundwater pathway at each site. Areas where there are likely links between the upland groundwater and river sediment were observed on the west bank of the river at RM 6 and RM 8.5.

Surface Water

Round 2 surface water samples were collected in November 2004, March 2005, and July 2005. Although designed to reflect water quality during different seasonal flow conditions, comparable, low-flow levels occurred during all three events. Consistent temporal trends in contaminant concentrations were not apparent in this Round 2 surface water data set. Spatial trends were also difficult to discern. Chemical concentrations in surface water samples were generally much lower than those measured in sediments; however, certain parameters (e.g., PAHs, PCBs, dioxins, furans, and DDx) were elevated in some near-bottom water samples relative to others, suggesting input from localized sources. PCB composition patterns in suspended solids generally reflected patterns found in nearby surface sediment, suggesting that bottom sediment may become entrained in the water column at these locations. Also, concentrations of many organic COPCs were somewhat higher in river transect sample locations within the Study Area than in the transect from the upstream boundary at RM 11. Together, these data suggest that these contaminants are entering the Study Area both from upstream and within Study Area sources.

Tissue Samples

Data for a variety of tissue samples were collected to support the human health and ecological risk evaluations. Nine finfish species, representing different feeding guilds and home ranges, plus crayfish and epibenthic invertebrates, were collected from throughout the Study Area. Tissues from both field-collected and laboratory exposed clams and laboratory-exposed worm samples were also analyzed from numerous locations in the Study Area. PCBs, DDx and dioxins and furans were detected in nearly all tissues analyzed. Maximum concentrations for individual COPCs varied among species and sampling locations. The highest tissue concentrations were typically measured in laboratory exposed worms, carp, sculpin and

smallmouth bass. Fish with smaller home ranges and invertebrate samples with the highest tissue concentrations of PCBs or DDx tended to be co-located with sediment and/or water samples that also had elevated concentrations (relative to general conditions within the Study Area). Other chemical groups such as phthalates, phenolic compounds, and other semivolatile organic compounds were seldom detected in fish or invertebrates.

Additional Data/Next Steps

Sediments

The nature and extent sediment data set for the RI/FS is largely complete. Some additional sediment chemistry data will be collected as part of Round 3 for the following data needs:

- Upstream and downstream surface, subsurface, and suspended (sediment trap) sediment samples will be collected in Round 3 to help define final site boundaries, characterize background conditions, and support evaluation of contaminant loading to the Study Area from upstream.
- Study Area surface and subsurface sediment samples will be collected as part of Round 3 to address iAOPC-specific FS data needs.

Transition Zone Water

The Round 2 TZW investigation study has delineated the majority of TZW contamination in the Study Area originating from upland groundwater plumes, and no further TZW data collection is anticipated.

Surface Water

Additional far-field surface water data will be collected in Round 3 to complete the surface water nature and extent characterization. Round 3 water sampling will include an additional low flow period (summer/fall), a winter high flow period, an extreme high water event, and an early rainy season period to capture potential stormwater inputs.

Tissue Data

The tissue data collected through Round 2 will continue to be evaluated in the baseline risk assessments. Round 3 sampling will include the collection of lamprey ammocoetes and pre-breeding sturgeon to support the baseline risk assessments.

All additional nature and extent data collected in Round 3 or compiled from non-LWG sources will be evaluated as part of the final in-river chemical nature and extent discussion presented in the RI/FS report.

6.0 IN-RIVER CHEMICAL DISTRIBUTION

The distribution of chemicals in sediment, TZW, surface water, and biota is summarized in this section. The complete data set is provided in Appendix B of this report.

Summary statistics of the nature and extent data for all parameters analyzed in each type of medium are presented in tables included in Appendix C. For each analyte, the following summary statistics are tabulated: the frequency of detection, and the minimum, maximum, mean, median (nearest value), and 95th percentile (nearest value). Two sets of statistics are presented for each analyte. One set reflects only detected values and the other set shows detected and undetected values combined. The statistics have been compiled separately for areas inside the Study Area (RM 2-11 <13 ft NGVD) and areas outside of it. Except where specific exceptions are called out (e.g., in the preliminary background concentration calculations, Section 6.1.3), summary statistics presented in tables and text were calculated using one-half of the reported detection limit value for nondetected concentrations.

In certain cases, concentrations of closely related analytes were added together to create a group sum. This treatment occurred for total PCB Aroclors, total PCB congeners, total PCB TEQs, total dioxin/furan TEQs, TPH, total low molecular weight polycyclic aromatic hydrocarbons (LPAHs), total high molecular weight polycyclic aromatic hydrocarbons (HPAHs), total chlordanes, and total DDx (2,4'- and 4,4'-DDD, -DDE, -DDT). When calculating group concentrations for this nature and extent evaluation, a value of zero was used for nondetected concentrations on an individual sample basis; other analyte summing approaches were used in the Round 2 risk evaluations presented in Sections 8 and 9 of this report. The 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD) TEQ values for PCBs and dioxins/furans were calculated with World Health Organization 1997 toxicity equivalency factors (TEFs) for mammals (WHO 1997). Tables in Appendix C2 present the constituent concentrations used in each group sum.

Analytes detected in sampled media are referred to as chemicals of interest, or COIs. The COIs for each medium are presented in Table 6.0-1. Chemicals of potential concern, or COPCs, were identified from early ecological and human health risk screening steps (see the Round 2 risk evaluations presented in Sections 8 and 9 of this report) for surface sediments, tissue, and water (surface water and TZW) from the Study Area. A subset of the COPCs was subsequently identified as initial chemicals of concern, or iCOCs, based on further risk screening steps presented in Appendices F and G of this document. Indicator chemicals, selected from among the COPCs (see discussion below regarding indicator chemical selection) and listed in Table 6.0-2, are used to represent the nature and extent of contamination in sediment, surface water, and biota from the Study Area.

Where possible, indicator chemicals were selected to allow simple visual comparisons across media (e.g., concentrations of DDx isomers are presented for sediment, tissue, and water); however, in-depth analyses of potential inter-media indicator chemicals

relationships in this section are currently limited. Comparisons between chemicals detected in bedded sediment and TZW were presented in the Round 2 GWPA TZW SCSR (Integral 2006g). Estimated loading rates based on observed concentrations in surface water and TZW are compared in Section 11.1 of this document. Inter-media relationships, including contributions to biota from abiotic media, will be addressed in the RI report.

6.1 INDICATOR CHEMICALS IN SEDIMENT

The locations of all sediment samples in the nature and extent data set are shown in Maps 2.1-1a–t and 2.1-3a–t. Summary statistics for all analytical results in surface and subsurface sediment samples from the riverbed have been compiled separately for the six LWR areas listed below (Tables C1-1 through C1-10 in Appendix C1):

- Study Area (RM 2-11)
- Riparian Zone (between +13 ft and +22 ft NAVD88; see Figure 6.1-1)
- Downtown Corridor (RM 11-15.3)
- Upriver (RM 15.3-26)
- Downstream (RM 0-2)
- Multnomah Channel (from the Willamette River to the Sauvie Island Bridge, Highway 30).

The surface sediment data set includes all samples with intervals starting at 0 cm and extending to depths ranging to 40 cm bml[9].

For this Round 2 nature and extent discussion for sediment, 23 indicator chemicals were selected for detailed graphical presentation (e.g., maps, scatterplots) and data evaluation (Table 6.0-2). The selection was guided by the following considerations, although fulfillment of all three conditions was not a requirement for selection:

- The compound or compound group is a COPC in both the ecological and human health risk evaluations
- The compound shows a high frequency of detection compared to others in its category

Taken together, the compound suite represents a range of compound classes.

[9] The functional definition of surface sediments for this site is 0-30 cm based on physical system studies. However, the recorded lower depth of a few surface samples (i.e., grab or shallow cores that begin at the mudline) in the nature and extent data set reached 40 cm. These samples were grouped with the surface data set, thus extending the maximum depth to 40 cm. Core samples that extended from the mudline to depths greater than 40 cm were grouped with the subsurface sediment data set.

Summary statistics for grainsize, TOC, and indicator chemicals in the surface and subsurface sediment samples from the Study Area are presented in Tables 6.1-1 through 6.1-10. These summary statistics do not included results from locations that were dredged or capped subsequent to sample collection.

The surface and subsurface distributions of these indicator chemicals in sediment from the Study Area (RM 2-11) are discussed in detail in Section 6.1.1 below. Section 6.1.2 then presents and compares surface concentrations of key sediment chemicals among upstream and downstream subareas and the Study Area. Section 6.1.3 summarizes existing sediment chemistry data for all COPCs in the Upriver reach (RM 15.3-26) and estimates preliminary background concentrations from this data set for use in the Round 2 risk evaluations. Finally, Section 6.1.4 examines patterns of temporal and small-scale spatial heterogeneity within the nature and extent data set.

6.1.1 Nature and Extent of Indicator Chemicals in Study Area Sediment

The distribution of the 23 nature and extent indicator chemicals in surface and subsurface sediment within the Study Area are presented and discussed in this section.

The distributions are depicted in three graphical formats: surface and subsurface plan-view concentration maps, subsurface concentration maps, and scatter plot graphs. The composition of selected chemical groups is shown as pie charts on separate map sets.

The plan-view concentration maps (Maps 6.1-1a,b through 6.1-23a,b) present all surface sample data and the maximum concentration at each subsurface sample location (i.e., the highest concentration of all the samples analyzed from a sediment core), regardless of whether these concentrations represent a detected result or the detection limit for a U-qualified result (not detected). Nondetected concentrations are differentiated from detected concentrations on the maps by a dot in the center of the sample symbol (e.g., "●"). Subsurface locations where the maximum concentration was measured in the bottom-most sample are indicated by an "X" underlying the sample symbol (e.g., "■"), indicating that the depth of the maximum concentration at that station may not be captured by the existing data. The maps include data points from locations that were dredged or capped subsequent to the collection of the sample(s) (shown by a circle centered around the sample symbol "◉")[10], and indicate where concentrations are based on partial sums (i.e., concentrations of group totals that are based on less than the full constituent list, such as total PCB Aroclor concentrations based on seven rather than nine Aroclor results). In addition, the maps include histograms showing the distributions of the detected results and detection limits for

[10] Surface interval sample locations G088, G087, and G091 collected in 2004 in the International Terminals Slip were dredged subsequent to sampling. These locations were resampled in 2005 at C088, C087, and C091; surface sample results for chlorinated pesticides and/or TPH from the latter locations may appear within the "dredged" symbols if concentrations were higher than in the 2004 samples, although the 2005 samples represent post-dredging conditions.

nondetected results for each mapped analyte. Data from samples that have been dredged or capped are not included in the histograms.

Maps 6.1-24a–c through 6.1-46a–c show the distribution of indicator chemicals with depth at the subsurface sediment sampling stations. In these maps the actual core station is generally located at the midpoint of the core symbol; however due to size constraints, some core symbols are offset from their actual locations. The core segment divisions displayed on the maps are scaled to the thickness of each sample interval. Surface sample results are shown near the core symbol at those locations where the surface interval of the core was not analyzed, as was the case for many Round 2 cores (per the FSPs; Integral et al. 2004a, Integral and WEST Consultants 2005). Note that these maps include cores from locations that have been subsequently dredged or capped (shown in hatched polygons). The subsurface concentration maps do not indicate samples where concentrations are based on partial sums (the few cases where data are based on partial sums are from non-LWG studies).

The concentration ranges (or intervals) used in color-coding the chemical data shown on the maps (e.g., the threshold value for the red labels) are the same or similar to those used in the Programmatic Work Plan and previous sediment data presentations (i.e., Rounds 1 and 2). These concentration intervals were based on the frequency distributions (i.e., natural breaks) in the historical data set for these compounds and then modified and approved by EPA. Concentration intervals for chemicals not mapped in previous reports are also based on natural breaks observed in the data.

Scatter plots of the distribution of analytes in surface and subsurface sediment per river mile are presented in Figures 6.1-2 through 6.1-47. To aid in differentiating potential concentration trends, the data in these plots are further separated into East Bank, Navigation Channel, and West Bank stations as defined by the federal navigation channel boundary. The areas falling into these categories are shown in Map 6.1-47. Unlike the plan-view maps, the scatter plots do <u>not</u> include data for samples from locations that have been subsequently dredged or capped.

The following discussion of indicator chemical distributions focuses primarily on:

- A description of the data set for each analyte, including sample counts, concentration range, and frequency of detection
- A discussion of the concentration distributions in the Study Area organized by east bank, west bank, and navigation subareas. This discussion emphasizes areas of relatively high concentrations to provide a broad picture of the distribution of sediment contamination throughout the Study Area. This narrative is not intended to be comprehensive, however, and the maps, tables, and figures provide a complete picture of the Round 2 nature and extent data set.

In addition, the nature and composition of certain complex chemical groups (e.g., PCBs, DDx) are discussed to provide background on their environmental chemistry and to

provide a site-wide perspective on their distribution. Chemical distributions, particularly in relation to specific potential sources, are discussed in more detail in Section 11. Data gaps are addressed in Section 12.

Note that upland facility names used in the following sections are for geographic reference only and are not intended to imply sources.

6.1.1.1 Arsenic in Sediment

A total of 1,259 surface samples and 1,116 subsurface samples collected within the Study Area were analyzed for arsenic. Frequencies of detection were high, approximately 90 percent for surface samples and 96 percent for subsurface samples. Detected concentrations ranged from 0.7 to 132 mg/kg in surface sediment and from an estimated 0.5 to an estimated 44.5 mg/kg in subsurface sediment (Tables 6.1-1 and 6.1-2; Figures 6.1-2 and 6.1-3). Median detected concentrations were 3.79 mg/kg in surface sediment and 3.56 mg/kg in subsurface sediment.

Arsenic concentrations were relatively low (<10 mg/kg) throughout the majority of the Study Area, and lower still (<5 mg/kg) in most of the navigation channel. Clusters (i.e., more than one sample) of relatively elevated concentrations (>10 mg/kg) were identified in several areas (Figures 6.1-2 and 6.1-3). These clusters include both surface and subsurface samples unless otherwise noted. Along the eastern nearshore area these include the following:

- Between RM 8 and 9 in Swan Island Lagoon and near the Portland Shipyard slips, including the highest subsurface concentration, which was detected in the interval of 30-128 cm bml at Station C384 in the shipyard slip
- At approximately RM 8.5, along the Portland Shipyard riverfront (subsurface only)
- At approximately RM 7.3 near the McCormick & Baxter and Triangle Park facilities
- At RM 6 near the BES Water Pollution Control Lab (WPCL; surface only)
- At RM 5.5 near the former MarCom facility
- At approximately RM 4.5 in the Port of Portland Terminal 4 Slip 3
- At RM 3.7 near the head of the International Terminals Slip (subsurface only).

Clusters of relatively elevated concentrations (> 10 mg/kg) along the western nearshore zone occur in the following areas:

- Between RM 8.2 and 8.8 near the Gunderson facility
- At RM 6.9 near the railroad bridge

- Near RM 5.6 by the Advanced American Construction properties (surface only)
- At RM 3.8 near the Owens Corning facility (surface only).

The data show additional isolated instances of elevated concentrations at other locations. The highest concentration among surface sediment samples was detected at RM 2.3 near the OSM facility (Station RB08).

6.1.1.2 Mercury in Sediment

A total of 1,224 surface samples and 1,014 subsurface samples from the Study Area were analyzed for mercury. Frequencies of detection were high, approximately 91 percent in surface samples and 94 percent in subsurface samples. Detected concentrations ranged from an estimated 0.006 to 4.84 mg/kg in surface sediment and from an estimated 0.007 to 4.14 mg/kg in subsurface sediment. Corresponding detected median concentrations were 0.07 mg/kg (surface) and 0.088 mg/kg (subsurface) (Tables 6.1-1 and 6.1-2; Figures 6.1-4 and 6.1-5).

Mercury concentrations were relatively low (<0.45 mg/kg) throughout the majority of the Study Area (Maps 6.1-2a,b, Maps 6.1-25a–c). Relatively elevated concentrations (> 0.45 mg/kg) occurred at scattered locations in the eastern and western nearshore zones.

Clusters of relatively elevated concentrations (>0.45 mg/kg) along the eastern shoreline were found in the following areas (Figures 6.1-4 and 6.1-5):

- Between RM 8 and 9 in Swan Island Lagoon
- Between RM 6.4 and 6.8 near Willamette Cove (including the highest detected subsurface concentration, from the interval 153-256 cm bml at Station C295)
- Between approximately RM 5.6 and 5.8 near the former MarCom facility (including the highest detected surface concentration at Station WR-PG-27)
- Between RM 4.4 and 4.6 at the Port of Portland Terminal 4 Slip 3 area (subsurface only)
- At approximately RM 3.5 near the Time Oil facility (subsurface only).

Along the western nearshore zone, clusters of relatively elevated mercury concentrations (i.e., more than one sample >0.45 mg/kg) occurred in the following locations:

- Near the Gunderson facility between RM 8.5 and 8.8
- At RM 8.2 near the Front Avenue property (surface only)
- Near the railroad bridge at RM 6.8 (surface only)

- Between RM 6.0 and 6.2 near the U.S. Moorings and NW Natural (former Gasco) facilities (subsurface only)
- At approximately RM 4.9 near the BP West Coast Products facility.

Concentrations above 45 mg/kg were also detected at more than one location in the navigation channel at approximately RM 10.4 near the Sulzer Pump facility, and in samples upstream of the Study Area at approximately RM 11.5 near the western shoreline (Map 6.1-2a).

6.1.1.3 Zinc in Sediment

Zinc was detected in each of the 1,240 surface samples and 1,104 subsurface samples analyzed for it. Detected concentrations ranged from 17.3 to 2,010 mg/kg in surface sediment and from 24 to 1,930 mg/kg in subsurface sediment (Tables 6.1-1 and 6.1-2; Figures 6.1-6 and 6.1-7).

Zinc concentrations were typically low (<200 mg/kg) throughout the Study Area (Figures 6.1-6 and 6.1-7; Maps 6.1-3a,b and Maps 6.1-26a–c). Median concentrations in the data sets were 106 mg/kg (surface) and 101 mg/kg (subsurface).

The results of six surface samples located between RM 10.2 and 10.9, were N-qualified, indicating that the identification of the compound is not definitive. Concentrations in these six samples were relatively low, ranging from 75.5 mg/kg to 114 mg/kg.

The data show relatively elevated concentrations (>200 mg/kg) at many locations along the eastern and western nearshore zones, but few in the navigation channel (Figures 6.1-6 and 6.1-7). Where the latter elevations appear, extent is generally limited (Map 6.1-3a,b and Map 6.1-26a–c).

Prominent clusters of concentrations above 300 mg/kg occurred in several locations in the nearshore zones. Along the eastern shoreline, these areas include the following:

- Between RM 8 and 9 in Swan Island Lagoon, and near the Portland Shipyard facility riverfront shoreline (subsurface only), including the highest subsurface concentration in the Study Area, which was detected in the interval of 30-128 cm bml at Station C384
- At RM 6.8 in Willamette Cove (subsurface only)
- At RM 6 near the BES WPCL (surface only)
- At RM 5.6 near the former MarCom facility, where the highest surface concentration in the Study Area was detected at Station SED02
- Between RM 4.4 and 4.6 at the Port of Portland terminal
- Near the head of the International Terminals Slip at RM 3.7
- Between RM 2.1 and 2.3 near the OSM facility.

Prominent clusters (>300 mg/kg) along the western shoreline occur in the following areas:

- In Balch Creek Cove at RM 9.7
- Between approximately RM 8.2 and 9.2
- Near the railroad bridge at RM 6.9.

6.1.1.4 Tributyltin Ion in Sediment

Sediment samples at selected locations were analyzed for butyltins. TBT characterization in the Study Area results from 274 surface samples and 308 subsurface samples.

TBT was more commonly detected in the surface samples (95 percent frequency of detection) than in subsurface samples (59 percent frequency of detection). Detected concentrations ranged from an estimated 0.45 to 47,000 µg/kg in surface sediment and from an estimated 0.32 to 90,000 µg/kg in subsurface sediment (Tables 6.1-1 and 6.1-2; Figures 6.1-8 and 6.1-9). Median detected concentrations were 30 µg/kg in the surface data set and 25 µg/kg in the subsurface data set. The result of one surface sample, estimated at 7.6 µg/kg in sample SD066 from RM 6.4, was N-qualified.

TBT concentrations varied among locations, generally ranging up to 1,000 µg/kg or less (Maps 6.1-4a, b and Map 6-27a–c). Though relatively elevated concentrations (>1,000 µg/kg) were measured in surface samples near the Gunderson facility/Equilon dock and near the entrance to the International Terminals Slip, most of the elevated concentrations were found near RM 8: in areas surrounding Swan Island, and immediately downstream near the Triangle Park facility (Maps 6.1-4a,b and Map 6-27a–c).

6.1.1.5 PCBs in Sediment

PCB concentration data for the Study Area are available for 948 surface and 1,002 subsurface samples. Most of the PCB data are based on Aroclor analyses (Table 6.1-1 and 6.1-2). PCB congener analyses were completed on a subset of the samples analyzed for Aroclors and on two samples not analyzed for Aroclors (LW2-C019-B2 and LW2-C025-B2). Aroclor concentrations in samples analyzed for congeners ranged from <1.7 µg/kg (not detected) to 27,400 µg/kg.

This subsection summarizes the distribution of PCB Aroclor concentrations, compares the PCB Aroclor and congener concentrations, and discusses the nature of the detected PCB Aroclors and congeners across the Study Area. For the purpose of sediment characterization, total PCB Aroclor concentrations represent the sum of detected Aroclor concentrations in a sample. In cases where no Aroclors were detected, the highest detection limit is used to represent the total value. Similarly, total PCB congener values reflect only the sum of detected congeners in a sample.

6.1.1.5.1 Distribution of Total PCB Aroclor Concentrations

The distribution of maximum total PCB Aroclor concentrations at each sampling station throughout the Study Area is depicted in Maps 6.1-5a,b; concentrations with depth at subsurface stations are depicted in Maps 6-28a–c. The complete data set is plotted on scatter plots presented in Figures 6.1-10 and 6.1-11.

Aroclors were detected in 713 surface samples (approximately 75 percent) and 607 subsurface samples (approximately 60 percent); detected total PCB Aroclor concentrations ranged from an estimated 0.851 to an estimated 27,400 µg/kg in surface samples, and from 0.906 to 26,000 µg/kg in subsurface samples (Table 6.1-1 and 6.1-2). Median detected concentrations in the surface and subsurface data sets were an estimated 33.9 µg/kg and 78 µg/kg, respectively.

Detection limits ranged from 1.3 to 150,000 µg/kg, although detection limits were generally low for most samples. The distribution of detection limits is shown in Maps 6.2-5a,b.

Total PCB Aroclor concentrations varied along the Study Area. With few exceptions, concentrations were relatively low (generally less than 100 µg/kg) throughout the navigation channel, while many areas in the nearshore zones contained relatively elevated concentrations (>100 µg/kg) in both surface and subsurface samples (Figures 6.1-10 and 6.1-11). The most prominent data peaks shown in the scatter plots generally coincide with areas where concentrations over 1,000 µg/kg occurred (indicated in red on the maps). The Aroclor compositions of samples with these concentrations are discussed in Section 6.1.1.5.3 below.

Along the eastern nearshore zone concentrations over 1,000 µg/kg occurred in the following areas:

- In surface and subsurface samples between RM 8 and 9 in Swan Island Lagoon and near the Portland Shipyard
- At RM 6.8 near Willamette Cove (surface sample)
- In a subsurface samples at RM 5.6 near the former MarCom facility
- In a surface sample at RM 4 near the Schnitzer property riverfront
- In surface and subsurface samples at RM 3.7 and 4 near the Schnitzer property riverfront and Industrial Slip; this area includes the highest subsurface concentration, which was detected in the interval of 30-152 cm bml at Station C092.
- In surface and subsurface samples between RM 2 and 2.6 near the OSM facility.

Prominent peaks in the surface and subsurface data from the western nearshore zone occurred at RM 8.8 near the Gunderson facility by the Equilon dock, where the highest surface concentration in the data set was detected (Station G453). Concentrations above 1,000 µg/kg were detected in three other areas along the western bank:

- In surface samples near the upstream portion of the Gunderson facility at RM 9.1
- In a subsurface sample at RM 8.3 near the Front Avenue LLP property
- In subsurface samples at RM 7.3 near the Arkema facility.

A concentration over 1,000 µg/kg was detected in one sample from the navigation channel at RM 10.3 near the Sulzer facility.

6.1.1.5.2 Distribution of Total PCB Congener Concentrations

A total of 233 surface samples and 27 subsurface samples were analyzed for PCB congeners. Detected total congener values ranged from 0.032 to 35,400 µg/kg in surface sediment and from 13.6 to 36,800 µg/kg in subsurface sediment.

Not surprisingly, the detected total PCB concentrations based on congeners show a strong, statistically significant correlation with the total PCB concentrations based on Aroclor concentrations in both the surface (coefficient of determination, $r^2 = 0.62$) and subsurface data ($r^2 = 0.85$). Plots of the surface (n = 138) and subsurface (n =23) data for samples analyzed for both Aroclors and congeners are presented in Figure 6.1-48.

The locations of total PCB congener concentrations greater than 1,000 µg/kg generally match those of the total Aroclors in samples analyzed for both. Exceptions occur in the samples listed in the following table, which show some cases of order-of-magnitude differences between the total Aroclor and total congener results.

Location	Sample ID	River Mile	Total Aroclors (µg/kg)	Total Congeners (µg/kg)
Surface Sediment				
G390	LW2-G390	8.2	1430	725
BT016	LW2-GBT016	6.9	850	8100
G025	LW2-G025	2.4	432	9780
G019	LW2-G019	2.3	1530	849
BT002	LW2-GBT002	2.3	1130	848
02R001	LWG0102R001SDS015C00	2.4	1090	544
07R006	LWG0107R006SDS015C00	7.3	2200 U	496
Subsurface Sediment				
C382	LW2-C382-B	8.2	1340	291

6.1.1.5.3 Composition of PCB Aroclors and Congeners

Identification of PCB Aroclors at the analytical laboratory can be subjective if the PCB pattern in the sample does not closely reflect the Aroclor standards. This is frequently the case in environmental samples as a result of fate and transport processes (e.g., degradation), the presence of more than one Aroclor in a sample, and chromatographic interference. The PCB congener content of Aroclors has been reported by several authors (e.g., Erickson 1997; Frame et al. 1996) and is shown in Figure 6.1-49.

This subsection includes a general description of the distribution of PCB Aroclors and homologs in sediment to provide preliminary information that may be used to infer the presence of different sources (Maps 6.1-48a–i, 6.1-49a–i, 6.1-50a–i, and 6.1-51a–i). Aroclor distributions are compared to homolog distributions to evaluate the Aroclor identifications made by the laboratories. PCB homologs are congeners grouped according to chlorination level, i.e., the number of chlorine atoms (1-10) bonded to the biphenyl molecule. All of the PCB congeners in each homolog group are isomers. Homolog groups are labeled monochlorobiphenyl (1 chlorine atom [C12H9Cl]; monoCB) through decachlorobiphenyl (10 chlorine atoms [C12Cl10]; decaCB). A comparison of Aroclor and homolog composition in the surface samples is provided for areas with total PCB Aroclor concentrations above 1,000 µg/kg and for any unusual Aroclor identifications. Subsurface Aroclor versus homolog patterns are discussed only for the depth interval with the highest PCB concentration at each location. The PCB composition at other depths may differ from that at the depth of maximum concentration.

Aroclors 1248, 1254, and 1260 were identified throughout the Study Area, while Aroclors 1221, 1242, and 1268 were identified locally but were not widespread (Maps 6.1-48a–i, 6.1-49a–i). Aroclors 1232 and 1016 were each identified at only one location and Aroclor 1262 was not identified in any sample. The relative abundance of Aroclors 1248, 1254, and 1260 varied from area to area, reflecting differences in the dominant sources of the PCBs and weathering processes.

PCB Composition in Areas with Total Aroclor Concentrations Above 1,000 µg/kg
Total PCB Aroclor concentrations exceeded 1,000 µg/kg in six areas in the eastern nearshore zone, as discussed above. Aroclors 1248, 1254, and 1260 were the dominant Aroclors in five of these areas and Aroclor 1242 was additionally identified in one area. The relative concentrations of these Aroclors varied in the different areas, apparently reflecting contributions from different PCB sources. The Aroclor identifications were as follows (Maps 6.1-48a–i, 6.1-49a–i):

- Aroclors 1254 and 1260 dominated the surface and subsurface Aroclor composition in Swan Island Lagoon (RM 8 to 9), with lower concentrations of Aroclor 1248 at several locations.
- PCBs in surface sediment from Willamette Cove at RM 6.8 were predominantly Aroclor 1260, with lower concentrations of Aroclors 1248 and 1254.
- Aroclor 1254 was the most abundant of four Aroclors found in subsurface sediment at RM 5.6 near the former MarCom facility. This area was notable for the presence of Aroclor 1268, as described below.
- Aroclor 1242 was reported in high relative abundance near RM 4, with additional contributions by Aroclors 1254 and 1260.
- Aroclor 1254 was the most abundant Aroclor in surface and subsurface sediment at the head of the International Terminals Slip. Aroclors 1260 and 1248 were also reported in this area.

- In surface sediment from the eastern nearshore zone of RM 2-2.5, Aroclor 1248 was most abundant, with lower relative abundance of Aroclor 1260 at most sampling locations. Aroclor 1254 was also identified at several locations within this reach at lower relative abundance than Aroclor 1248.

Aroclor identities also varied along the western side of the river, reflecting different sources as on the east side of the river. Total Aroclor concentrations exceeded 1,000 µg/kg at RM 10.3 on the western margin of the navigation channel and in four areas of the western nearshore zone (Map 6.1-5a,b) as described in the previous section. Aroclor identifications in these areas were as follows:

- Aroclor 1254 was present in highest abundance in subsurface sediment at RM 10.3, with lower abundance of Aroclor 1260. PCB concentrations were below 1,000 µg/kg in surface sediment, with Aroclors 1254 and 1260 reported in varying proportions.
- Aroclors 1248, 1254, and 1260 were reported in varying proportions in surface sediment near RM 9.1. Total PCBs in subsurface sediment were below 1,000 µg/kg and were dominated by Aroclor 1248.
- Aroclors 1242 and 1248 dominated the PCBs in surface and subsurface sediment near RM 8.8. These Aroclors appear similar on a gas chromatogram and can be difficult to differentiate at the laboratory. PCBs at this location are described further below.
- Aroclor 1242 was most abundant in subsurface sediment at RM 8.3. Lower concentrations of Aroclors 1254 and 1260 were also reported.
- Aroclors 1248 and 1254 were most abundant in subsurface sediment near RM 7.3, with a lower concentration of Aroclor 1260.

The relative abundance of PCB homologs in the 10 areas with total Aroclor concentrations above 1,000 µg/kg was generally consistent with the Aroclors identified by the laboratories, with one exception described below. PentaCBs are abundant in Aroclor 1254, and hexa- and heptaCBs are abundant in Aroclor 1260 (Figure 6.1-49). As expected, these homologs were present in areas where Aroclors 1254 and 1260 were reported. TetraCBs, the dominant components of Aroclor 1248, were more abundant when Aroclor 1248 was reported, notably in the eastern nearshore zone near RM 2-2.5. TriCBs, the dominant components of Aroclor 1242, were consistent with reporting of Aroclor 1242 (e.g., in the eastern nearshore zone near RM 4 and in the western nearshore zone near RM 8.3).

Both Aroclors 1242 and 1248 were reported in the western nearshore zone near RM 8.8. Aroclors 1242 and 1248 are generally difficult to differentiate on a gas chromatogram and the identification of PCB congeners, the individual components of PCB homologs, is more definitive. The PCB homolog distribution in the western nearshore zone near RM 8.8 supports the identification of Aroclor 1242, although it does not definitively rule out the additional presence of Aroclor 1248 (Map 6.1-48d and 6.1-49d). TriCBs

were notably abundant in the sediment, often in a pattern that resembled Aroclor 1242 more than Aroclor 1248. The presence of diCBs further supports the identification of Aroclor 1242. Consequently, the two Aroclors reported are likely to reflect the difficulty of Aroclor identification rather than a difference in the PCBs represented in the samples.

PCB Composition in Areas with Infrequently Reported Aroclors

Aroclor identifications were evaluated using PCB homolog data for Aroclors not commonly reported for the Study Area (i.e., detections of Aroclors other than 1242, 1248, 1254, and 1260). These are described in the following paragraphs.

Aroclor 1221 was reported in surface sediment in the eastern nearshore zone between RM 9.3 and RM 10 at concentrations up to 109 µg/kg (location G472; Table C2-2). However, the PCB homolog pattern is not consistent with Aroclor 1221 in the two samples from this area that were analyzed for PCB congeners. MonoCBs and diCBs are the dominant homologs in Aroclor 1221 (Erickson 1997; Figure 6.1-49), but tetra- through heptaCBs dominated the homolog profiles in this area. The same homolog profile was also present at adjacent location BT031, which was sampled at a later date and analyzed by a different lab, and for which Aroclor 1221 was not identified. Based on the PCB homolog patterns, the identification of Aroclor 1221 in this area appears questionable. Aroclor 1221 is rarely reported in environmental samples.

Aroclor 1221 was also identified in surface sediment at four isolated locations: in the eastern nearshore zone near RM 11, in the western nearshore zone near RM 10.3 and at RM 7, and in the navigation channel near RM 8. PCB congeners were analyzed at all of these stations, and in all four cases, mono- and diCBs were not reported at sufficient levels to support the identification of Aroclor 1221. A focused review of PCB chromatograms for the areas with Aroclor 1221 identifications may provide additional insight into the discrepancy with the PCB homolog profile.

Aroclor 1268 was reported in surface and subsurface sediment in the eastern nearshore zone near RM 5.5 at concentrations up to 474 µg/kg (Maps 6.1-48a–i, 6.1-49a–i). PCB congener profiles generally confirm the presence of Aroclor 1268. NonaCBs and decaCB are present in Aroclor 1268 (Figure 6.1-49) and were more abundant in both surface sediment locations and in one of the two subsurface sediment locations analyzed in this area than in areas without Aroclor 1268 detections.

Aroclor 1268 was also identified in isolated locations in several other areas. Aroclor 1268 identifications were confirmed by the PCB homolog profile in surface sediment in the eastern nearshore zone at RM 3.7, off the mouth of the International Terminals Slip. PCB homolog profiles did not confirm the presence of Aroclor 1268 reported in surface and subsurface samples in the eastern nearshore zone near RM 4. Aroclor 1268 could not be evaluated at other locations because either no PCB homolog data were available, or Aroclor 1268 constituted a relatively small fraction of the Aroclor total.

Highly chlorinated PCBs are present in the International Terminals Slip, although Aroclor 1268 was not identified. At one subsurface location in the International Terminals Slip (i.e, location C093-B), nonaCBs and decaCBs together accounted for approximately 25 percent of the PCB congener total.

Aroclors 1232 and 1016 were each identified in only one sample. Aroclor 1232 was identified in subsurface sediment at location PSY36C (243-365 cm) in the navigation channel near RM 8, and Aroclor 1016 was identified in surface sediment sample PP01M105 near the east bank of Swan Island Lagoon at approximately RM 5. The unique Aroclor constituted a small fraction of the total PCB Aroclors at both locations. PCB homolog data are not available at either location to corroborate the identification. The identity of these Aroclors is questionable and should be verified. The use of detection limits for these Aroclors and Aroclor 1221 in risk assessment may not be warranted.

6.1.1.6 Total Dioxin/Furan Toxicity (2,3,7,8-TCDD TEQ) in Sediment

Dioxin/furan toxicity with respect to 2,3,7,8- TCDD was calculated from concentrations of dioxin/furan congeners designated by the World Health Organization as similar in mechanism of toxicity to 2,3,7,8-TCDD (WHO 1997). Each WHO-designated congener is assigned a specific TEF indicating its degree of toxicity compared to 2,3,7,8-TCDD, which is given a reference value of 1. This section describes the distribution of TEQ concentrations in the Study Area, and discusses observed trends in the relative abundance of dioxin/furan homologs in surface and subsurface samples.

6.1.1.6.1 Dioxin/Furan TEQ Distribution

A total of 155 surface samples and 182 subsurface samples were selected for analysis of dioxins and furans. Frequencies of detection were high, 100 percent for surface samples and approximately 92 percent for subsurface samples. The resulting calculated TEQs show a wide range of values, ranging from an estimated 0.00803 pg/g to an estimated 16,600 pg/g in surface sediment, and from 0.0002 pg/g to an estimated 9,680 pg/g in subsurface sediment (Tables 6.1-1 and 6.1-2; Figures 6.1-14a,b and 6.1-15a,b).

The data show that dioxin/furan TEQ values vary spatially along the length of the Study Area (Maps 6.1-14a,b and 6.1-15a,b). In general, values were higher in the western nearshore zone than in the eastern nearshore and navigation channel zones. The most significant peak in the data in the western nearshore occurred between approximately RM 6.4 and 7.5, where data points are relatively dense and samples with concentrations above 10 pg/g, shown in red on the maps, were abundant in both the surface and subsurface. Other areas along the western nearshore zone where concentrations exceeded 10.0 pg/g include the following:

- In Balch Creek Cove at RM 9.7 (surface only)
- Near the Gunderson facility at RM 8.8
- Near the Front Avenue LLP property at RM 8.3 (subsurface only)

- Near the Hendren Tow Boat dock at RM 5.8 (subsurface only)
- Near the Linnton Plywood Association facility, between RM 4.5 and 4.6 (subsurface only).

Concentrations >10 pg/g occur in six isolated areas along the eastern nearshore zone:

- In Swan Island Lagoon near RM 9.1 (surface only)
- In surface samples near the McCormick & Baxter facility between RM 6.9 and 7.2, including several that have been subsequently capped (Map 6.1-7a)
- In Willamette Cove (surface only)
- At RM 5.5 near the former MarCom facility (surface only)
- In Terminal 4, Slip 3 at RM 4.3 (surface only)
- In the International Terminals Slip at RM 3.7 (surface only).

Limited dioxin/furan data are available for sediments in the navigation channel (Maps 6.1-7a,b and 6.1-30a–c). Dioxin/furan TEQ concentrations within the channel are relatively low; concentrations over 10 pg/g were reported only at one subsurface station near the western channel boundary at RM 6.6 near the Siltronic facility (Figure 6.1-15).

6.1.1.6.2 Dioxin/Furan Homolog Distribution

The distribution of detected homologs at each location is presented in Maps 6.1-52a–i for surface sediments and in Maps 6.1-53a–i for subsurface sediments. Octachlorodibenzo-p-dioxin (OCDD) is consistently the dominant homolog (>50 percent of the total concentration) present in surface and subsurface sediments throughout the Study Area, with heptachlorodibenzo-p-dioxins (HPCDD) present to a significant but lesser degree, reflecting dioxin/furan contributions from similar sources (Maps 6.1-52a–i and 6.1-53a–i). Exceptions where dioxin/furan homolog distributions vary significantly (reflecting isolated areas of various sources) are clustered throughout the Study Area, with the largest cluster occurring along the western nearshore area between RM 6.8 and 7.4.

In general, the surface and subsurface homolog distributions do not vary greatly for any given location, with some distribution differences likely attributable to natural biodegradation of the homologs present (i.e., biodegradation of OCDD to HPCDD), as seen at several locations where surface sediments contain larger fractions of OCDD but subsurface sediment contains larger fractions of HPCDD at depth (e.g., near the Portland General Electric facility at RM 3.4, the Hendren Tow Boat dock near RM 6, and the Tanker Basin facility at RM 8).

6.1.1.7 Dioxin-like PCB Congener TEQs in Sediment

Toxic equivalent concentrations were calculated for PCB congeners designated by the World Health Organization as similar in mechanism of toxicity to 2,3,7,8-TCDD (WHO 1997). Each WHO-designated dioxin-like PCB congener is attributed a specific TEQ factor indicating its degree of toxicity compared to 2,3,7,8-TCDD, which is given a

reference value of 1. This subsection describes the distribution of PCB TEQ concentrations in Study Area sediment.

PCB TEQ concentrations were calculated for 155 surface samples and 27 subsurface samples. Resulting concentrations range from an estimated 0.0133 to 324 pg/g in surface sediment, and from 0.117 to 318 pg/g in subsurface sediment (Tables 6.1-1 and 6.1-2). Median detected concentrations are 1.45 pg/g for the surface data and an estimated 7.43 pg/g for the subsurface data. The distributions of surface and subsurface concentrations are shown in Figures 6.1-16 and 6.1-17.

The PCB TEQ values also vary spatially along the length of the Study Area; this is particularly apparent in the surface sediment data, as the subsurface data are less abundant.

Concentrations above 10 pg/g were identified in the following five areas along the eastern nearshore:

- Between RM 8 and 9 in Swan Island Lagoon and near the Portland Shipyard docks
- In Willamette Cove at RM 6.9 (surface only)
- Near the former MarCom facility at RM 5.6 (subsurface only)
- At the head of the International Terminals Slip at RM 3.7 (surface only; the subsurface sample LW2-C093-B has been dredged)
- Near the OSM facility between RM 2.1 and 2.4.

Concentrations exceeding 10 pg/g were identified in the following areas along the western nearshore:

- At RM 9.7 (previous subsurface sediment, subsequently dredged)
- Between RM 9.1 and 9.2 near the Gunderson facility
- At RM 8.8 near the Equilon dock and Gunderson facility (includes the highest surface and subsurface concentrations in the data set)
- At RM 8.3 near the Front Avenue LLP property (subsurface only)
- At RM 7.7 near the Willbridge facility (subsurface only)
- Between RM 7.3 and 7.4 near the Arkema facility.

6.1.1.8 2,4' and 4,4' DDx in Sediment

The distribution of total DDx total concentrations (i.e., the 2,4'- (o,p-) and 4,4'- (p,p-) isomers of DDT and its primary breakdown products, DDD and DDE) in Study Area sediment are summarized in this section.

6.1.1.8.1 Distribution of Total DDx Concentrations

The results of the 850 surface samples and 848 subsurface samples that were analyzed for both the 2,4'- and 4,4' isomers of the DDx compounds are depicted in Maps 6.1-9a, b and 6.1-32a–c. Detected concentrations ranged from an estimated 0.051 µg/kg to an estimated 16,200 µg/kg in surface sediment and from an estimated 0.07 µg/kg to an estimated 95,400 µg/kg in subsurface sediment (Tables 6.1-1 and 6.1-2; Figures 6.1-18 through 6.1-25). Median detected concentrations for the Study Area data sets were relatively low: an estimated 7.93 µg/kg in surface sediment and an estimated 14 µg/kg in and subsurface sediment.

The individual total DDT, DDD, and DDE concentrations (totals of the 2,4'- and 4,4'-isomers) are depicted in Maps 6.1-10a,b through 6.1-12a,b and Maps 6.1-33a–c through 6.1-35a–c.

Some of the results of the component isomers that were summed in the total concentrations were N-qualified. The N qualifiers were not propagated to the total DDx value during summing. Percentages range from zero (2,4' DDE) to approximately 30 percent (2,4' DDD) of both the surface and subsurface data. N-qualified concentrations ranged from 0.051 to 12,000 µg/kg in surface sediment and from 0.054 to 51,800 µg/kg in subsurface sediment.

Areas of relatively elevated total DDx concentrations (>100 µg/kg) occur at several locations scattered along the nearshore zones and channel margins. The most prominent area of elevated concentrations occurs between RM 6 and 7.5. Concentrations above 10,000 µg/kg (shown in red on the maps) occur only in surface and subsurface samples near the Arkema facility at RM 7.5, and an area of relatively elevated concentrations extends downstream along this side of the river to approximately RM 6 (Maps 6.1-10a,b and 6.1-32a–c).

The DDD, DDE, and DDT components show generally similar patterns of distribution, though relative abundances vary (Maps 6.1-10a,b through 6.1-12a,b and Maps 6.1-33a–c through 6.1-35a–c).

6.1.1.8.2 DDx Composition

A summary of trends observed in the distribution of DDx isomers is presented in this subsection. In addition to discussing the composition of DDx at the location of the highest concentrations (>10,000 µg/kg), observations of general trends in composition of the surface and subsurface maximum concentrations are presented. Pie charts illustrating the relative abundance of detected isomers in samples containing the maximum concentration per station are presented in Maps 6.1-54a–i and 6.1-55a–i. Unlike the plan-view concentration maps and core plot maps presented in the subsection above, the pie charts in Maps 6.1-54a–i and 6.1-55a–i include samples that may lack results for the 2,4' isomers of a DDx compound (see Tables C2-6 and C2-17 in Appendix C). The discussion of subsurface sediment trends is based on the evaluation of DDx patterns only for the depth interval with the highest concentration at each

location, presented in Maps 6.1-55a–i. The DDx composition at other depths may differ from that at the depth of maximum concentration.

Total DDx concentrations exceeded 10,000 µg/kg in only one area near RM 7 in the western nearshore zone, as noted above. In this area, the 4,4' isomer of DDT dominated in the surface sediment, while DDT and DDD dominated in the subsurface sediments. This pattern may indicate degradation of DDT to DDD in deep anoxic sediments. The magnitude of concentrations in this particular area compared to the rest of the Study Area likely indicates dominance of DDx contributions from sources in this area.

The relative abundance of the DDx isomers appears highly variable from station to station across the rest of the Study Area in both surface and subsurface sediment samples. However, a few general trends were observed:

- The 4,4' isomers were more abundant than the 2,4' isomers of the DDx constituents.
- At several points throughout the Study Area, samples with a relative abundance of DDT tended to represent localized relatively high concentrations, but this DDT dominance was typically of limited areal extent.
- Overall, samples with the highest concentrations tended to display a dominance of DDT and/or DDD isomers, particularly below RM 8.
- Between RM 8 and 11, surface and subsurface samples were generally dominated by DDE and/or DDD, particularly between RM 8.5 and 9 in the western nearshore near the Gunderson facility and Equilon dock. Samples with an abundance of DDE isomers more commonly occurred between RM 8 and 11, or in samples of relatively low concentrations at points farther downstream. An exception to this trend occurs in the surface sediment near the railroad bridge crossing at RM 6.9, where a localized high concentration was dominated by DDE.

6.1.1.9 Aldrin in Sediment

Aldrin analyses were conducted for 880 surface samples and 770 subsurface samples in the Study Area. Detected concentrations ranged from an estimated 0.00333 µg/kg to an estimated 691 µg/kg in surface sediment and from an estimated 0.119 µg/kg to an estimated 1,340 µg/kg in subsurface sediment (Tables 6.1-1 and 6.1-2; Figures 6.1-26 and 6.1-27). Median detected concentrations were an estimated 0.574 (N) µg/kg in surface sediment and an estimated 1.38 (N) µg/kg in subsurface sediment. Frequencies of detection were relatively low: 24 percent for surface samples and 12 percent for subsurface samples. These low frequencies were due in part to elevated reporting limits for some samples, which ranged up to 99 µg/kg in surface samples and up to 3,800 µg/kg in subsurface samples. The distribution of detection limit values is shown on Map 6.1-13a,b.

Detected aldrin concentrations in about 5 percent of samples from the Study Area are "N"-qualified, indicating that the identification of the compound is not definitive. Forty-eight surface samples were N-qualified, with estimated concentrations ranging from 0.115 to 25.9 µg/kg, and 38 subsurface samples were N-qualified, with estimated concentrations ranging from 0.13 to 92.7 µg/kg.

Detected concentrations were generally less than 1 µg/kg, though higher concentrations occurred at several locations scattered along the nearshore zones and navigation channel (Figures 6.1-26 and 6.1-27). Samples with detected concentrations over1 µg/kg, shown in red on the maps, represent 36 percent of the surface data and 57 percent of the subsurface data. As with DDx, the most prominent area of detected aldrin concentrations is near the Arkema facility near RM 7.5, where the maximum surface (G355) and subsurface (C356, 136-256 cmbml) concentrations were detected. Elevated concentrations (>1 µg/kg) extend downstream along the western shoreline to approximately RM 6.7 (Maps 6.1-13a, b and 6.1-36a–c).

Two other prominent peaks are shown by the data, one indicated by concentrations exceeding 100 µg/kg in surface and subsurface samples at RM 8.8 near the Gunderson facility and Equilon dock, the other indicated by concentrations approaching 100 µg/kg in the subsurface at approximately RM 6.3 near the Gasco facility (Figures 6.1-26 and 6.1-27). Some of these data are N-qualified.

6.1.1.10 Beta-Hexachlorocyclohexane in Sediment

A total of 917 surface samples and 782 subsurface samples in the Study Area were analyzed for beta-hexachlorocyclohexane (beta-HCH). Detected concentrations ranged from an estimated 0.00138 µg/kg to an estimated 20.3 µg/kg in surface sediment and from an estimated 0.057 µg/kg to an estimated 318 µg/kg (N) in subsurface sediment (Tables 6.1-1 and 6.1-2; Figures 6.1-28 and 6.1-29). Median detected concentrations in the data sets were an estimated 1.91 (N) µg/kg for the surface samples and an estimated 2.59 µg/kg for the subsurface samples.

Many of the detected beta-HCH results are N-qualified, including the maximum concentration reported in the subsurface data set as noted above. In all, 207 surface samples (approximately 23 percent) and 232 subsurface samples (approximately 30 percent) were N-qualified, with estimated concentrations ranging from 0.262 µg/kg to 12.4 µg/kg in the surface, and from 0.205 µg/kg to 318 µg/kg in the subsurface.

Frequencies of detection for beta-HCH were relatively low, 45 percent for surface samples and 43 percent for subsurface samples, due in part to somewhat elevated detection limits that, as with aldrin results, ranged up to 99 µg/kg in the surface data and up to 3,800 µg/kg in the subsurface data. The distribution of detection limit values is shown on Maps 6.1-14a,b.

Detected beta-HCH concentrations were variable, but generally below 10 µg/kg throughout most of the Study Area (Figures 6.1-28 and 6.1-29; Maps 6.1-14a,b and 6.1-

37a–c). Concentrations in the subsurface were largely below detection limits in the navigation channel upstream of RM 9 and downstream of RM 5.

Detected concentrations above 10 µg/kg, shown in red on the maps, represent approximately 2 percent of the current surface data and 7 percent of the current subsurface data (Maps 6.1-14a,b and 6.1-37a–c). Concentrations of this magnitude were detected in several areas, but the largest area again appears to occur along the western nearshore zone between RM 7.5 and approximately RM 6. The highest detected concentrations occurred in this area. The highest among the surface data occurred at Station G274 (at RM 6.2 near the Gasco facility), and the highest among the subsurface data occurred in the 198-299 cm bml interval at Station C302 (at RM 6.4 near the Siltronic facility).

6.1.1.11 Total Chlordanes in Sediment

Total chlordane values consist of the summed results of cis-chlordane, trans-chlordane, oxychlordane, cis-nonachlor, and trans-nonachlor constituents available for a sample.

The data set for Study Area sediment includes results from 810 surface samples and 682 subsurface samples. Detected total concentrations ranged from an estimated 0.0349 µg/kg to an estimated 669 µg/kg in surface sediment and from an estimated 0.038 to an estimated 2,330 µg/kg in subsurface sediment (Tables 6.1-1 and 6.1-2). The maximum surface concentration was detected at Station G355 at RM 7.3 (Figure 6.1-30), and the maximum detected subsurface concentration occurred in the interval of 30-152 cm bml at Station C455 at RM 8.8 (Figure 6.1-31). Median detected concentrations in the data sets were an estimated 0.991 µg/kg for surface samples and an estimated 1.94 µg/kg for subsurface samples.

Chlordanes were detected in 68 percent of the surface samples and 61 percent of the subsurface samples, in part attributable to somewhat elevated detection limits for some samples (Map 6.1-15a,b). Detection limits ranged up to 230 µg/kg in the surface data and 56 µg/kg in the subsurface data. Some of the results for the component chlordane compounds were N-qualified.

Overall, detected concentrations were below 5 µg/kg throughout most of the Study Area and, with few exceptions, were generally lower along the navigation channel (Figures 6.1-30 and 6.1-31). As with the other indicator pesticide compounds detected in sediment, relatively elevated concentrations (>5 µg/kg) were detected at several locations throughout the Study Area, but occurred most extensively along the western nearshore zone between approximately RM 7.4 and RM 6.

Except for an isolated detection at approximately RM 11.5, peaks in the navigation channel were typically located near elevated concentrations in the nearshore.

6.1.1.12 Total Polycyclic Aromatic Hydrocarbons in Sediment

The distribution and composition of total PAH concentrations in Study Area sediment is summarized in this subsection.

6.1.1.12.1 Total PAH Distribution

The data set of total PAH concentrations in Study Area sediment includes analysis of 1,329 surface samples and 1,090 subsurface samples. Frequencies of detection of PAH compounds were high, approximately 99 percent in surface samples and 96 percent in subsurface samples. The concentration range varies widely, from an estimated 3.3 µg/kg to 7,260,000 µg/kg in surface sediment, and from an estimated 0.15 to 53,300,000 µg/kg in subsurface sediment. Median detected concentrations were an estimated 1,324 µg/kg in the surface data set and 1,450 µg/kg in the subsurface data set.

The data, particularly above RM 6.5 where samples are more abundant, show variable concentrations throughout the Study Area. Except for limited areas of relatively higher concentrations, total PAH levels were generally 1,000 µg/kg or less in channel and nearshore zones of the main stem of the river (i.e., outside Swan Island Lagoon) in the upper portion of the Study Area between RM 7 and 11(Maps 6.1-16a,b).

Scattered areas of relatively elevated concentrations (i.e., >1,000 µg/kg) were found throughout the Study Area, but the highest concentrations (>30,000 µg/kg) were most commonly found in the eastern and western nearshore zones between approximately RM 3 and 7.5, particularly in Terminal 4, Slip 3 on the east side of the river, and along the western nearshore zone between RM 5.2 and 6.6, where concentrations exceeding 30,000 µg/kg were frequently detected in surface and subsurface samples. The western nearshore area included the highest subsurface concentration in the data set, which was detected in the sample from 198-288 cm bml at Station C302 near the downstream property line of the Siltronic facility, as well as samples from locations that have been subsequently capped near the Gasco facility. PAH concentrations above 30,000 µg/kg were found in surface and subsurface sediment in the navigation channel adjacent to and downstream from this area, including the highest surface concentration in the data set, which was detected at Station G225 offshore of the General Construction property at RM 5.7.

Concentrations exceeding 30,000 µg/kg were also detected at one subsurface sample location along the eastern shore of the river upstream of the Study Area, at approximately RM 11.5, but this location has since been dredged (Maps 6.1-16a,b and 6.1-39a–c).

6.1.1.12.2 PAH Composition

The relative proportions of individual PAHs in surface and subsurface sediment varied widely within the Study Area, reflecting PAH contributions from multiple current and historical sources and degradation. The distribution of detected PAHs at each location is presented in Maps 6.1-56a–i (surface sediment) and 6.1-57a–i (subsurface sediment). In order to simplify the pie charts in these maps, PAHs were grouped according to the number of fused aromatic rings in the PAH. A list of individual PAHs included in the sum for each of these groups is provided in Table 6.1-11. Only PAHs analyzed for LWG samples are included in Table 6.1-11. Of these PAHs, two-ring PAHs include only naphthalenes (i.e., naphthalene and 2-methylnaphthalene). LPAHs include PAHs with two or three rings (orange and yellow segments), and HPAHs include PAHs with

four to six rings (green, blue, and purple segments). Only the depth interval that contained the highest total PAH concentration is shown in Maps 6.1-57a–i (i.e., the subsurface maps represent a variety of depths based on the interval of the maximum concentration) and evaluated below.

PAHs were present at concentrations above 30,000 µg/kg in many nearshore areas and one area in the navigation channel, as described in the previous section. The PAH composition was evaluated for nine areas where high PAH concentrations were reported at multiple sampling locations for surface or subsurface sediment, or both. In the eastern nearshore zone, these areas included surface and subsurface sediment in Willamette Cove (RM 6.9), subsurface sediment near the former MarCom facility at RM 5.5 to 5.6, surface and subsurface sediment in Terminal 4, Slip 3 (RM 4.5), and surface sediment in Terminal 4, Slip 1 (RM 4.3).

In Willamette Cove, locations with high PAH concentrations (maximum of 59,300 µg/kg excluding capped surface sediment, location C293-B2) were dominated by LPAHs, with secondary abundance of the four-ring HPAHs. Subsurface sediment contained naphthalenes (i.e., two-ring LPAHs) in addition to this pattern. A higher relative abundance of four-, five-, and six-ring PAHs was present at locations with lower PAH concentrations.

PAHs in subsurface sediment near RM 5.5 to 5.6 contained predominantly the three-ring LPAHs and four-ring HPAHs in samples with the highest PAH concentrations. In contrast, PAHs in Slips 1 and 3 at Terminal 4 were dominated by HPAHs, with the four-ring PAHs present in greatest abundance and additional contributions by five- and six-ring PAHs. LPAHs, mostly three-ring PAHs, constituted only a minor component of the total PAH content in surface and subsurface sediment at most Slip 3 locations and in surface sediment in Slip 1.

In the western nearshore zone, total PAH levels above 30,000 µg/kg were reported at multiple sampling locations near the Arkema facility at RM 7.3, near the railroad bridge at RM 6.8, and between RM 5.4 and 6.6.

Near RM 7.3, high PAH concentrations were found in surface and subsurface sediment samples at two locations each. The four- and five-ring HPAHs were most abundant in both surface and subsurface sediment. Three-ring PAHs were more abundant in subsurface sediment than surface sediment.

Near RM 6.8, the three-ring LPAHs dominated the PAH profile at three of the four locations with the highest PAH concentrations, including two surface and one subsurface sediment locations. At the location with the highest total PAH concentration, however, the four-ring HPAHs dominated the PAH profile, implying a different source of PAHs at this location.

As mentioned above, the highest PAH concentrations in the Study Area were found in the western nearshore zone and the adjacent edge of the navigation channel between

RM 5.4 and RM 6.6 (Tables 6.1-1 and 6.1-2). Three-ring LPAHs and four-ring HPAHs dominated the samples with the highest concentrations in this area. Naphthalenes were also present in some locations, particularly in subsurface sediment. Samples in adjacent areas with relatively lower concentrations of total PAHs contained a greater relative abundance of five- and six-ring HPAHs and a lower abundance of three-ring LPAHs (e.g., near RM 5.9 and RM 6.8).

Preliminary background concentrations for total PAHs are 88 µg/kg (calculated assuming nondetected values equal zero; Table 6.1-15) and 128 µg/kg (calculated using detection limits at half the reported value). In areas with total PAH concentrations below 100 µg/kg in surface sediment (i.e., concentrations similar to preliminary background levels), PAHs were generally dominated by 4-ring PAHs, with secondary abundance of 5-ring PAHs and lower proportions of 6-ring PAHs and LPAHs. However, differences in PAH composition were evident even among these low PAH concentrations.

6.1.1.13 Total HPAHs in Sediment

HPAH compounds were detected in 1,309 (approximately 99 percent) of surface samples and 1,030 (95 percent) of subsurface samples. The distributions of HPAH concentrations in the Study Area are similar to those of the total PAH concentrations, as shown in Figures 6.1-34 and 6.1-35, and Maps 6.1-17a,b and 6.1-40a–c. As with total PAHs, detected total HPAH concentrations ranged widely, from an estimated 2.16 to 4,350,000 µg/kg in surface sediment and from an estimated 0.15 to 13,400,000 µg/kg in subsurface sediment, but median concentrations were relatively low: 1,080 µg/kg in the surface data and 1,110 µg/kg in the subsurface data. As with total PAHs, the highest HPAH concentrations were detected in surface sample G225 and the subsurface sample from 198-288 cm bml at Station C302.

6.1.1.14 Phenanthrene in Sediment

Phenanthrene was detected in 1,257 (approximately 95 percent) of the surface samples analyzed for PAHs, and 967 (approximately 89 percent) of the subsurface samples analyzed. Detected concentrations ranged from an estimated 0.53 to 1,700,000 µg/kg in surface sediment and from an estimated 0.24 to 8,500,000 µg/kg in subsurface sediment; median detected concentrations were 102 µg/kg and 170 µg/kg, respectively (Tables 6.1-1 and 6.1-2; Figures 6.1-36 and 6.1-37).

The pattern of distribution of phenanthrene in the Study Area is similar to that shown by the total PAH and HPAH concentrations (Figures 6.1-36 and 6.1-37). Except for limited areas of relatively higher concentrations, phenanthrene levels were generally 100 µg/kg or less in channel and nearshore zones of the main stem of the river (i.e., outside Swan Island Lagoon) in the upper portion of the Study Area between RM 7 and 11 (Figures 6.1-36 and 6.1-37). Overall, both surface and subsurface concentrations were relatively lower in the navigation channel than in the nearshore zones, except for the reach between approximately RM 5 and 6.6 near the Siltronic and Gasco facilities (Figures 6.1-36 and 6.1-37). As with total PAHs, the highest concentrations (>5,000

µg/kg, shown in red on the maps) occurred most often in the eastern and western nearshore zones between approximately RM 3 and 7.5. An area of concentrations exceeding 100,000 µg/kg occurred along the western nearshore zone between approximately RM 5.5 and 6.8. The highest surface concentration of phenanthrene in the Study Area occurred at RM 5.7 at Station G225 in the navigation channel offshore of the General Construction property, and the highest subsurface concentration occurred at RM 6.4 in the interval of 198-288 cm bml at Station C302 located near the downstream property line of the Siltronic facility.

Phenanthrene concentrations above 5,000 µg/kg were also detected at one subsurface sample location along the eastern shore of the river upstream of the Study Area, at approximately RM 11.5, but this location has since been dredged (Maps 6.1-18a,b and 6.1-41a–c).

6.1.1.15 Benzo(a)anthracene in Sediment

Benzo(a)anthracene (BAA) was detected in 1,261 (approximately 95 percent) of the surface samples analyzed for PAHs, and 968 (approximately 89 percent) of the subsurface samples analyzed. The data show a wide range of detected concentrations, from an estimated 0.5 to 320,000 µg/kg in surface sediment and from an estimated 0.17 to 760,000 µg/kg in subsurface sediment (Tables 6.1-1 and 6.1-2; Figures 6.1-38 and 6.1-39). Median detected values in the data sets were 87 µg/kg for surface sediment and 97 µg/kg for subsurface sediment.

The distribution of BAA in the Study Area resembles that of the other PAH results discussed above (Figures 6.1-38 and 6.1-39; Maps 6.1-19a,b and 6.1-42a–c).

6.1.1.16 Benzo(a)pyrene in Sediment

The results and distribution of benzo(a)pyrene (BAP) in Study Area sediment are similar to those of BAA (Figures 6.1-40 and 6.1-41; Maps 6.1-20a,b and 6.1-43a–c). BAP was detected in 1,257 surface samples (frequency of detection approximately 95 percent) and 951 subsurface samples (frequency of detection approximately 87 percent). Detected concentrations range up to 340,000 µg/kg in surface sediment and 940,000 µg/kg in subsurface sediment (Tables 6.1-1 and 6.1-2; Figures 6.1-40 and 6.1-41). Median detected concentrations were 109 µg/kg in the surface data set and 120 µg/kg in the subsurface data set.

6.1.1.17 Bis(2-ethylhexyl)phthalate in Sediment

The data set for BEHP in the Study Area includes results from 1,224 surface samples and 1,067 subsurface samples. BEHP was detected in 59 percent of surface samples and approximately 35 percent of subsurface samples. The relatively low frequencies of detection are representative of actual site concentrations, since elevated detection limits (e.g., >1,000 µg/kg) were reported for less than 2 percent of the samples (Maps 6.1-21a,b).

Detected concentrations ranged from an estimated 7 to an estimated 440,000 µg/kg in surface sediment, and from an estimated 2.4 to 18,000 µg/kg in subsurface sediment,

with median detected values of 160 µg/kg (surface) and 98 µg/kg (subsurface) (Tables 6.1-1 and 6.1-2; Figures 6.1-42 and 6.1-43).

Concentrations of BEHP were relatively low (≤1,500 µg/kg) in the majority of samples analyzed (Maps 6.1-21a,b and Map 6.1-44a–c; Figures 6.1-42 and 6.1-43). Limited areas of relatively elevated (>1,500 µg/kg) concentrations were found at several locations within the Study Area.

Clusters of relatively elevated concentrations (>1,500 µg/kg) occurred in the surface data set from the eastern nearshore, in Swan Island Lagoon, and between RM 3.8-4.1 in the International Terminals Slip and along the Schnitzer facility riverfront (Figures 6.1-42 and 6.1-43). The highest surface concentration detected in the Study Area was found at Station G367 near the Coast Guard facility.

Along the western shoreline clusters of concentrations >1,500 µg/kg were detected over a 1.4-mile stretch:

- At RM 9.7 in Balch Creek Cove
- At RM 8.8 near the Gunderson facility and Equilon dock
- At RM 8.3 near the Front Avenue facility.

Additional isolated occurrences of relatively elevated concentrations were found.. With few exceptions, these concentrations occurred outside the navigation channel, in the eastern and western nearshore zones. The most notable exception is the western side of the navigation channel at RM 10.3 near the Sulzer Pumps facility, where the highest subsurface concentration in the Study Area was found in the interval of 0-195 cm bml at Station WR-VC-110. A similarly elevated subsurface concentration was detected in the channel at RM 8 near the mouth of Swan Island Lagoon.

6.1.1.18 Hexachlorobenzene in Sediment

Hexacholorobenzene analysis was performed on 1,128 surface sediment samples and 871 subsurface samples. Frequencies of detection were low, approximately 31 percent in surface sediment and 19 percent in subsurface sediment, due in part to elevated reporting limits; detection limits ranged from 0.0151 to 10,000 µg/kg in surface samples and from 0.0162 to 14,000 µg/kg in subsurface samples. The distribution of detection limit concentrations is shown on Map 6.1-22a,b.

Detected concentrations ranged from an estimated 0.0122 to 340 µg/kg in surface sediment and from an estimated 0.066 to 1,400 µg/kg in subsurface sediment (Tables 6.1-1 and 6.1-2; Figures 6.1-44 and 6.1-45). Median detected concentrations were an estimated 0.825 µg/kg in surface sediment and an estimated 1.12 µg/kg in subsurface sediment. The data include N-qualified results from six surface samples and six subsurface samples, for which detected concentrations ranged from 0.1 µg/kg to 2.9 µg/kg.

Detected concentrations were relatively low (≤10 µg/kg) throughout most of the Study Area, typically lower along the eastern nearshore zone and navigation channel than along the western nearshore zone (Figures 6.1-44 and 6.1-45; Maps 6.1-22a,b and 6.1-45a–c). Clusters of samples with detected concentrations above 10 µg/kg occurred in the surface and subsurface sediment along the western nearshore zone between approximately RM 7.5 (near the Arkema facility) and RM 6.4 (near the Gasco facility (Figures 6.1-44 and 6.1-45). Samples with the highest detected concentrations (>1,000 µg/kg), shown in red on the maps, were found only in the subsurface in the western nearshore zone at RM 7.3 (Maps 6.1-22a,b and 6.1-45a–c).

6.1.1.19 Total Petroleum Hydrocarbons in Sediment

The TPH data set consists of the summed results of gasoline- (GRH), diesel- (DRH), and/or residual-range petroleum hydrocarbons (RRH) for the 443 surface samples and 718 subsurface samples analyzed for at least two of these constituents. The method for TPH-Dx analyses (i.e., for DRH and RRH) is used to identify petroleum hydrocarbons present in the samples and to provide an approximate quantification based on specific calibration standards (i.e., diesel fuel and motor oil). An optional silica gel cleanup was not used for the Round 2 samples in accordance with the laboratory's standard procedures. Silica gel cleanup procedures are used to remove biogenic hydrocarbons from the sample but may also remove petroleum-related components such as PAHs and sulfur-containing hydrocarbons.

A variety of hydrocarbons were identified by the laboratory in the Round 2 sediment samples, including both petrogenic and biogenic substances. Total TPH results are described generically in this section with the understanding that the TPH in the samples varies with respect to the composition of petrogenic constituents as well as the relative contributions and chemical nature of biogenic constituents.

Frequencies of detection were approximately 97 percent in surface samples and 84 percent in subsurface samples, with detected concentrations ranging from an estimated 8.4 mg/kg to an estimated 33,100 mg/kg in surface samples and from an estimated 3 mg/kg to an estimated 321,000 mg/kg in subsurface samples (Tables 6.1-1 and 6.1-2; Figures 6.1-46 and 6.1-47).

Overall, concentrations generally ranged from 200 to 1,000 mg/kg throughout much of the Study Area, with clusters of relatively elevated concentrations (>1,000 mg/kg), particularly in the subsurface along the western nearshore zone (Figures 6.1-46 and 6.1-47). The predominant area of the elevated TPH concentrations was found near the Gasco facility between RM 6.1 and 6.4 along the western nearshore zone, where concentrations exceeding 10,000 mg/kg were detected in several surface and subsurface samples.

6.1.2 Upstream, Downstream, and Riparian Zone Data Evaluation

This section is designed to provide regional context for the Study Area sediment chemistry data detailed in Section 6.1.1. The upstream areas discussed include the LWR from RM 11 to the Willamette Falls, while downstream areas extend from RM 2 to the Columbia River (RM 0) and include the upper end of Multnomah Channel from the Willamette River to the Sauvie Island Bridge.

Section 6.1.2.1 discusses surface and subsurface sediment chemistry in the area immediately upstream of the Study Area to the head of the -40 ft federal navigation channel (RM 11 to 11.7). Unlike other upstream and downstream reaches, this short stretch of the river is relatively well sampled and the existing data have been compiled and included in the Section 6.1.1 maps.

Section 6.1.2.2 then summarizes and compares the existing surface sediment chemistry data from upstream and downstream areas as well as selected samples from the upper Study Area (RM 9.2 to 11). This data evaluation was initiated in the Upstream and Downstream Sediment FSP (Integral 2006d), which identified sediment data gaps from RM 1 to 2 and from RM 11 to 12 to be filled in Round 3A investigations (winter 2006-2007). The revised evaluation here reflects EPA comments on the Upstream/Downstream Sediment FSP. It supports development of the preliminary background values presented in Section 6.1.3, site boundary considerations, and identification of potential Round 3B data gaps.

6.1.2.1 RM 11 to 11.7

The maps and graphs presented in Section 6.1.1 include data from samples located between RM 11 and 11.7. As shown, several indicator chemicals (PCB Aroclors, total PAHs, phenanthrene, and BAP) were detected at relatively high concentrations at the former Cargill facility on the east bank of the river at approximately RM 11.5. In addition, elevated detection limits for BAA results were reported for samples collected at the Cargill facility and along the western portion of the navigation channel (Map 6.1-13a). This stretch of the LWR upstream of the Study Area will be investigated further as part of Round 3A activities (Integral 2006d).

No other mapped COPCs were evident at high concentrations in the existing samples from RM 11 to 11.7.

6.1.2.2 Upstream and Downstream Subareas of Interest

To compare surface sediment quality in upstream and downstream areas, five subareas of interest (Map 6.1-58) were defined for this evaluation based on the current conceptual model of physical site conditions (see Section 4.5):

1. **Upriver (UR):** This subarea includes all Category 1 (i.e., data of known quality) surface sediment data from approximately RM 15.3 (upper end of Ross Island) to RM 26 (Willamette Falls). Upstream of both the industrialized and urban portions of the LWR, bedded sediments in this reach should reflect the quality of material entering the system from upstream of Willamette Falls, from

any tributaries (e.g., the Clackamas River), and from any within-reach sources of contamination (e.g., runoff, aerial deposition). Most of the Upriver reach is dynamic relative to the Study Area and the channel is coarse-grained with finer-grained sediments generally restricted to small off-channel areas (see Map 6.1-59). In fact, most of the main channel above RM 20 could not be sampled with a grab sampler because the riverbed is cobbled or hard (GeoSea Consulting 2001). Recent surface water sampling efforts at RM 16 have confirmed that the relatively narrow river channel in that area is also deep (~100 ft) and fast flowing, with a cobbled riverbed.

2. **Downtown Corridor (DT):** This subarea includes both Category 1 and Category 2 surface samples in the data set from RM 11 to RM 15.3. Category 2 data (i.e., unknown or poor quality) were included for this reach to capture the relatively large sediment chemical data set collected offshore of the Zidell DEQ cleanup site at RM 13.5 to RM 14. This data set is most likely good quality but it was not validated at a level that would allow a Category 1 ranking. All samples from Ross Island Lagoon were excluded from the Downtown Corridor data set as this area was historically used as a confined dredged material disposal site and material placed in lagoon has been capped and is physically isolated from the hydrodynamic regime of the main river. The Downtown Corridor extends from upper Ross Island through downtown Portland to just downstream of the Fremont Bridge on Interstate-205. As noted in Section 4.5.1, the relatively narrow Downtown Corridor contrasts sharply with the upstream end of the Study Area in hydrodynamic and physical sediment characteristics. The bathymetric change data (see Figure 4.4-2) show that, except for some off-channel areas around Ross Island, there are no sizable depositional zones in this reach. In contrast, two large mid-channel depositional zones are evident at and immediately downstream of RM 11 and these features help define the upstream boundary of the Study Area (and the downstream boundary of this reach: see Section 4.5.1). The sharp transition from a sand-dominated riverbed to muddy sands at RM 11 is shown in Map 6.1-59.

   There are several areas of known historical sediment contamination in the Downtown Corridor (e.g., the Zidell Site). Sediment data collected as part of the dredged material characterization studies in the upstream end of the authorized -40 ft CRD federal navigation channel between RM 11 and 11.7 are also included in the Downtown data set. Two areas of interest for sediment contamination—offshore of the Cargill facility along the east bank from RM 11.2 to 11.5 and off the former Portland Coke Plant along the west bank at RM 12—are being evaluated by the LWG as potential upstream sources of contamination in Round 3A (Integral 2006d).

3. **Upper Study Area (USA):** A subset of Category 1 surface samples from depositional, offshore areas between RM 9.2 (the upstream ISA boundary) and RM 11 (the upstream Study Area boundary) was selected for comparison with the upstream and downstream reaches (Map 6.1-60). Based on the working physical conceptual model of the LWR, this station suite is expected to reflect

the quality of fine-grained sediment entering the Study Area from upstream and settling out in mid-channel depositional areas before being significantly influenced by in-reach sources of contamination. The data evaluation presented below will be one line of evidence in testing this hypothesis. The Upper Study Area stations selected share the following attributes: they are in the navigation channel, at least 400 ft offshore, and in areas that showed shoaling of at least 0.5 ft between January 2002 and February 2004 (the period over which the time-series bathymetric survey data were collected). Suspended sediments are deposited in this reach because flow velocities diminish as the cross-sectional area of the river increases by approximately 40 percent between RM 12 and 10. This effect is reflected in the widespread shoaling measured in the Upper Study Area as well as in surface grain-size distributions, which show an increasing percentage of fines from RM 12 downstream to RM 9 (Map 6.1-59). Between RM 10.5 and 11, a pair of former borrow pits (depressions) appear to be acting as "natural" traps for sediments entering the harbor. Sediments in the Upper Study Area will have passed through the Downtown Corridor (RM 11-15.3) and should reflect any contaminant inputs from the water column or resuspended sediments in that reach.

4. **Downstream (DS):** This subarea includes all Category 1 surface samples from RM 0 (Columbia River) to just above RM 2 that are located in the navigation channel or along the west (Sauvie Island) bank (Map 6.1-60), avoiding stations near the OSM site along the east bank. As a group, samples from this reach should illustrate the nature of fine-grained sediments leaving the Study Area. Ideally, these samples would all be located on shoaling areas to reflect current or recent sediment quality. Because there were too few stations in depositional zones, samples from no-change and scour areas (based on the 2002 to 2004 bathymetric change data) were also included. This suite of stations should reflect the quality of material both settling out downstream of the Study Area and moving along the riverbed. Note that within the Downstream reach a distinct change in the hydrodynamic/sediment transport conditions occurs at approximately RM 1.5. At this location, the river narrows, the modeled bottom shear stresses increase, and the broad area of sediment deposition in eastern portion of the channel ends.

5. **Multnomah Channel (MC):** This subarea includes Category 1 surface samples located at the head of or in Multnomah Channel. Due to the limited number of samples in the channel proper, samples across the head of the channel were included in this grouping. The Multnomah Channel samples are all surface samples and include one LWG-generated shoreline composite sample.

The existing sediment data from the subareas defined above were extracted from the project database that consists of all LWG-generated and non-LWG-generated data collected from May 1997 through 2005. Only Category 1 data (data of known quality) were compiled for all reaches except for the Downtown Corridor, where both Category 1 and Category 2 data were used. Map 2.1-1a–t shows the distribution of all sampling

locations in the project data set from RM 0 to 26 (Willamette Falls), coded by survey. Table 6.1-12 lists the specific samples extracted for each subarea as described above for the statistical comparisons detailed below. For each sample, Table 6.1-12 also includes the subarea, river mile, survey/sample identification, sample depth, and year sampled. Map 6.1-60 shows the distribution of these samples in relation to the distribution of surface sediment samples in the entire data set.

6.1.2.2.1 Subarea Sediment Chemistry Comparisons

The surface sediment quality between the upstream and downstream reaches was compared for seven indicator organic and inorganic chemicals, plus grain size (percent fines) and TOC. The seven indicator chemicals are a subset of the ERA and HHRA COPCs mapped and discussed for the Study Area in Section 6.1.1 and were selected to include a range of major compound types for which analyses were generally conducted. The chemicals are arsenic, mercury, total PAHs, BEHP, total PCBs (based on Aroclors), total DDx, and dioxin/furan TEQ concentrations.

Figure 6.1-50 presents scatter plots for these data. Because detected concentrations were relatively low for many of the analytes in these reaches and because the sample sizes were often small, both detected and undetected values are plotted versus river mile, with data coded by subarea. In addition to showing upstream-downstream concentration gradients or a lack thereof, these plots illustrate that the percentage of nondetect values (censored data) can be very high and that the reported nondetected concentrations can vary so widely as to fully encompass the detected values (e.g., see total PCBs in Upriver samples, Figure 6.1-50).

To examine spatial trends further, statistical significance between subareas was tested. In order to maximize the robustness of these limited data sets before conducting the statistical tests, the analytes with censored (i.e., nondetected) data were handled according to the techniques described by Helsel (2005) and the USGS manual *Statistical Methods in Water Resources* (Helsel and Hirsch 2002). For analytes with at least 20 percent detected values, a method called Regression on Order Statistics (ROS) was used to "impute" values for the censored data. Imputing a value simply refers to substituting a value (for example, zero or ½ the detection limit) for a nondetected result. The ROS method imputes or estimates a value for nondetected results between 0 and the reported detection limit based on three criteria: 1) the distribution of the detected data, 2) the number of nondetected concentrations reported with the same detection limit, and 3) the value of the particular detection limit relative to the rest of the detected data (i.e., some censored records are dropped because the imputed value is greater than the maximum detected value). Whether this estimated value for the censored data will be closer to 0 or the reported detection limit depends on the mean and variance of the detected data, and the number of detected values above each nondetected value. Also, imputed values are not assigned to any particular sample but are simply included in the data and used to estimate summary statistics of the complete data set (i.e., censored + uncensored).

Once the censored data were appropriately incorporated into the data sets for each analyte, the summary statistics were generated. Table 6.1-13 lists the summary statistics for each indicator chemical, including both the original (pre-ROS) number of samples and the post-ROS (total) number of samples, and the underlying data distribution. The table lists the percentage of detected values for each analyte. For analytes with 100 percent detected values, the ROS method was not needed. For qualitative comparison purposes, Table 6.1-13 also includes the summary statistics for the Study Area. However, because the Study Area data set is much larger, the ROS approach was not used and the summary statistics presented are based on detected concentrations only.

To evaluate whether the overall concentrations of indicator chemicals varied between subareas, pair-wise statistical tests of the means for each analyte and subarea (except for the Study Area) were conducted using the data sets listed in Table 6.1-13. Because of small and largely non-normally distributed data sets, the nonparametric Mann-Whitney U test was used for all statistical comparisons. Table 6.1-14 summarizes the results of this statistical testing. The p-values for each comparison are included in Table 6.1-14; a p-value <0.05 was considered to be indicative of a statistical difference. Figure 6.1-51 is a matrix summarizing the statistical difference testing results and Figure 6.1-52 plots the means of each subarea for each analyte.

With the exception of the Upriver and Downtown Corridor subareas, the data sets statistically compared here typically have sample sizes of approximately 10 or less. As a result, the statistical results may lack robustness. Nonetheless, the results in Table 6.1-14, when considered in conjunction with qualitative examination of the data (e.g., scatter plots in Figure 6.1-50, the means plots in Figure 6.1-52, and the summary statistics in Table 6.1-13), point to some notable trends by analyte or analyte group. These trends are noted below:

- **Grain Size:** The Upriver and Downtown Corridor samples include both coarse- and fine-grained surface textures, reflecting the heterogeneity of conditions in those reaches (Table 6.1-13 and Figure 6.1-50). The Upper Study Area, Downstream, and Multnomah Channel subareas show a relatively narrow grain-size range, with Multnomah Channel dominated by sandy sediments (<20 percent fines), the Downstream reach by fines (>80 percent fines), and the Upper Study Area ranging from 40 to about 60 percent fines. The Study Area average (54.3 percent) is similar to the Upper Study Area average (52.8 percent). Excluding Multnomah Channel, a trend of increasing fines from Upriver to Downstream is evident in Figure 6.1-52.
- **TOC:** TOC concentrations among the five subareas reflect the grain-size trends (Figure 6.1-52). TOC levels are lowest in the Multnomah Channel subarea. TOC levels show comparable maximum values between about 2.5 and about 2.7 percent in the other subareas. The average TOC level in the Study Area (1.82 percent) is similar to the Upper Study Area average (1.98 percent)

- **Mercury:** Average mercury values are less than 0.1 mg/kg in all reaches except for the Downtown Corridor (0.16 mg/kg) and the Study Area (0.10 mg/kg) (Table 6.1-13 and Figure 6.1-52). Figure 6.1-50 suggests a very slight increasing trend in detected concentrations from Upriver to Downstream, excluding Multnomah Channel. The statistical test results support this apparent pattern and indicate that Upriver levels equal those in Multnomah Channel, while the Downtown Corridor, Upper Study Area, and Downstream subareas are slightly elevated relative to Upriver and Multnomah Channel (Table 6.1-14 and Figure 6.1-51). This pattern may in part reflect the relatively lower percent fines fractions in Upriver and especially Multnomah Channel sediments. The Study Area average mercury concentration falls between the Downtown Corridor average and the other reach averages (Figure 6.1-52).
- **Arsenic:** Excluding the Study Area, arsenic shows a relatively narrow concentration range from approximately 2 to 6.5 mg/kg across all subareas, and no upstream-downstream spatial gradients are evident (Figures 6.1-50 and 6.1-52). The maximum arsenic value in the Study Area is 132 mg/kg, although the average value of 4.9 mg/kg is comparable to the average values from the other reaches (2.7 to 3.8 mg/kg).
- **Total PCBs:** Upstream-downstream trends in total PCB (Aroclor) concentrations are shown in Figures 6.1-50 and 6.1-52. A number of relatively high undetected values are apparent in the Upriver data set. These are accounted for in ROS data reduction, and results of the statistical testing suggest that the Upriver PCB values (mean = 3.3 µg/kg) are less than those of the Downtown Corridor (281 µg/kg), Upper Study Area (10.2 µg/kg), and Downstream (7.7 µg/kg) (Figure 6.1-51). The lone detected value in Multnomah Channel (2.4 µg/kg) could not be compared statistically. The Downtown Corridor PCB values are greater than those measured in both the Upper Study Area and Downstream, while Upper Study Area levels were not different from the Downstream levels. The average Study Area concentration (200 µg/kg) is comparable to the Downtown Corridor mean (Table 6.1-13).
- **Total DDx:** Spatial trends in total DDx are shown in Figures 6.1-50 and 6.1-52. Measured concentrations in the upstream and downstream subareas range from less than 1 µg/kg to 25 µg/kg; the highest value in the Study Area is 16,200 µg/kg. Excluding the Study Area, a slight upward trend in measured values from Upriver to Dowstream is suggested, and the statistical testing results support this pattern. Figure 6.1-51 indicates that the Upriver (mean = 1.4 µg/kg) values are significantly less than those of the Downtown Corridor (3.8 µg/kg), Upper Study Area (2.9 µg/kg), Downstream (5.8 µg/kg), and Multnomah Channel (2.4 µg/kg). Downtown Corridor levels are not statistically different from Upper Study Area, Downstream, or Multnomah Channel levels, and Downstream concentrations are greater than those in the Upper Study Area and Multnomah Channel. The Study Area total DDx average (156 µg/kg) is notably higher than any of the upstream or downstream levels.

- **Total PAHs:** The spatial trends in total PAH values between the subareas show relatively low Upriver values that contrast with higher levels elsewhere (Figures 6.1-50 and 6.1-52). The statistical testing results support this graphical pattern. The mean Upriver concentration (63 µg/kg) is less than the mean concentrations in the Downtown Corridor (1,462 µg/kg), Upper Study Area (452 µg/kg), Downstream (446 µg/kg), and Multnomah Channel (1,602 µg/kg) subareas (Table 6.1-14 and Figure 6.1-51). The Downtown Corridor subarea is not statistically different from the Upper Study Area or Downstream reach. The Multnomah Channel levels are statistically greater than the other up- and downstream reaches. The Study Area mean value (33,300 µg/kg) greatly exceeds the mean values in all subareas (Table 6.1-13).

- **BEHP:** Figures 6.1-50 and 6.1-52 suggest that BEHP is elevated in the Downtown Corridor and Upper Study Area relative to the other subareas. BEHP was not detected in any of the Multnomah Channel samples. The variability in the BEHP data is relatively high, so the statistical testing results are not robust. Nonetheless, the statistical results support the graphed trends and indicate that the Downtown (mean = 215 µg/kg) and Upper Study Area (229 µg/kg) levels are comparable and that both exceed the Upriver (95 µg/kg) and Downstream (48 µg/kg; $p = 0.05$ in the latter case) levels (Figure 6.1-51). The Study Area mean BEHP value (1,300 µg/kg) is considerably higher than the mean values in any of the upstream and downstream subareas (Table 6.1-13).

- **Dioxin TEQ:** With the exception of the Upriver subarea (21 data points), there are very few dioxin TEQ data points in the subarea data sets (one in the Downtown Corridor, two in the Downstream subarea, one in Multnomah Channel, and none in the Upper Study Area); this largely precludes statistical comparisons between subareas. The limited data suggest that the upstream and downstream reaches have comparably low levels (i.e., less than 0.5 pg/g) with a single higher measured value of 4.19 pg/g in the Downtown Corridor (Figure 6.1-52). The average Study Area dioxin TEQ value of 124 pg/g greatly exceeds these values (Table 6.1-13).

6.1.2.3 Riparian Zone Data

A preliminary database of analytical results from samples within the Riparian Zone, which is defined as the riverbank between +13 ft and +22 ft NAVD (Figure 6.1-1), has been built using information provided by DEQ Site Cleanup Managers. Table 2.2-1 lists the investigations reviewed and riparian zones samples compiled. For completeness, data from upstream and downstream reaches as well as the Study Area were compiled. However, the focus of this discussion is the Study Area riparian data. The locations of the riparian zone sample stations in the Study Area are shown in Map 2.2-1. Summary statistics based on these samples for the indicator chemicals discussed in Section 6.1.2 (as available) are provided in Table 6.1-15 for each reach (Downstream, Study Area, Downtown, and Upriver). Surface and subsurface data are compiled separately if available. Tables C1-3 (surface samples) and C1-4 (subsurface

samples) in Appendix C1 include summary statistics for all analytes in the riparian data set.

Table 6.1-15 shows that there is limited existing soil/sediment chemistry data from the riparian zone, with a maximum of 22 samples for any given analyte (e.g, total PAHs in surface samples). Map 2.1-3 further illustrates that most of the data come primarily from three shoreline areas—OSM, Arkema, and the area from the downstream end of the Gunderson property to Lakeside Industries (see Section 7.1.5.2 for additional discussion of riparian data sources). Based on this limited spatial coverage it is difficult to draw conclusions about overall riverbank soil quality. Nonetheless, if one considers the data set overall, the means listed in Table 6.1-15 can be compared with the Study Area means compiled in Table 6.1-13. A qualitative comparison of riparian zone means suggests that arsenic (12.6 mg/kg), and BEHP (4,000 µg/kg) are potentially elevated in riparian soils relative to Study Area surface sediments, while the other analytes listed in Table 6.1-15 (mercury, PCBs, total DDx, and total PAHs) show lower average levels in riparian samples than in Study Area surface sediments.

6.1.3 Background Sediment Concentrations

The general concept of background for the Portland Harbor site was introduced in the Programmatic Work Plan (Integral et al. 2004b). The definition of background, an overall approach for determining background levels for the Site, and the uses of background in the RI/FS are described by Kennedy/Jenks et al. (2006): *Portland Harbor RI/FS Technical Memorandum: Approach to Determining Background.* In addition, the potential site-specific data needed to establish effective background levels were introduced in EPA's Round 3 scoping documents and discussed further in EPA and LWG responses thereto (EPA 2005a, 2006; LWG 2006a).

The final determination of background for the RI/FS will likely consist of a weight-of-evidence approach that will evolve from the preliminary approach described below in this Comprehensive Round 2 report through Round 3 data collections and the final RI data evaluations. The contribution of background concentrations to risks associated with the Site will be considered in the development of PRGs for COCs that warrant remedial action. Background information will also be useful for risk communication.

The final determination of background concentrations will include an evaluation of multiple data types. These include upstream surface water, bedded sediment, and sediment trap data to be collected in Round 3 and the existing bedded sediment data from the upstream reaches described in Section 6.1.2.

6.1.3.1 Preliminary Background Concentrations

This subsection details the assumptions and statistical methods used to estimate preliminary background sediment concentrations for use in this comprehensive Round 2 report. These preliminary or interim background estimates serve as replacement values in the "hill topping" (i.e., iterative truncation) approach used in Section 10 to define iAOPCs for this Round 2 report; they also serve as a basis for direct comparison to

Study Area data (for analytes that do not show strong correlations between sediment and tissue concentrations).

As indicated above, the approach detailed here will be replaced by the more comprehensive background determination approach described in the LWG's response documents to EPA's Round 3 Scope memoranda, the LWG's *Approach to Determining Background Technical Memorandum* (Kennedy/Jenks et al. 2006), and the LWG's responses to EPA comments on that technical memorandum. The more comprehensive approach requires the surface water, sediment trap, and bedded sediment data to be collected during Round 3 sampling and therefore cannot be developed for this Round 2 report. The approach described here uses only existing sediment data from the Upriver subarea described in Section 6.1.2.2.

6.1.3.1.1 Preliminary Background Data Set

As a conservative first approach to developing preliminary background sediment concentrations for the Study Area, the Upriver data set described in Section 6.1.2.2 was used. This data set consists of surface sediment data from the upper end of Ross Island to Willamette Falls (RM 15.3 to 26). It includes only post-May 1997 Category 1 data, the same time frame and data quality criteria used to define the Study Area nature and extent data set. Map 6.1-60 shows the distribution of the Upriver samples and Table 6.1-12 includes associated details (e.g., survey codes, year sampled).

The bedded surface sediments in the Upriver reach reflect material entering the Lower Willamette River from upstream of Willamette Falls, from any tributaries (e.g., the Clackamas River), and from any in-reach sources of contamination (e.g., runoff, aerial deposition) that settle out in the Upriver reach. The use of bedded sediment quality data from only this reach to define background conditions for the Portland Harbor site represents a conservative approach because it ignores potential chemical inputs from within the Downtown Corridor subarea (RM 11-15.3); these inputs are unrelated to Study Area releases but have the potential to contribute contaminant loads to the Study Area from upstream. The use of only Upriver data to define background also ignores suspended loads that pass through the higher energy Upriver and Downtown reaches but settle out in the more depositional Study Area.

6.1.3.1.2 Statistical Evaluation of Preliminary Background for Use in "Hill Topping"

Table 6.1-16 provides the summary statistics for the Upriver data set for the COPCs from the Study Area (RM 2-11) identified during the risk screening process. Grain size and percent TOC are also included in Table 6.1-16. In addition, for the summed parameters (e.g., total DDx), summary statistics were calculated with detection limits for the undetected component analytes set at both 0 (the nature and extent convention) and at ½ the reporting limit (the risk assessment convention). Thus there are two rows of summary statistics for each summed parameter and the convention used for the nondetected values is indicated in the analyte name.

Figure 6.1-52 shows scatter plots for a subset of 28 of these COPCs (plus grain size and TOC) to illustrate spatial trends and concentration ranges in the Upriver data set. Both detected and nondetected concentrations are plotted versus river mile in Figure 6.1-53. These plots illustrate that there are no obvious upstream-downstream concentration gradients within the Upriver reach. They also illustrate that the percentage of nondetected values (censored data) can be very high (e.g., see pentachlorophenol) and that the reported nondetected concentrations can vary widely enough to encompass the detected values (e.g., see total PCBs).

The first step in the statistical analysis of the Upriver data set was to handle the censored data in a manner that is statistically appropriate and that, to the fullest extent possible, incorporates information contained in the censored data about overall sediment quality in the Upriver reach. The approach used in Section 6.1.2.2 and described by Helsel (2005) was used here when appropriate (i.e., detections were greater than 20 percent) to reduce the data sets by imputing values for the nondetected values for each analyte. The columns immediately to the right of the analyte name in Table 6.1-16 show the original sample size, which includes both detected and nondetected values, as well as the total number of samples following the ROS application. The latter is the sample set from which the summary statistics were derived. As prescribed by Helsel (2005), all imputed values greater than the maximum detection limit were dropped from the data set.

Once the censored data were appropriately incorporated into the data sets, the summary statistics were generated. Table 6.1-16 lists the summary statistics for each COPC and the underlying data distributions. The COPCs plus grain-size and TOC are listed in decreasing order of percentage of detected values. This ranking is important because that percentage determines the nature of the censored data reduction performed on each analyte, as detailed below (the color coding and footnotes in Table 6.1-16 also explain the approaches used):

1. For analytes with 100 percent detected values, the data were used directly to calculate the summary statistics.
2. For analytes with more than 20 percent but less than 100 percent detection, robust ROS was used to impute values for the censored data. The ROS method estimates a value between 0 and the reported detection limit based on three factors: the distribution of the detected data, the number of nondetected values reported with that same detection limit, the value of a particular detection limit relative to the rest of the detected data. This estimated value cannot be predicted, because it depends on the mean and variance of the detected data, and the number of detected values above each nondetected reporting limit. Also, the imputed values are not assigned to any particular sample but are simply included in the data and used to estimate summary statistics of the complete data set (i.e., censored + uncensored).

Note: One of these first two methods was used for approximately 79 percent of the COPCs listed in Table 6.1-16.

3. For analytes with ≤20 percent detection and more than one detected value, the ROS method is not recommended and was not used. Instead the upper quantiles were calculated on the whole data set with nondetected values set at the detection limit.
4. For analytes with a single detected value, that value is the single "summary" statistic for that analyte.
5. Finally, if all the data were nondetected values, both the maximum detection limit and ½ of the maximum detection limit are listed in Table 6.1-16.

Preliminary Background Statistic Selection

The summary statistic selected for use as the preliminary background concentration level varied depending on the percent detected for each analyte as detailed below. The objective of the selections was to provide a reasonable measure of the central tendency (e.g., average) of the preliminary background data set. The use of central tendency measures as the selected background statistics is appropriate, as these levels represent the concentrations to which the Study Area might return post-cleanup absent future releases from the Study Area and, in this conservative case, future inputs from the Downtown Corridor subarea. The statistic selected as the preliminary background concentration based on this evaluation is highlighted in blue in Table 6.1-16; its derivation is described below:

1. For analytes with >20 percent detected values (green and yellow highlighted analytes in Table 6.1-16), the 95th upper confidence limit (UCL) of the mean was selected as the preliminary background level. ProUCL (EPA 2004c) was used to estimate this 95th UCL of the mean. Like the mean and geometric mean, 95th UCL represents the range over which means from a given data set may occur and still represent similar conditions. ProUCL checks the distributional shape of the data (normal, lognormal, gamma, or nonparametric) and then computes values of the 95th UCL.
2. For analytes with ≤20 percent detection and more than one detected value, the 90th percentile was selected at the background statistic.
3. For analytes with a single detected value, that value was selected as the background level.
4. If all data were nondetected value, then ½ of the maximum the detection limit was selected as the background statistic.

The primary use of these preliminary background levels in this Round 2 data evaluation is to support definition of iAOPCs as described in Section 10.

6.1.3.1.3 Statistical Evaluation for Direct Comparisons with Study Area Data

For crustal elements, it may be appropriate to compare Study Area sample concentrations directly with a background level, addressing the question: Does this sample fall within the upriver/background range of conditions?

This is a different use of the preliminary background data than the replacement values noted above and an alternative statistical analytical approach was used to develop tolerance limits on the background data. Unlike the replacement values, which are intended to provide an indication of levels to which the Site will return, the "tolerance" limits are purposely biased to the high end of data set distribution (e.g., 95th UCL on the 90th percentile) to provide a value that, if exceeded, indicates with a high level of certainty that the Study Area data fall outside the Upriver data set.

A tolerance limit is a confidence bound on a percentile of the data set. The existing Upriver concentration distributions are from a single set of samples from the population of all possible Upriver concentration values. A percentile computed from this particular data set is one of many possible percentiles, and so the percentile itself is a random variable with a distribution. In the case of concentration data, an upper confidence bound on an upper percentile of the upriver distribution—the 95th UCL on the 90th percentile—was selected as an appropriate threshold. These threshold levels for metals in the Upriver data set are listed in Table 6.1-17. A similar approach to establishing upper bound tolerance limits has been used for bioassay survival responses (Hunt et al. 1998) in the San Francisco Bay Protection and Toxic Cleanup Program (BPTCP) toxicity assessments. Also, EPA (1989c, Chapter 5, pp. 20-24, Chapter 6, pp. 11-15) proposes using similar tolerance limits to compare chemical concentrations at compliance wells with concentrations at background wells and compliance limits.

An independent measurement from the Study Area data set that falls above the threshold levels in Table 6.1-17 is unlikely to have come from the Upriver/preliminary background distribution and is considered to be outside or greater than the Upriver distribution, while an observation that falls below the tolerance limit would be considered within the range of Upriver values.

Additional details on the treatment of COIs that are naturally occurring crustal elements in the ERA are provided in Section 2 of Appendix G.

6.1.3.1.4 Statistical Evaluation for COPCs lacking Upriver Data

For iron and manganese, two COPCs for which Upriver data are not available, regional soil background values were used in the ecological risk evaluation. Background soil values of 36,100 mg/kg for iron and 1,500 mg/kg for manganese were obtained from the Washington Department of Ecology (Ecology 1994). Iron in sediments range from 9,900 to 180,000 mg/kg (NOAA 1999). Study Area measurements in excess of these background values were assumed to be elevated relative to background in this Round 2 data evaluation.

6.1.4 Temporal Trends in Surface Sediment Chemical Data

This section examines temporal changes in concentrations of selected chemicals in surface sediments throughout the Study Area (RM 2 to 11). As described in Section 2, the Portland Harbor RI/FS nature and extent database consists of LWG and non-LWG sediment chemistry data collected over an approximately 9-year period from May 1997 through December 2005. The period extends back to a time following the last major flood event on the lower Willamette in February 1996 (see Figure 4.3-2). One aspect of the physical conceptual site model for the Study Area is that in the absence of extreme hydrologic events such as occurred in February 1996, surface sediment quality is relatively stable when measured in the uppermost 30 cm of the sediment column. This hypothesis is based on the extent of riverbed elevation changes measured directly with time-series precision bathymetric surveys over the 25-month period from January 2002 through February 2004 (see Section 4.4.1). These survey data indicated an elevation change of less than 30 cm over approximately 90 percent of the riverbed examined during the 2-year study.

This section examines this conceptual model by evaluating the degree to which chemical concentrations in surface sediments (0 to a maximum of 30 cm depth) collected from the same approximate locations vary as a function of time. Samples in the nature and extent data set span a 9-year period. For this evaluation, surface samples were considered overlapping or collocated pairs if they were within 25 ft of each other horizontally and 10 ft of each other vertically (mudline elevation in NAVD88). Vertical elevation for any station location in the database can be estimated in the GIS by overlaying the February 2004 precision bathymetry survey of Portland Harbor over the station's horizontal coordinates. The depth criterion was used to avoid selecting proximal stations that spanned steep contour gradients and therefore could represent very different sedimentological environments.

6.1.4.1 Collocated Surface Sediment Data

This evaluation was conducted using only Category 1 (data of known quality) surface sediment data from the Study Area (RM 2-11) for the following analytes: arsenic, mercury, total PCBs (Aroclors), total DDx, total PAHs, BEHP, percent fines, and TOC. A query of the nature and extent database using the 25-ft horizontal and 10-ft vertical criteria yielded 49 (total DDx) to 162 (TOC) collocated surface samples in the Study Area. The complete data table for these collocated pairs and eight analytes is provided in Appendix C3.

The collocated data were compiled, analyte-by-analyte, and measured differences in concentrations between paired samples were compared. Nondetected values were included at the reported detection limit. Table 6.1-18 provides an example of the compiled data for total PCBs (Aroclors) and includes the paired sample codes, dates, and reported concentrations. Ratios (larger/smaller value) and the absolute value of the concentration differences for each sample pair are included. Table 6.1-19 lists the number of collocated pairs; the range of ratios and concentration differences; and the percentage of the ratios that exceed factors of 2, 5, and 10. As can be seen from the

sample codes in Table 6.1-18, many of the collocated pairs represent field replicates (e.g., from the LWG Round 2A sampling event) sampled on the same day (0 days between samples). These same-day pairs were extracted from the full data set and are tabulated separately in the bottom half of Table 6.1-19 for comparison purposes.

Table 6.1-19 shows that the maximum ratios and absolute concentration differences for the collocated pairs can be quite large, indicating considerable heterogeneity in some collocated pairs. However, at least half of the collocated values across all analytes are within a factor of 2 of each other, and 77 percent or more are within a factor of 5 of each other.

Compared to the full data set, the same-day pairs are somewhat less variable (e.g., compare percentage of <10X ratios). Nonetheless, it is evident that much of the heterogeneity in collocated measurements appears to reflect actual small-scale heterogeneity in the system, the heterogeneity associated with the sediment sampling and analysis process, or both.

6.1.4.2 Collocated Surface Sediment Time Trends

To further investigate time trends in the collocated data sets, the differences in reported concentrations per collocated sample pairs were plotted against the time between samples for the key analytes (Figure 6.1-54). For the organic compounds—PCB Aroclors, total DDx, total PAHs, and BEHP —two plots are provided. The top scatter plot includes all sample pairs, while the bottom shows the same data with the highest 8 to 15 percent concentration differences removed, depending on the analyte. This treatment allows the distribution of the smaller differences to be examined.

Figure 6.1-54 indicates that concentration differences between paired samples do not vary in magnitude with time. Except for arsenic (which is minimally variable overall), the range of concentration differences measured in same-day pairs (which plot along the y-axis in Figure 6.1-54) approximately equals or exceeds the range measured in samples collected up to 3,000 days apart.

The data summarized in Table 6.1-19 and plotted in Figure 6.1-54 suggest that the nature and extent data set represents a temporally coherent characterization of surface sediment quality in the Study Area; that is, for this suite of analytes, collocated sample concentrations do not vary directionally as a function of time between samples.

6.2 TRANSITION ZONE WATER AND GROUNDWATER SEEPS

This section summarizes the analytical results from groundwater seep and TZW sampling completed by the end of the Round 2 field characterization program. For seeps and TZW, the available data of adequate quality for use in decision-making at the Site, per the Portland Harbor RI/FS Programmatic Work Plan (Integral et al. 2004b), are presented in summary tables in Appendix C. In this section, a series of tables, plan view maps, histograms, and two-dimensional plots present an overview of the nature

and extent of the seep and TZW sampling results. For TZW, this presentation builds on the detailed site-by-site presentation and analysis of TZW results in the Round 2 GWPA TZW SCSR (Integral 2006g). To minimize redundancy, figures and maps from the TZW SCSR are not reproduced here, but are instead referenced, as needed, to support the discussion. Note: This discussion of seeps and TZW includes use of facility names for location reference; mention of facility names does not necessarily indicate source origin.

6.2.1 Groundwater Seeps

This section summarizes the location, available chemical data, and data quality assessment for upland groundwater seeps. Groundwater seeps were assessed because of the potential for humans to come into contact with contaminated water. The potential effects of human exposure to groundwater discharge in surface seeps are presented in the initial HHRA summary in Section 8 of this report. Seep data are not appropriate for assessing ecological risks, and therefore were excluded from the TZW ERA.

6.2.1.1 Groundwater Seep Locations

A seep reconnaissance survey was conducted during Round 1 of the Portland Harbor RI/FS (GSI 2003b) to support the HHRA and CSM. This survey documented readily identifiable groundwater seeps based on visual observations along approximately 17 miles of riverbank from RM 2 to 10.5. For the purposes of this study, a seep is defined as groundwater discharge above the Willamette River water line. This groundwater may be discharged from local shallow groundwater systems, perched groundwater, water seeping through utility backfill, or return flow from tidally-influence bank storage. Observed seeps were classified into one or more of five types:

1. Seepage line at the base of embankments (nine seeps)
2. Linear and point seeps at the foot of beaches (six seeps)
3. Seepage through backfill surrounding outfalls (four seeps)
4. Seepage of NAPL (two seeps)
5. Potential seep locations identified by observation of extensive ferric hydroxide staining of bank materials (eight potential seeps).

Additionally, eight seeps were categorized as combinations of the above seep types.

Twelve seeps were observed at or near potential human-use areas (GSI 2003b). No additional seeps or other surface expressions of groundwater have been observed on or near a human-use beach since the seep reconnaissance survey.

6.2.1.2 Groundwater Seep Water Quality Data

This section summarizes all groundwater seep data collected to date; associated data tables presented in Appendix C focus only on the seep locations with Category 1 data validated to the QA2 level (City of Portland Outfalls 22B and 22C).

Water quality data have been collected at six seeps in four general areas (Figure 6.2-1). Groundwater seep discharge rates have not been empirically quantified. The water quality sampling efforts to date for upland groundwater seeps include:

1. Outfalls 22B and 22C—City of Portland stormwater Outfalls 22B and 22C, located directly north and south of the railroad bridge at RM 6.89 and 6.82, respectively, are type 3 (backfill surrounding outfalls) seeps. Both Rhone-Poulenc and NW Natural have collected water quality samples at Outfalls 22B and 22C:
2. Rhone-Poulenc sampled Outfall 22B on five occasions between October 1, 1993 and September 23, 2004 and Outfall 22C four times between August 13, 2002 and September 23, 2004. Samples were analyzed for 231 individual parameters, including conventionals, dioxins/furans, herbicides, metals, PAHs, PCB Aroclors, pesticides, petroleum hydrocarbons, phenols, phthalates, SVOCs, and VOCs. The results are Category 1 data validated to the QA2 level. Analytical data from Outfalls 22B and 22C are presented in Table C1-11 in Appendix C.
3. NW Natural sampled Outfall 22C on February 24, 2005 for 89 individual parameters, including conventionals, metals, PAHs, phenols, phthalates, SVOCs, and VOCs. Validation was still pending at the time of this Round 2 Report. To date, data were validated to Category 2, QA1 level.
4. Seep-01, -02, and -03—These three seeps are located at the Gunderson site near RM 8.5. These type 3 seeps are associated with cracked stormwater drain pipes. Each seep was sampled once in November 2004 and again in April 2005, with samples analyzed for 31 individual parameters, including conventionals, metals, PCB Aroclors, petroleum hydrocarbons, and phthalates. Data were validated to Category 1, QA1.
5. ExxonMobil—ExxonMobil sampled areas with visible sheen on sand and in pooled water along the riverbank at the ExxonMobil site under the direction of DEQ on August 13, 2004 (Kleinfelder 2004b). Two composite samples were analyzed as soils for DRH, GRH, and RRH. Data were validated to the QA1 level.

For this nature and extent discussion, a subset of the detected Category 1, QA2 Outfall 22B and 22C seep data was compared to nearshore upland groundwater data and TZW data from the Rhone Poulenc site (Figure 6.2-2). Due to the small number of seep, upland groundwater, and TZW samples, these data are presented as a simple comparison and should not be considered statistically significant. At Outfall 22B, detected seep concentrations of Silvex (0.14 µg/L), benzene (0.19 µg/L), and TCE (0.34 µg/L) were below the minimum concentrations found in upland groundwater and in TZW. The measured concentration of 1,2-dichlorobenzene at Outfall 22B (0.864 µg/L) falls within the lower end of the range for upland groundwater and TZW. Sample concentrations from Outfall 22C were below detection limits for Silvex, TCE, and 1,2-dichlorobenzene. Benzene was detected at Outfall 22C at a concentration of 3.15 µg/L,

higher than the maximum TZW concentration and within the range of upland groundwater concentrations.

6.2.2 Transition Zone Water Analytical Results—Nature and Extent Summary

This section presents a summary of the nature and extent of chemicals in TZW, focusing on a subset of chemicals relevant to the ecological and human health risk assessments. A more detailed analysis of TZW results is available in the TZW SCSR (Integral 2006g), which includes comparison to sediment and upland groundwater conditions. The TZW data set discussed in this section was generated from the following sources:

- 2004 Pilot Study results collected by Trident and small-volume peepers, discussed in detail in Appendix B of the GWPA SAP (Integral 2005a), the Discharge Mapping FSP (Integral 2005b), and the TZW FSP (Integral 2006e).
- Round 2 TZW sampling results, discussed in detail in the TZW FSR (Integral 2006f) and the TZW SCSR (Integral 2006g).
- TZW data collected by member site Siltronic (MFA 2005a,b).

These sampling activities focused on the offshore area of nine sites along the west bank of the river (see Map 2.1-4):

- Kinder Morgan Linnton Terminal
- ARCO Terminal 22T
- ExxonMobil Oil Terminal
- Gasco
- Siltronic
- Rhone Poulenc
- Arkema (Acid Plant and Chlorate Plant Areas)
- Willbridge Bulk Fuels Terminal
- Gunderson.

These nine sites were identified as high-priority Category A sites, based on a confirmed or reasonable likelihood for discharge of upland groundwater COIs to Portland Harbor. The approach to site selection is summarized in Section 2.3.3 and presented in detail in the GWPA SAP (Integral 2005a). TZW sampling at each site was focused largely on the nearshore area adjacent to the site shoreline, often extending to and occasionally just beyond the navigation channel boundary. As such, the TZW sampling effort was not a harbor-wide study of TZW, but instead a focused investigation offshore of the nine Round 2 study sites. Based on the approach taken for site selection, this study is

expected to have delineated the majority of TZW contamination in the Study Area originating from upland groundwater. TZW sample locations are shown on Map 2.1-4.

Two general types of sampling techniques were used to collect the TZW samples: small-volume peepers and push-point samplers; Trident and GeoProbe®[11] tools were used as push-point samplers. These are described in detail in the Pilot Study FSP (Integral 2004a). Paired unfiltered and filtered samples were collected with the push-point sampling techniques where possible. (Collection of unfiltered samples was given priority, and volume limitations prevented collection of filtered samples in some cases.) All peeper samples were collected over the depth interval of 0 to 38 cm bml). Trident samples were collected at 30 cm bml as well as at greater depths where planned (90 to 150 cm bml, depending on conditions at the specific sampling station). Results for all analytes, sampling methods, and sampling depths are summarized in Table C1-12 in Appendix C.

For this nature and extent discussion, a subset of TZW analytes is presented on plan view maps or scatterplots. Most of these analytes were selected from the Round 2 COPCs identified by screening the full TZW data set against human health and ecological screening levels. Additionally, TPH, for which there are no relevant screening levels, is plotted. A total of 80[12] individual analytes and calculated sums (total xylenes, total DDE, total DDD, total DDT, and dioxin TEQ) were identified as exceeding one or more screening criteria. Table 6.2-1 presents the results of this screening and identifies the analytes selected for presentation on the plan view maps. These analytes are also identified on Table 6.0-2 with the sediment, surface water, and biota analytes selected for mapping.

A total of 12 map series have been created for selected individual TZW analytes or analyte-group totals. Analytes were selected to present the understanding of the spatial distribution of COPCs and selected upland groundwater COIs. The objective of this data presentation is not to present distribution of risk, but instead to present chemical distributions in support of the risk assessment. The analytes selected for mapping and/or plotting are listed below, organized by analyte group:

- PAHs
  - Total PAHs, (including distinction of LPAHs and HPAHs)
  - BAP

- TPH

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[11]GeoProbe® sampling of TZW was performed by Siltronic. The data are included in the SCRA as non-LWG collected data.

[12]Note: The table shows 92 analytes. The additional 12 are filtered metals for which the same unfiltered metal also exceeds at least one screening value. Filtered and unfiltered metals are listed separately; however, filtered and unfiltered results for other analytes are not distinguished (filtered and unfiltered data sets were combined before the screening).

- Total TPH (including distinction of DRH, RRH, and GRH)

- Metals
  - Aluminum (Al)
  - Arsenic (As)
  - Barium (Ba)
  - Cadmium (Cd)
  - Lead (Pb)
  - Manganese (Mn)
  - Mercury (Hg)
  - Thallium (Tl)
  - Zinc (Zn)

- Pesticides
  - DDx (total DDD, total DDE, and total DDT)

- VOCs
  - Monochlorobenzene (MCB)
  - Dichlorobenzenes (total of 1,2-DCB and 1,4-DCB)
  - Total BTEX
  - Total aliphatic CVOCs[13] (including designation of highest individual concentration)

- Other
  - Perchlorate
  - Cyanide

The maps of these selected analytes are presented with color-coded symbols and flyout labels of individual concentration values. All samples presented on maps are from the 0 to 38 cm bml interval. Paired sets are presented for each river mile to show filtered and unfiltered results, where available. Peeper samples are presented with a unique symbol on both sets of images to allow for a detailed evaluation of results. A chemical concentration histogram is inset on each map to provide context for the results presented on the given river mile relative to the results from the entire Study Area. Available human health and ecological screening levels[14] are also shown on the

[13]A total of 17 aliphatic CVOCs were detected in TZW and are included in the aliphatic CVOC sums. These are: 1,1,1-trichloroethane, 1,1,2,2-tetrachloroethane, 1,1,2-trichloroethane, 1,1-dichloroethane, 1,2,3-trichloropropane, 1,2-dichloroethane, 1,2-dichloropropane, chloroethane, chloroform, chloromethane, cis-1,2-dichloroethene, methylene chloride, tetrachloroethene, trans-1,2-dichloroethene, trichloroethene, vinyl chloride, and vinylidene chloride.

[14]Chronic ecological screening values and human health screening values (including Region 9 Tap Water PRGs, the Safe Drinking Water Act [SWDA], MCLs, and the AWQC for fish consumption of 17.5 g/day) shown on all figures are the same values applied in the initial risk evaluation sections of this document (Sections 8 and 9).

histogram. TZW sampling analyte lists were based on site-specific upland groundwater COIs for the adjacent upland sites; therefore, analyte lists varied by study site, and it was often unnecessary to produce maps for each river mile for a given analyte. Table 6.2-2 presents the analytes mapped over each river mile.

Patterns in the mapped data sets are discussed in the following subsections for each chemical group evaluated. As needed to support the discussion, additional data evaluation tools are presented or cross-referenced from the TZW SCSR (Integral 2006g).

6.2.2.1 PAHs in TZW

River mile maps of total PAHs and BAP are presented in Maps 6.2-1a–d and Maps 6.2-2a–c, respectively. Total PAH values observed in TZW cover a large concentration range, varying between 0.003 µg/L and 1,200 µg/L in filtered samples and between 0.003 µg/L and 15,050 µg/L in unfiltered samples. The highest concentrations of total PAHs in TZW appear between RM 6 and 7, as is apparent in the color distribution of the concentration indicators and on the inset histograms of Map 6.2-1c.

LPAH concentrations are higher than HPAH concentrations across the entire Study Area. The concentration difference between the LPAHs and the HPAHs, on a point-by-point basis, is as large as 2 orders of magnitude in some cases. Additional discussion of this ratio and analysis of observed partitioning are presented on a site-by-site basis in the TZW SCSR (Integral 2006g).

Comparison of the filtered and unfiltered data sets on the paired river mile maps shows a decrease in total PAH concentrations with filtration. The harbor-wide histogram inset on each figure shows a large decrease in total PAH concentrations in the filtered samples as compared to the unfiltered samples; this apparent shift is largely attributable to the inclusion of Siltronic-collected unfiltered results. The Siltronic unfiltered results account for most of the >1,000 ppb values, and there were no filtered Siltronic-collected PAH results to allow for a thorough comparison. Box plot presentations from the TZW SCSR (Figures 2-3g,h,j,l, and m in Integral 2006g) exclude the Siltronic-collected results and show a decrease in the mean total PAH concentration with filtration, but only a small decrease in the overall concentration range. The observed decreases with filtration are attributable to removal of particulate matter >0.45 µm by filtration. River mile maps for BAP (Maps 6.2-2a–d) also show a consistent decrease in concentrations with filtration[15] for this HPAH constituent.

These screening values are shown only to provide perspective on the presented results and to support the risk evaluation discussions in Sections 8 and 9.

[15]A literature review of the Versapor filter material used in the TZW sampling (white acrylic copolymer coating over a nonwoven substrate) revealed that the filter material has been tested and applied successfully for use in environmental sampling of low concentrations of inorganic (Gaillard et al. 1986; Magaritz et al. 1989; Ronen et al. 1987a; Geotech 2004) and organic analytes (Ronen et al. 1987b; Krajenbrink et al. 1988; Kaplan et al. 1991; Shati et al. 1996; Laor et al. 2003).

Figures 6.2-3a –f present concentration graphs[16] for all individual PAH results at each TZW study site. These figures show several trends. First, the general signature of PAHs is similar in TZW across all of the sites, with PAH concentrations generally increasing with decreasing molecular weight down through acenaphthene. This general signature matches the observed overall trend of higher LPAH concentrations than HPAH concentrations. The signature at the Gasco site (Figure 6.2-3d) differs from those at the other sites at the low–molecular-weight end of the scale, exhibiting higher naphthalene and 2-methylnaphthalene concentrations.

Concentrations graphs of individual PAH data for the Kinder Morgan and Willbridge facilities show no instances where human health or chronic ecological screening levels are exceeded (Figures 6.2-3a and 6.2-3f). At the ARCO and ExxonMobil facilities (Figures 6.2-3b and 6.2-3c), screening levels were slightly exceeded for only two or three PAHs. In contrast, screening levels for both LPAH and HPAH were exceeded more frequently in TZW samples collected offshore of the Gasco and Siltronic facilities (Figure 6.2-3e).

Finally, there are no strong trends with depth apparent in the TZW data for PAHs. Paired filtered shallow (0 to 38 cm bml) and deep (90 to 150 cm bml) TZW samples for PAH were successfully collected only at the ARCO and ExxonMobil sites, and the deep results fall within the range of shallow results.

Additional discussion and analysis of PAH trends are presented in the TZW SCSR (Integral 2006g), including comparison to sediment results, equilibrium analysis, and consideration of upland concentrations and the physical pathway.

6.2.2.2 TPH in TZW

River mile maps for TPH, presented in Maps 6.2-3a–d, including flyout boxes, indicate diesel-range, residual-range, and gasoline-range TPH contribute to the total TPH concentration. As noted previously, there are no relevant screening levels for TPH. Further, the Round 2 analyses for TPH measure all hydrocarbons and non-hydrocarbons that can be quantified in the carbon range from n-C_{12} to n-C_{40}, regardless of natural or anthropogenic source. The descriptions of diesel-, residual-, and gasoline-range are simply descriptive laboratory terms, not source assignments, and measures should not be assumed to be compositionally or toxicologically consistent from site to site.

The highest TPH concentrations in TZW were observed offshore of Gasco and Siltronic, followed by ARCO and ExxonMobil. As shown on the inset harbor-wide

[16]Concentration graphs show individual results for all analytes in the analyte group, providing a visual tool for identifying the range and general chemical signature in TZW at each study site. Detected concentrations are shown using solid symbols; nondetected results are shown using open symbols. Shallow and deep TZW samples are presented using different colors to allow for assessment of trends. Plots are presented on logarithmic scales to allow for clearer presentation of all results. Additionally, chronic ecological screening levels (SLs) and human health SLs for water are presented to provide perspective and to support discussions in the risk evaluations presented in Sections 8 and 9.

histograms on each map, filtration consistently reduced total TPH concentrations slightly but did not significantly change the range or distribution of concentrations. Additional discussion of TPH in TZW on a site-specific basis is provided in the TZW SCSR (Integral 2006g).

6.2.2.3 Metals in TZW

River mile maps for manganese are presented in Maps 6.2-4a–e and those for arsenic are presented in Maps 6.2-5a–e. Additionally, metals concentrations for aluminum, arsenic, barium, cadmium, lead, and manganese are plotted against river mile in scatter plots in Figures 6.2-4a–c. These metals were selected for presentation on plots because of the consistency with which their concentrations exceed screening values. Mercury, thallium, and zinc scatterplots (Figures 6.2-4d,e) were developed to support load estimates and risk assessment of these metals.

Several observations can be drawn from these presentations of the metals data. First, arsenic, barium, and manganese concentrations consistently exceed screening levels, while aluminum, cadmium, and lead do so less frequently and are more localized. The highest concentrations of barium, cadmium, and manganese in TZW were measured offshore of the Arkema Chlorate Plant Area (RM ~7.4). TZW in this area also has a very high ionic strength (total dissolved solids, or TDS, in Arkema TZW samples ranged from 800 to 48,000 mg/L) because of historical salt operations at the site, and it is hypothesized that these conditions (i.e., trace minerals in the salts) may have contributed to the elevated concentrations of these metals. The highest concentrations of lead and, to a lesser extent, arsenic, were observed offshore of ARCO and ExxonMobil (RM 4.7-5.2). Aluminum concentrations in TZW are more sporadically distributed across the study sites.

Thallium and zinc rarely exceeded screening levels, exceeding them in only one sample for thallium and in two samples for zinc. No filtered or peeper mercury samples exceeded screening levels. For each of these three metals, the highest concentrations in TZW were also measured offshore of the Arkema Chlorate Plant Area (RM ~7.4).

Elevated concentrations of all these metals are distributed fairly evenly between filtered Trident samples and small-volume peepers, as seen by the method designations on Figures 6.2-4a–e. No depth-related trends could be discerned, as shown on Figures 6.2-4a–e.

As part of the loading, fate, and transport analysis presented in Section 7, a geochemical evaluation of the Round 2 TZW chemistry data was completed for three metal species—arsenic, barium, and manganese—that were consistently detected in TZW at concentrations above relevant risk-based screening values. The detailed geochemical analysis is presented in Appendix D, Section 7. The analysis includes a statistical evaluation of the spatial distribution of these metals in TZW across the nine TZW study sites and a comparison of TZW concentrations with available upland groundwater concentrations. Geochemical controls on arsenic, barium, and manganese in TZW were

evaluated by exploring correlations between metal concentrations and measured variables (e.g., pH, oxidation-reduction potential [ORP], alkalinity, and TOC) that could be expected to exert an influence upon their geochemical behavior. Geochemical modeling was performed to identify stable mineral and aqueous phases as a function of pH and Eh, mineral saturation indices, and mineral phases controlling the aqueous solubility of arsenic, barium, and manganese. (Iron was also included in the analysis because hydrous iron oxides can be an important substrate for adsorption of many trace metals, including arsenic.)

Overall, the geochemical analysis indicates that geochemical conditions in the TZW environment, and the resulting solubility controls on concentrations of arsenic, barium, and manganese, appear to be influenced by the presence organic carbon sources (either natural or introduced) and associated microbial activity. The results of the geochemical analysis are discussed in detail in Appendix D, and evaluated in the context of loading, fate, and transport in Section 7.

6.2.2.4 Pesticides in TZW

Among the nine TZW study sites, pesticides (specifically DDx) were identified as an upland groundwater COI only for the former Acid Plant Area of the Arkema site. TZW samples collected offshore of this area were analyzed for DDx pesticides. Additionally, one sample from the Rhone Poulenc offshore area (RP03C) was inadvertently analyzed for DDx pesticides because of an error in the chain of custody. This Rhone Poulenc sample result and the Arkema sample results are presented on Map 6.2-6.

As shown on Map 6.2-6, detected pesticide concentrations are substantially lower in filtered samples than in collocated unfiltered samples, with the exception of minimal differences in the low-concentration filtered and unfiltered sample set from RP03C. The decrease in concentration with filtration matches the expected behavior (i.e., removal of particulate matter during filtration for this highly hydrophobic analyte group).

Where detected (three samples), filtered DDx pesticides in TZW samples exceeded the human health AWQC screening value. DDx pesticides were widely detected in the sediment samples at the Acid Plant area. Notably, unfiltered TZW DDx concentrations are higher than concentrations observed in nearshore upland groundwater as shown in Figures 10-5d, 10-5f, 10-5j, and 10-5l.of the TZW SCSR (Integral 2006g). This may be due to the presence of particulate matter in the unfiltered samples, mobilized by the sampling process. It could also relate to the direct discharge of DDT manufacturing residues through a historical outfall pipe (the use of which was discontinued many years ago) during the first year of the Arkema DDT plant operations.

6.2.2.5 VOCs in TZW

River mile detail maps for MCB, DCBs, total BTEX, and total aliphatic CVOCs in TZW are presented in Maps 6.2-7a and 6.2-7b, Maps 6.2-8a–e, Figures 6.2-5a and 6.2-

5b, and Maps 6.2-9a–c. (Note: No filtered Trident samples were collected for VOCs in accordance with standard operating procedures (SOPs) for sampling of VOCs.)

Maps 6.2-7a and 6.2-7b present MCB and DCB (total of 1,2-DCB and 1,4-DCB) concentrations for the two river miles where these analytes were detected (RM 6-7 and RM 7-8). MCB was detected at concentrations exceeding ecological or human health screening levels offshore of the Arkema (former Acid Plant Area) and Rhone Poulenc sites, with the highest concentration (12,000 µg/L) observed offshore of the Arkema site at location AP03D. The TZW SCSR discusses these data in greater detail on a site-by-site basis, with additional lines of evidence considered in the analysis (Integral 2006g).

Maps 6.2-8a–e, with supporting detail in Figures 6.2-5a–b, present the measured total BTEX concentrations in TZW over the Study Area. The upper half of each map presents the total BTEX concentration, and the lower half presents the relative contribution of each BTEX constituent in the form of a pie chart. The maps and figures exhibit a large range of detected total BTEX concentrations in the TZW samples over the study sites, varying between 0.11µg/L and 1,600 µg/L.

The highest total BTEX concentrations were measured offshore of the Gasco and Siltronic sites. Substantially lower concentrations of total BTEX were observed offshore of the Kinder Morgan Linnton, ARCO, ExxonMobil, and Willbridge sites. These sites with lower concentrations exhibit similar patterns in the composition of the BTEX constituents observed. As shown in the pie chart representation, total BTEX at these sites is primarily composed of toluene and xylenes. In contrast, the areas of higher BTEX concentrations offshore of the Gasco and Siltronic sites exhibit higher proportions of benzene and ethylbenzene, with a pattern indicating the possibility of a higher proportion of xylenes in the areas closest to shore. The area offshore of the Rhone Poulenc site exhibits relatively low BTEX concentrations with a composition dominated by benzene and xylenes. Relatively elevated total BTEX concentrations were also measured at several locations offshore of the Arkema site, with at least two general signatures across the site: toluene-dominated composition for the higher concentrations and benzene-dominated composition for the lower concentrations.

Total aliphatic CVOCs[17] are presented on Maps 6.2-9a and 6.2-9b[18], which include a designation for the analyte with the highest individual concentration at each point. Additionally, individual CVOC concentrations are plotted for each site in scatter plots in Figures 6.2-6a–j. Offshore of the Siltronic site, the CVOCs with the highest

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[17]A total of 17 aliphatic CVOCs were detected in TZW and are included in the aliphatic CVOC sums. These are: 1,1,1-trichloroethane, 1,1,2,2-tetrachloroethane, 1,1,2-trichloroethane, 1,1-dichloroethane, 1,2,3-trichloropropane, 1,2-dichloroethane, 1,2-dichloropropane, chloroethane, chloroform, chloromethane, *cis*-1,2-dichloroethene, methylene chloride, tetrachloroethene, *trans*-1,2-dichloroethene, trichloroethene, vinyl chloride, and vinylidene chloride.

[18]River mile maps were not created for RM 4-5 and 5-6 because CVOCs were detected in these reaches at two or fewer locations, and corresponding screening levels were not exceeded.

individual concentrations in TZW are TCE and two of its degradation products, *cis*-1,2-DCE and vinyl chloride. Offshore of the Arkema and Gunderson sites, the CVOCs with the highest individual concentrations are chloroform and methylene chloride, respectively. All elevated CVOC concentrations in TZW are located in areas of suspected groundwater discharge to the river, with the possible exception of the northernmost CVOC concentrations at the Siltronic site (see MFA 2005a,b for further discussion). Gunderson and Siltronic show a possible trend of increased VOC concentrations with increasing TZW sample depth. A similar pattern with depth is not clearly apparent in the Rhone Poulenc and Gunderson TZW data sets (see TZW SCSR [Integral 2006g] Figures 8-3c, 9-3a, 10-CP3b, and 12-3b). Additional site-specific discussion of VOCs in TZW is presented in the TZW SCSR (Integral 2006g).

6.2.2.6 Other Selected Analytes in TZW (Perchlorate and Cyanide)

Samples were analyzed for perchlorate and cyanide in TZW only at selected sites—offshore of the Arkema site for perchlorate, and offshore of the Gasco and Siltronic sites for cyanide. The sampling results for perchlorate in TZW are shown in Figure 6.2-7 and those for cyanide are shown in Figure 6.2-8. Also, for each of these analytes, only unfiltered samples were collected[19], since neither is expected to sorb significantly to solids (both are ionic).

Cyanide concentrations in TZW range from 0.006 µg/L to 23.1 µg/L. These concentrations are generally lower than those in the nearshore groundwater monitoring wells at the Gasco and Siltronic sites. Cyanide concentrations in the three deeper TZW samples (90 to 150 cm bml) collected offshore of the Gasco and Siltronic sites were comparable to the concentrations observed in the 0 to 38 cm bml samples. This information is presented and discussed in greater detail in the TZW SCSR (Integral 2006g).

Detected perchlorate concentrations in TZW samples from 0 to 38 cm bml range from 105 µg/L to 177,000 µg/L. These values are comparable to or higher than those observed in the upland nearshore groundwater. Perchlorate concentrations in the deeper TZW samples (90 to 150 cm bml) collected offshore of the Arkema site were often higher than in the shallower samples (0 to 38 cm bml). The highest perchlorate concentrations were found along transect 7 (sampling locations CP-07-A, CP-07-B, and CP-07-D), which also corresponds to the highest VOC concentrations. The lines of evidence for groundwater discharge (discussed in greater detail in the TZW SCSR [Integral 2006g]) suggest this may be a possible focus area for offshore plume discharge.

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[19]Note: Six filtered samples of perchlorate were collected during the Pilot Study. These samples are presented with the unfiltered results on the plan view figure, recognizing that the perchlorate ion is highly soluble. Therefore, perchlorate concentrations are not expected to be altered by the presence or absence of particulate matter and should not be affected by filtration.

6.2.3 Spatial and Temporal Nature of the TZW Data

This section presents information regarding the spatial and temporal nature of the available TZW data. TZW sampling was limited to offshore areas with a confirmed or reasonable likelihood for discharge of upland groundwater COIs to Portland Harbor. TZW was sampled offshore of nine sites in the Round 2 GWPA. It is expected that the TZW results from these nine sites are representative of TZW concentrations at the majority of other sites where there is a similar discharge and concentration of chemicals originating from upland groundwater[20]. Additional consideration of whether any of the remaining Category A sites warrant further assessment is presented in Section 12 of this report.

Because TZW samples were collected at a single point in time (for Trident and Geoprobe® sampling) or over a 3-week equilibration period (for peeper sampling), field sampling was carefully timed to maximize the expected upland groundwater signal (i.e., the time of greatest groundwater discharge rate). Temperature differences between groundwater and surface water can help reveal locations of groundwater discharge (see Discharge Mapping FSP [Integral 2005b] for additional details). Discharge mapping, which included measurement of this temperature differential, occurred in August and September (8/1/05–9/9/05), the period of lowest river water levels and greatest temperature differential between upland groundwater and surface water. TZW analytical samples were collected shortly after discharge mapping (10/3/05–12/2/05), before river water levels increased to the typically high rates of mid-winter through spring.

Daily tidal fluctuations were not considered relevant for either peepers or the Trident sampler. Peeper samplers were left in place over 3 weeks, allowing equilibration over many tidal cycles. Seepage meter results suggest that Trident samples from depths of 30 cm bml or deeper are unlikely to be affected by tidal changes. The typical discharge rate measured by seepage meters was on the order of 2 cm/day (average = 1.61 cm/day; minimum daily average = -18.9 cm/day; maximum daily average = 14.2 cm/day). The largest net negative recharge rate[21] among seepage meter locations showing an average positive discharge (i.e., locations where the tidal influence could potentially have a significant timing impact on TZW chemistry) was observed offshore of the Siltronic site. At this location, the negative recharge period covered roughly 9.5 hours, with an average seepage rate of -6.7 cm/day during this period. This corresponds to a net seepage of 2.65 cm. Assuming sediment porosity of 25 percent, the maximum depth of influence for this period of negative seepage is likely to be about10.6 cm. At this location with the greatest period and magnitude of negative flux (among all locations

[20]In areas not directly affected by transport of chemicals originating in upland groundwater, chemicals may be present in TZW as a result of desorption from contaminated sediments and/or geochemical processes within the sediments and associated TZW. The approach to this evaluation is presented in Section 7.

[21]The negative seepage rate values are the focus here because they correspond to observed recharge to the TZW from surface water, which is the concern related to tidal influence on the timing of TZW sampling.

with net positive flux), this estimated periodic depth of influence of surface water is still well above the minimum sampling depth of 30 cm bml.

6.3 INDICATOR CHEMICALS IN SURFACE WATER

The geographic locations of all Round 2A surface water samples are shown on Map 6.3-1. Summary statistics for all Round 2A sampling events are provided in Table C1-13 (Appendix C1). The surface water data set includes results from all three Round 2A sampling events.

A total of 52 COPCs were identified based on ecological and human health risk evaluations (see Sections 8 and 9). A subset of 14 COPCs was selected as indicator chemicals, as indicated in Table 6.0-2, based on several factors:

- The compound is a COPC in the ecological and/or human health risk evaluations
- The compound shows a high frequency of detection in Round 2A surface water samples
- Taken together, the compound suite represents a wide range of compound classes (e.g., metals, pesticides, PAHs)
- An effort was made to include chemicals that are also indicator chemicals for sediment.

The following sections provide a brief description of the non-LWG surface water data, Round 2A sample collection conditions, the spatial and temporal distribution of the surface water indicator chemicals in the Study Area, and a comparison of COPCs in suspended particulates to the preliminary background sediment concentrations developed in Section 6.1.3.

6.3.1 Non-LWG Data

Limited data for conventional analytes, metals, and organic compounds were available through non-LWG sources including DEQ, USGS, City of Portland, and site-specific monitoring programs. Data were collected as part of several programs, including the DEQ ambient monitoring program, the USGS National Water Quality Assessment program, Willamette River Basin Water Quality Study cooperative program between USGS and DEQ, City of Portland BES watershed program, the Rhone-Poulenc water quality survey (Woodward-Clyde 1995), and McCormick & Baxter water quality survey (PTI 1992, OSU undated). The USGS and DEQ data were obtained through EPA's STORET and DEQ's LASAR databases.

Data from non-LWG sources are summarized in Table 6.3-1. The ambient monitoring programs established by DEQ monitor for metals, but not for organic pollutants; recent organic data in the LWR are limited to herbicide and pesticide analyses reported by USGS. TSS data (see Section 6.3.2.1) were obtained from the City of Portland BES watershed program. The Rhone-Poulenc survey analyzed water samples for SVOCs,

VOCs, herbicides, pesticides, and dioxins/furans; the McCormick & Baxter survey analyzed water samples for PAHs only. Oregon State University (OSU) also deployed passive sampling devices at its surface water grab station at the McCormick & Baxter site. Semipermeable membrane devices (SPMDs) were used to monitor PCP and PAHs, and diffusive gel thinfilms were used to assess metals. Except for the City of Portland 1992–2006 TSS data, the limited non-LWG sampling results are not included in the discussions below.

6.3.2 Round 2A Sample Collection Conditions

Surface water samples were collected at 23 target locations from RM 2 to RM 11 in the Lower Willamette River during three Round 2A sampling events in 2004 and 2005. Samples were collected by peristaltic pump at all locations. Additional samples were collected using the high-volume XAD sampling method at 7 of the 23 locations, including three cross-sectional river locations and four discrete locations. The surface water study is described in Section 2.1.3.4. The Round 2A TZW SCSR (Integral 2006g) provides details regarding the sampling program, sample collection procedures, and laboratory analyses.

The surface water samples were analyzed for conventional analytes, metals, and organic compounds (PCB Aroclors, organochlorine pesticides, SVOCs). High-volume samples were analyzed by high-resolution gas chromatography/high-resolution mass spectrometry (HRGC/HRMS) for PCB congeners, dioxins/furans, organochlorine pesticides, phthalate esters, and PAHs. PCB Aroclor concentrations in the XAD samples were estimated using the PCB congener data. All three Round 2A sample collection events are displayed on Figure 6.3-1.

Several rainfall events occurred during the November 2004 sampling event, and one day of measurable rainfall occurred during each of the March and July 2005 sampling events. Figures 6.3-2 through 6.3-4 display daily average and historical average discharge rates and daily precipitation levels for the November 2004, March 2005, and July 2005 sampling events, respectively.

The Round 2A surface water study was designed to characterize surface water samples during three different flow regimes: Low-flow conditions (early fall), early rainy season (mid- to late fall), and high-flow conditions (late winter, timed to coincide with the period of early exposure of amphibian egg masses) (Integral 2004d). However, rainfall was lower than normal for the early fall and late winter sampling events, with the result that low-flow conditions were present during all three sampling events (Figure 6.3-1). As a result, stormwater input was relatively minor overall during all of the sampling events and differences in the distributions of COPCs between sampling events are the result of stormwater input for selected samples and other factors such as water temperature, day length and solar irradiation, biological activity, and groundwater flux. Seasonal variations in conditions upstream of the Study Area, such as runoff of agricultural chemicals during the growing season, may also contribute to seasonal changes in the Study Area.

6.3.3 Nature and Extent of Surface Water Indicator Chemicals

A wide range of analyses, including 18 analytical methods and hundreds of individual organic and inorganic chemical analytes, were completed for surface water samples for the Round 2A surface water investigation (Integral 2006l). Fourteen COPCs were selected for discussion in this section, as described in the introduction to Section 6.3 and identified in Table 6.0-2. Summary statistics for the COPCs are included in Table 6.3-2. The distributions of these COPCs and of TSS are described below. The composition of multi-component analytes (i.e., PCBs, dioxins/furans, DDx, and PAHs) is also described.

6.3.3.1 Total Suspended Solids

Each Round 2A surface water sample collected with a peristaltic pump was analyzed for TSS. Results ranged from undetected (at a detection limit of 5 mg/L) to 16 mg/L, with the highest concentration found at Station W001-RM 2 during the July 2005 sampling event. Figure 6.3-5 displays the Round 2A surface water TSS results.

Figure 6.3-6 displays Willamette River TSS values and precipitation levels collected between February 5, 1992 and March 15, 2006 by the City of Portland (Sanders 2006, pers. comm.). City of Portland surface water samples were collected at a 10-ft depth from the east, middle, and west locations along transects at RM 1.1, RM 6.8, RM 8.8, RM 12.7, RM 17.9, and RM 20, and were composited by transect. The range of TSS concentrations measured in the City of Portland 1992-2006 composite samples (0.4 to 243 mg/L) is wider than that measured by LWG or the City of Portland during the time period of the Round 2A sample collection events. Figure 6.3-7 displays the City of Portland TSS results during the Round 2A surface water sampling timeframe of November 2004 through July 2005

There was no obvious difference in TSS concentrations or detection frequency between transect and near-bottom stations. However, a temporal trend was evident: TSS was detected more often and at generally higher concentrations during the July 2005 sampling event. The stream velocity and river flow were lower during this sampling event than the November 2004 event and similar to the March 2005 event (Integral 2006l) and a lower TSS concentration would be expected. The higher TSS levels may have been related to increased biological productivity resulting from the higher summer water temperatures and increased sunlight.

6.3.3.2 PCBs in Surface Water

High-volume surface water samples were analyzed for PCB congeners (reported in units of pg/L) by HRGC/HRMS, and samples collected by peristaltic pump were analyzed for PCB Aroclors (reported in units of µg/L) by routine methodology (i.e., EPA Method 8081). Total PCB congener concentrations in Round 2A surface water XAD column (i.e., "dissolved") and 0.5-µm glass fiber filter samples are depicted in Figure 6.3-8 and Map 6.3-2, and discussed below.

For the three upstream transect samples, the total PCB congener concentrations ranged from a low of 171 pg/L (March, upriver transect [W023, RM11]) to a high of 609 pg/L (November, upriver transect, RM11). For the March and July 2005 sampling events, the concentrations in the upstream transects were lower than the concentrations observed in the mid-stream and downstream transects. Excluding station W013 in Willamette Cove, the near-bottom samples' total PCB congener concentrations ranged from 201 to 1,290 pg/L in the XAD filters, and from 137 to 639 pg/L in the XAD columns. Total PCB congener concentrations at Station W013 were an order of magnitude greater, ranging from 3,340 to 12,000 pg/L. PCB Aroclors were detected at only four locations, including stations W001 (July 2005), W004 (November 2004 and March 2005), W014 (November 2004), and W021 (July 2005), at concentrations fairly close to the detection limit of 0.0025 µg/L for most samples. The highest total PCB Aroclor concentration, 0.0154 µg/L (15,400 pg/L), was reported for station W014 in Willamette Cove. This result is similar in magnitude to the highest result for total PCB congeners for station W013, also located in Willamette Cove. Human health and chronic ecological screening levels for surface water are included on Figure 6.3-8 to provide perspective. Additional information on the screening levels is included in Appendix B and Section 9.

The proportion of PCBs present in the particulate fractions appears to increase relative to the total PCB load at higher total PCB concentrations (Figure 6.3-8). Total PCB congener concentrations were lower in the transect samples (W005-RM 4.0, W011-RM 6.3, and W023-RM 11) than in the single-point nearshore/near-bottom samples (W013-RM 6.9, W015-RM 6.9, W016-RM 7.2, and W018-RM 8.3) (Figure 6.3-8). This difference is possibly due to differences in sample collection techniques (vertical integration of the water column along numerous equal-discharge intervals (EDIs) along each river transect versus stationary near-bottom sampling) or proximity to sources. Except at transect W023 (RM 11) in November 2004, the concentration of total PCB congeners in the transect samples is lower upriver than in the Study Area (Figure 6.3-8). A substantial rain event occurred during the November 2004 sampling of transect station W023 (average of approximately 0.42 inches of rain over the sample collection period), which may have caused the increased signal of PCB congeners in the filter sample.

TEQ concentrations were calculated for PCB congeners designated by the World Health Organization (WHO 1997) as similar in mechanism of toxicity to 2,3,7,8-TCDD. Total PCB congener TEQs for XAD column and filter samples were calculated by multiplying the congener's attributed TEF by the total PCB congener concentration found in each sampling event. The total PCB congener TEQs calculated for the transect stations ranged from 0.00157 pg/L (July 2006 upstream transect) to 0.00734 pg/L (March 2006 mid-stream transect) for the XAD columns, and ranged from 0.00596 pg/L (March 2006–Station W016) to 0.04798 pg/L (March 2006–Station W013) for the XAD filters. Figure 6.3-9 and Map 6.3-3 display the total PCB congener TEQs for each XAD column and filter sample for each sampling event; TEQs were higher in the filter samples than in the XAD column samples for each sampling event.

6.3.3.2.1 PCB Composition

At all sampling locations, PCBs in the particulate fraction consistently exhibited a more highly chlorinated pattern than PCBs in the dissolved phase. This PCB distribution reflects the greater solubility and lower partitioning coefficients of the less chlorinated congeners, as described in Section 7.2. Pie charts depicting total PCB congener concentrations and PCB homolog distributions for the Round 2A surface water XAD column and filter samples are presented in Map 6.3-4.

The PCB composition was similar at the three transect locations during all sampling events, with the exception of PCBs associated with the particulate fraction sampled at transect W023 (RM11) in November 2004. Dissolved PCBs at the transect locations consisted of a fairly equal mixture of diCBs, triCBs, tetraCBs, and pentaCBs during all of the sampling events, and PCBs associated with the particulate phase contained predominantly tetraCBs, pentaCBs, hexaCBs, and heptaCBs. The PCBs at transect W023 in November 2004 contained a higher proportion of hexaCBs and heptaCBs and a higher total concentration of PCB congeners than samples collected at other times. This sample may have been influenced by stormwater discharges from a nearby outfall resulting from a rainfall event on the day the sample was collected (Integral 2005e); the other transect samples collected in November 2004 were not collected on days when stormwater outfalls were obviously discharging. The PCB data for this sample were excluded from consideration in the following discussion.

The PCB homolog composition in samples from the nearshore/near-bottom locations was distinct from the composition in the transect samples to varying degrees, likely reflecting local sediment conditions or upland sources at these locations (Section 11.2.4.1). On the west bank, at location W016 near RM 7.3, tetraCBs were present in higher relative abundance than at the transect stations in both the particulate and dissolved phases. TetraCBs are the most abundant PCB congeners in Aroclor 1248 (Map 6.3-4).

At location W015, near RM 6.9 and the west bank, the abundance of tetraCBs was generally intermediate between location W016, less than half a mile upstream, and the transect locations. However, in November 2004, an abundance of triCBs was present at this location. TriCBs are prevalent in Aroclors 1016, 1242, and 1248. The PCB concentrations and profiles imply PCB contributions from an additional source in November 2004 compared to March and July 2005. Because rainfall of 0.24 in. was recorded on the sampling date (Integral 2006l), a source related to stormwater discharge near this sampling location is possible.

The PCB profile for particulate-phase PCBs in Willamette Cove (W013) was dominated by hexa- and heptaCBs in a pattern that was very similar to Aroclor 1260 (Map 6.3-4). The dissolved PCB profile was similar to that of the transect locations, with slightly more triCBs in March 2005.

PCBs in Swan Island Lagoon (W018) were slightly more chlorinated overall than PCBs at the transects and the near-bottom sampling locations in the main river channel, with

the exception of particulate-bound PCBs in Willamette Cove (W013). The profiles for particulate-bound PCBs in Swan Island Lagoon and Willamette Cove are similar to the profiles found in surface sediment at these locations (Map 6.3-4).

6.3.3.3 Dioxin/Furans in Surface Water

Concentrations of total polychlorinated dibenzo-p-dioxin/furan (also referred to as dioxins/furans or PCDD/Fs) in Round 2A surface water XAD column and filter samples are depicted in Figure 6.3-10 and Map 6.3-5.

Total dioxin/furan concentrations were lower in the transect samples (W005-RM 4.0, W011-RM 6.3, and W023-RM 11), which ranged from 16.7 pg/L to 50.5 pg/L, than in the single-point near-bottom samples (W013-Willamette Cove, and W015-RM 6.9), which ranged from 45.6 pg/L to 163 pg/L, possibly due to differences in sample collection techniques or proximity to sources. As shown in Figure 6.3-10, there was a strong preferential distribution of dioxin/furans in the particulate phase (0.5-µm glass fiber filter samples) as opposed to the water column (XAD column samples), and total dioxin/furan concentrations were slightly lower in the upriver transect samples (Station W023-RM 11) than in the stations downriver in the Study Area during each sampling event.

TEQs were calculated for all dioxin/furan congeners. Figure 6.3-11 and Map 6.3-6 display the total dioxin/furan congener TEQs for each XAD column and 0.5-µm glass fiber filter sample for each sampling event. TEQs were higher in the 0.5-µm glass fiber filter samples than in the XAD column samples for each sampling event.

6.3.3.3.1 Dioxin/Furan Composition

Pie charts depicting total dioxin/furan concentrations and dioxin/furan homolog distributions for the Round 2A surface water XAD column and filter samples are presented in Map 6.3-7. Bar charts depicting the homolog distributions are presented in Map 6.3-8.

Overall, dioxin/furans in surface water at all sampling locations were dominated by octaCDD and heptaCDDs in both the dissolved and particulate phases. At the transect locations, octaCDD accounted for more than half of the dioxins in the filter samples (particulate fraction) at almost all locations and sampling events, and heptaCDD accounted for another 15 to 30 percent. The less chlorinated dioxins and furans were more abundant in the dissolved phase than in the particulate phase. The homolog pattern for dissolved dioxin/furans varied little from transect to transect moving downstream from W023 (RM 11) to W011 (RM 6.3) and W005 (RM 4) during each sampling event. However, the pattern did vary seasonally, with the dissolved tetra- through hexaCDD/Fs more abundant in March 2005 than during the other two sampling events.

At location W015, on the western riverbank at RM 6.9, furans were somewhat more abundant than at other locations during all sampling events, in the particulate as well as

dissolved phases. The pattern of the dioxins was similar to that of the transect stations. This area may be influenced by a different dioxin source than the river as a whole.

In Willamette Cove (W013, RM 6.9), the profile for dioxin/furans in both the dissolved and particulate phases closely resembled the profile at the transect locations during each sampling event, despite the consistently higher concentrations of particulate-sorbed dioxin/furans found at this location. The concentration of dissolved dioxin/furans at W013 was higher than at transect W011 (RM 6.3) only in July 2005, but the homolog composition was quite similar.

Differences were found in the field replicates collected in Willamette Cove during two of the sampling events. Total dioxin/furan concentrations and homolog profiles for the replicates were different in March 2005 in the dissolved phase, and in July 2005 in the particulate phase (Map 6.3-7). In March 2005, total homolog concentrations were 0.897 and 12.5 pg/L for dissolved dioxin/furans in the sample and field replicate. The field replicate, sample LW2-W2013-2 C, contained a distinctly higher relative abundance of tetraCDDs and a lower abundance of heptaCDDs and octaCDD than sample LW2-W2013-1 C. These samples were collected over 2 days (March 1 and 2, 2005; Integral 2006l). The concentration of dioxin/furans in the particulate phase was similar between these replicate samples, with a similar homolog profile. In July 2005, the profile for particulate-sorbed dioxin/furans for the field replicate contained a higher abundance of tetra- through hexaCDDs and a much lower concentration of dioxin/furans than the original sample. The July 2005 concentrations of particulate-sorbed total homologs were 156 and 26.3 pg/L for particulate-sorbed dioxin/furans in the sample and field replicate. The variability of the replicate samples implies spatial or temporal variability of the dioxin/furans in Willamette Cove or may reflect a different source.

6.3.3.4 DDx in Surface Water

In general, the 2,4'- and 4,4'-isomers of DDT and its primary breakdown products, DDD and DDE, occur at relatively low concentrations in the Study Area, with two notable exceptions. Stations W015 and W016, nearshore stations located along the western bank of the LWR, exhibited elevated concentrations of DDx compounds as compared to other surface water stations (see Figures 6.3-12 through 6.3-15 and Map 6.3-9). Station W013, located almost directly across the river from W015 and W016 along the eastern bank, did not exhibit elevated concentrations of these chemicals (see Map 6.3-9). The total 2,4'- and 4,4'- DDx concentrations at the transect stations ranged from 42.8 pg/L (November 2005 upstream transect) to 236.5 pg/L (July 2005 mid-stream transect) and the concentrations at the near-bottom stations ranged from 60.9 pg/L (November 2004, Station W018) to 9,760 pg/L (July 2005, Station W016).

Transect station W011 (RM 6.3) did not typically exhibit elevated DDx concentrations despite its downstream proximity to stations W015 and W016. Results associated with the upstream transect at RM 11 (W023) and the downstream transect at RM 4.0 (W005) suggest a consistent load of DDx compounds entering or departing the Study Area (see Map 6.3-9). The DDx concentration in surface water, which is predominantly localized

around stations W015 and W016, appears to become diluted rapidly in the water column; concentrations are substantially lower at stations located immediately downstream.

From a compound-specific perspective, the majority of DDx compounds present in Willamette River surface water appear to be the 2,4'- and 4,4'-isomers of DDD and DDT (see Map 6.3-10). The high DDD/DDE ratio is typical of an anaerobic environment; DDT degrades to DDD via dehydrohalogenation in the absence of oxygen. The high DDD/DDE ratio may indicate DDT degradation to DDD in anoxic sediments prior to its suspension (particulate-bound) or dissolution in LWR surface water. DDD was detected at W015 and W016 in the dissolved (XAD column) and particulate (XAD filter) fractions in almost equal proportions (see Figure 6.3-12). Conversely, DDE and DDT were detected to a higher degree in the particulate fraction. This pattern was most evident at station W016 (see Figures 6.3-13 and 6.3-14).

The greatest abundance of DDx compounds is isolated in a nearshore area at approximately RM 7 (see Map 6.3-9). During the July 2005 sampling event, DDx concentrations spiked at station W016 (see Figure 6.3-15 and Map 6.3-9). The concentrations of the 2,4'- and 4,4'- isomers of DDx compounds (individual and combined) were higher in July 2005 than during the previous sampling events. This spike was not evident at station W015, located immediately downstream, and again may reflect the rapid dilution of DDx in LWR surface water. Previously, the highest concentrations of total DDx (2,4' and 4,4' isomers) had been detected at station W015 in November 2004 and March 2005 (see Figures 6.3-13, 6.3-14, and Map 6.3-9).

With the exception of 2,4'- and 4,4'-DDD, the majority of the DDx was present in the particulate fraction in July 2006 (see Figure 6.3-13 and Map 6.3-9), possibly due to particulates in the XAD filter following localized disturbance in the shallow sediment.

6.3.3.5 Aldrin in Surface Water

The organochlorine pesticide aldrin was identified throughout the surface water Study Area at quite similar concentrations, with one notable exception. The aldrin concentrations in the transect samples ranged from 0.30 pg/L (November 2004 downstream transect) to 2.7 pg/L (July 2005 mid-stream transect). The aldrin concentrations at the near-bottom stations, excluding W015, ranged from 0.4 pg/L (July 2005, Station W018) to 2.1 (July 2005, Station W013). In November 2004, aldrin concentrations were an order of magnitude higher at station W015 than elsewhere (see Figure 6.3-16 and Map 6.3-11).

In general, aldrin concentrations tended to increase slightly from November 2004 to July 2005. At some stations, detection limits for this compound were elevated to concentrations similar to those measured at other stations (see Figure 6.3-16). The higher levels of aldrin in July may have resulted from greater solubility due to increased seasonal surface water temperatures or from localized disturbances in the shallow sediment.

The majority of aldrin detected in surface water was in the XAD column, or dissolved phase. The exception to this pattern occurred at station W015 in November 2004 (see Figure 6.3-16), when greater than 80 percent of aldrin detected was in the particulate phase (XAD filter). Rainfall of 0.24 in. was recorded on the November 2004 sampling date for W015 (Integral 2006l); a source related to stormwater discharge near station W015 may be the cause of the higher aldrin concentration and the higher percentage of aldrin detected in the particulate phase.

Surface water concentrations of aldrin at upstream (W023 at RM 11) and downstream (W005 at RM 4.0) transects in the Study Area were very similar to one another. Aldrin inputs within the Study Area appear to become quickly diluted, as indicated by significantly lower levels at stations immediately downstream of W015. The surface water transect samples appear to suggest that sources of aldrin within the Study Area are not substantially greater than those that may exist upstream.

6.3.3.6 Beta-Hexachlorocyclohexane in Surface Water

According to XAD data, beta-HCH is generally present within the dissolved phase in Willamette River surface water. The proportion of this pesticide detected in XAD filters was extremely low (see Figure 6.3-17). The concentrations of beta-HCH were similar throughout the surface water Study Area, except at stations W015 and W016 (approximately RM 7) (see Map 6.3-12), where they were higher. The total beta-HCH concentrations at the transect stations ranged from 1.7 pg/L (November 2004 upstream transect) to 9.4 pg/L (July 2005 upstream transect). At station W015, concentrations were highest in November 2004 (34.7 pg/L) and decreased successively during the next two sampling events (March and July 2005). The opposite pattern was observed at station W016, with successive increases from November 2004 (5.9 pg/L) to July 2005 (20.6 pg/L).

In general, beta-HCH concentrations in surface water increased from November 2004 to July 2005. Elevated concentrations at stations W015 and W016 did not result in elevated levels at the transect station located directly downstream (W011) (see Map 6.3-12), possibly indicating rapid dilution of beta-HCH in the river. The presence of relatively equal concentrations in samples collected from the upstream, mid-stream, and downstream surface water transects suggest that sources of beta-HCH within the Study Area are not substantially greater than those that may exist upstream.

6.3.3.7 Total Chlordanes in Surface Water

Total chlordanes were detected in every surface water sample collected during the Round 2A sampling events. The total chlordane concentration at the transect stations ranged from 13.4 pg/L (November 2004 upstream transect) to 37.1 pg/L (July 2005 mid-stream transect). The total chlordane concentration in the near-bottom stations, excluding the November 2004 result for W015, ranged from 19.2 pg/L (November 2004, Station W013) to 42.4 pg/L (July 2005, Station W015). The concentrations were generally low, except for one sample from station W015 (RM 6.9) in November 2004 (see Figure 6.3-18 and Map 6.3-13). This concentration was almost an order of

magnitude greater than the majority of others measured during the three sampling events. As stated above, 0.24 in. of rainfall were recorded on the November 2004 sampling date for W015 (Integral 2006l); a source related to stormwater discharge near station W015 may be the cause of the higher total chlordane concentrations. The concentrations found in samples collected at W015 in March and July 2005 were only slightly elevated compared to the majority of samples from the other stations. The data from stations collected immediately downstream of station W015 in November 2004 did not reflect a significant total chlordane load moving through the system.

Like other pesticides detected in the surface water Study Area, chlordanes occur primarily in the dissolved phase (see Figure 6.3-18). At station W015 in November 2004, however, approximately 75 percent of total chlordanes detected were in the particulate phase (XAD filter samples). Excluding station W015, total chlordane concentrations increased between November 2004 and July 2005 (see Figure 6.3-18).

6.3.3.8 Benzo(a)pyrene in Surface Water

BAP was generally detected in the particulate fraction of surface water samples collected during the Round 2A events. This heavy aromatic compound tends to associate with particles because of its limited solubility in water and was retained in the XAD filter almost exclusively (see Figure 6.3-19). The concentrations of BAP were relatively low in the surface water Study Area, except at stations W015 and W016 (see Figure 6.3-19 and Map 6.3-14). The total BAP concentrations for the transect stations ranged from 26.3 pg/L (November 2004 upstream transect) to 1,180 pg/L (July 2005 mid-stream transect) and the concentrations for the near-bottom samples ranged from 18.3 pg/L (March 2005, Station W013) to 3,030 pg/L (November 2004, Station W015).

The concentrations of BAP at stations W015 and W016 were higher during July 2005 than during the two earlier sampling events. The same phenomenon occurred at the other surface water stations, with one exception. At station W018 (RM 8.3), the level of BAP increased from November 2004 to March 2005, but BAP was not detected subsequently in the XAD filter and was virtually undetected in the XAD column.

The highest BAP concentration was associated with the July 2005 sample collected from station W015. This concentration was more than twice the value measured from station W016 during the corresponding sampling event. The highest BAP concentration at station W016 (July 2005) was approximately equal to the November 2004 value at station W015 (see Figure 6.3-19).

Data from the upper end of the surface water Study Area (station W023 at RM 11) do not indicate a substantial upriver source of BAP. Its presence at other transect stations (W011 at RM 6.3 and W005 at RM 4.0) suggests more local sources of this chemical (see Map 6.3-14).

6.3.3.9 Total PAHs in Surface Water

Samples for PAH analysis were collected both by peristaltic pump and by XAD column (dissolved PAHs) with glass fiber prefilter (suspended particles). Total PAH

concentrations in Round 2A surface water XAD column and filter samples are depicted in Map 6.3-15 and Figure 6.3-20. Total PAH concentrations in samples collected by peristaltic pump are shown in Figure 6.3-21. The composition of PAHs in high-volume (XAD) and peristaltic surface water samples at the various sampling locations is shown in Figures 6.3-22 and 6.3-23, respectively. Note that PAHs are reported in units of pg/L and µg/L in XAD and peristaltic samples, respectively.

Total PAH concentrations from 23 peristaltic pump stations were below 0.1 µg/L, with three exceptions. At location W012 (RM 6.3), total PAH concentrations were 1.32 and 2.46 µg/L in November 2004 and July 2005, respectively. A relatively low concentration, 0.0321 µg/L, was measured at this location in March 2005. Another relatively high total PAH concentration, 288 µg/L, was measured at station W021 during July 2005.

PAHs were detected at all seven XAD sampling stations during each sampling event, at similarly low concentrations to those in samples collected by peristaltic pump. Total PAH concentrations in XAD samples were below 100 ng/L (0.1 µg/L) except at station W015 (RM 6.9) in July 2005. However, the concentrations varied somewhat between the two sampling methods at each location and sampling event (Figures 6.3-20 and 6.3-21).

Total PAH concentrations were generally higher in the dissolved phase than in the particulate fraction (Figure 6.3-20). However, the PAH concentration was higher in the particulate fraction at station W016-1 (RM 7.2) during the November 2004 sampling event and at station W018 (RM 8.3) during the March 2005 sampling event.

Transect stations (i.e., W023, W011, and W005) showed an increase in the concentration of particle-sorbed PAHs at the two downstream locations compared to the upstream location (see Map 6.3-15 and Figure 6.3-20). Because TSS concentrations were similar at the upstream and downstream transect locations (i.e., W023 and W005), the trend reflects an increase in the PAH concentrations in the solids, rather than an increase of TSS, as river water passes through the Study Area (see Section 6.5). Concentrations of dissolved PAHs also increased from the upstream station W023 to the locations in the Study Area, except during the March 2005 sampling event.

Total PAH concentrations in XAD samples were below 68 ng/L except at station W015 (RM 6.9). There, total PAH concentrations ranged from 17.8 to 61.9 ng/L in the particulate fraction and from 56.4 to 169 ng/L in the dissolved fraction. At almost all stations, total PAH concentrations were higher in the dissolved phase than in the particulate fraction (Figure 6.3-20). However, the PAH concentration was higher for the particulate-bound PAHs than for dissolved PAHs at station W016-1 (RM 7.2) during the November 2004 sampling event and at station W018 (RM 8.3) during the March 2005 sampling event. Total PAH concentrations were higher for stations W005, W015, W016, and W018 during the July 2005 sampling event.

Particulate-sorbed total PAH concentrations at station W013 were generally lower than at transect sampling stations in the Study Area, while PAH concentrations at locations W015, W016, and W018 were higher during at least one sampling event. Dissolved total PAH concentrations were more variable both among the transect stations and the near-bottom stations.

6.3.3.9.1 PAH Composition

During all sampling events, LPAHs represented the dominant contribution to the dissolved concentration (Figure 6.3-24). Likewise, at all but one of the stations, HPAHs represented the dominant contribution to the particulate phase (see Figure 6.3-25). Station W018 (RM 8.3) exhibited an exception to this pattern in that both LPAH and HPAH concentrations were higher in the particulate fraction than in the dissolved phase, particularly during the March 2005 sampling event (see Figures 6.3-24 and 6.3-25).

With the exception of naphthalene and 2-methylnaphthalene, individual PAH concentrations at XAD transect locations were all below 6.55 ng/L. Naphthalene constituted a large fraction of the total PAHs at all of the dissolved transect stations for one or more sampling events (Table 6.3-2); concentrations ranged from 0.835 to 34.5 ng/L. The XAD column may have contributed naphthalene to the samples, with a resultant positive bias in the naphthalene concentrations, because naphthalene is one of its breakdown products. In compliance with data validation guidelines (Integral 2006l; EPA 1999b), selected XAD results were restated as undetected at the reported concentrations because naphthalene had been detected in the XAD system blanks. Concentrations of 2-methylnaphthalene (detected in the dissolved fraction of all XAD transect stations and at one particulate station) ranged from 1.63 to 24.1 ng/L; 2-methylnaphthalene may also be a breakdown product of the XAD column, although it was detected in only one blank (LW2-W2902 C) at a low concentration (0.0496 ng/L).

PAH profiles for all of the XAD stations are shown for July 2005, the sampling event with the highest PAH concentrations overall, in Figure 6.3-26. Apart from naphthalene and 2-methylnaphthalene, the most abundant PAHs in the dissolved phase at the transect locations included acenaphthene, fluorene, phenanthrene, fluoranthene, and pyrene. These PAHs were generally also abundant at locations W016, W015, and W013, in the main stem of the river, although the proportions varied between the transect and single-point near-bottom stations. Dissolved PAHs in Swan Island Lagoon (W018) showed a distinctly different pattern that was dominated by acenaphthene.

PAHs in the particulate phase varied between transect stations. Among all XAD stations, phenanthrene was abundant in the particulate phase only at transect W011 (RM 6.3). The particle-sorbed PAHs at station W018 were notable for their very low concentrations. In contrast, particle-sorbed PAHs at location W013 constituted a larger fraction of the total PAHs than at other locations.

Although the concentrations varied between sampling events, the PAH composition was generally similar between sampling events at each location (Figure 6.3-22). Variations

in PAH concentrations were particularly evident at station W018 (RM 8.3, Swan Island Lagoon), which exhibited elevated concentrations of almost all individual PAHs in the particulate-sorbed fraction during the March 2005 sampling event and in the dissolved phase during the July 2005 event

6.3.3.10 Hexachlorobenzene in Surface Water

Figure 6.3-27 and Map 6.3-16 display concentrations of hexachlorobenzene in XAD column and 0.5-µm glass fiber filter samples during each Round 2A sampling event. As seen in Figure 6.3-27, hexachlorobenzene preferentially distributes into the water column (XAD column samples) over the particulate phase (0.5-µm glass fiber filter samples). Concentrations ranged from 19.3 to 85.4 pg/L, but were relatively consistent across all of the XAD sampling locations; the lowest concentration was found at upstream transect W023 (RM 11) during the November 2004 sampling event, and the highest concentration was found at station W016 (RM 7.2, single-point, near-bottom) during the July 2005 sampling event. Except at W016, concentrations of hexachlorobenzene were highest during the March 2005 sampling event.

6.3.3.11 Arsenic in Surface Water

Figure 6.3-28 and Map 6.3-17 display concentrations of arsenic in peristaltic pump samples during each Round 2A sampling event. As seen in Figure 6.3-28 and Map 6.3-17, arsenic preferentially distributes into the water column. Concentrations of arsenic, which were similar from the upriver transect and throughout the Study Area, ranged from 0.33-0.75 µg/L. Both the lowest and highest concentrations were found at station W001 (RM 2, single-point, near-bottom), the lowest during the November 2004 sampling event, and the highest concentration during July 2005. With the exception of stations W004 (RM 3.7), W013 (RM 6.9), W020 (RM 9.1), and W022 (RM 9.7), concentrations of arsenic increased slightly during successive sampling events.

6.3.3.12 Lead in Surface Water

Figure 6.3-29 and Map 6.3-18 displays concentrations of lead in peristaltic pump samples during each Round 2A sampling event. As seen in Figure 6.3-29 and Map 6.3-18, lead concentrations were highest in the particulate phase. Concentrations of total lead were similar from upriver peristaltic pump stations through the Study Area, and ranged from 0.077-1.8 µg/L; the lowest concentration was found at Station W021 (RM 8.7, single-point, near-bottom) during the March 2005 sampling event, and the highest concentration was found at Station W008 (RM 4.6, single-point, near-bottom) during the July 2005 sampling event.

6.3.4 Particulate-Phase COPC Concentrations

Particulate-phase concentrations in units of µg COPC per kg suspended particles (mg/kg for arsenic) were derived by normalizing the COPC concentration in each XAD filter sample to the associated TSS concentration (Tables C1-13 and 6.3-2). This calculation constitutes an approximation because the pore size used for the TSS filtration (1.2 µm) was larger than the pore size of the filters used for dissolved metals (0.45 µm) and organic compounds (0.5 µm). However, the approximate particulate-

phase COPC concentrations are adequate for comparison of concentrations in suspended solids to preliminary background sediment values.

Samples for TSS analysis were collected by peristaltic pump at all sampling locations. Reported TSS values were above the detection limit (1-5 mg/L) in 13 of 21 samples collected from the seven XAD stations over three sampling events, and in 40 of 69 Round 2A surface water samples overall (Figure 6.3-5).

A review of City of Portland TSS data (Sanders 2006, pers. comm.) shows that the TSS concentration at four locations from RM 1.1 to 12.7 were all close to 5 mg/L in November 2004, March 2005, and July 2005, when samples were collected for Round 2A. This value, which is also the detection limit for much of the Round 2A study, was used to calculate particulate-phase COPC concentrations when TSS was reported as undetected. This protocol may introduce a low bias in that TSS concentrations lower than 5 mg/kg would yield proportionally higher particulate-phase COPC concentrations; this potential bias may to some extent be compensated for by the difference in filter pore sizes used to process the TSS versus the chemical analytes.

TSS concentrations were fairly uniform for all of the Round 2A samples. As a result, the trends and patterns of particulate-phase COPCs in the Study Area were similar to particulate-sorbed COPCs expressed as concentrations in the surface water, i.e., without TSS-normalization. The distributions of particulate-sorbed COPCs are described in Section 6.3.3.

Particulate-phase COPC concentrations in Round 2A surface water samples were generally higher than preliminary background concentrations for upstream sediment (Table C1-13; also see Section 6.3.1). Exceptions were found largely among the pesticides: Particulate-phase concentrations of total chlordanes, aldrin, and beta-HCH in the surface water samples were generally lower than the respective background sediment concentrations. Particulate-phase HCH concentrations in surface water samples were also generally lower than the background sediment concentration. For the remaining indicator chemicals, particulate-phase concentrations were generally higher than the preliminary background sediment values (Table C1-13).

The preliminary background sediment concentrations were generally only slightly higher than the particulate-phase concentration for many of the indicator COPCs, including the individual and total PAHs, total chlordanes, the individual and total DDx compounds, hexachlorobenzene, and arsenic. The particulate-phase total PCB concentrations were similar to the preliminary background sediment value for total PCB Aroclors in March 2005 and July 2005, the two sampling events that were not influenced by stormwater input. Particulate-phase HCH and aldrin concentrations were lower at transect W023 than the preliminary background concentration. The preliminary background value for aldrin, however, is based on a single detection (see Section 6.1.3). No preliminary background value is available for total dioxin/furan homologs.

Particulate-phase COPC concentrations were generally lower at the upstream transect (W023) than at the near-bottom locations. Particulate-phase COPC concentrations were highest at near-bottom stations W015 and W016 overall. PCBs were an exception to this pattern, with the highest particulate-phase concentrations found in Willamette Cove. For many of the indicator COPCs, particulate-phase concentrations were higher at the transects in the Study Area than at the upstream transect, but lower than the near-bottom locations overall.

6.4 BIOTA CHEMICAL DISTRIBUTION

Biological tissues from organisms in the LWR are discussed in this section. The data set includes analyses of fishes, benthic invertebrates, and epibenthic communities conducted as part of Rounds 1 and 2 of the Portland Harbor RI/FS by the LWG as well as recent data collected by other parties. Eleven fish species are represented: brown bullhead, black crappie, carp, juvenile and adult Chinook, largescale sucker, northern pikeminnow, Pacific lamprey, peamouth, sculpin, smallmouth bass, and sturgeon. The types of tissue examined were whole-body fish (all species except sturgeon) and fillets (limited to black crappie, brown bullhead, carp adult Chinook, smallmouth bass, and sturgeon). Tissues from three invertebrate species were analyzed: the Asiatic clam, an oligochaete worm, and crayfish. Both field and lab exposures are considered for the clam and lab exposures only for the worm. Epibenthic communities from multiplate samplers were composited for analysis. Stomach contents (primarily aquatic organisms and terrestrial insects) of juvenile Chinook salmon were also analyzed and discussed as part of the invertebrate data. (Additional details regarding the number and type of tissues collected from the Study Area are provided in Section 2 of this report and Section 2.2 of Appendix G, ERA.)

Summary statistics (sample size, frequency of detection, minimum, maximum, mean, and 95th percentile) for all analytes measured in all tissue samples are provided in Tables C1-14 through C1-27) in Appendix C1. Two sets of summary information are provided in the appendix: one set for detected values only (discussed, in part, in this section) and a second set for detected and undetected values combined.

Data are presented separately for the Study Area, upriver conditions, and downstream conditions (including Multnomah Channel). The sturgeon (sampled between RM 3.5 and RM 9.2), adult spring Chinook from the Clackamas River hatchery, and adult Pacific lamprey from Willamette Falls, although included in the tissue data summaries, are not used to characterize the nature and extent of contamination within the Study Area because their tissue burdens are representative of exposures throughout the Columbia River basin and beyond. However, people fishing in the LWR may catch these species; thus, they were evaluated as part of the HHRA (Appendix F).

6.4.1 Indicator Chemicals

The examination herein is based on the indicator chemicals listed in Table 6.0-1. Indicator chemicals were selected in a multistage screening process. COPCs were

identified from initial risk analysis work (Windward 2005a; Windward et al. 2006). The list of COPCs was refined by further risk screening (see Sections 8 and 9) to generate iCOCs. Indicator chemicals for tissue were selected from among the COPCs on the basis of potential risk to human health; potential risk to ecological receptors; high frequency of detection in tissue; or support for discussion of relationships among sediment, surface water, and tissue (TBT, LPAHs, and HPAHs were included as indicator chemicals for tissue for the latter reason).

As shown in Table 6.0-2, the following indicator chemicals are included in the discussion of the nature and extent of chemicals in tissue:

- Arsenic
- Mercury
- Zinc
- TBT
- Total PCBs (Aroclor sum)
- Total PCBs (congener sum)
- Total PCBs expressed as 2,3,7,8-TCDD TEQs
- Total dioxin/furans expressed as 2,3,7,8-TCDD TEQs
- dioxin/furans homologs (presented to characterize nature of dioxin/furans)
- Sum DDD
- Sum DDE
- Sum DDT
- Total DDx
- Aldrin
- beta-HCH
- Total Chlordanes
- Total PAHs
- Total LPAHs (presented to characterize nature of total PAHs)
- Total HPAHs (presented to characterize nature of total PAHs)
- BAA
- BAP
- BEHP.

6.4.2 Nature and Extent of Indicator Chemicals in Study Area Tissue

A summary of the results of indicator chemical analyzed in biological tissue is presented in Tables 6.4-1 (invertebrates) and 6.4-2 (fish). Data are not available for every indicator chemical in every tissue. The following analytes were not examined in the tissue noted:

- Metals in juvenile Chinook stomachs
- Mercury in epibenthic community tissue
- Butyltins in fish and invertebrates, except the Asiatic clam (*Corbicula fluminea*), worm (*Lumbriculus variegatus*), and several juvenile Chinook samples
- PAHs in black crappie, northern pikeminnow, peamouth, smallmouth bass fillets, and epibenthic community (multiplate) samples
- Phthalates in black crappie, northern pikeminnow, peamouth, smallmouth bass fillets, adult Chinook, sturgeon fillets, Pacific lamprey, juvenile Chinook stomachs, and epibenthic community (multiplate) samples
- PCB congeners in largescale sucker, northern pikeminnow, peamouth, all fillet samples (except adult Chinook), and field-collected clams collected during Round 1
- dioxin/furans in juvenile Chinook stomach contents from Round 2 and largescale sucker, northern pikeminnow, peamouth, all fish fillets except adult Chinook from the Clackamas hatchery, and field-collected clams collected during Round 1

Fish and invertebrate sampling locations are displayed in Map 2.1-2a–c, and represent either points or areas. For Rounds 1 and 2, the sampling design specified collection of species over areas similar in size to likely home ranges. Crayfish and epibenthic community collection methods (traps and artificial substrates) reflect essentially single-point samples. Clams, sculpins, and sediments used in laboratory bioaccumulation tests were composite samples collected at multiple points, transects, or tows within discrete nearshore areas. Smallmouth bass, largescale sucker, northern pikeminnow, and peamouth are thought to utilize fairly localized areas and were collected and composited over 1-mile river segments; all other fish species (black crappie, brown bullhead, carp) may utilize home ranges on the scale of the entire Study Area (or greater) and were collected and composited over 3-mile river segments. Juvenile Chinook also have large home ranges; however, the samples were composited within discrete beach seine areas. Map symbols represent the approximate central point within the sampling areas.

Sample locations are labeled according to the following scheme:

- Round 1 field-collected clams, crayfish, sculpin and juvenile Chinook use a sample nomenclature similar to sediment samples (river mile plus unique location code)
- Round 2 invertebrate tissue sampling locations refer to FCnn for field-collected clam tissue samples or BTnn sediment collection sites for laboratory bioaccumulation testing with clams and worms
- Epibenthic community tissue composites were collected from multiplate samplers deployed at locations referenced as MITnn

- Smallmouth bass, largescale sucker, northern pikeminnow, and peamouth were sampled over 1-mile increments of the Study Area, referenced as river mile areas (RMAs) 03Rnnn through 09Rnnn
- Juvenile Chinook whole-body and stomach samples were collected at beach transects during Round 2 and are referenced as T01 through T04
- The remaining fish species (brown bullhead, black crappie, carp) have larger home ranges and were collected in a fishing zone representing RM 2.5 to 6.0 (FZ0306) or a zone representing RM 6.0 to 9.0 (FZ0609)
- Samples collected by parties other than the LWG retain the label assigned by the original authors and represent single-point data.

Indicator chemical concentrations in species that may reflect more location-specific conditions (sculpin, smallmouth bass, clams, worms, crayfish, and epibenthic communities) are presented in Maps 6.4-1 through 6.4-5. Juvenile Chinook data not previously presented are posted on these same maps, combining Round 1 and 2 results. The *Portland Harbor RI/FS Round 1 Site Characterization Summary Report* (Integral 2004b) presents a set of maps for all species collected as part of Round 1.

The following discussion of the nature and extent of indicator chemicals in tissue is based on statistics calculated for detected concentrations only.

6.4.2.1 Conventional Analytes

6.4.2.1.1 Fish

The lipid content was measured in all tissue samples with sufficient volume (e.g., no lipid was measured in epibenthic community samples). The average lipid content in fish whole-body tissues ranged from 1.4 percent (black crappie) to 8.93 percent (peamouth). The maximum lipid content (13 percent) in an individual composite was found in carp from FZ0609. Fillets typically had lower lipid content, with averages ranging from 0.82 percent (smallmouth bass) to 4.63 percent (carp). The maximum percent lipid in fillet was also found in carp from FZ0609.

6.4.2.1.2 Invertebrates

Average lipid content in invertebrates ranged from 0.78 percent (crayfish) to 2.32 percent (lab-exposed worms). The maximum lipid content occurred in field-collected clam tissue from Station BT028 (4.63 percent). Lipids were not measured in epibenthic multiplate samples.

6.4.2.2 Arsenic in Tissue

6.4.2.2.1 Fish

Arsenic was detected in all fish species and tissues analyzed within the Study Area, with whole-body concentrations consistently higher than those of fillets. Average whole-body arsenic concentrations by species ranged from 0.056 mg/kg (brown bullhead) to 0.425 mg/kg (peamouth). The highest concentrations were associated with peamouth from Swan Island Lagoon (0.48 mg/kg), black crappie (whole body) from FZ0609 (0.42 mg/kg), and smallmouth bass and northern pikeminnow from RMA 03R014 (0.39 mg/kg and 0.36 mg/kg, respectively). Fillet average concentrations ranged from 0.02 mg/kg to 0.21 mg/kg, with the maximum concentration in smallmouth bass from RMA 03R014 (0.28 mg/kg).

6.4.2.2.2 Invertebrates

Arsenic was detected in all invertebrate samples. Average concentrations by species ranged from 0.352 mg/kg (crayfish) to 1.04 mg/kg (lab-exposed worms). The maximum concentrations (3.04 mg/kg) occurred in worms exposed in a laboratory to sediment collected from BT019. The majority of the field-collected and lab-exposed clam samples were below 1.0 mg/kg; most of the worm sample concentrations were higher, but below 2.0 mg/kg.

6.4.2.3 Mercury in Tissue

6.4.2.3.1 Fish

Mercury was detected in all fish species and tissues analyzed within the Study Area, with fillet concentrations consistently higher than whole-body concentrations. Average whole-body mercury concentrations by species ranged from 0.0139 mg/kg (juvenile Chinook) to 0.28 mg/kg (northern pikeminnow). The maximum concentration in an individual sample was measured in northern pikeminnow from RMA 07R009 (0.494 mg/kg). Maxima for all other species were only one-fourth that of the pikeminnow. Fillet average concentrations by species ranged from 0.0608 mg/kg (brown bullhead) to 0.127 mg/kg (carp); the maximum concentration in an individual sample occurred in a skinless carp fillet composite from FZ0609 (0.191 mg/kg). Similar concentrations also occurred in black crappie skinless fillets from FZ0609 (0.101 mg/kg) and smallmouth bass skinless fillets from RMA 03R014 (0.129 mg/kg).

6.4.2.3.2 Invertebrates

Mercury was detected in all invertebrate tissues, with the exception of one worm sample. Average concentrations by species ranged from 0.00488 mg/kg (lab-exposed worm) to 0.0283 mg/kg (crayfish). The maximum concentration in an individual sample (0.041 mg/kg) was from crayfish from 06R001. Mercury concentrations in field-collected and lab-exposed clam tissues were below 0.02 mg/kg; in most worm tissues, concentrations were below 0.01 mg/kg.

6.4.2.4 Zinc in Tissue

6.4.2.4.1 Fish

Zinc was detected in all fish species and tissues analyzed within the Study Area, with whole-body concentrations consistently higher than fillet concentrations. Average whole-body zinc concentrations by species ranged from 14.1 mg/kg (brown bullhead) to 99.3 mg/kg (carp). The maximum individual sample concentration was measured in carp from FZ0609 (112 mg/kg); sample maxima for all other species were only one-third as high. Fillet average concentrations ranged from 5.23 mg/kg (brown bullhead) to 23.3 mg/kg (carp). The maximum individual fillet sample concentration occurred in carp from FZ0306 (29.8 mg/kg), a value several times higher than the maximum measured in other species fillets.

6.4.2.4.2 Invertebrates

Zinc was detected in all invertebrate tissues analyzed. Within-species averages ranged from 13 mg/kg (lab-exposed clams) to 35.1 mg/kg (field-collected clams). The maximum concentration (54 mg/kg) in a composite sample was measured in field-collected clams from FC023. All epibenthic community sample composites were less than 25 mg/kg. Zinc concentrations in crayfish tissue did not exceed 21 mg/kgLab; in lab-exposed worms and clam samples, concentrations were below 55 mg/kg.

6.4.2.5 Tributyltin in Tissue

6.4.2.5.1 Fish

TBT was analyzed only in whole-body samples of juvenile Chinook. The average concentration within the Study Area samples was 2.51 µg/kg TBT ion. The maximum concentration occurred in samples collected from T-02 (west bank downstream of RM 7.0 between Siltronic and Arkema).

6.4.2.5.2 Invertebrates

TBT was detected in the majority of field-collected clams (76 percent) and lab-exposed worms (55.8 percent), but less frequently in lab-exposed clams (44.2 percent). TBT was not measured in crayfish or epibenthic community samples.

Average TBT concentrations in invertebrate species ranged from 38.4 µg/kg (field-collected clams) to 80.4 µg/kg (lab-exposed worms). The maximum concentration in an individual composite sample (1,700 µg/kg) was measured in worms exposed in the laboratory to sediment from BT023 near the Portland Shipyard at the entrance to Swan Island Lagoon. The next-highest concentrations were also found at this location in the field-collected and lab-exposed Asiatic clams (both reported at 530 µg/kg) and lab-exposed worms (680 µg/kg) and in lab-exposed worms (49 µg/kg) from BT022 near the Coast Guard station in Swan Island Lagoon.

6.4.2.6 PCBs in Tissue

This section presents a summary of the distribution of PCBs based on Aroclors, compares those results to PCB congener totals, and discusses the characteristics of the Aroclor and homolog constituents of the totals.

PCBs were analyzed as Aroclors[22] in all Round 1 fish and invertebrate tissues using standard methodology (GC/ECD by EPA Method 8082); the majority of samples were also analyzed for PCB congeners (exceptions were whole-body largescale sucker, northern pikeminnow, peamouth, all fillets, and some crayfish samples). Aroclors in Round 2 samples were quantified from congener data. Analytical patterns used to quantify Aroclors from congeners did not match standards well; thus, Round 2 fish and invertebrate data are qualified as tentatively identified. All data are presented here; however, total congener sums are considered a more reliable estimate of total PCBs.

6.4.2.6.1 Fish

One or more Aroclors were detected in all fish species. By species, average total Aroclor concentrations in whole-body tissues ranged from 55.8 µg/kg (juvenile Chinook) to 1,640 µg/kg (carp). The maximum concentration (6,500 µg/kg) was measured in a carp composite sample from RMA 03R004. Individual composite sample concentrations greater than 1,000 µg/kg occurred throughout the river (Map 6.4-6a–c):

- Sculpin from 02R001, 02R015, 06R002
- Largescale sucker from RMAs 03R014 and 07R009
- Smallmouth bass from RMAs 04R023 and 08R010
- Carp from FZ0306 and FZ0609
- Northern pikeminnow from RMAs 07R009 and 09R006
- Brown bullhead from FZ0609.

Average congener totals in whole-body samples ranged from 147 µg/kg (juvenile Chinook) to 1,920 µg/kg (carp). The highest individual concentration occurred in a carp sample from FZ0306 (8,150 µg/kg total PCB congeners). Concentrations greater than 1,000 µg/kg were found in composited sculpin tissues from Stations 03R001 and 06R002, whole-body smallmouth bass from RMA 08R010, and carp from FZ0306 and FZ0609 (Map 6.4-7a–c).

In fillets, average within-species concentrations based on Aroclors ranged from 24.1 µg/kg (black crappie) to 812 µg/kg (carp). The highest concentration in an individual sample was measured in brown bullhead (skinless) from FZ0609 (1,300 µg/kg total PCB Aroclors); carp fillets from this location had a similar maximum. Congeners were not measured in fillets.

[22]During data review, a question about the identification of individual Aroclors in sediment and tissue samples arose. Aroclors 1242, 1248, 1254, and 1260 were reported for Round 1 sediment samples, while only Aroclors 1248 and 1260 were reported for Round 1 tissue samples. Chromatograms for a subset of the sediment and tissue samples were reviewed to evaluate the PCB Aroclor identifications performed by the analytical laboratories. The difference in identification of PCB Aroclors in fish tissue and sediment samples appears to be an artifact of the analytical method used for fish tissue samples and was discussed in the Round 1 RI/FS SCSR (Integral 2004b).

Total PCBs based on Aroclors were composed of Aroclor 1260 only or a combination of Aroclors 1260 and 1248. This Aroclor distribution applied for all fish species, except juvenile Chinook and one smallmouth bass tissue composite (Map 6.4-6a–c). Juvenile Chinook tissues from Round 2 transects T01, T02, and T03 contained Aroclors 1260, 1254 and 1242 (listed in descending proportional order); however, the identification of these Aroclors should be considered tentative. In one smallmouth bass composite collected from RMA 06R024, a small fraction of Aroclor 1232 was found in addition to Aroclor 1260. In the samples where Aroclor 1248 was present, this Aroclor tended to be more prevalent in samples collected between RM 2 and 5, where samples composed solely of Aroclor 1260 were rare. Between RM 5 and 10, samples with only Aroclor 1260 were more frequently encountered (e.g., sculpin at Stations 06R001, 06R002, 06R004, 08R003, 09R001, and 09R002; northern pikeminnow, smallmouth bass, and largescale sucker from RMAs 07R009 and 08R010; and carp and brown bullhead from FZ0609).

The PCB homolog distribution was examined in samples whose congener sums exceeded 1,000 µg/kg PCBs to minimize the effect of non-detects. Although PCB homolog composition varied throughout the river, tetra-, penta-, hexa-, and heptaCBs were typically present in proportions greater than 10 percent on average (Map 6.4-7a–c). Tetra- and pentaCBs tended to dominate below RM 4.0, with hexa- and heptaCBs dominant farther up the river. TriCB homologs tended to be rare, with slightly larger percentages below RM 4.0 and in the juvenile Chinook sampled at T02 near RM 7.0. The homolog composition of the one sample that contained Aroclor 1232 was very similar to that of adjacent samples where Aroclor 1232 was not detected, perhaps because of the small fraction of Aroclor 1232 that contributed to the Aroclor total.

The correlation between Aroclor distribution and homolog distribution appears relatively strong, but not always consistent. As an example, hexa- and heptaCBs are abundant in Aroclor 1260 and would thus be expected to be dominant in those samples characterized solely by Aroclor 1260. This relationship held true for a number of samples, but not all. In the sculpin composite from 06R004, only Aroclor 1260 was detected and although hexaCBs were dominant, pentaCBs were uncharacteristically found in equal proportion to heptaCBs.

6.4.2.6.2 Invertebrates

At least one Aroclor was detected in every invertebrate species. In whole-body tissues, average within-species total Aroclors ranged from 15.2 µg/kg (lab-exposed clams) to 438 µg/kg (lab-exposed worms). The maximum concentration (3,230 µg/kg) was measured in worms from BT028 (west bank, RM 8.8 adjacent to Gunderson). Individual sample concentrations greater than 1,000 µg/kg occurred in worm samples exposed in the laboratory to sediment from BT002 (east bank near RM 2.3 adjacent to OSM), BT016 (Willamette Cove), BT017 (west bank near RM 6.9 between Arkema and Siltronic), and BT028. A field-collected clam sample from FC016 also had a total Aroclor concentration greater than 1,000 µg/kg (Map 6.4-8a–c).

In comparison, total congener averages by species ranged from 44.2 µg/kg (lab-exposed clams) to 635 µg/kg (lab-exposed worms). The maximum congener sum (4,310 µg/kg) was measured in lab-exposed worms from BT028; concentrations greater than 1,000 µg/kg also occurred in worms exposed in the laboratory to sediment from Stations BT002 (RM 2.3 near OSM), BT016 (Willamette Cove), BT017 (RM 6.9 between Arkema and Siltronic), and BT032 (Fireboat Cove). Field-collected clams from FC016 also had similar concentrations (Maps 6.4-9a–c). The distribution of higher total congener concentrations was patterned after the distribution of higher Aroclor totals because Aroclors were estimated from congener data for these samples.

The Aroclors constituting the total PCBs in invertebrates consisted primarily of combinations of 1242, 1254, and 1260, with the following exceptions:

- Only Aroclor 1260 was detected in crayfish
- Only Aroclor 1242 was detected in Asiatic clams tested as part of the USACE investigation (Tetra Tech 2006)
- Only Aroclor 1254 was detected in worms tested as part of the USACE investigation (Tetra Tech 2006)
- Aroclor 1248 was a dominant constituent (based on relative percent) of total PCBs in four epibenthic community tissue composites (MIT001, MIT002, MIT356 and MIT810), several field-collected clam samples (07R003, 07R006, and FC017), a lab-exposed worm sample (BT017) and a lab-exposed clam sample (BT028).

Within the Round 2 data for field-collected Asiatic clams and lab-exposed worms, Aroclor 1254 tended to be the most abundant constituent. In lab-exposed clams, either Aroclor 1242 or 1254 was the most abundant.

The PCB homolog distribution was examined in samples with greater than 1,000 µg/kg PCBs based on congener sums. In those samples, either tetra- or hexaCBs were the most abundant homolog group. PCB homolog composition varied throughout the river, but tetra-, penta, and hexa-, and heptaCBs each represented 10 percent or more of the total, on average (Map 6.4-9a–c). Penta- and hexaCBs tended to be the most abundant homologs in lab-exposed clams and worms. HeptaCBs were often the most abundant homolog in crayfish tissue; however, one sample from 06R031, in which no Aroclors were detected, had a unique homolog composition in that mono- and diCBs made up half of the homolog total.

The correlation between Aroclor distribution and homolog distribution appears relatively strong in invertebrates, in part because Aroclor concentrations were estimated from congeners in Round 2 tissues. In lab-exposed clams where Aroclor 1242 was often the dominant Aroclor, triCB contributed an average of 16 percent of the total PCBs. In those few samples where Aroclor 1248 was the dominant Aroclor (e.g., lab-exposed clams from BT017 and BT028), tetraCBs were one of the dominant groups

contributing to the PCB total. There were two cases (lab-exposed worms from BT001 and BT002) where tetraCBs were abundant, but Aroclor 1248 was reported as not detected; however, the detection limits were high. Where Aroclor 1254 was the dominant Aroclor (most field-collected clams and lab-exposed worms), pentaCBs made a substantial contribution to total PCBs. Where Aroclor 1260 was dominant (e.g., worms exposed in the lab to sediment from BT013 and BT032), hexa- and heptaCBs were major contributors to the total.

6.4.2.7 Dioxin/furan TEQs in Tissue

Dioxins and furans were measured in all invertebrate tissue types (although not all clams or crayfish samples were analyzed) and in all fish species except largescale sucker, northern pikeminnow, and peamouth. Results are expressed in terms of 2,3,7,8-TCDD by applying mammalian TEFs (WHO 1997) to the individual isomers and calculating a final 2,3,7,8-TCDD TEQ concentration (see Section 6.0 for group summing rules).

6.4.2.7.1 Fish

The calculated within-species average TEQs ranged from 1.24 pg/g (black crappie) to 6.31 pg/g (sculpin). The maximum TEQ (38.6 pg/g) in an individual sample occurred in sculpin collected from Station 07R006. The next three highest TEQs occurred in smallmouth bass composites collected from RMA 07R009 (see Maps 6.4-1a–c). All TEQs greater than 5.0 pg/g were found in this reach of the river (RM 6.0). Below RM 4.0, TEQs in fish tissue were typically less than half that amount.

6.4.2.7.2 Invertebrates

The average dioxin TEQs by species ranged from 0.989 (epibenthic invertebrates) to 18.9 pg/g (lab-exposed worms) where dioxin/furan congeners were analyzed. The maximum 2,3,7,8-TCDD TEQ in an individual sample occurred in a worm sample (472 pg/g) exposed in the laboratory to sediments from Station BT017 (RM 6.9 between Arkema and Siltronic). Other locations with TEQ concentrations greater than 20 pg/g included crayfish from 07R006 (west bank adjacent to Arkema), worms from BT008 (head of Terminal 4, Slip 1) and BT018 (west bank adjacent to Arkema), and clams exposed in the lab to sediments from BT017 (TEQ data for invertebrates, including Chinook stomach contents, are presented in Maps 6.4-1f through 6.4-5c).

6.4.2.8 PCB TEQs in Tissue

6.4.2.8.1 Fish

Concentrations of dioxin-like PCBs were also expressed as 2,3,7,8-TCDD TEQs by applying mammalian TEFs to individual congener concentrations and summing the results (see Section 6.0 for summing rules). Where congeners were analyzed, the resulting product by species averaged 2.8 to 15.7 pg/g. The maximum PCB TEQ in an individual sample (43.7 pg/g) occurred in a sculpin composite from Station 02R001 (Map 6.4-1a). TEQs exceeded 20 pg/g at three other locations (smallmouth bass from RMAs 04R023, 08R010, and 09R006) (Maps 6.4-1b-d).

6.4.2.8.2 Invertebrates

Where congeners were analyzed, the average PCB TEQs by species ranged from 0.64 to 5.38 pg/g. The maximum PCB TEQ in an individual sample (48.8 pg/g) occurred in a worm exposed in the laboratory to sediments from BT002 (RM 3.2 near OSM). TEQs at two other locations were greater than 20 pg/g (worms exposed to sediments from BT017 [RM 6.9 between Arkema and Siltronic] and BT028 [RM 8.8 adjacent to Gunderson]) (Maps 6.4-1f through 6.4-5c).

6.4.2.9 Dioxin Homologs in Tissue

Dioxin homologs are represented by tetra-, penta-, hexa-, hepta-, and octa-chlorodibenzofurans (TCDF, PECDF, HXCDF, HPCDF, and OCDF, respectively) and tetra-, penta-, hexa-, hepta-, and octa-chlorodibenzo-p-dioxins (TCDD, PECDD, HXCDD, HPCDD, and OCDD, respectively). Dioxins and furans were analyzed in tissues representing all species sampled as part of Rounds 1 and 2.

6.4.2.9.1 Fish

The average total homolog concentrations in individual fish tissue samples ranged from 10.7 pg/g (black crappie) to 73.8 pg/g (sculpin). The maximum concentration in an individual sample (388 pg/g) was measured in a sculpin sample from 07R006. Homolog sums greater than 50 pg/g occurred in sculpin samples from 06R002 and carp samples from FZ0306 and FZ0609 (Maps 6.4-10a–c).

The homolog distribution in fish tissue was highly variable, with no apparent trend by area or species. In the few fish tissues with greater than 50 pg/g total dioxins based on homolog sums, dominant homologs included TCDFs, PECDFs, HXCDFs, HXCDDs, HPCDDs, and OCDDs, depending on the sample. In many samples, no single homolog group dominated. OCDDs contributed to about half the total homolog concentration in several juvenile Chinook samples (from T01 and T03), several sculpin samples (from Stations 06R002 and 09R002), and one carp tissue sample (from FZ0609). TCDF and HPCDD were abundant in a number of samples from all reaches within the Study Area. Smallmouth bass samples from Swan Island Lagoon (RMA 08R010) were unique in having a diverse distribution of dioxin and furan homologs, with no one group being dominant.

6.4.2.9.2 Invertebrates

Average total homolog concentrations in individual invertebrate tissue samples ranged from 44.2 pg/g (lab-exposed clam) to 377 pg/g (lab-exposed worm). The maximum concentration in an individual sample (6,440 pg/g) was measured in worms exposed in the laboratory to sediment from BT017 (RM 6.9 between Arkema and Siltronic). All worm and epibenthic community samples and many field-collected clams and crayfish composites had total homolog concentrations greater than 50 pg/g. Homolog sums greater than 250 pg/g occurred in worm samples exposed in the lab to sediments from BT005 (mouth of the International Terminals Slip), BT007 (near mouth of Terminal 4, Slip1), BT008 (head of Terminal 4, Slip 1), BT012 (RM 4.8 downstream of ARCO seawall), BT017 (RM 6.9 between Arkema and Siltronic), BT018 (RM 7.2 adjacent to Arkema), BT019 (Reidell Cove), and BT028 (RM 8.8 adjacent to Gunderson) (Maps

6.4-11a–c). One field-collected clam sample from FC017 also had a homolog total greater than 250 pg/g. Homolog concentrations appear strongly associated with species in that concentrations in worms were typically higher than in field-collected clams, which in turn were higher than those in lab-exposed clams. Concentrations in epibenthic tissues and crayfish fell between worms and field-collected clams from similar locales.

The homolog distribution was fairly consistent across invertebrate species in that OCDD was the most abundant homolog, usually followed by TCDF. PECDD, HXCDD, and OCDF tended to be the least abundant homolog groups. Unique signatures were seen in several samples:

- Lab-exposed clams and worm samples from BT017 and BT018, where TCDF was the most abundant group, followed by PECDF
- Epibenthic samples from the same area (MIT003, -005, and -006), where TCDF was the most abundant group, followed by PECDF
- Crayfish from 08R003, where PECDF was the most abundant group.

6.4.2.10 DDT Isomers in Tissue

The distributions of DDT isomers—represented by sums of ortho (2,4'-) and para (4,4'-) forms of DDD, DDE, and DDT, and by the sum of all isomers (total DDx)—are used in this section to discuss both the extent and nature of this pesticide group in tissue samples from the Willamette River.

6.4.2.10.1 Fish

Average concentrations of total DDx by species ranged from 77.4 µg/kg (juvenile Chinook) to 322 µg/kg (northern pikeminnow) in whole-body tissues. Fillet average concentrations ranged from 11.4 µg/kg (black crappie) to 148 µg/kg (carp). The maximum concentration in an individual sample was measured in sculpin from 07R006 (3,060 µg/kg total DDx). Fish tissue concentrations greater than 100 µg/kg occurred in samples from RM 2.5 to about RM 10.0. Concentrations greater than 100 µg/kg were also found for the following species and locations:

- Brown bullhead (FZ0306 and FZ0609)
- Carp whole body and fillets (FZ0306 and FZ0609)
- Chinook (T02 [west bank between Arkema and Siltronic)]
- Largescale sucker (RMAs 03R014, 05R006, 07R009, and 08R010 [Swan Island Lagoon])
- Northern pikeminnow (RMAs 03R014, 05R006, 07R009, and 08R010 [Swan Island Lagoon])
- Peamouth (RMAs 03R014, 05R006, and 08R010 [Swan Island Lagoon])

- Sculpin (Stations 03R005 [head of the International Slip], 03R004 [east bank upstream of RM 4.0], 06R004 [west bank between Arkema and Siltronic], 07R003 [west bank between Willbridge Cove and Arkema], 07R006 [west bank adjacent to Arkema], and 09R002 [Fireboat Cove])
- Smallmouth bass (RMAs 03R014, 04R023, 05R006, 06R024, 07R009, 08R032, and 08R010 [Swan Island Lagoon]).

Contributing more than 50 percent to the total DDx concentration, 4,4'-DDE dominated in fish tissues, with some exceptions (Maps 6.4-12a–c). In most of the sculpin samples, 2,4'-DDT dominated; in a few juvenile Chinook samples from T01 (east bank near Time Oil) and T03 (Fireboat Cove), 4,4'-DDT dominated; and in Chinook samples from T02 (Fireboat Cove), 4,4'-DDD dominated four of the five whole-body samples. DDDs constituted 25 percent or more of the total DDx in selected samples of sculpin, carp, and smallmouth bass throughout the river.

6.4.2.10.2 Invertebrates

Average within-species concentrations of total DDx ranged from 11.7 µg/kg (crayfish) to 118 µg/kg (lab-exposed worms). The maximum concentration in an individual sample (1,490 µg/kg total DDx) was measured in worms exposed in the lab to sediments from BT017, with similar concentrations in lab-exposed worm tissues from Station BT018. Invertebrate tissue concentrations greater than 100 µg/kg were reported in the following samples, with over two-thirds contributed by 4,4'-DDD:

- Worms exposed in the laboratory to sediment from BT012 and BT028
- Field-collected and lab-exposed clams from FC017 and FC018
- Clams exposed in the laboratory to sediment from WR-VC-66.

In other samples with concentrations greater than 100 µg/kg, 4,4'-DDD contributed about half of the total DDx concentration. In general, 4,4'-DDD and 4,4'-DDE were the dominant isomers in invertebrate tissues, although the two DDT isomers tended to dominate in crayfish samples (Maps 6.4-13a–c). Asiatic clam samples from the USACE investigation (Tetra Tech 2006) and Round 1 also had a high percentage of 4,4'-DDT.

6.4.2.11 Aldrin in Tissue

6.4.2.11.1 Fish

Aldrin was not detected in any fish tissue. Detection limits ranged from 0.2 to 13 µg/kg.

6.4.2.11.2 Invertebrates

Aldrin was detected in all invertebrate tissues, except crayfish. The frequency of detection ranged from 40 to 90.6 percent. Average concentrations ranged from 0.0242 µg/kg in the contents of juvenile Chinook stomachs to 1.56 µg/kg in lab-exposed worms. The maximum concentration (37 µg/kg) occurred in worms exposed in the

laboratory to sediment from BT028 on the west bank near RM 9.0 (Gunderson). Field-collected and lab-exposed clams contained their maximum concentrations at Station BT028 (5.07 µg/kg field and 2.14 µg/kg lab). The maximum aldrin concentrations in Chinook stomach contents and epibenthic community composites were below 0.1 µg/kg (see Maps 6.4-1f through 6.4-5c).

6.4.2.12 Beta-Hexachlorocyclohexane in Tissue

6.4.2.12.1 Fish

Beta-HCH was only detected in sculpin (46 percent of the samples) and one smallmouth bass fillet composite. The average sample concentration for sculpin was 3.92 µg/kg; the bass fillet concentration was reported as 4.5 µg/kg. The maximum concentration in sculpin was 6.2 µg/kg from RMA 03R002 (see Maps 6.4-1a–c); all values were N-qualified and should be considered estimates only.

6.4.2.12.2 Invertebrates

Beta-HCH was detected in one or more samples for all invertebrate tissues, except crayfish, at frequencies of detection between 2 percent and 42.9 percent. Average concentrations by species ranged from 0.00993 µg/kg in epibenthic tissue composites to 0.377 µg/kg in field-collected clams. Species maxima were below 0.03 µg/kg for epibenthic community composites, below 0.052 µg/kg for lab-exposed clams, below 0.22 µg/kg for invertebrates in juvenile Chinook stomachs, below 1.5 µg/kg for lab-exposed worms, and below 8.5 µg/kg for field-collected clams. Locations of the highest detected concentrations include BT015 (west bank between Gasco and Siltronic), BT018 (adjacent to Arkema), and BT021 (Willbridge Cove) (see Maps 6.4-1f through 6.4-5c).

6.4.2.13 Total Chlordanes in Tissue

6.4.2.13.1 Fish

Chlordanes were detected in all species except northern pikeminnow. The frequency of detection ranged from 14.3 percent (smallmouth bass) to 100 percent (black crappie). Within-species average whole-body concentrations ranged from 3.2 µg/kg (juvenile Chinook and peamouth) to 20 µg/kg (brown bullhead); the maximum individual composite concentration was measured in brownbullhead at 67 µg/kg. Average fillet concentrations ranged from 1.1 µg/kg (black crappie) to 4.3 µg/kg (carp). Across species, the maximum (4.3 µg/kg) occurred in brown bullhead from FZ0306 (see Maps 6.4-1a–c).

6.4.2.13.2 Invertebrates

Total chlordanes were calculated for most invertebrate samples; the calculation was made only for 5 of the 27 crayfish samples because chlordane constituents were infrequently detected. Species mean concentrations ranged from 1.1 µg/kg (epibenthic community composites) to 6.69 µg/kg (lab-exposed worms). Maximum concentrations were below 8 µg/kg in juvenile Chinook stomach contents, lab-exposed clams, crayfish, and epibenthic community samples. For field-collected clams, the maximum was 16 µg/kg; for lab-exposed worms, the maximum was 71.9 µg/kg. These highest

concentrations were measured in samples exposed in the laboratory to sediments from BT028 (west bank near Gunderson). The next highest concentrations were measured in lab-exposed Asiatic clams and worms from WR-VC-118 on the west bank below RM 11 (near Riverscape) (see Maps 6.4-1f through 6.4-5c).

6.4.2.14 Total PAHs in Tissue

6.4.2.14.1 Fish

Individual PAHs were rarely detected in fish tissues and those detected were mostly low molecular weight. Given the few PAHs detected, total PAH concentrations tend to have been calculated from just a few constituents.

Average total PAH concentrations by species for whole-body tissues ranged from 16.2 µg/kg (juvenile Chinook) to 167 µg/kg (carp), with LPAHs ranging from 14.6 to 167 µg/kg and HPAHs ranging from 2.03 to 110 µg/kg. Only brown bullhead fillets were analyzed for PAHs; total concentrations ranged from 110 ugµg/kg to 250 ugµg/kg (180 µg/kg average). The maximum concentration of total PAHs in an individual sample was measured in smallmouth bass composite sample from RMA 07R009 (308 µg/kg). Concentrations were generally above 100 µg/kg where analyzed, with the exception of tissue samples collected below RM 3.5, between RM 4.5 and 6.5, and upstream of RM 8.

The nature of the PAHs was further evaluated by examining the number of aromatic benzene rings in the constituents (Maps 6.4-14a–c). The relative percentage of PAHs with two or three benzene rings was greater than those of with four or more benzene rings, reflecting the prevalence of LPAHs in tissues. Several tissue samples were composed solely of two-ring PAHs (juvenile Chinook from 02R113, and smallmouth bass from RMAs 07R009 and 08R010), or three-ring PAHs (sculpin from Stations 03R002, 04R003, 04R004, 05R020, 06R001, 06R002, 07R003, and 08R003, 08R001; largescale sucker and smallmouth bass from RMA 05R006 and 08R010). Trace fractions of four-ring PAHs (components of HPAHs) were found in a few juvenile Chinook whole-body samples from T01, T02, and T03.

6.4.2.14.2 Invertebrates

Except for epibenthic community composites, all invertebrate tissues were analyzed for individual PAHs. They were detected frequently, with the exception of crayfish (detected in 11.1 percent of the samples), and most were of high molecular weight.

Average total PAH concentrations by species ranged from 143 µg/kg (lab-exposed clam) to 3,000 µg/kg (lab-exposed worm). LPAH average concentrations ranged from 25.4 to 436 µg/kg; HPAH averaged 118 to 2,570 µg/kg. The maximum total PAH (33,600 µg/kg) in an individual sample was measured in worms exposed in the laboratory to sediments from BT014 (RM 6.0 near U.S. Moorings). Concentrations in worms exposed in a laboratory to sediments from BT012 (RM 4.8 downstream of the ARCO seawall) were the same order of magnitude. Other concentrations greater than 1,000 µg/kg were measured in the following samples (Maps 6.4-15a–c):

- Worms exposed in a laboratory to sediment from BT008 (head of Terminal 4, Slip 1), BT009 (Wheeler Bay), BT011 (RM 4.7 near Linnton Plywood), BT013 (RM 5.7 near Cathedral Park), BT015 (RM 6.5 near Gasco), BT017 (RM 6.9 between Arkema and Siltronic), BT018 (RM 7.2 adjacent to Arkema), BT023 (RM 8.2 adjacent to Portland Shipyard), BT024 (RM 8.2 adjacent to Front Avenue, BT028 (RM 8.8 adjacent to Gunderson), BT030 (RM 9.5), WR-VC-28 (RM 4.8 near BT012), and WR-VC-46 (approximately RM 5.6 near Station 05R020)
- Field-collected clams from FC012, FC014, FC015, and FC017 (all are the paired field stations associated with BTnn of the same number)
- Juvenile Chinook stomach contents from T02 (RM 6.9 between Arkema and Siltronic).

The range of concentrations differed by species. Worm samples consistently had the highest total PAH concentrations, followed by field-collected clams. Lab-exposed clam concentrations tended to be about an order of magnitude lower than the associated field samples. Crayfish tended to exhibit the lowest concentrations. Juvenile Chinook stomach contents fell within the range exhibited by field-collected clams (excluding the highest concentrations found in several clam samples).

Invertebrate tissues from the Study Area exhibited a high relative abundance of four-ring PAHs (Maps 6.4-15a–c). Three- and five-ring PAHs were present, albeit at a lower relative percentage. Two- and six-ring PAHs were rare. PAHs in the three clam samples and two crayfish composite samples from Round 1 were composed solely of four-ring PAHs. In a few cases, six-ring PAHs were slightly more abundant—for example, in field-collected clams from FC014 and FC015 and lab-exposed clams from BT026. Two-ring PAHs were present in some laboratory-exposed Asiatic clam samples analyzed as part of the USACE investigation (Tetra Tech 2006).

6.4.2.15 BAA in Tissue

6.4.2.15.1 Fish

Six fish species were analyzed for BAA: brown bullhead, carp, juvenile Chinook, largescale sucker, sculpin, and smallmouth bass (whole body only). It was detected only in two juvenile Chinook composite samples from T02 (0.20 µg/kg and 0.21 µg/kg).

6.4.2.15.2 Invertebrates

BAA was detected in all lab-exposed Asiatic clams and worms and in epibenthic community composites. It was detected frequently in field-collected clams (93.3 percent); only crayfish had a low frequency of detection (3.7 percent). Average concentrations by species ranged from 6.23 µg/kg in lab-exposed Asiatic clams to 189 µg/kg in lab-exposed worms. The maximum concentration detected was 2,600 µg/kg in a worm sample exposed in the laboratory to sediment from BT014 (west bank at RM 6.0 downstream of U.S. Moorings). Concentrations in field-collected clams from this

same location were also high (670 µg/kg), as was the case in Asiatic clams (both field-collected and lab-exposed) from FC/BT012 (west bank at RM 4.8 downstream of ARCO seawall) and BT015 (RM 6.5 near Gasco) (see Maps 6.4-1f through 6.4-5c).

6.4.2.16 BAP in Tissue

6.4.2.16.1 Fish

Six fish species were analyzed for BAP: brown bullhead (whole body and fillet), carp, juvenile Chinook, largescale sucker, sculpin, and smallmouth bass. It was not detected in any sample.

6.4.2.16.2 Invertebrates

BAP was frequently detected in all invertebrate samples except crayfish, where it was never detected and Chinook stomach contents where it was detected in 40 percent of the samples. Average concentrations by species ranged from 2.22 µg/kg in lab-exposed Asiatic clams to 105 µg/kg in lab-exposed worms. The maximum concentration detected was 1,500 µg/kg in a worm sample exposed in the laboratory to sediment from BT014 (west bank at RM 6.0 downstream of U.S. Moorings). Concentrations in field-collected clams from this same location were also high (460 µg/kg), as was the case in field-collected clams from FC015 (RM 6.5 near Gasco), which was reported at 630 µg/kg. Worm samples downstream from these locations at WR-VC-46 were reported at a similar concentration (750 µg/kg) (see Maps 6.4-1f through 6.4-5c).

6.4.2.17 BEHP in Tissue

6.4.2.17.1 Fish

Phthalates were rarely detected in fish tissue. Of the 75 fish samples analyzed from the Study Area, BEHP was detected in only 9, and was not detected in juvenile Chinook or carp. Average detected concentrations by species in whole-body tissues ranged from 1,900 µg/kg (largescale sucker) to 59,500 µg/kg (smallmouth bass). Phthalates were only analyzed in brown bullhead skinless fillets and BEHP was detected in only one composite at 100 µg/kg. The maximum concentration in an individual sample (87,000 µg/kg) was measured in a smallmouth bass from RMA 04R023 (Map 6.4-1a–c). An individual sculpin sample from Station 08R003 was reported at 28,000 µg/kg. All other concentrations were 1 to 2 orders of magnitude lower.

6.4.2.17.2 Invertebrates

BEHP was most frequently detected in lab-exposed clams (75.8 percent), followed by lab-exposed worms (58.1 percent) and field-collected clams (30.8 percent). BEHP was not detected in crayfish; epibenthic community composites were not analyzed for phthalates. Average concentrations by species ranged from 128 µg/kg (lab-exposed worms) to 376 µg/kg (lab-exposed clams). The maximum concentration (8,600 µg/kg) was measured in lab-exposed clams at BT028 (RM 8.8 adjacent to Gunderson). All other concentrations were below 350 µg/kg, and most were below 200 µg/kg (Maps 6.4-1f through 6.4-5c). Paired clam and worm samples exposed in the lab tended to have concentrations within the same order of magnitude (typically a factor of 5 or less).

6.4.3 Nature and Extent of Selected Indicator Chemicals in Tissue Collected Upriver from the Study Area

Five locations upriver from the Study Area were sampled: Station T04 on the east bank of the river below RM 18 (Map 2.1-6c and d) and Station 26R111 (just above Willamette Falls), where juvenile Chinook whole-body tissue (and stomach tissues in the case of T04) were collected; Station 20R001 (sampling locations between RM 21 and 24) and Station 28R001 (sampling locations between the Tualatin River mouth and approximately RM 32, above Willamette Falls) where whole body brown bullhead and smallmouth bass were collected; and Station WR-PG-Ref03 below RM 19, where sediment was sampled as part of the USACE investigation (Tetra Tech 2006) for bioaccumulation testing using worms and Asiatic clams. These data are discussed here to assist in establishing typical tissue concentrations of indicator chemicals outside of the Study Area. The results are summarized in this section and in Tables 6.4-1 and 6.4-2.

6.4.3.1 Conventional Analytes

6.4.3.1.1 Fish

Average percent lipids ranged from 2.1 percent (juvenile Chinook composites) to 5.4 percent (smallmouth bass composites). These values were very similar to the range reported for the same species from the Study Area. Lipids were not reported for the adult hatchery fish.

6.4.3.1.2 Invertebrates

Lipid levels in the single Asiatic clam and single worm composite sample from the bioaccumulation teststests were reported as 1.1 and 1.6 percent, respectively. These values fall within the range reported for clams and worms within the Study Area, although the reference area worm lipid value is lower (1.6 percent) than that reported for worms used in Study Area bioaccumulation tests (2.3 percent). No lipid data are available for the Chinook stomach contents.

6.4.3.2 Arsenic in Tissue

6.4.3.2.1 Fish

Average arsenic concentrations in the upriver fish tissues ranged from 0.045 mg/kg (juvenile Chinook) to 0.233 mg/kg (a maximum of 0.36 mg/kg occurred in a smallmouth bass composite collected near RM23 [part of 20R001]; see Map 6.4-1e).

6.4.3.2.2 Invertebrates

The arsenic concentration in the Asiatic clam was reported as 0.392 mg/kg; the worm composite sample had a higher concentration, at 1.52 mg/kg (Maps 6.4-3d and 6.4-4f). Arsenic was not measured in juvenile Chinook stomach contents.

6.4.3.3 Mercury in Tissue

6.4.3.3.1 Fish

Average concentrations of mercury in fish tissue ranged from 0.0117 (juvenile Chinook salmon) to 0.322 mg/kg (smallmouth bass). The maximum concentration (0.549

mg/kg) occurred in a smallmouth bass sample collected near RM 23 as part of 20R001 (Map 6.4-1e).

6.4.3.3.2 Invertebrates

The concentration of mercury in the Asiatic clam was reported as 0.0113 mg/kg; the worm composite sample concentration was lower, at 0.00891 mg/kg (Maps 6.4-3d and 6.4-4f). Mercury was not measured in juvenile Chinook stomach contents.

6.4.3.4 Zinc in Tissue

6.4.3.4.1 Fish

The average concentrations of zinc in upriver fish tissue composites ranged from 14.3 mg/kg (brown bullhead) to 29.7 mg/kg (juvenile Chinook) with a maximum concentration (34 mg/kg) reported in a juvenile Chinook composite from Willamette Falls (Map 6.4-1e).

6.4.3.4.2 Invertebrates

The zinc concentration in the Asiatic clam was reported as 10.6 mg/kg; the worm composite sample concentration was higher, at 22 mg/kg (Maps 6.4-3d and 6.4-4f). Zinc was not measured in juvenile Chinook stomachs.

6.4.3.5 TBT in Tissue

6.4.3.5.1 Fish

TBT ion concentrations ranged from 0.37 µg/kg to 0.45 µg/kg (average of 0.413 µg/kg) in juvenile Chinook from T04 (Map 6.4-1d). TBT was not measured in other upriver fish tissues.

6.4.3.5.2 Invertebrates

The TBT ion concentration was reported as 0.091 µg/kg in clams (although qualified as tentatively identified) and was not detected in worms exposed to sediment from the USACE (Tetra Tech 2006) reference area (Maps 6.4-3d and 6.4-4f). TBT was not measured in juvenile Chinook stomachs.

6.4.3.6 PCBs in Tissue

6.4.3.6.1 Fish

Total PCB average concentrations in fish from the upriver area ranged from 15.6 µg/kg in juvenile Chinook to 183 µg/kg in smallmouth bass. The maximum concentration (290 µg/kg) was measured in a smallmouth bass composite collected near RM 24 as part of 20R001 samples (Map 6.4-6e). The smallmouth bass composite collected near RM 23 had a similar concentration (260 µg/kg).

Aroclor 1254 was the most abundant Aroclor in juvenile Chinook tissue from T04, whereas Aroclors 1260 and 1248 were found in equal proportions in the juvenile Chinook sample collected at Willamette Falls (Maps 6.4-6 d and e). All other upriver fish tissue samples contained solely Aroclor 1260, with the exception Aroclor 1248 in two smallmouth bass replicate samples from 20R001 and 28R001. The representation

of Aroclor concentrations was quantified from congener data and should be considered an estimate.

Total PCB congeners averaged 16.7 µg/kg in juvenile Chinook, 33.2 µg/kg in brown bullhead, and 169 µg/kg in smallmouth bass (Map 6.4-7d and e). The maximum concentrations were reported in two smallmouth bass replicates from 20R001 (275 µg/kg and 317 µg/kg total PCBs as congeners).

A least five homolog groups were present in all upriver tissues (tetraCB through octaCB) with similar composition across species. PentaCB and hexaCB were the dominant homologs in whole-body tissues, followed in relative percent by heptaCB (Map 6.4-7d and e). The relative percentage of the homolog groups is a more accurate representation of the PCB composition, as Aroclors were identified from congener data and did not match standards well.

6.4.3.6.2 Invertebrates

Total PCBs as were detected in juvenile Chinook stomach contents only (although they were quantified from congeners); the single composite concentration was reported as 9.17 µg/kg. No Aroclors were quantified in lab-exposed clam or worm tissues tested using reference area sediment. PCB congeners were analyzed in all invertebrate tissues. Congener sums were 6.86 µg/kg in lab-exposed worms, 10.6 µg/kg in juvenile Chinook stomach contents, and 16.6 µg/kg in lab-exposed clams (Map 6.4-9d).

6.4.3.7 2,3,7,8-TCDD TEQs in Tissue

6.4.3.7.1 Fish

Dioxin TEQs calculated for fish tissue averaged 0.697 pg/g for juvenile Chinook, 1.43 pg/g for bullhead, and 1.59 pg/g for smallmouth bass. Maximum concentrations were measured in a brown bullhead composite collected near RM 23 (2.95 pg/g) and a smallmouth bass composite collected near RM 21 (2.81 pg/g).

6.4.3.7.2 Invertebrates

Analyses of dioxins and furans were not conducted for juvenile Chinook stomach contents or bioassay organisms.

6.4.3.8 PCB TEQs in Tissue

6.4.3.8.1 Fish

TEQs calculated for dioxin-like PCBs ranged from 0.634 pg/g (juvenile Chinook) to 5.04 pg/g (smallmouth bass) on average. The highest concentrations (8.21 and 8.15 pg/g) were measured in smallmouth bass composites collected near RM 23 and RM 24 as part of 20R001.

6.4.3.8.2 Invertebrates

The TEQ concentration reported for the contents of the single juvenile Chinook stomach composite was 0.423 pg/g. The TEQ for lab-exposed Asiatic clams tested in

reference area sediment was 0.16 pg/g; the associated lab-exposed worm sample TEQ was 0.057 pg/g.

6.4.3.9 Dioxin Homologs in Tissue

6.4.3.9.1 Fish

Total dioxin averages ranged from 5.18 pg/g in brown bullhead to 6.66 pg/g in smallmouth bass. The maximum concentration (10.5 pg/g) was measured in a smallmouth bass composite collected near RM 21. Seven to nine homolog groups were present in fish tissue composites (OCDF was rare; see Maps 6.4-11d and e. Composition varied by species and sampling location; in most cases TCDFs, furans, and HXCDs were major groups represented in the total.

6.4.3.9.2 Invertebrates

Dioxin and furan analyses were not conducted for juvenile Chinook stomach contents or bioassay organisms.

6.4.3.10 DDT Isomers in Tissue

6.4.3.10.1 Fish

Total DDx concentrations ranged from an average of 9.63 µg/kg in juvenile Chinook whole-body tissues to an average of 84.8 µg/kg in smallmouth bass. The highest concentrations were measured in smallmouth bass (20R001 replicates collected near RM 23 and RM 24; 120.4 µg/kg and 104.5 µg/kg, respectively). The most abundant isomer in all tissues was 4,4'-DDE, which contributed at least 50 percent of the total DDx concentration. The 4,4'-DDT isomer was typically the next most abundant isomer; all other isomers except 2,4'-DDE were also present (Maps 6.4-12d and e).

6.4.3.10.2 Invertebrates

Total DDx concentration in the juvenile Chinook stomach contents sample was 6.61 µg/kg. The most abundant isomer was 4,4'-DDE, which contributed at least 60 percent of the total DDx concentration. Other isomers present in small amounts were 4,4'-DDT, 2,4'-DDT, and 4,4'-DDD (Map 6.4-13d).

Worm and lab-exposed clam samples were reported as 11.3 and 5.89 µg/kg for total DDx, respectively. In worms, 4,4'-DDE and 2,4'-DDT were the two most abundant isomers; in the lab-exposed clams, 4,4'-DDE, 4,4'-DDT, and 2,4'-DDT were the most abundant (Map 6.4-13d).

6.4.3.11 Aldrin in Tissue

6.4.3.11.1 Fish

Aldrin was not detected in any upriver fish tissues.

6.4.3.11.2 Invertebrates

Aldrin was not detected in the juvenile Chinook stomach composite from fish collected at T04 or in the clams exposed to reference area sediments. The worm sample concentration was reported as 0.36 µg/kg.

6.4.3.12 Beta-HCH in Tissue

6.4.3.12.1 Fish

Beta-HCH was not detected in fish tissues from the upriver area.

6.4.3.12.2 Invertebrates

Beta-HCH was not detected in any of the upriver invertebrate tissue samples.

6.4.3.13 Total Chlordanes in Tissue

6.4.3.13.1 Fish

Chlordanes were detected in all but one fish tissue composite (juvenile Chinook composite from Willamette Falls). Total chlordanes averaged 2.3 µg/kg in brown bullhead, 2.4 µg/kg in juvenile Chinook, and 8.13 µg/kg in smallmouth bass. The maximum concentration (15 µg/kg) was reported in a smallmouth bass composite sample collected near RM 23.

6.4.3.13.2 Invertebrates

Total chlordanes were reported at 2.26 µg/kg in the juvenile Chinook stomach sample and 4.6 µg/kg in clam tissues analyzed from the reference area bioaccumulation tests. This pesticide group was not detected in the worms.

6.4.3.14 Total PAHs in Tissue

6.4.3.14.1 Fish

PAHs were only measured in Chinook fish tissues. Total PAHs averaged 7.35 µg/kg in juvenile Chinook tissue (a maximum of 10.1 µg/kg). The two- and three-ring LPAHs dominated (Map 6.4-14d).

6.4.3.14.2 Invertebrates

Total PAHs were reported at 87.4 µg/kg in the juvenile Chinook stomach contents sample, 29.7 µg/kg for clams exposed in a laboratory to reference area sediments, and 27 µg/kg for worms used in the reference area bioaccumulation tests. HPAHs dominated in all three samples (Maps 6.4-15d). This composition was reflected in the high relative percent of four-ring PAHs in these samples. Three-ring PAHs (components of LPAHs) were also relatively abundant in the Chinook stomach composite and the Asiatic clam composite.

6.4.3.15 BAA in Tissue

6.4.3.15.1 Fish

BAA was not detected in any upriver fish tissues.

6.4.3.15.2 Invertebrates

BAA was detected in all three invertebrate samples from the upriver area. Concentrations were reported at 2.66 µg/kg in the juvenile Chinook stomach contents composite, 0.51 µg/kg in the clam composite, and 1.1 µg/kg from the worm composite.

6.4.3.16 BAP in Tissue

6.4.3.16.1 Fish

BAP was not detected in any upriver fish tissues.

6.4.3.16.2 Invertebrates

BAP was detected in all three invertebrate samples from the upriver area. Concentrations were reported at 1.07 µg/kg in the juvenile Chinook stomach contents composite, 0.26 µg/kg in the clam composite, and 0.82 µg/kg from the worm composite.

6.4.3.17 BEHP in Tissue

6.4.3.17.1 Fish

BEHP was detected in 4 of the13 upriver fish tissue samples. Average concentrations ranged from 140 µg/kg (in two juvenile Chinook composites) to 4,800 µg/kg in smallmouth bass.

6.4.3.17.2 Invertebrates

Contents of juvenile Chinook stomachs were not analyzed for phthalates. BEHP was reported at 85 µg/kg in clams and 66 µg/kg in worms used in the bioaccumulation tests from the USACE investigation reference area (Tetra Tech 2006).

6.4.3.18 Comparison of Indicator Chemicals in Tissue Collected Upriver to Study Area Tissues

Limited data are available to represent conditions outside the Study Area, so only a general assessment is made in this section. Five locations have been sampled above RM 11. Asiatic clams and worms exposed to sediments from one location and juvenile Chinook, brown bullhead, and smallmouth bass from four locations are used to represent upriver conditions.

6.4.3.18.1 Upriver

In general, upriver samples represented the lowest concentrations measured in fish and invertebrate samples. Concentrations of most organic indicator chemicals were several times to orders of magnitude lower than in the Study Area. Exceptions were noted in several pesticides (total chlordanes and total endosulfans), where the concentrations in clams exposed to sediment from WR-PG-Ref03 and the juvenile Chinook stomach composite from T04 were greater than or similar to Study Area concentrations. Metals in fish tissues from upriver locations tended to be similar to or lower thanin the Study Area, depending on the metal. Clams and worms exposed to sediments in the lab from upriver locations had metals concentrations similar to downriver locations and lower than those samples from the Study Area.

6.4.4 Nature and Extent of Selected Indicator Chemicals in Tissue Collected Downstream from the Study Area

Two downriver locations were sampled as part of the Round 2 investigations. One station (BT/FC001) is on the east bank of the river just below RM 2.0 (downstream of OSM). The second sampling location (BT/FC003) is within Multnomah Channel (Map

2.1-6a). Data associated with field-collected clams and with clam and worm bioaccumulation organisms exposed to sediment from these two locations are summarized in this section and in Table 6.4-1. No fish tissue samples are available to represent downriver conditions.

6.4.4.1 Conventional Analytes

Lipid levels in organisms associated with the two downriver sites were similar. Lab-exposed clams had the lowest percentage (0.77 percent at both locations); lab-exposed worms had the highest percent lipid (2.07 percent for BT001 sample composite; 2.34 percent for BT003). Lipid levels in field-collected clams were 1.89 percent at FC001 and 1.57 percent at FC003.

6.4.4.2 Arsenic in Tissue

Arsenic was detected in all downriver samples, with concentrations ranging from 0.411 mg/kg (lab-exposed clam from BT003) to 1.25 mg/kg (worms from BT001). Sample concentrations were similar for a given species and exposure condition (i.e., field versus lab), with the exception of the worm sample from BT001, which had a concentration over double that at BT003.

6.4.4.3 Mercury in Tissue

Mercury was detected in all samples; concentrations ranged from 0.0034 mg/kg (worms from BT003) to 0.0096 mg/kg (lab-exposed clam from BT001). Sample concentrations were similar for a given species and exposure condition (i.e., field versus lab), with the exception of the worm sample from BT001, which had a concentration more than double that at BT003.

6.4.4.4 Zinc in Tissue

Zinc was detected in all samples; concentrations ranged from 12.2 mg/kg (lab-exposed clam from BT003) to 33.2 mg/kg (field-collected clam from FC001). Sample concentrations were similar for a given species and exposure condition (i.e., field versus lab), although BT/FC01 samples had slightly higher concentrations.

6.4.4.5 TBT in Tissue

TBT was detected only in field-collected clams from both stations and worms from BT003. Concentrations ranged from 2.6 µg/kg (worm from BT003) to 5.1 µg/kg (field-collected clam from FC001).

6.4.4.6 PCBs in Tissue

Downriver total PCB concentrations ranged from 15.8 µg/kg in lab-exposed clams from BT003 to 296 µg/kg in worms from BT001. For all species and exposure types, concentrations at BT/FC001 were consistently higher than those at BT/FC003. In the case of field-collected clams, FC001 was several times higher; in worms, BT001 was an order of magnitude higher in total PCBs.

Aroclor 1254 was the dominant Aroclor in all downriver samples, with the exception of lab-exposed clams, where Aroclor 1242 contributed at least as much to the total concentration as Aroclor 1254 (Map 6.4-8a).

Total congener concentrations ranged from 19.1 µg/kg (lab-exposed clams from BT003) to 402 µg/kg (worms from BT001). The relationship between sites and among species was similar to that exhibited for Aroclors. Tetra-, penta-, and hexaCBs were the most abundant homologs (Map 6.4-9a). TriCBs were present in other than trace amounts in lab-exposed clams, where Aroclor 1242 was detected.

6.4.4.7 2,3,7,8-TCDD TEQs in Tissue

Dioxin TEQs ranged from 0.000238 pg/g (lab-exposed clams from BT003) to 2.01 pg/g in worms exposed to sediment from BT001. Dioxin TEQs were consistently higher in all samples from BT/FC001.

6.4.4.8 PCB TEQs in Tissue

TEQs for dioxin-like PCBs ranged from 0.315 pg/g (lab-exposed clam from BT001) to 8.45 pg/g (worms from BT001). Concentrations in tissues and exposure types between locations were similar, except that the worm TEQ at BT001 was an order of magnitude higher than that at BT003.

6.4.4.9 Dioxin Homologs in Tissue

Average homolog concentrations were 0.399 pg/g (lab-exposed clams at BT001) to 14.1 pg/g (worms exposed to sediment from the same location). Dioxins were not detected in lab clams from BT003. OCDD, TCDD, and TCDF were the most abundant (based on relative percentage) homolog groups present in the downriver samples (Map 6.4-11a). All other homolog groups were present in trace amounts, with the exception of OCDF, which was not detected in any of the clam samples.

6.4.4.10 DDT Isomers in Tissue

Total DDx in invertebrate tissue from the two downstream locations ranged from 1.23 µg/kg (lab-exposed clams from BT001) to 41 µg/kg (worms from BT001). Concentrations were similar between locations for each species and exposure type (concentrations at BT/FC001 were slightly higher than BT/FC003). Based on relative percentages, the dominant isomers were 4,4'-DDE and 4,4'-DDD in all invertebrate tissues (Map 6.4-13a).

6.4.4.11 Aldrin in Tissue

Aldrin was detected in all tissues analyzed at the two downriver locations. Concentrations ranged from 0.0118 µg/kg (lab-exposed clams from BT003) to 0.335 µg/kg (worms from BT001). Concentrations in samples from BT/FC001 were consistently higher than those from BT/FC003, with clam samples slightly higher, and worm samples an order of magnitude higher.

6.4.4.12 Beta-HCH in Tissue

Beta-HCH was detected only in lab-exposed clams from BT003 (0.00343 µg/kg).

6.4.4.13 Total Chlordanes in Tissue

Total chlordane concentrations were calculated for all downriver tissue samples. Concentrations were very similar in all species and exposure types (range of 1.89 µg/kg in worms from BT001 to 3.4 µg/kg in worms from BT001).

6.4.4.14 Total PAHs in Tissue

Total PAHs were calculated for all invertebrate tissues. Concentrations ranged from 27.5 µg/kg (lab-exposed clams from BT003) to 517 µg/kg (worms from BT003). Concentrations in field-collected clams and worm samples from BT/FC003 were higher than those for BT/FC001, in contrast to other indicator chemicals. Lab-exposed clam results represent the lowest concentrations and were similar at both locations.

Total PAHs were composed primarily of HPAHs, with pyrene, fluoranthene, and chrysene the greatest contributors to the total concentrations.

PAH composition based on number of benzene rings showed dominance by the four-ring PAHs in all downriver invertebrate samples (Map 6.4-15a). Other PAHs also contributed substantially to total concentrations: three-ring PAHs in lab-exposed samples, and five-ring PAHs in worms.

6.4.4.15 BAA in Tissue

BAA was detected in all downriver invertebrate tissues. Concentrations ranged from 0.78 µg/kg (lab-exposed clams from BT001) to 60 µg/kg (field-collected clams from FC003). Concentrations in all tissues from BT/FC003 were slightly higher than those from BT/FC001. Lab-exposed clams had the lowest concentrations at both locations.

6.4.4.16 BAP in Tissue

BAP was detected in all downriver invertebrate tissues. Concentrations ranged from 0.51 µg/kg (lab-exposed clams from BT001) to 24 µg/kg (field-collected clams from FC003). Concentrations in all tissues from Multnomah Channel were slightly higher than those from the main stem downriver station. Lab-exposed clams had the lowest concentrations at both locations.

6.4.4.17 BEHP in Tissue

BEHP was not detected in field-collected clams. Concentrations in lab-exposed clams and worms were very similar and ranged from 100 µg/kg (lab-exposed clams from BT001) to 140 µg/kg (worms from BT001).

6.4.4.18 Comparison of Indicator Chemicals in Tissue Collected Downstream to Study Area Tissues

Limited data are available to represent conditions outside the Study Area, so only a general assessment is made in this section. Two locations have been sampled in the lower river (below RM 2 or within Multnomah Channel). Only Asiatic clams and sediments for bioaccumulation testing have been collected from these locations.

Concentrations in invertebrate tissues analyzed from downriver locations tended to be less than those from Study Area samples, but greater than in upriver samples. (No fish tissue was available for a downriver comparison.) In the case of total PCBs, the downriver station (BT/FC001) invertebrate concentrations were the same order of magnitude as the Study Area samples and were 2 to 10 times higher than the Multnomah Channel invertebrate samples. The PCB TEQ in field-collected clams from FC001 was slightly higher than in the Study Area.

In most cases, invertebrate tissues analyzed from the downriver station at BT/FC001 had slightly higher concentrations that those reported for BT/FC003 in Multnomah Channel. Exceptions included HPAHs and LPAHs in field-collected clams where the Multnomah Channel samples were similar to concentrations reported for the Study Area and were higher than those reported for the BT/FC001 downriver location.

Metals in field-collected clam tissues tended to be similar in all areas of the river. Lab-exposed organisms representing downriver conditions had concentrations that were either similar to or slightly lower than those from the Study Area.

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EXECUTIVE SUMMARY

SECTION 7 – ASSESSMENT OF LOADING, FATE, AND TRANSPORT PROCESSES

Abstract

Section 7 provides an overview of contaminant inputs and relevant fate and transport mechanisms for key containments in the Study Area as identified through the Round 2 risk assessment process (iCOCs and potential iCOCs). Primary contaminant inputs (or loading terms) to the Study Area from external sources are identified and estimated, where feasible. The physical, chemical, and biological processes affecting the transport and fate of contaminants once they enter the river are described. Available data types and sources, the approach used in these interim Round 2 calculations and evaluations, and the anticipated path forward for completing these assessments in the RI/FS are presented. This section also describes the purpose and objectives of and approach to the planned hybrid fate and transport modeling, which will be used to assess and predict the important aspects of loading, fate, and transport for the Study Area.

Section 7 identifies the following additional data needs and next steps:

- Refined estimates of loading from upstream surface water and sediments based on planned Round 3 sampling (surface water and sediment) and modeling
- Refined estimates of current stormwater loading rates, based on additional analysis of drainage basin information as well planned Round 3 stormwater and surface water sampling
- Compilation of permitted wastewater discharge information and monitoring data to estimate loading associated with permitted discharges
- Additional review of information related to historical loading terms, as needed for the RI/FS.

The hybrid fate and transport modeling effort is ongoing and will continue though mid-2007. No hybrid model-specific data needs beyond the planned Round 3 data collection activities are anticipated.

Work Plan and Field Sampling Plan Directives

The Programmatic Work Plan (April 2004) identified the need to understand chemical fate and transport in Portland Harbor to support the CSM (see Section 11) and resolve specific FS questions, such as the potential for recontamination and natural attenuation. The need for physical studies and modeling was also identified in the Work Plan to understand short- and long-term sediment movement in the Study Area, an important element of contaminant fate and transport, particularly for sediment-bound iCOCs, such as PCBs and dioxins. The general approach for integrating and assessing information on upland and upstream contaminant

sources and determining the relative inputs from different potential sources of contaminants to the Study Area (e.g., upstream loading, stormwater, etc.) is derived from scoping documents and correspondence with EPA and its partners.

Data Collection Activities

The chemical loading and fate and transport assessments were based on available upland site data, physical system data (e.g., hydrology, see Section 4) and chemical nature and extent data (sediment, surface and transition zone water chemistry, see Section 6) either compiled or collected by the LWG through Round 2. In addition, generalized information and data from the literature were used, where site-specific data were not available.

Preliminary Assessment Methods

The approaches used to develop qualitative to semi-quantitative current loading rate estimates for upstream surface water, stormwater, upland groundwater, and atmospheric deposition loading terms are presented. Additionally, transport of sediment contamination to the water column by groundwater discharge (groundwater advection transport term) was estimated semi-quantitatively. Potential current loading rates from upstream sediment, bank erosion, permitted wastewater discharges, and overwater releases (e.g., spills, etc.) are not estimated. Similarly, historical loading rates for each term are not estimated. Data sources and assumptions for loading estimates included:

- Surface water loading rates derived from historical flow data for the Willamette River and high volume/high resolution chemistry data collected from the upstream transect at RM 11 between November 2004 and July 2005
- Land use information for the Willamette River basin and stormwater chemical characteristics from published studies used for stormwater loading rate estimates
- Upland groundwater plume contribution estimates based on Study Area-specific transition zone water (TZW) and seepage meter data
- Generalized groundwater loading rate estimates based on area-weighted sediment chemistry, estimates of average groundwater seepage through the river bottom, and literature-derived partitioning constants between the sediment solids and the porewater
- Atmospheric deposition to the river surface derived primarily from literature-reported regional air quality data and deposition rates (either measured or modeled).

For all estimated terms, ranges of loading rates were generated to reflect the uncertainty in the assumptions. The detailed loading calculations are provided in Appendix D of the Round 2 report and the relative contributions of the various loading terms (based on this Round 2 data set and evaluation) are presented and discussed within the context of the CSM in Section 11.

Some important fate and transport characteristics of the Study Area are discussed below.

Many iCOCs in the Study Area are chlorinated organics (e.g., PCBs, dioxins, and DDx pesticides). These compounds are persistent in the environment and exhibit a strong tendency to be associated with sediment particles, especially those with high organic content. Consequently, the fate and transport of these chemicals is strongly associated with bedded and suspended sediment and the physical processes that move sediment. Bioaccumulation of these chlorinated compounds would also be expected and is shown by both the empirical and modeled data for the Study Area. Other contaminants exhibit a wide range of chemical properties that affect where they are found and how long they persist in the environment. Many metals sorb strongly to fine-grained sediments and are therefore also controlled by sediment transport processes. Some chemicals, such as volatile organic compounds, are not expected to bioaccumulate. Several COPCs, such as PAHs and phthalates, can be metabolized or transformed by biological processes, which results in changes in chemical concentrations and bioavailability.

The movement, erosion, deposition, and resuspension of sediments through and within the Study Area are a function of the complex interactions of temporally and spatially varying flow regimes, total suspended solids concentrations, and physical and biological disturbance. A numerical hydrodynamic/sediment transport model (Environmental Fluid Dynamics Code, EFDC) is being used with Study Area-specific data (e.g., settling and erosion rates) to predict water and sediment movement in the LWR over a range of hydrological conditions. The bioaccumulation of chemicals is predicted by food web models (FWMs), which mechanistically describe these processes. The Arnot and Gobas (2004) FWM is being used, with the extensive sediment, water, and tissue chemistry data set for the Portland Harbor Study Area, to develop initial preliminary remediation goals for PCBs, DDx, and dioxin-like chemicals.

Through discussions with EPA, a modeling approach that integrates biological, chemical, and physical fate and transport processes has been identified for use in the RI/FS. Termed the "Hybrid Model", it consists of three primary components: the EFDC-based hydrodynamic and sediment transport model to describe the movement of water and sediments throughout the Study Area, an abiotic chemical fate and transport box model developed by EPA to describe chemical movement and distribution within abiotic environmental media in smaller areas, and a food web model to describe the movement of chemicals through the aquatic food chain within the river. By 2007, these pieces will be combined into a Hybrid Model that should be capable of describing the movement of chemical masses in particulates (sediments), water, and through the food web for the Study Area.

Additional Data/Next Steps

The RI/FS will expand upon and complete the preliminary analysis of current chemical loading rates and fate and transport processes relevant to completion of the RI/FS. Round 3 data needed to complete the assessment of upstream inputs of contaminants in surface water and sediments have been identified and are being collected in 2006/2007. These include upstream surface water and sediment trap data as well as bedded sediment chemistry and radioisotope data from upper Study Area cores. These data will be used to calculate or update contaminant

loads entering the Study Area on sediments and in surface water. The preliminary stormwater load estimates calculated here will be updated based on additional analysis of drainage basin information as well as the Study Area-specific stormwater data that will be collected by the LWG and EPA/DEQ. No additional refinements of the groundwater and atmospheric loading estimates are needed for the RI. Permitted wastewater discharge loads will be estimated for the RI based on a compilation of information and monitoring data on permitted discharges. Current bank erosion is a highly uncertain loading term; however, estimation of this term is not considered necessary for the purposes of the RI/FS and will instead be evaluated on an area-specific basis, as needed, as a part of the remedial design process for each SMA As needed, additional review of information related to historical loading terms may be performed to support the RI/FS.

The hybrid fate and transport modeling effort is ongoing and will continue though mid-2007. No hybrid model-specific data needs beyond the planned Round 3 data collection activities are anticipated.

7.0 OVERVIEW AND APPROACH TO ASSESSMENT OF LOADING, FATE, AND TRANSPORT PROCESSES

This section presents an overview of the current general understanding of external loading mechanisms and in-river processes affecting the concentration, transport, and fate of iCOCs, potential iCOCs[23], and other selected analytes within the Study Area. This section also presents the approach to assess (qualitatively to quantitatively) these loading terms, where possible. The purpose of this section is to lay the foundation for the iCOC-specific discussions of loading, fate, and transport in Section 11.1, noting areas of uncertainty, which, in turn, support development of data gaps for the RI.

The primary focus of this analysis is on current external loading mechanisms to the Study Area and current in-river fate and transport processes. It is recognized that each loading term has a corresponding historical component that may be very significant to the Study Area; however, limited quantitative data are available to support estimates of these historical terms. Therefore, historical loading is discussed only qualitatively in this Round 2 Report.[24]

The section is divided into three main subsections: (1) Loading Terms, (2) Fate and Transport Processes, and (3) the Hybrid Fate and Transport Model. First, Section 7.1 describes each of the loading terms identified in the LWG Response to EPA CSM Questions (Integral et al. 2006). The discussion of each loading term includes currently-available relevant data sources, including a discussion of data set adequacy and uncertainties, the approach to assessment of the loading term at this stage in the RI/FS process, including the target level of load quantification; and the path forward for the remainder of the RI/FS. Next, in Section 7.2, individual in-river fate and transport processes are discussed. The approach to assessment of each of these processes, including the data sources and paths forward, is also provided. For both Sections 7.1 and 7.2, corresponding calculations, additional approach details, and complete results of the qualitative/quantitative analyses are presented in Appendix D. Discussion, comparison, and analysis of the results are presented in Section 11.1, in the context of the CSM. Finally, Section 7.3 provides a description of the planned Hybrid Fate and Transport Model, which will be a tool to assess and predict the most important aspects of loading, fate, and transport for the Study Area. The discussion presents the purpose and objectives of the modeling, as well as a description of the integration of multiple models to create the Hybrid Fate and Transport Model.

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[23]Potential iCOCs are differentiated from iCOCs because they were identified through less certain and/or less rigorous evaluations based on fewer lines of evidence.

[24]Section 5 provides a more detailed qualitative discussion of some historical sources. Historical sources are discussed again in Section 11.1, relative to current loading terms, citing stratigraphy-based comparisons of sediment concentration statistics to support the discussions.

7.1 CHEMICAL LOADING TO THE STUDY AREA FROM EXTERNAL SOURCES

This section describes the external loading terms that may contribute iCOCs to the Study Area, as identified in the May 5, 2006 LWG Response to EPA CSM Questions (Integral et al. 2006). The loading terms considered here are upstream surface water, upstream sediment, stormwater, groundwater, atmospheric deposition, industrial discharge, and upland soil and riverbank erosion. For each of these loading terms, a description of the term is presented, followed by a summary of the available applicable data sets. Next, the approach and assumptions to estimation of loading ranges[25], developed based on the available data set, are presented. Finally, the proposed path forward for further evaluation of each loading term is presented. Calculations and complete results of the evaluations are presented in Appendix D. Section 11.1 provides discussion and analysis of the results in the context of the CSM.

As previously mentioned, historical loading—which may be very significant to the Study Area—is discussed qualitatively only for each loading component, because quantitative information for these historical terms is very limited. In addition, chemical releases from current and/or historical overwater activities (e.g., sandblasting, painting, material transfer, maintenance, repair, and operations at riverside docks, wharves, or piers), discharges from vessels (e.g., gray, bilge, or ballast water), fuel releases, and spills are not considered quantifiable and are not addressed in this section. However historical releases of this nature are important in the overall CSM because these releases are considered a significant source of the existing contamination in the Study Area. While improved best management practices (BMPs) are likely to reduce the occurrence of overwater releases significantly, it is acknowledged that current and future releases could occur. No attempt is made in this report to predict and quantify such releases as a "current" loading term, and no additional analysis of this term is planned for the RI/FS. Additional discussion of historical sources, along with current and future overwater activities, is provided in Section 11.

The loading estimates developed in this section (and Appendix D) include a large range of certainty, from quantitative and empirically based estimates, to semi-quantitative literature-based estimates, to wholly unestimated terms and no estimates of historical contributions for each term. The purpose of presentation and discussion of this loading analysis at this stage in the RI/FS process is to examine the information available to date, and to allow for relative comparison of terms in Section 11.1, with careful consideration of the associated uncertainty and unknowns.

The target analyte list included in the loading analysis varies by loading term. These lists were developed considering:

[25]Due to significant uncertainty associated with many of the individual parameters in the loading calculations, upper- and lower-bound estimates are generated for all terms for which numerical estimates are developed.

- iCOCs and potential iCOCs identified in the Round 2 human health and ecological risk evaluations for specific receptors and exposure pathways (see Sections 8 and 9)
- Relevance of each receptor/exposure pathway to the loading term and associated transport mechanism
- Anticipation that the loading estimate results could be useful in decision-making in the risk assessment process (e.g., selected additional COPCs identified based on the screening-level risk evaluation of TZW).

A summary of the chemicals considered in the loading analyses is presented in Table 7.1-1. The specific rationale for selecting chemicals for analysis, relevant limitations, and the final analyte list for each loading term is presented in each approach discussion in the following subsections.

7.1.1 Upstream Loading

Upstream loading is defined as chemical mass entering the Study Area at RM 11 via surface water and sediment transport. Upstream surface water and sediment loading are discussed separately in this section, and the path forward is provided for each.

7.1.1.1 Upstream Loading from Surface Water

Round 2 estimates of mass loading of selected iCOCs entering the Study Area at RM 11 in surface water are semi-quantitative, site-wide estimates. The calculations and results are presented in detail in Appendix D and discussed in the context of the CSM in Section 11.1.

7.1.1.1.1 Data Sources—Surface Water Upstream Loading

This harbor-wide upstream surface water loading analysis is based on Round 2 surface water sampling results from RM 11 and USGS flow information from RM 12.8 (Morrison Bridge). Three surface water sampling events from the Round 2A sampling effort provided the data for the upstream surface water loading calculations. These events occurred in:

- November 2004 (November 8–December 2)
- March 2005 (March 1–17)
- July 2005 (July 5–20).

During these events, samples were collected at three surface water transect stations located:

- At the upstream end of the Study Area at RM 11 (W023)
- In the central Study Area at RM 6 (W011)
- Near the downstream end of the Study Area at RM 4 (W005).

Upstream loading estimates are based on the data from the transect at RM 11; however, surface water loads were also calculated for transects at RM 6 and RM 4 to offer additional insight into the changing conditions across the Study Area.

Average discharge rates (recorded as cfs) for each event are based on measurements collected by the USGS at the stream flow station located upstream of the Morrison Bridge at RM 12.8. Flow measurements from the USGS gauge at Morrison Bridge are collected every 30 minutes and were used to calculate flow rates for each of the three sampling events[26]. In the mass loading calculations, the event-specific Morrison Bridge flow rate was applied to all three transects for a given sampling event, for lack of transect-specific flow rate measurements.

Loading rate calculations were performed for the analyte list presented in Table 7.1-2, which is based on the human health and ecological iCOCs for all receptors and pathways, with the exception of iCOCs that were identified only using the TZW line of evidence for ecological risk to the benthic community (because surface water loading is not expected to influence TZW chemistry directly). The analytes are further limited to chemicals that were included in the surface water analyte list.[27]

For organic analytes, dissolved and particulate concentrations were determined from the XAD columns and filters, respectively. Total water column concentrations of organic chemicals were simply calculated from the summation of these fractions. Total and dissolved arsenic concentrations were reported directly by the laboratory (Columbia Analytical Services, Kelso, Washington). Loading calculations were performed on the dissolved, particulate, and total concentrations.

7.1.1.1.2 Approach—Surface Water Upstream Loading

The data described above were used to develop semi-quantitative surface water loading estimates at RM 11, RM 6, and RM 4. The mass loading rate estimates were generated by multiplying the observed surface water concentrations at each transect by the USGS-reported river flow rates, applying appropriate unit conversions. The general formula is provided below:

Chemical concentration (μg/L)*(28.32 L/ft^3)*flow (ft^3/s)*(86,400 s/d)*(kg/10^9 μg)*(365 d/year) = Chemical load (kg/year)

[26]Note: The flow rate values presented here are daily mean stream flow measurements from the USGS National Water Information System, www.waterdata.usgs.gov. These values were taken from the USGS website on 7/19/06 at 6:00 a.m., and are considered to be draft and subject to change by USGS, which may refine ratings and calculations as needed.

[27]For calculating analytical totals (e.g., LPAHs), a value of zero was used for individual chemicals that were not detected in a given sample at the laboratory method reporting limit.

Results below detection limits were assigned zero concentrations for the loading calculations. All calculated mass loading rates are presented in Appendix D Tables D2-1 through D2-3.

Limitations to this approach reflect data availability and concerns of representativeness. The Round 2 surface water loading calculations are representative of conditions observed during the three sampling events in 2004 and 2005. All three of these sampling events occurred during low-flow periods on the river. The timing of the events is presented against the river hydrograph in Figures 6.3-1 through 6.3-4. At this time, it is not clear whether chemical concentrations can be expected to be higher or lower during periods of higher flow; therefore, an extrapolation of the results to a more realistic annual loading rate is not possible. Appendix D provides additional detail on data uncertainties and adequacy.

Due to the integrated nature of chemical movement in the surface water column, iAOPC-specific estimates of surface water loading are not provided. Historical loading to the Study Area, as compared to current loading, is relevant to the extent that associated suspended solids were deposited and remain within the Study Area. This contribution cannot be quantified, and is not expected to be comparable to other historical loading terms such as historical industrial discharges and overwater releases.

7.1.1.1.3 Path Forward—Surface Water Upstream Loading

Four surface water sampling events are planned for Round 3, including two high-flow events, an additional low-flow event, and a stormwater runoff event. The first Round 3 high-flow sampling event was conducted in January 2006 (Integral 2006n). Round 3 low-flow event samples and stormwater runoff event samples were collected in September 2006 and November 2006, respectively. The second Round 3 high-flow event will take place in early 2007.

Data analysis and use relevant to fate and transport of chemicals in surface water is discussed in Section 7.3 of this report. Section 11.1 provides discussion and analysis of the loading estimate results in the context of the CSM, and additional information collection currently planned to address RI/FS data gaps is discussed in Section 12.

7.1.1.2 Upstream Loading from Sediment

Upstream loading estimates need to account for inputs associated with typical hydrologic conditions observed during the RI/FS to date, as well as inputs associated with more extreme hydrologic conditions that are unlikely to occur during the RI/FS.

At this stage in the RI/FS, consideration of mass loading of selected iCOCs associated with suspended and bedload sediments entering the Study Area is largely qualitative and descriptive. No attempt is made in this report to quantify upstream loading from sediments because most of the empirical data needed for that analysis is being collected in Round 3. Additionally, the fate and transport modeling effort, critical to certain aspects of this quantification, is ongoing. Instead, this section summarizes the physical

CSM that provides the framework for evaluating upstream sediment loading, the objectives of that evaluation, data sources, the proposed approach, and the path forward.

As described in Section 4.5, the physical character of the LWR transitions rather abruptly in the upper Study Area from a relatively narrow, higher-flow-velocity reach characterized by coarse-grained riverbed sediments (e.g., upstream of RM 12) to a broader, slower reach conducive to the deposition and accumulation of fine-grained sediments downstream of RM 10. The upstream end of the federally authorized -40 ft CRD navigation channel, which extends downstream to the Columbia River, occurs within this transitional reach at RM 11.7 (Broadway Bridge). Historical dredging of Portland Harbor to maintain the navigation channel has drastically altered the equilibrium sediment transport regime within Portland Harbor, resulting in a broad area of flow velocity reduction and associated sediment deposition.

Suspended sediment loads entering the Study Area from upstream vary as a function of river flow (see Figure 4.4-1). In a typical year, flows in the LWR (as measured at the Morrison Bridge) can vary by a factor of 10 (e.g., 20,000 to 200,000 cfs) with associated TSS levels varying annually by at least a factor of 10 (range from 1992–2006 was roughly 5 to >200 mg/L; see Figure 6.3-6). It is evident from the measured bathymetric change data set collected from 2002 to 2004 (Map 4.4-2) and the surface sediment grain-size map (Map 4.4-3) that a portion of the fine-grained sediments entering the Study Area from upstream settles out and accumulates in the relatively wide reaches from RM 8 to 10, RM 4 to 5, and around RM 2. The period from 2002 to 2004 represents typical water years on the LWR; therefore, this depositional pattern appears to be typical of the long-term fine-grained sediment accumulation pattern. An important objective of the fate and transport analysis for this RI/FS will be to assess the pattern of deposition/erosion of fine-grained sediment (and sediment-associated iCOCs) during non-observed, high-energy events, i.e., floods. This objective will be addressed using a combination of empirical observations and modeling, as described in the sections that follow.

Upstream sediments may also be transported into the Study Area along the riverbed as bedload. Based on riverbed morphology and hydrodynamics, bedload transport into the Study Area is not expected to be significant under typical hydrologic conditions. Sediments moving downstream along the riverbed are likely trapped in a series of borrow pits or dredged depressions that are situated across the channel west to east from about RM 10.5 to 12 (see Map 4.4-1). The same hydrodynamic conditions at and downstream of RM 10 that are conducive to cohesive suspended sediment deposition are unlikely to transport significant non-cohesive material as bedload. In addition, high concentrations of iCOCs are less likely to be associated with the non-cohesive (e.g., sand) fractions that move as bedload. Bedload transport into and through the Study

Area is included as part of the hydrodynamic/sediment transport model[28], described generally in Section 7.2.1.2, and will therefore be incorporated into the Fate and Transport Model discussed in Section 7.3. Bedload input levels to the Study Area during non-observed, high-energy events will be addressed using a combination of empirical observations and modeling, as described in the sections that follow.

7.1.1.2.1 Data Sources—Upstream Sediment Loading

Four major sources of data being collected as part of this RI/FS will be used to address upstream chemical loading from sediments:

1. **Surface Water:** As noted in Section 7.1.1.1.1, the Round 2A surface water sampling program collected measurements of total, dissolved, and particulate concentrations at RM 11 during three different seasonal sampling events. The Round 3A surface water sampling program is designed to expand this data set to include a broader range of hydrologic conditions. Moreover, surface water will be collected at RM 16, upstream of the Downtown Corridor, and at RM 11 (the upstream boundary of the Study Area), downstream of the Downtown Corridor. This data set provides "snapshots" of suspended sediment quality entering the Study Area under various observed conditions.
2. **Sediment Traps:** Round 3 sediment trap data collected from RM 11 and 16 will provide chemical concentrations in suspended sediments (integrated over four 3-month deployment periods) for one water year.
3. **Surface Sediment Data:** Surface sediment data currently include non-LWG- and LWG-generated bedded bulk sediment chemical concentration data from upstream of the Study Area. Additional upstream bulk sediment chemistry data will be collected in Round 3A in early 2007.
4. **Subsurface Sediment Data:** Subsurface sediment samples (collocated radiochemistry and chemistry cores) from long-term depositional areas in the Upper Study Area are scheduled for collection in Round 3A in early 2007 and are designed to provide empirical information on chemical inputs to the Study Areas during high-flow events.

7.1.1.2.2 Approach—Upstream Sediment Loading

The approach to estimating chemical loading from upstream sediments combines both empirical methods and modeling to address loading during typical and extreme hydrologic events.

Empirical data, such as surface water (TSS and chemical loads), sediment trap, and bedded sediment data, will be used to estimate chemical loads to the Study Area during the typical hydrologic periods over which the measurements were made. In

[28]Bedload input into the upstream model boundary at RM 26.6 (Willamette Falls) is assumed to be zero. Bedload movement from cell to cell downstream from this upper boundary is then calculated by the EFDC model. The hydrodynamic sediment model is described in Section 7.2.1.2.

combination, these data will also be used as lines of evidence in developing estimated ranges of the temporal (e.g., seasonal or high- versus low-flow periods) and spatial (e.g., upstream and downstream of the Downtown Corridor) variability in suspended sediment chemical concentrations.

These empirically derived estimates have been and will be used to inform the physical hydrodynamic/sediment transport [Environmental Fluids Dynamics Code (EFDC)] model and ultimately the EPA Fate and Transport Model. The EFDC model, first developed in 2005, is being recalibrated in late 2006 with site-specific data (TSS, settling velocities, and erosion rates) collected earlier in the year. Once adequately calibrated, the physical (abiotic) elements (e.g., water and suspended sediment fluxes between model cells) will be linked with the food web portion of the Fate and Transport Model to provide a more accurate physical basis for that model. This model hybridization is scheduled to occur in the winter/spring of 2006/2007. The final Hybrid Model will be used to simulate future input of sediment-associated chemicals over a range of modeled hydrologic events.

Finally, a series of collocated radiochemistry and bulk chemistry core samples will be collected from long-term depositional areas in the Upper Study Area as part of the Round 3A upstream sediment sampling event. Vertical profiles of chemical concentrations with depth will be generated from these cores, and the radioisotope data should allow depositional time frames to be assigned to the profiles. The cores will be located in the Upper Study Area borrow pits described above, and sediments accumulating in these areas should reflect the nature of sediments (both suspended and bedload) that enter and accumulate in depositional areas at the upstream end of the Study Area. This information will be evaluated on its own relative to known temporal benchmarks (e.g., the 1996 flood) and may be useful for comparison with model predictions of chemical input over time.

The relative contribution of historical upstream sediment loading, as compared to current upstream sediment loading, is uncertain. Factors including historical dredging, rapid river flow velocities associated with high-flow events, and complex sediment deposition patterns make it difficult to predict or generalize about the duration and long-term impact of upstream sediment migration and loading. Additional discussion of observed concentrations in sediment, as a function of depth, is presented in Section 11.1 on an analyte-by-analyte basis to provide additional insight into the relative contribution of historical loading to sediments in the Study Area.

7.1.1.2.3 Path Forward—Upstream Sediment Loading

The path forward for assessing upstream inputs of sediment-associated chemicals includes additional data collection and evaluation and additional modeling (both physical and fate and transport).

The data sets needed to complete this assessment are currently being collected or are planned for collection in Round 3. These include:

- Upstream (RM 11 and 16) Round 3 sediment traps, which were deployed in November 2006
- Upstream surface water sampling during high-flow and stormwater runoff events (a stormwater event was sampled in early November 2006)
- Upstream radioisotope and chemistry cores to be collected in the Round 3A sediment sampling effort scheduled for early 2007
- Additional upstream bedded sediments to be collected as part of Round 3B later in 2007 (Note: this data set will serve to enhance the understanding of background conditions, and does not constitute an upstream loading data need).

Modeling efforts are ongoing. These include:

- Recalibration of the physical hydrodynamic/sediment transport model (EFDC) and future simulations
- Hybridization of the physical elements of the EFDC model with EPA's Fate and Transport Model in the winter/spring of 2006/2007 (see Section 7.3).

Data analysis and use relevant to fate and transport of chemicals in upstream sediment is discussed in Section 7.3 of this report. RI/FS data gaps are discussed in Section 12.

7.1.2 Stormwater

The area of interest for stormwater loading estimates to the Study Area consists of the overall drainage area that is routed to the LWR between RM 2 and 11. iCOCs present in the Study Area watershed can be transported to the river by stormwater. These iCOCs may be found on pavement, roofs and other impervious or semi-pervious surfaces, as a result of upland soil contamination, atmospheric deposition, and various human activities. Stormwater-related chemicals are transported mostly via conveyance systems and discharged through numerous outfalls along the river shoreline within the Study Area. Note that groundwater may infiltrate into some stormwater conveyance systems. Overland flow of stormwater to the river also occurs in some relatively limited areas. Stormwater that infiltrates into the ground to become groundwater is evaluated as part of the groundwater loading term in Section 7.2.3. Specific potential industrial stormwater sources near observed areas of elevated iCOC concentrations in river sediment are described in Section 5. In this report, evaluation of mass loading of selected iCOCs associated with stormwater is preliminary and qualitative. This section describes the approach and methods for assessing the potential magnitude of stormwater as a loading term for chemicals to the river. Results of the assessment are presented in Appendix D and described in the context of the CSM in Section 11.1.

7.1.2.1 Data Sources—Stormwater Loading

In order to estimate a stormwater source load to the Study Area for the Round 2 Report, the following general types of information are needed:

1. Delineation of the overall Site drainage boundary and characteristics
2. Volumes of stormwater flow to the Site over a set unit of time
3. Dissolved and suspended concentrations of chemicals present in the stormwater flowing to the Site.

The data available to support loading estimates are reviewed in the following paragraphs as an overview of potentially useful information. Note that not all of the data sources discussed are used in the evaluations presented in this report. In some cases, these data sources could be used later in RI development.[29]

For information type 1 above, the initial characterization of the Site drainage area and initial delineation of outfall basins within that area are described in Section 4 and 5 and summarized in Table 4.1-1 and Map 4.1-4. The sources of this information and methods for compiling them are also described in Section 5. As noted there, the basin characterization represents an initial attempt to quantify the overall Site drainage, and it will continue to be refined, corrected, and updated through the RI as new information becomes available. Although inaccuracies are known to exist, this information provides a reasonable first estimate of current Site drainage basin conditions.

For information type 2, stormwater volumes are typically estimated based on relationships between rainfall and runoff for different land use types and characteristics, such as amount of impervious surfaces or degree of vegetation present. These estimates can be expressed as simple relationships between incident rainfall, land use type, and runoff (e.g., the rational method or curve number approaches), or using simple or complex runoff models. Simple runoff estimates or models can be developed relatively quickly assuming that information on land use within the overall drainage similar to that described in Section 5 is available. In addition, the City has developed the "GRID" model (City of Portland 2006d) for the Site drainage, which is a GIS-based runoff model that uses the "Simple Method" developed by Schueler (1987) for determining the amount of runoff for various generalized land use types. This model is not used in any calculations presented in this report due to inadequate availability of empirical data, but could be used for RI-level evaluations. For the evaluation herein, simple runoff estimates are made using information about land use and overall drainage.

For information type 3, very limited and sporadic site-specific data are available on concentrations or loads of chemicals entering the Site via stormwater outfalls. Two primary types of chemical sampling and analysis data are most relevant to the Site

[29]The level of spatial detail needed for this information will increase as the Site moves through the RI/FS, Remedial Design, and Remedial Action process. For the RI/FS, some differentiation and additional spatial resolution of stormwater loading estimates (by region of the river, at a minimum) will be necessary to support decision-making for AOPCs. For Remedial Design to proceed, sources will need to be understood in sufficient detail for each AOPC to allow remediation to proceed without major risk of recontamination of sediments or impact to the river water column.

RI/FS: (1) stormwater and (2) solids. Water chemical concentrations can be used directly in loading estimates and solids chemical data can provide an indirect estimate of water concentrations, when assumptions or estimates of the TSS concentrations in the stormwater are also made. It should be noted that there are a number of potential pitfalls associated with extrapolation from solids data to water concentrations; however, when complete water data sets are unavailable, such extrapolated data can be a valuable source of information for first-level estimates of loads. Specific available information is reviewed below and some of this information is used in evaluations described in the following subsection (7.2.2.1.2).

DEQ has identified approximately 26 sites within the Site that have conducted some type of stormwater-related sampling (e.g., stormwater and catch basin sediments) either prior to or under the JSCS program (Table 7.1-3) (Tarnow 2006a,b, pers. comm.). In addition, DEQ has indicated stormwater-related sampling under the JSCS program will or could possibly take place at approximately 41 sites during the winter of 2006/2007 (Tarnow 2006a,b, pers. comm.). Of these 41 sites, 22 have not previously conducted stormwater sampling under DEQ programs (Tarnow 2006a,b, pers. comm.) (Table 7.1-3). Sampling under the JSCS program is in addition to any sampling conducted for NPDES permit compliance. JSCS sampling is generally focused on site-related chemicals, and can range widely in scope and approach, from screening-level sampling (catch basin sediments and/or stormwater grab samples) to extended stormwater monitoring programs. The scope of the sampling is negotiated between DEQ and the owner/operator on a site-specific basis. To date, no comprehensive data set or summary has been compiled by DEQ or LWG. The LWG will continue to work with DEQ to obtain a comprehensive data set for use in the RI. In addition, any data available through early fall 2007 are expected to be incorporated into the RI. Data collected after that time are expected to be too late for incorporation into the RI under the existing schedule.

The City has conducted stormwater-related sampling mostly within sub-basins of outfalls, including sampling of in-line solids within basins Outfall M-1, Outfall 18, Outfall 17, Outfall 22B, and Outfall 53A for a variety of metals and organic compounds. This information was collected for source tracing and may have little or no value for determining source loads.

Also, as part of the Portland MS4 NPDES permit, the City conducted land-use-specific stormwater sampling in 1991-1996 at ten stations representing various land uses (residential, commercial, industrial, transportation, parks and open space, and mixed land uses). Three land use monitoring stations were located within the Site: two industrial stations and one transportation station. Industrial station I2 was located at City Outfall M-1, and industrial station I1 was located within a sub-basin of City Outfall 18. Transportation station T1 was located with a sub-basin of City Outfall 18 and represented runoff from Highway 30 (Woodward-Clyde 1996). Metals were extensively sampled, and between two and five storm events were sampled for pesticides, SVOCs, VOCs, phenols, and cyanide. Pesticides, SVOCs, and VOCs were

mostly undetected in stormwater using standard laboratory detection limits. PAHs were also analyzed with ultra-low detection limits; detected PAH concentrations ranged from 0.1 to 30 µg/L, with the highest concentrations associated with industrial land use.

In most cases, samples collected for the private and City-related source tracing and MS4 efforts were analyzed for only a subset of chemicals in the RI/FS target analyte list. In many cases, samples were collected at specific locations within the conveyance system, and are likely not representative of overall chemical contributions across the entire basin. This makes much of this information difficult to use in a consistent manner to develop stormwater loading estimates for either these specific outfalls or the Site as a whole.

7.1.2.2 Approach—Stormwater Loading

Due to the limited availability of empirical physical and chemical data for stormwater at the Study Area, estimates of stormwater loads for this report are very generalized and heavily augmented by literature information (where available). Further, because the delineation of basins and their associated characteristics is still in progress, outfall-basin-specific loading estimates have not been developed. In accordance with the objectives for the Round 2 report, harbor-wide loading estimates in the form of large ranges of possible loads have been generated for use in general comparison to other potential loading terms to the Study Area. The uncertainty in the stormwater loading estimates will be considered in these comparisons and in resulting determinations of data gaps. This section presents the approach applied to the calculations.

It is expected that the overall rate of stormwater loading to the Study Area may have been more significant historically, prior to implementation of upland stormwater runoff controls in some areas. However, ongoing effects of historical loading cannot be easily quantified. Additional discussion of observed concentrations in sediment as a function of depth is presented in Section 11.1 on an analyte-by-analyte basis to provide additional insight into the relative contribution of historical loading to sediments in the Study Area.

The LWG developed an initial estimate of runoff volumes using the Simple Method (Schueler 1987)[30] and GIS basin and land use information (presented in Section 5) similar to the City's GRID model. It should be noted that this calculation is less detailed that the City's GRID model in some respects, such as the details of land use, but it provides a relatively simple means of generally estimating stormwater runoff

[30]Schueler's Simple Method was developed to help understand the relative contributions of various types of land uses for chemicals such as metals and nutrients and is not commonly applied to organic chemicals on the COI list for this Site. The method was originally intended for use in relatively small basins to evaluate the impacts of new developments on water quality. Thus, the Simple Method is not specifically designed for use in developing site-wide loads of toxic chemicals from large urbanized areas for a relatively large segment of a river. Despite these limitations, the Simple Method provides a means to calculate a range of potential stormwater loads using general Site information and is a useful first step in understanding the potential importance of stormwater as a source to the Site.

volumes. This approach should be more than sufficient to generate a reasonable range of potential loads that will help identify the data and quantitative approaches needed to refine the estimates for the RI.

The Simple Method for estimating loads is determined from:

$$L = R * C * A$$

where:

L = Annual load (kg/yr)

R = Annual runoff per unit area (cm/yr)

C = Chemical concentration (mg/L)

A = Area (ha)

In addition, unit conversion is necessary to yield units of kg. The R value is determined from:

$$R = P * Pj * Rv$$

where:

P = Annual rainfall (cm)

Pj = Fraction of annual rainfall events that produce runoff (usually 0.9)

Rv = Runoff coefficient (unitless)

The P value was obtained from WRCC (2006) and the annual average rainfall in Portland of 42 in. (107.63 cm) was used for all calculations. Rv is calculated based on a correlation relationship with impervious cover in the basin developed by Schueler (1987). Impervious cover values were assigned to each land use category available from the Basin Characterization report based on urban data for such typical land uses (SMRC 2006). The value for A was obtained from the overall drainage basin information presented in Section 5.

Concentration values were obtained from a variety of stormwater pollutant studies, as described in Appendix D.3. Studies that examined concentrations from various types of land uses were used and associated with each of the land use categories available from Section 5. Appendix D.3 provides additional detail on data uncertainties, adequacy, and potential data gaps. The Simple Method calculation was conducted individually for each land use area and these loads were summed to obtain a total load estimate for the Site drainage basin.

The availability of chemical concentration data varies. The literature was initially reviewed to determine which of the Round 2 iCOCs and potential iCOCs[31] was relatively well represented in the literature. Based on this review, all readily available data were compiled on the chemicals listed below and in Table 7.1-4:

- Arsenic
- Copper
- Lead
- Mercury
- Zinc
- BEHP
- DDT
- PAHs
- PCBs
- Phenol.[32]

In addition, literature stormwater TSS data were compiled so that literature values for in-line sediment trap chemical concentrations could be converted to water concentrations and included in the data set. While only a subset of Round 2 iCOCs and potential iCOCs, this analyte list includes chemicals and chemical classes representative of many of the major human health and ecological risk drivers.

Stormwater investigations have typically focused on metals and nutrients. Consequently, the number of available metals data points for each land use was usually in the hundreds, while there were usually only a few data points per land use for most of the organic chemicals, with some exceptions (see Appendix D.3). The maximum, median or mean (depending on the data source), and minimum reported concentration values for each chemical were also compiled. These values provide ranges that were used in the calculations to yield high, mid, and low estimates of loading for each chemical and basin.

The methods for utilizing literature concentration values and assigning them to high, mid, or low categories for each land use type are described further in Appendix D.3. The appendix also discusses the representativeness of the literature and site-specific chemical data used, and how this contributes to uncertainties in the analysis.

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[31]Potential iCOCs are differentiated from iCOCs because they were identified through less certain and/or less rigorous evaluations based on fewer lines of evidence. Identification of a chemical as a potential iCOC may be based one or more of the following lines of evidence: TZW screening evaluations, floating percentile model (FPM) results, or other high uncertainty lines of evidence. See Sections 8 and 9 for detailed discussions.

[32]Phenol was not identified as an iCOC or potential iCOC, but was included as an initial target analyte during the preliminary stormwater literature data research, and is included here to provide additional insight into the overall stormwater loading term.

One important limitation of chemical information based on general land use is that it does not include data points associated with site-specific industrial or other land use activities at the Site. Many of these site-specific activities, either historical or ongoing, would be expected to contribute some specific chemicals to stormwater at concentrations that may differ significantly from typical literature land use values or even from other portions of this Site. These sites may contribute loads of specific chemicals that are beyond the range presented in Appendix D. This could contribute to non-conservatism in the overall loading estimates generated, which is considered in the stormwater data gaps discussion in Section 12.

The resulting range of loads for each chemical from the entire Site drainage basin is presented in Table D3-1 and in Section 11.1. These harbor-wide loading estimates in the form of large ranges of possible loads have been generated for use in general comparison to other potential loading terms to the Study Area. The significant uncertainty in the stormwater loading estimates, largely associated with use of literature-based information, will be considered in these comparisons and in resulting determinations of data gaps, as discussed in Section 12.

7.1.2.3 Path Forward—Stormwater Loading

The RI will expand upon and complete the preliminary analysis of stormwater presented in this report as needed to meet RI/FS objectives. The additional information collection relevant to stormwater sources, fate, and transport currently planned for the RI is listed below. This is discussed in greater detail, in the context of the RI/FS objectives, in the data gaps section (Section 12) of this report.

1. Empirical information
    a. Round 3A sediment trap data
    b. Round 3A surface water data
    c. Historical individual party stormwater data from DEQ and City
    d. DEQ-directed stormwater data results
    e. LWG-collected stormwater results
    f. LWG refinements of stormwater basin, outfall, and land use maps.
2. Data analysis information
    a. Refined estimates of runoff volumes, based on Item 1e above, and possibly more sophisticated runoff models developed by the City, DEQ, and/or the LWG.
    b. Refined estimates of stormwater loading based on items 1c, 1d, and 1e
    c. Hybrid Fate and Transport Model analysis using above information and inputs (in addition to some other inputs for some model components).

The Round 3A surface water and sediment trap data collection is currently underway and will be used to understand the potential impact of stormwater discharges to surface water and sediments in the river. The Round 3A surface water sampling includes sampling during times with and without stormwater discharges at locations relatively near and away from groups of outfalls on either side of the river. Similarly, Round 3A sediment traps were deployed near and away from groups of outfalls in late October 2006 and will be sampled approximately quarterly for 1 year so that both rainy and dry season conditions will be examined.

In addition, the LWG is currently undertaking collection of stormwater samples at 31 basins around the Study Area drainage to identify the chemical concentrations and loads associated with stormwater entering the river. The data collection will extend from February through May 2007 and will include in-line stormwater sediment trap samples collected over a 3-month period and flow-weighted composite sampling for three storm events.

Data analysis and use relevant to fate and transport of chemicals in stormwater is discussed in Section 7.3 of this report. Section 11.1 provides discussion and analysis of the loading estimate results in the context of the CSM, and additional information collection currently planned to address RI/FS data gaps is discussed in Section 12.

7.1.3 Upland Groundwater Plumes

Upland groundwater plumes flowing toward the river are a possible source of chemicals to the in-river sediments, TZW, and surface water in the Study Area. This section presents the Round 2 approach, data sources, and path forward to semi-quantitatively assess the loading of chemicals to the Site from upland groundwater plumes. Discussion and evaluation of the transport process for remobilization of iCOCs in river sediment by groundwater advection into the surface water column is presented separately in Section 7.2.1.3.2. The basis for this distinction is that upland groundwater plume loading is considered an external loading term to the system, whereas remobilization caused by groundwater advection is a transport process for chemicals present within the in-water portion of the Site.

The loading estimates presented here are based on information collected in the Round 2 GWPA at the nine TZW study sites (see GWPA SAP [Integral 2005a] for a discussion of site selection), including the identification of potential plume discharge zones, TZW chemistry sampling results, and groundwater flux measurements using seepage meters. In many cases, they represent highly conservative, upper-bound estimates of potential loading from upland groundwater plumes, as discussed below and in Appendix D. The estimates are presented as estimated loads of selected chemicals from the transition zone to surface water in areas identified as potential plume discharge locations. In cases where the chemicals detected in TZW may be partly or wholly attributable to desorption of chemicals in river sediment or entrainment of sediment particles into TZW samples (e.g., PAHs and pesticides) or to geochemical processes occurring in sediments (e.g., arsenic, barium, and manganese), the estimates may be unrealistically

conservative with respect to upland contributions to the Site via the groundwater transport pathway. In such cases, further evaluation of upland fate and transport processes may be needed either as part of the RI or in the context of upland source control efforts under separate oversight by DEQ or EPA.[33] Data gaps for the RI associated with upland groundwater plume loading are discussed in Section 12 of this report.

7.1.3.1 Data Sources—Groundwater Plume Loading

Upper-bound estimates of groundwater plume chemical loading to the Study Area are based on identification of potential plume discharge zones, measured concentrations of upland groundwater COIs in TZW, and groundwater discharge rates in potential plume discharge zones. The following data sources were used to determine these terms:

- Twenty-eight flow zone areas identified offshore of the nine TZW study sites were used to group data sets for the calculations. These flow zones are presented with discussions supporting the interpretations in the GWPA TZW SCSR (Integral 2006g). The zones are also presented in Appendix D of this document in support of the detailed approach discussion presented in Appendix D.4.1. Flow-zone designations match those presented in Integral (2006g). These zones were determined using multiple lines of evidence, including:
  - Trident probe temperature mapping results
  - Direct measurements of flux across the sediment-water interface using seepage meters
  - Upland and in-river subsurface stratigraphic information (e.g., coring logs, stratigraphic cross-sections)
  - Surface sediment texture mapping
  - Information on upland groundwater flow patterns (e.g., potentiometric surface maps, preferential flow paths, remediation systems, and shoreline structures)
  - Nature and extent of COIs in upland groundwater
  - Analysis of spatial patterns in TZW chemistry, sediment chemistry, and upland groundwater chemistry
  - Major ion analysis
  - Chemical partitioning analysis.

[33]Elements of such an assessment may include site-specific information and evaluation of physical, chemical, and biological attenuation mechanisms along the transport pathway from the upland groundwater through the transition zone; consideration of the kinetics of sorption/desorption of COIs to/from sediments; and analytical or numerical modeling of fate and transport.

- Measured TZW chemical concentrations from 127 sample locations at the nine study sites were applied to the calculations. These samples represent the complete TZW data set for the sample depth interval from 0 to 38 cm bml. The sampling methods included in this data set are small-volume peepers, Trident, and Geoprobe®. Both unfiltered and filtered (where available) results were evaluated.
- Seventy flow meter measurements were used to estimate groundwater flux. The 24-hour average seepage rates are presented spatially on Map D4-1.

Analytes for the upland groundwater plume loading rate calculations were selected based on the following criteria:

- All human health iCOCs (see Section 8) and ecological iCOCs (see Section 9) were included, with the exception of certain hydrophobic iCOCs (e.g., PCBs) that were not sampled in TZW and/or are not expected to be present in, or readily transported by, upland groundwater plumes.
- Chemicals in TZW were included if they exceed the chronic ecological screening level by a factor of 10 or more. This criterion was established as a conservative tool to identify chemicals in discharging groundwater plumes that may be relevant for further evaluation of ecological risk to benthic receptors and fish in near-bottom surface water (Section 9).
- Chemicals in TZW were included if they exceed the AWQC for fish consumption (17.5 g/day consumption rate) by a factor of 10 or more. This criterion was established as a conservative tool to identify chemicals in discharging groundwater plumes that may be relevant for further evaluation of risk to human health from consumption of fish and shellfish that dwell in near-bottom surface water (Section 8).
- Chemicals in TZW were included if they exceed either the MCL or the Region 9 tap water PRG by a dilution factor that was estimated based on the assumption that chemical concentrations in TZW would be diluted by at least 10 percent of the minimum average monthly low flow rate in the LWR before reaching a hypothetical drinking water exposure point in the surface water column. This factor was calculated as the ratio between 10 percent of the minimum average monthly flow rate (0.10×6901 cfs = 690 cfs) and the entire estimated groundwater flux to the Study Area (6.6 cfs, see Section 7.2.1.3.2). The resulting value of 105 was rounded down to 100 to define the exceedance factor used to select chemicals for the loading analysis. This criterion was established as a conservative tool to identify chemicals in discharging groundwater plumes that may be relevant for further evaluation of drinking water scenarios in the Round 2 HHRA (Section 8).

The criteria above were applied to identify the analyte list presented in Table 7.1-5 for the groundwater plume loading calculations.

The approach to estimating chemical concentrations and flow rates within each flow zone is presented in the following subsections.

7.1.3.2 Approach—Groundwater Plume Loading

Groundwater plume chemical loads to surface water were estimated semi-quantitatively based on observed TZW chemical concentrations and seepage meter flow rates applied to each flow zone area. It is possible that overall groundwater loading to the transition zone may have been more significant historically, prior to institution of groundwater controls at several upland sites. However, the time delay in transport of chemicals from upland groundwater to the river can be significant, making it difficult to predict or generalize about the duration of migration or the timing of the peak concentrations. Note that the current loading analysis approach estimates only current groundwater plume loading to the Study Area; however, in many cases, this term reflects historical upland releases of iCOCs and potential iCOCs.

Loading estimates were prepared for each flow zone area using the following general equation:

$$\text{Load (kg/yr)} = C\ (\mu g/L) \times Q\ (ft^3/yr) \times 28.32\ (L/ft^3) \times 10^{-9}\ (kg/\mu g)$$

where C is the chemical concentration the TZW and Q is the measured groundwater discharge rate to surface water. Concentrations were assigned from the measured TZW concentration data set described above. Both filtered and unfiltered TZW samples were used to generate a range of estimates. The flow rate was based on the seepage meter measurement data set described above. Mean and maximum flow rates were applied to each flow zone to generate a range of flow rate inputs. The total loading estimates for the nine study areas were generated by summing the loading estimates for each individual flow zone. The results of these calculations, as well as additional detail regarding application of data, assumptions, and calculations, are presented in Appendix D.4.1.

For all 76 chemicals, loading estimates are considered conservatively high approximations of upland groundwater plume loading to surface water. This is because of the assumptions made for assignment of flow rates, the study design for selection of sampling locations and seepage meter locations (discussed in greater detail in Appendix D.4.1), and the fact that chemicals detected in TZW may be partly or wholly attributable to in-river sources, including desorption of chemicals in river sediment or entrainment of sediment particles into TZW samples (e.g., PAHs and pesticides) or to geochemical processes occurring in sediments (e.g., arsenic, barium, and manganese), rather than to migration from upland groundwater. Consequently, these loading estimates can be considered upper-bound estimates.

7.1.3.3 Path Forward—Groundwater Plume Loading

These loading calculations are conservatively high estimates of loading from the nine Round 2 TZW study sites. These nine sites were identified as "high-priority Category A sites" based on a confirmed or reasonable likelihood for discharge of upland

groundwater COIs to Portland Harbor. Based on the approach to site selection34, it is expected that these nine sites represent the majority of discharge of COIs originating in upland groundwater and migrating to the in-water portion of the Site.

Data analysis and use relevant to fate and transport of chemicals in porewater is discussed in Section 7.3 of this report, while Section 11.1 provides discussion and analysis of the loading estimate results in the context of the CSM. Additional information collection currently planned to address RI/FS data gaps is discussed in Section 12 and may be further refined in the scoping process for Round 3B investigations in early 2007.

7.1.4 Atmospheric Deposition

Air pollution (e.g., vehicle emissions, industrial smokestacks, fugitive dust) can be a source of chemicals to the Study Area through the processes of wet and dry deposition. Wet deposition refers to transfer of air pollutants from atmospheric suspension to fog, cloud or rain droplets, or frozen precipitation elements (e.g., snow, freezing rain) followed by precipitation of the droplet. Dry deposition refers to the deposition of a pollutant from atmospheric suspension to a fixed surface in the absence of precipitation. From the available literature it is apparent that the relative importance of the atmospheric deposition loading term, relative to other loading terms, varies by site and by chemical. For instance, atmospheric deposition was found to be the dominant source term to the total loading of PCBs to the North and Baltic Seas (Struyf and van Grieken 1993; Wania et al. 2001) and HCH to the North Sea (Struyf and van Grieken 1993). By contrast, one study of numerous urban US streams (not including the Willamette River) evaluated the relative importance of different non-point sources to total loading of VOCs, finding that atmospheric deposition was of secondary importance compared to the loading from urban land sources (Lopes and Bender 1998).

The following subsections present the approach and data sources applied to generate a qualitative to semi-quantitative preliminary estimate of the annual loading rate of selected analytes to the Study Area (i.e., in this case, this refers to the river surface between RM 2 and RM 11) via atmospheric deposition. No iAOPC-specific loading estimates will be generated for the air deposition loading term. Further, air deposition loading estimates presented here focus on wet and dry deposition directly to the water surface within the Study Area. Air deposition to land, which could subsequently be transported to the Study Area via stormwater runoff, is not included in this analysis and is considered as part of the stormwater analysis (Section 7.1.2). Estimated loading results are presented in Appendix D, Section 5, and the results are discussed in the context of the CSM in Section 11.1. These harbor-wide loading estimates in the form of large ranges of possible loads have been generated for use in general comparison to other potential loading terms to the Study Area. The uncertainty in the air deposition

[34] The approach to site selection is summarized in Section 2.3.3and presented in detail in the GWPA SAP (Integral 2005a).

loading estimates will be considered in these comparisons and in resulting determinations of data gaps, as discussed in Section 12.

7.1.4.1 Approach and Data Sources—Atmospheric Deposition

Atmospheric deposition to the Study Area was evaluated based on simplified calculations, applying values obtained from a literature review. Semi-quantitative estimates of dry deposition were generated. Due to the extreme complexity of estimating the atmospheric process of wet deposition (Seinfeld and Pandis 1998), wet deposition was evaluated only qualitatively for selected analytes. It is possible that overall atmospheric loading to the Study Area may have been more significant historically, prior to widespread adoption of controls on chemical production and usage, including pesticides and PCBs. Additional discussion of observed concentrations in sediment as a function of depth is presented in Section 11.1 on an analyte-by-analyte basis to provide additional insight into the relative contribution of historical loading to sediments in the Study Area. Note that this loading analysis approach estimates only current atmospheric deposition load to the Study Area.

For a given analyte, dry deposition loading (kg/yr) to the Study Area can be calculated as the product of the air concentration (mass/volume), the deposition velocity (length/time), and the surface area of the Study Area (length^2). The rate of chemical deposition to a surface (deposition velocity) is a function of atmospheric turbulence, properties of the chemical species, and the relative reactivity of the species with the receiving surface (Seinfeld and Pandis 1998). Values for dry deposition velocity and air concentration were compiled from publicly available data sources, including DEQ and EPA.

The air deposition loading analysis was limited to iCOC chemicals for which geographically relevant values of air concentration and dry deposition are available. Additional analytes were added to the loading assessment list to serve as surrogates for iCOCs that could not be estimated. The complete list of chemicals considered in the dry deposition calculations is presented in Table 7.1-6.

To the extent possible, local information was gathered for atmospheric concentrations; however, local data were not available for some chemicals. Additionally, available concentration data were sometimes limited to short-term sampling events, which may not be representative of current or annual loading conditions. Additionally, deposition velocities were necessarily based on non-local information. The complete data set and supporting literature reference information are provided in Appendix D, Section 5, including a more detailed discussion of data adequacy and uncertainties.

In an effort to capture the uncertainty and variability of both the deposition velocity and concentration values used in the dry deposition calculations, a range of estimates was applied for each parameter. The results are expressed in terms of a central tendency (mean, median, or calculated value), an upper-bound estimate, and a lower-bound estimate.

Wet deposition loading rates are assessed qualitatively in Appendix D, Section 5, for a subset of the chemicals listed above, based on published observed relationships between wet and dry deposition rates.

7.1.4.2 Path Forward—Atmospheric Deposition

At this time, no additional analysis of the atmospheric deposition term is planned as part of the RI/FS. If refinement of atmospheric loading estimates is deemed necessary in the future, next step options would be analyte-specific and could include the following:

- Options for improvement of atmospheric concentration estimates:
  - Local monitoring could be performed to generate atmospheric concentration estimates that are more spatially and temporally representative. Monitoring protocols differ by target analyte, but could include continuous monitors, grab sampling, or filter-based particulate sampling followed by laboratory analysis.
  - For those analytes whose concentration comes from EPA's 1999 National Air Toxics Assessment (NATA) modeling program (EPA 1999a), spatial proximity of the concentration estimates could be improved by focusing on census tracts surrounding the study area as opposed to considering the whole of Multnomah County, which is the current approach.
- Options for improvement of dry deposition velocity estimates:
  - A more thorough literature search could be conducted to seek improved values for species-specific and water-surface/receiving-body-specific dry deposition velocities. Additionally, more detailed modeling of the partitioning of species between the gaseous and particulate phases, and more careful consideration of the particle size appropriate to the species and Study Area location, could be performed.
- Options for generating semi-quantitative wet deposition estimates:
  - Wet deposition could be assessed more quantitatively with a thorough literature review, consideration of species partitioning between the gaseous and particulate phases, modeling of wet deposition for both gaseous and particulate-phase species, and a detailed evaluation of precipitation patterns in Portland.

Section 11.1 provides discussion and analysis of the loading estimate results in the context of the CSM, and additional information collection currently planned to address RI/FS data gaps is discussed in Section 12.

7.1.5 Permitted Wastewater Discharge

Wastewater is generated at several upland facilities in the Study Area as part of manufacturing processes. Wastewater is both discharged to City sanitary systems and routed to treatment facilities and to the river via onsite and City conveyance systems and outfalls. Examples of wastewater discharge sources in the Study Area include oil/water separators, petroleum hydrocarbon cleanup systems (tank cleanup and groundwater treatment), vehicle and equipment wash water, boiler blowdown, filter backwash, cooling water/heat pump wastewater, log ponds, non-contact geothermal exchange water, and rinse water of various types.

Wastewater discharges are required to be permitted under NPDES permits as described in Section 5. Nine sites currently have individual NPDES wastewater permits: Oregon Steel Mills, Ash Grove Cement, Kinder Morgan Bulk Terminal, Columbia Sand and Gravel, Siltronic, Koppers/Gasco, Cascade General, Rhone Poulenc, and Univar USA. The monitoring requirements and permit limits for each of these sites are summarized in Table 5.1-4.

7.1.5.1 Data Sources and Approach—Permitted Wastewater Discharge Loading

In accordance with the LWG Response to EPA CSM Questions dated April 14, 2006 (Integral et al. 2006) regarding planned evaluation of the permitted wastewater discharge loading term, "quantitative data will be assembled to the extent possible and evaluated with Round 2 surface water data for the RI report." Quantitative data that would support an estimate of chemical loads from this source term have not yet been compiled. As such, estimates of current loading rates from permitted wastewater discharge will not be developed for the Round 2 Report, but will be included in the RI report. A discussion of the approach to be used is presented under the Path Forward subsection below. It should be noted that, because these are regulated discharges, it is assumed that significant exceedances of permit standards are likely rare, and it is expected that loading estimates for industrial discharge will be minor compared to other loading terms. Further, Section 11 will describe the monitored parameters for permitted wastewater discharges associated with AOPCs.

As noted above, the combined chemical mass load (considering number, volume, and expected concentrations) from current industrial discharges is expected to be minor relative to other sources. Historical loading to the Study Area from industrial discharges, however, may have been more significant, prior to adoption and regulation of discharge permits and controls. Additional discussion of observed concentrations in sediment as a function of depth is presented in Section 11.1 on an analyte-by-analyte basis to provide additional insight into the relative contribution of historical loading to sediments in the Study Area. Additional information collection currently planned to address RI/FS data gaps is discussed in Section 12.

7.1.5.2 Path Forward—Permitted Wastewater Discharge Loading

Estimation of current permitted wastewater discharge loading, to be prepared for the RI report, will involve the following general steps:

- Assembly of flow information for permitted discharges
- Review of monitoring reports for permitted discharges
- Calculation of loading based on permit limits and monitoring results
- Review of records for expired permits and information on historical discharge complaints and regulatory actions to provide a more complete assessment of historical discharges.

7.1.6 Upland Soil and Riverbank Erosion

Erosion of bank soils is a potential source of chemicals to the in-water portion of the Site. For the purposes of this analysis, bank soils are defined as soils that are between the Mean High Water Mark (MHWM)[35] and the Ordinary High Water Mark (OHWM)[36]. Erosion of soils containing chemicals from above the OHWM, including soils much farther upland, is also possible; however, such upland erosion is primarily caused by stormwater runoff, which is discussed in the Section 7.1.2.

The two primary mechanisms for erosion of bank soils into the river are river water moving over bank soils and direct overland stormwater runoff across these soils. Wind erosion, shoreline construction and other human activities, activities of animals, etc. are also possible erosion mechanisms; however, these can reasonably be considered to be minor in comparison to river and stormwater flows. (Note: construction is considered minor because such projects are regulated and permitted to minimize erosion of soils into surface waters.) Sporadic mass wasting or slumping events can also occur as bank slopes become over-steepened or otherwise unstable.

River water can cause erosion at times when river levels rise and come into contact with the bank soils. The MHWM (elevation +13.3 ft NAVD88) is based on the monthly average water level for the 16-year period from 1987 to 2002. Thus, during some periods, particularly during winter months, soils above this elevation can become inundated by river water. Erosive mechanisms during these periods include the direct and shear stress forces of currents with sufficient nearshore velocity to suspend soil particles. Nearshore velocities can be affected by a number of factors, including:

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[35] The MHWM is the elevation defining the shoreline boundary of the Portland Harbor Superfund Site, which is +13.3 ft (NAVD88). This elevation is based on a DEQ memorandum dated July 9, 2003 to EPA regarding the upland/in-water boundary for the Superfund Site (DEQ 2003a).

[36] The OHWM refers to the upper edge of the riverbank and is defined as approximately +20 ft (NAVD88) (DEQ 2003a). The OHWM defines the elevation beyond which inundation by the river is limited to extreme flow events.

- Bends in the river, where outer bends tend to be subject to greater velocities
- Other shoreline features that may create eddies
- The presence of nearshore structures, which tend to slow nearshore currents unless localized focusing effects or strong eddies are generated
- The general "roughness" and physical complexity of the bank surface.

Wind-generated wave action or vessel wakes can also cause bank erosion as these waves break on the shoreline and dislodge soils. Wave action can be diminished or augmented in particular areas due to concentration of reflected waves and/or the length of wind fetch to which the shoreline is exposed.

Erosion of relatively exposed bank soils can occur in localized areas where stormwater sheet flow, particularly from nearshore impervious surfaces, flows to small low spots and becomes concentrated into rivulets or small streams. These flows can also cause saturation of bank soils, which may make them more unstable and susceptible to mass wasting.

For bank soils to represent a potential loading term to a river, two conditions must be met: 1) the soils must be in a form that is potentially available for erosion into the river; and 2) chemicals must be present at elevated levels within bank soils. Each of these issues is discussed in the following subsections.

7.1.6.1 Data Sources—Bank Soils Available for Erosion

Regardless of the exact force exerted on the bank, the degree of erosion generated is highly dependent on the physical conditions of the bank itself, the type of soils present, and how directly exposed the soils are to these forces. Primary factors affecting the susceptibility of banks to erosion include the following:

- Presence of protective and stabilizing vegetation (natural or actively planted)
- Presence of stabilizing structures such as bulkheads
- Presence of riprap, concrete, or other materials intended to protect the bank
- Steepness and overall profile of the bank
- Type of soils (e.g., consolidated, loose, gravel, sand, silt, cohesive clay, fill, or natural materials)
- Degree of soil saturation
- Presence of debris or artificial bank structures placed for purposes other than bank protection (e.g., boat ramps)
- Presence of docks, piers, dolphins, pilings, breakwaters, groins, and shoreline structures
- Presence of bench or beach areas below the bank, which can act to dissipate wave forces higher on the bank.

Where protective vegetation, structures, or materials are present, the type and condition of the soils underneath are often less important to erosion rates. A City of Portland study (Green Works et al. 2001) reviewed and inventoried the shoreline features within the harbor and broke them into seven general classifications based on these important features, including:

- Riprap—26.8 percent
- Unclassified fill—24.2 percent.
- Natural bank—17.5 percent
- Structures—17.1 percent
- River beach—8.1 percent
- Sea wall—4.4 percent
- Bio-technically engineered banks (banks that have been planted with vegetation intended to stabilize them)—1.9 percent.

Map 5.1-2, adapted from the Green Works study, maps these bank classifications. Of these classifications, only natural bank, river beach, and unclassified fill, which together represent approximately 50 percent of the shoreline, are likely to be at all susceptible to erosion. Within this group, natural bank generally has some type of natural vegetation on at least a portion of the bank profile, which can reduce erosion potential. The less steep profile of river beach areas can also often act as a buffer, as noted above. Thus, unclassified fill (at 24 percent) is likely to be the most susceptible to erosion. This classification, however, represents a diverse range of physical conditions, and review of shoreline videotapes indicates that some of these areas have surfaces composed of various sized rocks, sporadic vegetation, artificial debris of various types, and natural debris such as logs and wood, all of which may protect some of these areas to some extent.

A more detailed visual survey and inventory would be needed to identify bank areas that are truly susceptible to erosion and sort out many of these site-specific factors. However, in lieu of such detailed information, a conservative estimate is that approximately 25 percent of the shoreline is potentially susceptible to erosion of bank soils. This value overestimates the amount of unclassified fill that is susceptible to erosion, but it allows for the fact that some portions of the other categories may include small areas that are relatively susceptible to erosion.

7.1.6.2 Data Sources—Bank Soil Chemistry

The LWG has reviewed several sources of information for potential bank soil chemistry results. These efforts included review of individual site summaries, summarization of beach and/or bank sampling data collected by the LWG through 2006, and inquiries to DEQ for specific relevant site information. The data found to date are summarized in Table D6-1. Individual data tables that were obtained for some of these sites are

included in Appendix D. The locations of these data points relative to the bank categories described above are shown in Map D6-1 (note: the figure includes some samples that were taken near but not necessarily within the zone from +13 to +20 ft). In addition, DEQ has noted that collection of bank soils will or may occur at banks in front of GS Roofing, Rhone-Poulenc (near Outfall 22B), and Schnitzer Steel. Also, additional data may be collected for some sites presented in Table D6-1.

The table and figure show that a considerable portion of the harbor bank soils that may be generally susceptible to erosion have no existing bank chemistry data. In these cases, it is impossible to quantify the concentrations and extent of chemicals that may be present and available for transport to the river via bank erosion. Among the sites with available bank chemistry data, chemicals were detected in bank soils that are potentially susceptible to erosion at the following 11 sites (Table D6-1):

- Alder Creek Lumber
- Arkema
- Crawford Street Corp.
- Front Ave.
- Gasco
- Gunderson
- Mar Com
- Oregon Steel Mills
- Premier Edible Oils
- T4 Slip 1 and Slip 3
- Willbridge Terminal.

7.1.6.3 Approach—Bank Soils Loading

Due to the paucity of existing bank condition and chemistry information at multiple shoreline sites, it is not possible at this time to make even semi-quantitative estimates of loading from this source to the river. Although it is estimated that approximately 25 percent of the banks within the Site are potentially susceptible to erosion, it is not possible to estimate typical erosion rates or a range of rates that might apply to these areas given the wide range of conditions present. Similarly, where chemicals were detected in bank soil, the chemical assemblages and concentrations appear to be relatively unique to each site, and these data could not reasonably be extrapolated to the remainder of the shoreline.

7.1.6.4 Path Forward—Bank Soils Loading

Bank loading estimates are not possible given the data limitations described above. However, it is unnecessary to develop such loading estimates for the purposes of the RI/FS. Because bank erosion is an area-specific condition dependent on both the

erodibility and chemical concentrations of any given bank area, the data to understand these localized sources will need to be evaluated as a part of the remedial design process for each sediment management area (SMA). Bank erosion and chemistry data will need to be collected by individual upland property owners under the direction of DEQ, so that the data are available in time for the remedial design process. For the purposes of the FS, it will be assumed that potential bank erosion sources will be controlled before remedial action proceeds.

In order to develop semi-quantitative estimates of bank erosion loading to specific areas or SMAs for the purposes of remedial design, the following information would need to be collected by DEQ and/or individual upland property owners near these SMAs as directed by DEQ:

- A visual survey of the riverbanks near the area in question that notes particular areas of erosion or potentially erosive conditions, including detailed descriptions and photographs of the conditions occurring at each of these areas
- Compilation of existing DEQ bank soil chemistry data to identify data gaps associated with any SMAs defined in the FS
- Identification of bank soil chemistry data gaps that coincide with areas of erosion determined in the field survey and chemical sampling and analysis at those locations.

Note that it is likely that overall bank erosion to the Study Area may have been more significant historically, prior to installation of erosion controls in many areas, including riprap and sea walls. The composition of bank soils historically is highly uncertain; therefore, the overall impact of historical bank erosion is uncertain. Additional discussion of observed concentrations in sediment as a function of depth is presented in Section 11.1 on an analyte-by-analyte basis to provide additional insight into the relative contribution of historical loading to sediments in the Study Area.

7.2 FATE AND TRANSPORT PROCESSES WITHIN THE STUDY AREA

This section provides an overview of physical, chemical, and biological processes that influence the fate and transport of chemicals within the in-water portion of the Site. This discussion of fate and transport processes is organized in three subsections, corresponding to the major environmental compartments of the Study Area: the biologically active sediment and porewater environment, surface water, and biota. For each compartment, physical, chemical, and biological fate and transport processes are considered. Calculations, additional approach details, and semi-quantitative to quantitative results are presented in Appendix D. Discussion, comparison, and analysis of the results are provided in Section 11.1 in the context of the CSM.

7.2.1 Sediment and Porewater Fate and Transport Processes

The following subsections discuss fate and transport processes relevant to iCOCs in the sediment and porewater[37] environment. General discussion of organic and inorganic chemical behavior in the sediment and porewater environment is presented, followed by discussion of physical transport processes for sediment and for porewater.

7.2.1.1 Chemical Distribution between Sediment and Porewater

In the sediment and porewater environment, the most important physiochemical processes affecting the migration, bioavailability, and half-life of a chemical are often those that control its distribution between the solid and aqueous phases. Major processes and environmental factors that control this distribution are discussed in general terms in the following subsections for organic and inorganic analytes.

7.2.1.1.1 Organic Chemicals

The equilibrium distribution of a chemical between water (dissolved aqueous phase) and solids (sorbed to sediment or associated organic matter) is often generally described by a solid/water distribution coefficient (K_d):

$$K_d = C_s/C_w,$$

where:

C_s = the concentration of the chemical associated with solids

C_w = the concentrations of the chemical in solution.[38]

For organic analytes, the K_d term describes the combined effect of all possible distribution terms, including hydrophobic sorption into organic matter on the solid surface, electrostatic attractions of oppositely charged ionic functional groups, and covalent bonding or complexation of ionic organic molecules with reactive surface groups. Primarily, the organic analytes of interest for the Study Area are nonionic in nature; for these nonionic chemicals, the hydrophobic driving force for sorption controls the K_d. Therefore, for nonionic organic chemicals, K_d describes partitioning to the organic matter on the solid surfaces and is a function of the tendency of the chemical to sorb to organic carbon (K_{oc}) and the fractional organic matter content of the solids (f_{oc}):

$$K_d = (K_{oc} * f_{oc})/ C_w$$

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[37] The general term "porewater" is used here instead of TZW to acknowledge that the discussion also includes interstitial water in the sediment, which does not contain upland groundwater.

[38] The rigorous definition of K_d includes the ratio of the thermodynamic activity coefficient of the chemical sorbed to the solids to the thermodynamic activity coefficient of the chemical in the aqueous phase. For equilibrium environmental conditions (generally low concentrations relative to the water and solids), activity coefficients approach 1, and the K_d is considered equal to the ratio of the chemical concentrations in sediment to the chemical concentrations in the aqueous phase. It should also be noted that K_ds are defined for a given pH, temperature, and salinity.

where

K_{oc} describes the partitioning behavior of the chemical between water and the organic matter[39]

f_{oc} = the fraction of organic carbon in the solids.

In addition to temperature, several factors can affect equilibrium partitioning behavior:

- **Salinity:** High-salinity environments (e.g., seawater) can cause increased adsorption (decreased solubility and higher observed K_d than predicted at typical salinity). This may be relevant in the highly saline sediment and porewater environment local to the Arkema site where pore-water salinities in excess of typical seawater have been observed. It is unlikely to be a significant factor elsewhere in the river.
- **Cosolvents:** The presence of miscible organic liquids in solution with hydrophobic chemicals can result in increased solubility (and therefore decreased K_d) of the hydrophobic chemical. This effect, however, requires significant amounts of cosolvent chemicals in solution (more than 10 percent by volume [Yalkowsky et al. 1976]).
- **Colloids:** Colloids are organic and/or inorganic particles in the system defined by their behavior (tendency to remain dispersed in water, not settle rapidly, and not filter easily) and size (usually 1 nm to 1 μm in diameter [Lyklema 1991]). Colloids represent a portion of the surface area available for sorption of organic chemicals. Because colloids can be mobile in water within a sediment matrix, they can increase the "apparent" concentration of the hydrophobic chemical in the aqueous phase.
- **Natural organic matter structure:** The nature of the organic matter present in the sediment can also affect the extent of partitioning, making partitioning behavior variable across different environments.

7.2.1.1.2 Inorganic Chemicals

The fate and transport of inorganic species such as metals and metalloids in porewater is dependent on the distribution of the species between the aqueous and solid phases. A wide range of mechanisms control the distribution of metals between the aqueous and solid phases. Most commonly these mechanisms include precipitation/dissolution reactions and sorption/ion-exchange processes. Precipitation and dissolution are controlled by the concentration of species present both in solution and as mineral phases. Sorption and ion exchange are controlled by a variety of factors, including electrostatic attraction, covalent bonding, and weak intermolecular attractions such as van der Waals forces.

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[39] K_{oc} is organic-matter-specific; however, it is often generically calculated from empirical expressions based on the octanol-water partitioning coefficient (K_{ow}) for a given chemical, which describes partitioning of the chemical between water and highly non-polar liquid octanol.

The distribution of inorganic species between the aqueous and solid phases is controlled by a number of mechanisms that are a function of the physical, chemical, and biological characteristics of the solid-aqueous system. The characteristics most important for the aqueous solution phase include:

- pH
- Oxidation-reduction potential (Eh)
- Presence of competing ions
- Aqueous complexation reactions
- Ionic strength (closely related to the effects of competing ions).

The solid phase characteristics of importance include:

- Grain size
- Composition/mineralogy
- Surface characteristics such as charge, coatings, and area.

In addition, there is a range of factors that cannot easily be assigned to one phase, such as temperature and the fugacity of gases such as oxygen and carbon dioxide.

The aqueous-solid chemistry of the sediment and porewater environment can be strongly influenced by microbiological processes. Microbial oxidation of labile organic carbon, both natural and anthropogenic, frequently depletes dissolved oxygen in porewater, resulting in chemically reduced groundwater conditions and the production of alkalinity. Further, under anaerobic conditions, microbial processes can induce numerous environmentally relevant changes to the chemical environment, such as dissolution of iron and manganese oxide minerals and production of sulfides.

A basic understanding of the fate and transport of inorganic species requires an understanding of the saturation state of aqueous chemical species in the system with respect to minerals that are composed of those species and that may precipitate or dissolve, depending on the saturation state. For a given mineral phase, the solubility product, K_{sp}, defines the equilibrium condition between dissolved ions and the corresponding mineral. Generically, for the dissolution of a mineral A_bC_d:

$$K_{sp} = [a]^b * [c]^d$$

where [a] and [c] are the concentrations of ions a and c in solution, and b and d are the count of each ion that is present in mineral phase (A_bC_d). An excess of the ions in solution favors the precipitation of the mineral from solution, while a deficit of the ions in solution favors the dissolution of the mineral to solution (provided the mineral phase is present). The solubility product defines the aqueous-solid phase condition under

thermodynamic equilibrium. However, many reactions are kinetically limited and thus it is not uncommon for non-equilibrium conditions to exist in natural aqueous systems.

A geochemical evaluation of the Round 2 TZW chemistry data was completed for three metal species—arsenic, barium, and manganese—that were consistently detected in TZW at concentrations above relevant risk-based screening values. An in-depth discussion of this geochemical analysis is presented in Appendix D, Section 7. Briefly, the analysis included a statistical evaluation of the spatial distribution of these metals in TZW across the nine TZW study sites and a comparison of TZW concentrations with available upland groundwater concentrations. Geochemical controls on arsenic, barium, and manganese in TZW were evaluated by exploring correlations between metal concentrations and measured variables (e.g., pH, oxidation-reduction potential [ORP], alkalinity, and TOC) that could be expected to exert an influence upon their geochemistry behavior. Geochemical modeling was performed to identify stable mineral and aqueous phases as a function of pH and Eh, mineral saturation indices, and mineral phases controlling the aqueous solubility of arsenic, barium, and manganese. (Iron was also included in the analysis because hydrous iron oxides can be an important substrate for adsorption of many trace metals, including arsenic.)

The results of the geochemical analysis support the following overall findings, which are described in more detail in Appendix D7:

- No statistically significant differences were identified in TZW concentrations of arsenic, barium, and manganese across the nine study sites, with the exception of the Arkema Chlorate Plant.
- Based on an initial analysis of available upland groundwater data from the nine study sites, it cannot be concluded that differences in concentrations of arsenic, barium, and manganese in TZW and upland groundwater are statistically significant at the $p \leq 0.05$ level, with the exception of arsenic at Arkema, ExxonMobil, and Siltronic; barium at Willbridge; and manganese at Siltronic. (Comparisons between TZW and upland groundwater concentrations are viewed as tentative due to limitations on upland groundwater data available for this analysis.)
- Concentrations of metals in TZW appear to be positively correlated with alkalinity. Metals concentrations are also generally higher in TZW samples with negative ORP (reducing conditions) than positive ORP (oxidizing conditions). No trends or patterns are apparent in metals concentrations as a function of pH. These observations are consistent with increased levels of microbial activity—resulting in reducing conditions and the production of alkalinity—creating geochemical conditions that increase the aqueous solubility of the metals.
- Reducing conditions in TZW—which tend to increase the solubility of arsenic, barium, iron, and manganese—are frequently associated with higher sediment TOC content and with higher concentrations of TPH and TPAH in TZW and sediment. These observations are consistent with the expectation that organic carbon sources (either naturally occurring as TOC or introduced as TPH and/or

TPAH) promote increased levels of microbial activity, leading to chemically reducing conditions.

- An apparent correlation exists between barium concentrations and TPH/TPAH in TZW at most of the study sites. Concentrations of arsenic, iron, and manganese in TZW, on the other hand, are generally not well correlated to TPH and TPAH concentrations. A limited exception is offshore of Siltronic and Gasco, where somewhat higher manganese concentrations may be associated with higher TPH and TPAH concentrations in TZW.
- Arsenic in TZW is not maintained in equilibrium with any arsenic mineral phases that would control its aqueous solubility. However, the geochemical environment of both TZW and uplands groundwater was found to be generally consistent with iron- and manganese-reducing conditions—suggesting that elevated arsenic concentrations in these waters may be the result of dissolution of iron and manganese hydrous oxides and concomitant release of adsorbed arsenic.
- Barium in TZW from all nine sites is maintained at approximate equilibrium with the carbonate mineral witherite and is undersaturated with respect to the sulfate mineral barite. Barite, the most abundant barium mineral in the earth's crust, is moderately to strongly undersaturated in the chemically reducing conditions typical of the transition zone. Dissolution of barite from the sediment matrix, if present, is a potential source of barium in TZW. These geochemical controls are consistent with the generally alkaline and reduced conditions of the TZW and suggest that microbial interactions may be of importance.
- Manganese in TZW from all nine sites is maintained at approximate equilibrium with the manganese carbonate mineral rhodochrosite and is undersaturated with respect to manganese oxide minerals. If manganese oxides are naturally present in sediments, their dissolution under the geochemical conditions measured in TZW may be a source of manganese in TZW. These geochemical controls are consistent with the moderate alkalinity and reduced conditions of the TZW and suggest that microbial interactions may be of importance.
- Re-precipitation of hydrous manganese and iron oxides minerals above the redox potential discontinuity depth in near-surface sediments may be a removal mechanism for dissolved manganese and arsenic as TZW migrates into the oxidized zone of near-surface sediments.

Overall, geochemical conditions in the TZW environment, and the resulting solubility controls on concentrations of arsenic, barium, and manganese, appear to be influenced by the presence of organic carbon sources (either natural or introduced) and associated microbial activity. Because natural organic carbon is abundant in shallow sediments in the Study Area (see Map 4.4-4 and Table 6.1-1), it is considered likely that natural conditions in the majority of the Study Area can account for the geochemical conditions that control the observed concentrations of these metals in TZW.

See Appendix D, Section 7 for additional presentation and discussion of the analysis.

7.2.1.1.3 Degradation/Transformation Processes

A variety of abiotic degradation/transformation reactions, including hydrolysis, dehalogenation, oxidation, and reduction, can occur in aqueous systems. Hydrolysis is a well-known chemical reaction by which alkyl halides, esters, or ester analogs are split and hydrogen and hydroxide (the components of water) are added to produce alcohols or organic acids (or both in the case of esters). Dehalogenation refers to reactions in which chlorine atoms are removed from alkyl halides, including PCBs, pesticides such as DDT, and VOCs such as TCE. Oxidation and reduction are complementary reactions that involve the loss of one or more electrons (oxidation) by one chemical species and the gain of one or more electrons (reduction) by another. Degradation of organic chemicals in natural systems frequently occurs by microbially-mediated oxidation reactions. Metals in environmental systems are subject to both oxidation and reduction reactions, depending on the particular metal, its speciation in the environment, and other geochemical conditions.

Biodegradation is likely to provide a significant sink for some types of organic compounds in the Study Area. Biodegradation involves the metabolic oxidation or reduction of organic compounds and is carried out predominantly by bacteria in aqueous environments, but yeasts and fungi may also contribute to biodegradation. In general, oxidation of organic compounds occurs under aerobic conditions and reduction under anaerobic conditions, although both processes can occur under both conditions. Microbes may either gain chemical energy directly as a result of biodegradation of an organic compound, or during the process of co-metabolism, the concurrent degradation of another substrate with the organic compound.

The biodegradation rate depends on the chemical structure and concentration of the organic compound, the concentration of bacteria responsible for the biodegradation, and physical and chemical conditions at the site such as temperature and oxygen level. The extent to which the organic compound is bound to particles may also affect the biodegradation rate because the bound organic compounds are biologically less available for microbial uptake. Biodegradation models commonly used include the Michaelis-Menten equation and the Monod equation, which account for chemical concentrations, microbial density, changes in uptake rates with changes with concentration, and changes in microbial density over time. By assuming constant biodegradation rates and bacterial density, the power rate law can be used to describe biodegradation empirically:

$$dC/dt = kC^n$$

where:

C = chemical concentration
t = time
k = rate constant for biodegradation, determined experimentally in the laboratory or measured in the field
n = 0 for zero-order kinetics and 1 for first-order kinetics.

A wide variety of microbial species that use a large number of different biochemical pathways to metabolize anthropogenic chemicals have been identified. Biodegradation can proceed to full mineralization of the compound with end products of carbon dioxide and water, or an intermediate compound may be formed that is not easily biodegraded further. DDT, for example, is biodegraded to DDE relatively easily, but DDE is more recalcitrant. The susceptibility of organic compounds to biodegradation depends on several factors such as the presence and type of functional groups (oxygen- and nitrogen-containing groups increase biodegradation rates), the size and chemical structure of the organic compound (small molecules biodegrade more readily than large molecules), and solubility (more soluble organic compounds biodegrade more readily). A literature review will be completed to find appropriate biodegradation rate constants for use in the Fate and Transport Model. These will be presented in the modeling report.

7.2.1.1.4 Path Forward

No quantification of these processes, beyond the geochemical analysis presented in Appendix D, Section 7, will be presented in this report. The fate and transport processes for iCOCs will be evaluated further as part of the Hybrid Fate and Transport Model (described in Section 7.3), applying the concepts presented here. The results of the modeling will be applied to the RI.

7.2.1.2 Sediment Physical Transport Processes

Many of the Portland Harbor iCOCs are hydrophobic chemicals associated with sediment particles; therefore, the physical transport of sediments greatly influences chemical distribution and fate within the Study Area. Generally, sediment movement through the Study Area can be described as moving in the water column or as bedload. Suspended particulate transport in the water column refers to transport of solids suspended within the surface water (additional discussion presented in Sections 7.1.1.2.1 and 7.2.2.1). Bedload transport of sediment refers to sediment transported along the riverbed (additional discussion presented in Section 7.1.1.2.1). In addition, sediment particles can be episodically deposited and resuspended, mixed in varying degrees in the surface sediment mixed layers, or buried long-term in the sediment column.

Within the broad conceptual framework of sediment transport regimes described in Section 4.5, the transport processes relevant to chemicals associated with sediment within the Study Area are:

- **Sediment deposition:** The fate of suspended particles in aquatic settings is a complex interaction of hydrodynamics and particle properties. Settling rates vary as a function of particulate size, density, shape, and the degree of flocculation (for fine-grained, cohesive sediments). Fine-grained sediments also have larger surface-area-to-mass ratios and therefore adsorb and transport greater concentrations of chemicals through the system. Flocculation also affects sediment deposition. Flocculation is the dynamic process of particles

attaching to each other (aggregating) in suspension to form larger particles, or flocs. The rates of aggregation and disaggregation change over time as a function of individual particle size, internal fluid shear, and suspended particle concentration (Lick et al. 2006).

- **Sediment erosion/resuspension:** Sediment erosion rates are a function of particle properties, such as grain/floc size, bulk density, mineralogy, and organic content. Sediment erosion rates are also a function of bed properties, including bedded grain-size distributions, time since deposition/consolidation, gas content of the sediments, and the degree of the surface sediment reworking or mixing.
- **Sediment mixed-layer turbation:** Biogenic mixing by benthic infauna or bottom-foraging fish can preclude or slow consolidation of surface sediments, as can natural (e.g., wind waves) and anthropogenic (e.g., propwash) forces. These factors can greatly complicate the spatial and temporal degree of bed erodibility.
- **Long-term sediment burial beneath the mixed layer:** Particles and associated chemicals that are advectively transported or buried below the mixed layer may be "permanently" removed from the active transport system.
- **Sediment ingestion/uptake by biota:** Filter and deposit feeder organisms may actively or passively ingest particles in suspension or on the sediment bed. High densities of filter feeders can biologically enhance transfer of suspended particles to the sediment bed. Also, chemicals associated with ingested particles can enter the food web.

7.2.1.2.1 Data Sources

The importance of sediment transport has been recognized since the initiation of the Portland Harbor RI/FS. To develop the conceptual model, and to support development of a numerical hydrodynamic/sediment transport model (WEST Consultants 2004, 2005a,b, 2006), the physical sediment transport system has been studied extensively by the LWG since late 2001. The types of data collected and their project use are listed below:

- **Sediment Trends Analysis (STA)™ Survey:** An STA survey was conducted throughout the LWR (RM 0 to RM 26) in September 2000. This survey provided an extensive surface sediment grain-size data set as well as inferring general sediment transport patterns based on the STA statistical data evaluation approach. Along with the SPI data (see below), this information was used in the development of the initial physical CSM.
- **Sediment-profile photographic survey (RM 0 to RM 16):** This survey, conducted in November/December 2001, provided observational data on surface sediment features, such as grain-size, sediment layering, apparent mixed layer depths, and organism-sediment interactions, which informed the development of the initial physical CSM (SEA 2002a,b).
- **Time-series of precision bathymetric surveys (RM 0 to 16):** Four surveys were conducted in January 2002 and every 8-9 months thereafter through

February 2005 (DEA 2002a, 2003a, 2003b; Integral and DEA 2004). Riverbed elevation data provide an accurate site base map and time-series data provide empirical evidence of erosion/deposition areas over time. These data also provide boundary conditions and calibration/validation data for comparison with the numerical model riverbed elevation changes simulations.

- **Nearshore sediment stakes:** From July 2002 to June 2004, shoreline/beach sediment erosion/accretion rates were monitored at eight locations from RM 2 to 9 to obtain direct measurements of elevation changes in areas above the bathymetric survey coverage area (Anchor 2004). The results are discussed in Integral (2004b).
- **Current measurements:** Three sets of ADCP measurements were conducted in the LWR in April 2002, May 2003, and January 2004. The results are summarized in Integral (2004b). These measurements provided snapshots of flow data at multiple transects in the harbor over time and tidal cycles. These data were used empirically to describe flow interaction patterns between the LWR, Columbia River, and Multnomah Channel during different seasons. These data also provide calibration/validation data for comparison with the hydrodynamic output of the numerical model.
- **Surface and subsurface sediment data:** The extensive sediment data set, both LWG and non-LWG-generated for Portland Harbor, especially the spatial (both horizontal and vertical) distribution of physical properties data (e.g., grain-size, bulk density, TOC), provides important information on sediment transport patterns and broad-scale hydrodynamic regimes in the LWR.

The development of the hydrodynamic/sediment transport model led to the identification of several site-specific data needs determined to be critical to model simulations of sediment transport, i.e., erosion/deposition patterns (WEST Consultants 2005b). These included site-specific TSS, settling velocities, and critical erosion velocities and rates. Collection of these data in April 2006 is detailed in Integral (2006h) and summarized below:

- **TSS:** TSS data were collected as part of the LWG surface water sampling program. The modelers identified an additional need for TSS data over a range of flows at the upstream model boundary to verify the sediment inflow rating curve and within the Site to support model calibration/validation.
- **Settling velocities:** Due to complex interactions that control fine-grained sediment depositional rates, *in situ* settling rates were targeted as a key model data need. *In situ* suspended particle size and distribution at multiple locations in the area including the LWR were measured directly using a transmissometer, and these data were used to calculate site-specific settling rates for the model.
- **Erosion rates:** As with settling rates, site-specific erosion rates were identified by the modelers as an important data need. Critical erosion velocities and erosion rates for surface sediments (0-30 cm) were measured directly at 17

locations throughout the Study Area using the Sedflume system provided by SEA Engineering, Inc. of Santa Cruz, CA. These data were incorporated into the latest version of the physical transport model and can also be used in empirical calculations when combined with near-bottom current measurements or modeled flow regimes.

In addition to LWG-collected data, information from public-domain sources such as the USGS and National Weather Service (NWS) websites, including regional river flow, tides, sediment inflows/TSS, and wind data, has been compiled.

7.2.1.2.2 Approach

The numerical hydrodynamic/sediment transport model is still being refined using the data collected in 2006. Therefore, no attempt to quantify in-river physical sediment transport is provided in this Round 2 report. Section 7.3 details the overall fate and transport modeling objectives and the approaches to addressing critical sediment transport questions.

7.2.1.2.3 Path Forward

The path forward for assessment of physical transport of sediment in the Study Area includes collection of additional empirical data in Round 3. These include:

- **Bathymetry survey:** A bathymetric survey of the Multnomah Channel is planned for Round 3A to provided accurate riverbed elevations and support identification of potential depositional areas in the channel.
- **Additional surface water, sediment trap, and bedded sediment data:** Dissolved and particulate surface water loads will be further assessed following collection of the Round 3 surface water, sediment trap, and sediment core (radioisotope and chemical profile) data as detailed in Section 7.1.1.2.2.

The data identified above and in Section 7.1.1.2.2 will be incorporated, as appropriate, into the "hybrid" physical and fate and transport modeling framework described in Section 7.3.

Following development and application of the site-wide fate and transport modeling, alternative combinations and applications of empirical data and additional localized modeling efforts (e.g., propwash resuspension models) may be used to address location-specific RI/FS questions, as needed. The need to invoke these supplemental approaches will be assessed following evaluation of the site-wide Fate and Transport Model output in early 2007.

7.2.1.3 Porewater Physical Transport Processes

Chemicals in porewater are subject to diffusive and advective physical transport processes. These mechanisms are discussed in the following subsections.

7.2.1.3.1 Diffusive Transport

Diffusion is the movement of particles or dissolved chemical species from higher potential energy to lower potential energy (as represented by a difference in concentration in the case of diffusion from the porewater to the overlying water column). This is a spontaneous physical process that requires no additional energy inputs or expenditure. This mechanism is distinguished from advective transport of chemicals in porewater (described in the following section) in that it requires no driving force other than a concentration gradient (i.e., physical flux of porewater does not have to be occurring through the sediment).

Diffusive transport of iCOCs will be assessed for the Study Area as part of the Hybrid Fate and Transport Model (described in Section 7.3). Data sources to support the assessment will include the Round 2 GWPA TZW data set, the available sediment concentration data, and published equilibrium partitioning values.

7.2.1.3.2 Advective Transport

Advective transport of iCOCs in the sediment-porewater environment refers to the aggregate movement of chemicals by flow of porewater through the sediments. Flow through the sediments to the water column occurs in the form of groundwater discharge. This mechanism is a transport process for chemicals in the sediment-porewater environment to migrate to the water column. As such, it is distinguished from the upland groundwater plume loading term, described in Section 7.1.3, which represents advective loading of chemicals from upland groundwater sources to the porewater, sediments, and water column. In some parts of the Study Area, both mechanisms are likely occurring simultaneously (i.e., upland groundwater chemicals are being loaded to the river and the same groundwater discharge is moving chemicals originating in the sediments into the water column). The analysis of advective transport described here focuses on advective loading to the water column of iCOCs that are generally widespread throughout the sediment in the Study Area and not necessarily associated with areas of upland groundwater plume discharge.

The approach to estimating advective transfer of chemicals from the sediment-porewater environment to the water column is presented in detail in Appendix D.4.2, and summarized briefly here. The first step in estimation of the advective loading term was calculation of TZW concentrations from near-surface bulk sediment sampling results. Surface sediment concentrations and equilibrium partitioning coefficients were used to generate estimated TZW concentrations for each sediment sample in the Study Area, under an assumption of equilibrium conditions:

$$C_{TZW} = \frac{C_{bulk}}{1 + \left(K_{oc} f_{oc} - 1\right) \cdot \frac{\%solids}{100}}$$

where:

C_{TZW} = the chemical concentration in TZW

C_{bulk} = the chemical concentration in bulk sediment

K_{oc} = the organic-carbon equilibrium partitioning coefficient for the specific chemical

f_{oc} = the fraction of organic carbon in the sediments

percent solids = the weight percent of total solids in the sediment sample.

A total groundwater discharge rate of 6.6 cfs through sediments over the entire Study Area was conservatively estimated using hydrogeologic data from the CSMs and Darcy's Law (see Appendix D.4.2 for calculations). This discharge was assumed to occur uniformly over the entire sediment bed in the Study Area (sediment areas determined by Thiessen polygon[40] mapping of sediment sample results). Mass loading (kg/yr) by groundwater advection was estimated for each polygon and analyte based on the following equation:

$$MassLoad_{polygon}(kg/yr) = C_{TZW,polygon}(\mu g/L) \times 10^{-9} kg/\mu g \times A_{polygon}(ft^2) \times q_{gw}(ft/y) \times 28.32 L/ft^3$$

Advective mass loading for each analyte to the entire Study Area was estimated by summing the loads for all polygons.

Advective loading estimates were generated for the analytes presented in Table 7.1-7, for which Thiessen polygons were generated as part of the Round 2 evaluation.

A range of mass loading estimates to the water column was generated by varying two of the most uncertain variables in the calculation: K_{oc} and the total discharge area for the groundwater. First, recognizing the significant variation in published K_{oc} values for many of the analytes, both the minimum and maximum K_{oc} values in the compiled data were applied to the calculations. Second, two estimates of groundwater discharge area were applied to the calculations to help assess the sensitivity of the calculations to the discharge area assumption. Specifically, in one estimate, groundwater was assumed to discharge through all of the sediment area in the Study Area; in the second estimate, this area was limited to the area between the shoreline and the navigational channel.

A more detailed description of the approach, a presentation of the data sources (K_{oc}, hydrogeological parameters), additional discussion of assumptions, and the complete

[40]Thiessen polygons are formed as a network of polygons generated around seed points. In this case, the seed points are sampling locations. The polygon around each seed point delineates all areas that are closer to the seed point than any other seed point.

calculation results are presented in Appendix D.4.2. Discussion of the results in the context of the CSM is presented in Section 11.1.

At this time, no additional analysis of the groundwater advective loading term is planned as part of the RI/FS process beyond that presented here and in Appendix D.4.2. If, however, advective loading is identified as a significant source term for one or more iCOCs in the surface water column, refinement of the loading estimates presented here may be appropriate. If refinement of the groundwater advective loading estimate is deemed necessary, next-step options could include refined estimates of groundwater discharge rates (varying spatially throughout the Study Area), refinement of groundwater discharge area, and/or additional evaluation of equilibrium conditions in the sediment-porewater environment. At this time, no additional sampling or evaluation is planned for this loading term.

7.2.2 Surface Water Fate and Transport Processes

iCOCs in surface water are present in the dissolved phase and in association with suspended solids. Fate and transport processes for iCOCs in surface water, including movement of surface water and suspended solids, partitioning of iCOCs between water, air, and suspended solids, and degradation/transformation reactions, are described below in Sections 7.2.2.1 and 7.2.2.2. Section 7.2.2.3 provides a brief summary of planned additional data collection that will be used for the Fate and Transport Model (described in Section 7.2.3).

7.2.2.1 Physical Transport of iCOCs in Surface Water

Advection, the flow of river water in response to gravitational forces, is the primary mechanism for transport of surface water and its load of dissolved and particle-bound iCOCs. Water velocity and discharge are used to quantify river flow. Water velocity depends on the slope, shape, and physical characteristics of the riverbed and has the dimensional units length/time (e.g., ft/s). Discharge, the quantity of water passing a given river location over a given time interval, is calculated as the average velocity times the cross-sectional area of the river and has the dimensional units volume/time (e.g., cfs). The surface water mass flux of an iCOC is the product of the chemical concentration and the volumetric flow rate of the river, producing dimensional units of mass/time (e.g., kg/yr).

The dominant direction of water flow in the LWR is downstream, along the hydraulic gradient. However, seasonally the flow direction is reversed on flood tides during low-flow periods (see Section 4.3.3). Upstream flow has been identified as far upstream as RM 12.8 during low-flow conditions (Caldwell and Doyle 1995 and Figure 4.3-9c).

Lateral and vertical movement of iCOCs in surface water occurs primarily as a result of turbulent (eddy) dispersion (mechanical mixing), and to a lesser extent as a result of mixing/diffusion resulting from chemical, thermal, and density gradients. The velocity of river water is greatest near the center of the river and decreases toward the sides and bottom of the river. These differences in velocity of different water parcels result in

velocity shear, which gives rise to eddies. Eddies are also caused by channel irregularities, including structures in the water. These processes serve to mix the water and dilute iCOCs as they move away from the source. The suspended load of particle-sorbed iCOCs can also decrease due to particles settling out onto the riverbed sediment surface.

Some sources of iCOCs to surface water (such as industrial point discharges or groundwater plume discharge areas), can result in plume formation as the iCOCs mix with and diffuse into river water flowing downstream. Mixing patterns and plume sizes depend on differences in density between the effluent and the river water; the depth, velocity, and turbulence of the river; and any density stratification of the river itself. Density is a function of the temperature and salinity of the water.

Suspended particles provide an important vehicle for exchange of iCOCs between the sediment and the surface water. Suspended particles can be derived from mineral sources, including eroded and weathered rock, or from organic sources such as decaying plant material or plankton. The density of mineral particles is generally 2 to 3 g/cm^3, whereas the density of organic particles is close to the density of water (1 g/cm^3). The entrainment and settling of suspended particles are functions of river flow rate, particle size, particle shape, and particle density, as described in Section 7.2.1.1. The sediment carrying capacity of river water increases with increasing stream flow and turbulence, which vary spatially as well as temporally. Stream flow, turbulence, and TSS loads are greater in areas where the river is narrower (e.g., upstream of RM 10), and throughout the river during high-flow events. Within the water column, concentrations of suspended particles generally decrease semi-logarithmically from the riverbed to the water surface. A summary of TSS in the LWR is provided in Section 7.1.1.2.1.

Because of the opposing tendencies of the particles to settle out and the water to entrain them, sediment from the river bottom is entrained for a brief time as part of the bed load and redeposited on the river bottom. This process may disperse iCOCs in the sediment as they are transported downstream with the bed load (see discussion in Section 7.1.1.2.1); however, it is not a major contributor to iCOC transport in Portland Harbor relative to the suspended solids load.

7.2.2.2 Physiochemical and Biological Attenuation Processes in Surface Water

Once iCOCs enter the surface water, several major physical, chemical, and biological processes can result in transfer of iCOCs between abiotic media (water, suspended solids, sediment, and air) or degradation/transformation of iCOCs. These processes include sorption, precipitation, volatilization, abiotic degradation (chemical reaction or photolysis), and biodegradation. With the exception of volatilization and photolysis, these processes also pertain to porewater and sediment interactions and are discussed in Section 7.2.1.1.

Volatilization, the transfer of iCOCs dissolved in surface water to the atmosphere, is a process that transports iCOCs out of the water column. Volatilization is an important factor for small organic molecules, such as VOCs. The extent of volatilization of an iCOC depends on the temperature of the water and air and is a function of the concentration of the iCOC dissolved in water and its vapor pressure. The turbulence of the water and wind velocity at the air/water interface also affects the rate and extent of volatilization.

Henry's law constant is used to quantify the equilibrium partitioning of iCOCs between water and air:

$$H = [\text{conc. in air, mg/L}]/[\text{conc. in water, mg/L}]$$

The use of the same units for the concentration of the iCOC in air and water results in a unitless constant. Henry's law constant is temperature-specific.

Photolysis (degradation or transformation reactions that occur in response to solar irradiation) can occur either directly or indirectly. Direct photolysis involves the disruption of bonds in the molecule by electromagnetic radiation, particularly high-energy ultraviolet radiation. Organic compounds that are susceptible to direct photolysis include aromatic compounds such as PCBs, PAHs, dioxins, furans, and various pesticides, and other compounds with double bonds. Indirect photolysis involves the direct photolytic formation of a reactive species such as a hydroxyl radical or oxygen singlet, which subsequently reacts with an organic compound. Indirect photolysis can involve cleavage of aromatic rings, hydrolysis, hydroxylation, or dechlorination. The products of photolytic degradation of iCOCs are varied and may also be toxic. The degree to which photolysis occurs is affected by the depth and turbidity of the water, and by the intensity and angle of incidence of light.

7.2.2.3 Path Forward

The information included in Sections 7.2.2.1 and 7.2.2.2 is provided as general background related to the fate and transport models. Most surface water fate and transport processes are not quantified in this report, as preparation of the models is still in progress. Planned Round 3 data collection activities for surface water and sediment (two high-flow surface water sampling events, an additional low-flow event, a stormwater runoff event, a bathymetric profile of Multnomah Channel, sediment trap studies, and sediment bed chemical and radiometric profiles) will provide additional understanding of fate and transport processes occurring in the Study Area to support development of the Hybrid Model.

7.2.3 Biological Fate and Transport Processes

A number of processes govern how organisms living in the LWR are exposed to chemicals and how chemicals are transformed, excreted, or stored in tissue. Organisms living in the LWR take up chemicals through physically (e.g., diffusion), chemically, and biologically mediated processes, including transfer of waterborne chemicals across

gill structures or other tissues, consumption of prey, or ingestion of sediment. Organisms can modify the chemical burden in their tissues through growth, reproduction, excretion, metabolic transformation, or sequestration. Chemicals are transferred among organisms through trophic interactions, resulting in increases in concentrations of some chemicals at higher trophic levels. The bioaccumulation of chemicals may be predicted by food web models (FWMs), which describe these processes.

Several of the chemicals (e.g., PCBs, pesticides, dioxins and furans, PAHs) that have been measured in invertebrates and fish from the Study Area are hydrophobic and likely to be highly associated with organic materials (i.e., lipids in tissues, dissolved or particulate carbon in the surface water, porewater, and sediment). Exceptions include some VOCs detected in localized areas of groundwater discharges, some more soluble organic compounds (e.g., phenolic compounds, chlorinated benzenes) and some metals, which are more readily found in a dissolved or aqueous phase. However, some metals (e.g., lead and zinc) also tend to associate with organic and inorganic solids because the geochemical properties (e.g., ionic charge) governing their behavior tend to promote sorption.

Once released to the aquatic environment, chemicals enter the food web in a number of ways; the process is not sequential in that all trophic levels can interact with abiotic media. The behavior of chemicals within an aquatic food web is briefly described below.

Primary producers such as phytoplankton and plants take up chemicals mainly through diffusion from the water to which they are exposed, although the lipid content of phytoplankton also serves as a substrate for partitioning and binding for organic compounds that may be in a dissolved state or bound to colloidal organic carbon. Phytoplankton metabolic byproducts contribute to the colloidal material in the water column, which can also bind with chemicals dissolved in the water column. These colloidal materials can be directly utilized by bacteria, other phytoplankton, and zooplankton; this serves as an additional chemical uptake and transfer mechanism for recycling chemicals within the water column food chain. Zooplankton prey upon phytoplankton and other zooplankton, further recycling chemicals in the water column. More complex aquatic organisms (invertebrates and fishes) can take up dissolved or colloidally bound chemicals in surface water and porewater across gill membranes, skin, and other permeable tissues such as the mantle in clams (shells, exoskeletons, and scales are less permeable). Hydrophobic chemicals bind to sediment particles because of their organic carbon content. Sediment surfaces may be coated with bacteria and bacterial slimes, natural organic polymers, and other amorphous organic molecules that serve as binding sites. Finer grained sediment (silt and clay) has a greater surface area to volume ratio and may therefore have a higher percentage of organic carbon (and thus hydrophobic chemical concentrations).

Once sediment or prey is ingested by invertebrates and fishes, chemical absorption across gut membranes is affected by the size of the molecule (larger molecules being more difficult to transfer across membranes), concentration gradients between gut content and surrounding tissues, acidity of the gut, and other physical/chemical conditions in the gut. Organisms can react with absorbed chemicals through various metabolic processes that result in a change in the chemical structure and properties.

Absorbed metals that are not excreted may end up stored in calcium carbonate matrices (invertebrates) or bone (vertebrates); these storage sites tend to reduce the reactivity of the metal. Organic compounds that are not metabolized tend to be stored in organs or fatty tissues, including gametes. These stores can be released within the aquatic and terrestrial food webs when these organisms are ingested by others, upon their death and decomposition, or by transfer to their offspring.

For the Portland Harbor RI/FS, an FWM has been developed to describe a predictive relationship between the chemical concentrations present in abiotic media (i.e., sediment and water) and their concentrations in tissues. A summary of the development and application of the model is provided here, and details are provided in Appendix H. The specific goal for this report was to use the FWM to derive initial preliminary remedial goals (iPRGs) for PCBs, DDxs, and dioxin-like compounds. The iPRGs are spatially weighted average concentrations (SWACs) in sediment corresponding to chemical concentrations in fish tissue that are not predicted to exceed screening-level effect thresholds. The iPRGs are used to identify iAOPCs in this report (see Section 10.0). In future applications, the FWM may be used to set PRGs for the identification of AOPCs and the definition of SMAs and, in conjunction with fate and transport models, to evaluate different remedial options.

7.2.3.1 Conceptual Approach for Bioaccumulation Model

The Arnot and Gobas model (Arnot and Gobas 2004; EPA 2006c) was selected after an evaluation of several different FWMs (Windward 2004a,b; 2005b). The Arnot and Gobas (2004) FWM includes several advances over previous Gobas-type models; these were discussed in the 2005 FWM report (Windward 2005b). This model is most appropriate for hydrophobic organic compounds. Some general underlying assumptions include the following:

- The aquatic system is in steady state with respect to bioaccumulation of hydrophobic organic chemicals
- The flux of chemicals between water and organisms, between ingested media (sediment and other organisms) and organism tissue, and between different tissue types (e.g., lipid and non-lipid organic matter) is governed by fugacity relationships (Arnot and Gobas 2004).

7.2.3.2 RI/FS Food Web Model Applications

The development of iPRGs for sediment is the focus of FWM development and the applications presented in this document. At a June 6, 2006, meeting between EPA, its

partners, and the LWG, it was agreed that the FWM (specifically, the Arnot and Gobas [2004] model) would be applied for iPRG development for the following chemical groups: PCBs, DDx, and dioxin-like chemicals.

The use of an overly detailed food web with numerous species categories would have exceeded the availability of site-specific and literature-derived physiological data (DEQ 2006c). The LWR FWM working group, which consists of LWG members and EPA and its partners, had several discussions to agree on the species to be modeled. Because the model's primary purpose is to inform remediation decisions and not to precisely predict tissue residues, a simplified food web was deemed sufficient (EPA 2006c). Based on this premise, certain representative pelagic and benthic species were selected for modeling. The trophic groups modeled, and the representative species for which LWG data are available (listed in parentheses), are as follows:

- Phytoplankton
- Zooplankton
- Benthic invertebrate filter feeders (clams, *Corbicula* spp.)
- Benthic invertebrate consumers[41]
- Epibenthic invertebrate consumers (crayfish, unidentified species)
- Foraging fish (sculpin, *Cottus* spp.)
- Benthivorous fish (largescale sucker, *Catostomus macrocheilus*)
- Omnivorous fish (common carp, *Cyprinus carpio*)
- Small piscivorous fish (smallmouth bass, *Micropterus dolomieui*)
- Large piscivorous fish (northern pikeminnow, *Ptychocheilus oregonensis*).

7.2.3.3 Model Performance Evaluation and Goals

The primary model evaluation metric used to characterize the ability of the model to predict tissue chemical concentrations at specified sediment and water chemical concentrations was the species predictive accuracy factor (SPAF). The SPAF can be calculated in one of two ways: (1) if the model is overpredicting, such that the predicted value is greater than the empirical value, then the SPAF is calculated by dividing the predicted value by the empirical value; (2) if the model is underpredicting, the SPAF is calculated by dividing the empirical value by the predicted value. Thus, the SPAF is always a positive value greater than 1.

$$\text{SPAF} = \text{predicted/empirical} \quad \text{or} \quad \text{SPAF} = \text{empirical/predicted}$$

The LWR FWM working group established a performance goal of predictive capability within a factor of 10 on average. For this report, an average SPAF of 10 was defined as

[41] A generalized category designed to represent oligochaetes, insect larvae, and amphipods.

minimum performance. By definition, a SPAF of 1 demonstrates that the model is exactly predicting the empirical data.

7.2.3.4 Model Parameterization

The input parameters required by the Arnot and Gobas bioaccumulation model (Arnot and Gobas 2004) were derived from site-specific data where possible. The main sources of site-specific data were the Round 1 and Round 2 data collected for the Portland Harbor RI/FS. When an input parameter could not be defined using these data, literature values and best professional judgment were used. To describe the uncertainty in estimates of mean parameter values, distributions for parameter values were assigned.

Parameter distributions were defined based on shape (i.e., normal or triangular) and descriptive statistics (i.e., mean and standard deviation or mode, maximum, and minimum). The distributions were intended to reflect the uncertainty for estimates of central tendency. For example, according to the central limit theorem, estimates of the mean (with sufficient sample size) approach a normal distribution. The standard deviation of the distribution of estimates of the mean is defined by the standard error of the original data. The process for the selection of a distribution shape is described in detail in Appendix H. Appendix H also provides the distributions and values selected for over 100 model parameters, including dietary assumptions.

7.2.3.5 Probabilistic Modeling Approach

Model calibration was performed through probabilistic analysis. An overview of the calibration process is presented here, and details are presented in Appendix H. Briefly, the model for one of the PCB congeners selected for initial calibration was run thousands of times using Monte Carlo simulation (performed using Crystal Ball® software) with different combinations of plausible values for model input parameters. The best-performing model run (i.e., the one with the lowest SPAF) was identified. The values from that model run for non-chemical-specific parameters (i.e., all parameters except K_{ow}, chemical concentration in sediment, and chemical concentration in water) were applied to the model for another example PCB congener. After confirming that these parameters performed well for other chemicals with a range of K_{ows}, these calibrated parameter values were applied to the models for all other modeled chemicals (PCBs, DDx, and dioxin-like chemicals). Probabilistic analysis was also used to select the values for chemical-specific parameters (i.e., K_{ow} and chemical concentration in water) associated with the best model performance (i.e., lowest SPAF) at a specific sediment concentration.

7.2.3.6 Process for Human Health and Ecological iPRG Development

After the chemical-specific versions of the model were calibrated, the FWM was used to calculate iPRGs. The human health and ecological risk assessments (Appendices F and G) identified target tissue concentrations for chemicals for which iPRGs were needed. Target tissue concentrations are concentrations below which risks are

considered acceptable. Detailed discussion of iPRG development is provided in Section 10 and discussed briefly here.

Some assumptions were necessary to allow application of the FWM to iPRG development. Tissue chemical concentration predictions are dependent on both sediment and water chemical concentrations. Because the relationship between chemical concentrations in water and sediment is not yet well characterized, the conservative assumption was made that reducing the sediment concentration would not reduce the water concentration. Thus, in the iPRG development, as the sediment chemical concentration was lowered to achieve target tissue concentrations, the water concentration was held constant.

Because the FWM is a forward calculation (i.e., tissue concentrations are calculated based on specified water and sediment concentrations), the model was run numerous times with a range of sediment concentrations to achieve a target tissue concentration. This process was automated using Crystal Ball® software, using a sediment chemical concentration distribution with a range sufficient to yield a range of tissue concentration predictions that would bound target tissue concentrations (i.e., exceed the maximum and fall below the minimum target tissue concentration for all receptors and exposure scenarios).

As explained in Section 7.2.3.3, all models have less than perfect predictive capabilities, so some imprecision in the predicted tissue concentrations must be acceptable. Tissue concentration predictions within 10 percent but not exceeding the target tissue concentrations were considered sufficiently precise. For example, if the target tissue concentration was 100 µg/kg, the closest model predicted tissue concentration between 90 and 100 µg/kg was identified, and the sediment concentration associated with this tissue concentration was selected as the iPRG. If no predicted tissue concentrations fell between 90 and 100 µg/kg, the model was rerun with additional sediment concentrations until a predicted tissue concentration within the target range was achieved.

The FWM included representative trophic groups. The model was calibrated using LWR tissue chemistry data, where available (see Section 7.2.3.2). In some cases, the species of interest for iPRG development were not the same as the species used for model calibration for a particular trophic group. However, the trophic group was still assumed to represent the species of interest. Specifically, the forage fish category was modeled after and calibrated with sculpin data; but for human health and ecological iPRG development, this category was also assumed to represent black crappie. Similarly, the benthic fish category was modeled after and calibrated with largescale sucker data, but it was also assumed to represent brown bullhead for iPRG development.

7.2.3.7 Model Sensitivity and Uncertainty Analyses

The sensitivity of the model to different parameters was evaluated using Crystal Ball® software. These analyses are discussed in detail in Appendix H and described briefly here.

The model was run using distributions for all non-chemical-specific and chemical-specific parameters for which distributions were developed. Crystal Ball® calculates sensitivity by computing rank correlation coefficients between each input parameter and model output value (i.e., predicted chemical concentration in tissue). This sensitivity result can be evaluated as the percent contribution of each parameter to differences in model output. This percent contribution is useful in identifying the parameters that have the greatest influence on model prediction. This sensitivity analysis was performed using several example chemicals and chemical groups with a range of K_{ows}.

Several approaches were used to evaluate model uncertainty. First, results of the probabilistic model runs (including all parameter distributions developed) were evaluated to determine what percentage of the runs fell within the acceptable performance criteria (i.e., minimum average SPAF < 10). This approach used the same model output as the sensitivity analysis. Model predictions were also compared to empirical data on a species-by-species basis, including the mean empirical values and calibrated model predictions as well as the full range of empirical values and full range of model predictions.

The FWM was also applied at several smaller spatial scales. This application was intended to address uncertainty related to the model's predictive capability for organisms with smaller home ranges. Specifically, the model was run for several example chemicals for Swan Island Lagoon, focusing on species that might have home ranges confined to that area (i.e., plankton, invertebrates, sculpin, and smallmouth bass). The model was also applied to 1-mile catch areas (excluding the channel, as supported by Pribyl et al. [2005]) for smallmouth bass. For sculpin, clams, and crayfish, the model was applied on a sample-by-sample basis using individual collocated sediment and tissue samples for these species with smaller home ranges.

Results of the sensitivity and uncertainty analyses are presented in Appendix H.

7.2.3.8 FWM Path Forward

Detailed findings from the FWM are presented in Appendix H and Section 10 (as related to iPRG development). The calibrated FWM met minimum performance criteria (within a factor of 10) for all but one of the chemicals modeled and was generally within a factor of 5 or better. The model was successfully applied to estimate iPRGs for human health and ecological iCOCs when a reduction in sediment chemical concentration alone was sufficient to achieve target tissue concentrations (i.e., no change in water chemical concentrations was assumed). For some chemicals, sediment iPRGs could not be determined because chemical exposure from water alone (i.e., sediment chemical concentration = 0) was sufficient to yield tissue chemical

concentrations that exceeded target tissue concentrations. If a relationship is developed between sediment and water concentrations, it may be possible to determine iPRGs for these chemicals in future model iterations. The use of parameter distributions and probabilistic modeling facilitated model calibration and the model sensitivity and uncertainty analyses.

In future applications, the FWM will be used to set final PRGs for the identification of AOPCs and the definition of SMAs. Further, in conjunction with fate and transport models, the FWM will be applied to evaluate different remedial options. The model performed well when applied at smaller spatial scales, which provides confidence in the appropriateness of the model structure and parameter values for the trophic groups modeled. The uncertainty analysis indicated that even uncalibrated model predictions (i.e., those made using the full range of plausible mean parameter values) were better than minimum performance criteria for the majority of model runs for all chemicals except one. Again, this provides confidence in the model structure and selection of parameter distributions.

The evaluation of the model in the context of its applications in the RI/FS is useful for assessing data needs related to the FWM. In future applications, the list of chemicals to be modeled may be refined, allowing for more focused model calibration and, therefore, further improvements to model performance. The sensitivity analysis also provided information useful for future model improvements by identifying the parameters with the greatest influence on model predictions.

The sensitivity analysis indicated that chemical K_{ow} and sediment SWACs were the most important parameters influencing the FWM's predictions. By comparison, species-specific biological parameters, such as diet, weight, and lipid content, were of little importance for model predictions. Therefore, additional species-specific input parameter data (e.g., organism weights, lipids, and diet) would be expected to have little influence on model performance. Tissue chemistry data were used for FWM calibration as well as for the evaluation of human health and ecological risks (Appendices F and G). Tissue chemistry data sufficient to characterize risks are also considered sufficient to define the tissue chemical concentrations used to calibrate the FWM. The model achieved and surpassed almost all performance goals for all chemicals and spatial scales, indicating available tissue chemistry data are adequate for calibration.

The model was very sensitive to K_{ow} values, which are highly uncertain. Improved K_{ow} estimates might improve model performance. These are unlikely to become available for use in the RI/FS, but they will be incorporated if they are developed. The model was also sensitive to sediment chemical concentrations (i.e., SWACs). As with tissue chemical concentrations, uncertainty related to baseline SWACs is best evaluated from a risk assessment perspective (i.e., sediment concentration estimates need to be reliable enough to characterize risks from exposure to sediments).

7.3 RIVER-WIDE FATE AND TRANSPORT MODEL

The RI will expand upon and complete the preliminary analysis of chemical loading and fate and transport processes presented in this report. A key component of this further evaluation in the RI will be use of chemical Fate and Transport Model. The information supporting the model will include the estimates of various source loads as discussed in the "path forward" sections for each loading term discussed in Section 7.1. Data collection needed to support both the estimates of various source loads as well as the fate and transport modeling itself is identified in Section 12.

Through discussions with EPA, an in-river fate and transport modeling approach has been identified. This model has been termed the "Hybrid Model." The Hybrid Model includes three primary components:

- Hydrodynamic and Sediment Transport Model: This model has been developed by LWG to describe the movement of water and sediments around the Site. This model has been developed in several phases during the project and is most recently described in WEST Consultants (2006).
- Abiotic Chemical Fate and Transport Model: This model is being developed by EPA and partner agencies to describe chemical movement and distribution within abiotic environmental media at the Site (Hope 2006).
- Food Web Model: This model has been developed by Windward Environmental in collaboration with EPA and partner agencies to describe the movement of chemicals through the river food chain (Windward 2004a,b, 2005b). The FWM is described in greater detail in Section 7.2.3.

The objective is to combine these three independent models into a Hybrid Model capable of describing the movement of chemical masses in particulates (sediments) and water and through the food web. At present, a working version of the Hybrid Model combining these components has not yet been developed. However, the above concept for the model and the technical details of combining these models has been extensively discussed and agreed upon with EPA as the preferred approach for simulating fate and transport processes for this Site. In addition, EPA has developed a working version of a model that currently combines the abiotic chemical fate and transport and FWM components (Hope 2006). Discussions regarding the specific methods and procedures for combining these models to further include the Hydrodynamic and Sediment Transport Model are ongoing. A working version of the complete Hybrid Model ready for use in RI/FS evaluations is scheduled to be available by February 2007.

Under the Hybrid Model approach, the Hydrodynamic and Sediment Transport Model will be used to describe the movements of sediments and water throughout the system. The "fluxes" of these matrices will be input into the abiotic Fate and Transport Model, which assigns a chemical mass associated with both sediment and water-phase processes. These chemical masses are converted to concentrations present in water and sediment at each time step, which is used by the FWM component to calculate the

uptake of these chemicals from sediment and water into the food chain and modeled organisms' tissues.

7.3.1 Modeling Objectives

The primary objectives for fate and transport modeling for the RI/FS were agreed upon in discussions between EPA and the LWG. These objectives are:

1. Estimate the contribution of surface water relative to sediment with respect to risk in tissue (primarily an RI objective).
2. Estimate chemical concentrations in tissue, in support of risk estimates, in species/locations for which we do not have empirical data, e.g., tissue, prey items, etc. (primarily an RI objective).
3. Evaluate the long-term impact on remedial action alternatives of ongoing sources of chemicals associated with unacceptable risk in sediment, the water column, and tissue (primarily an FS objective).
4. Understand erosional and depositional processes to support risk predictions and remedial design (an RI and FS objective).
5. Estimate acceptable sediment and water concentrations based on acceptable tissue concentrations, i.e., PRGs (primarily an RI objective).

Objectives 1, 2, and 5 will primarily be determined as part of the RI using the FWM component of the overall model and based on empirical measurements of water and sediment concentrations representative of existing river conditions.

Objective 3 will be addressed using the combined Hybrid Fate and Transport Model and will include predictions of future sediment, water, and tissue concentrations under various proposed remedial alternatives to help evaluate the effectiveness of those alternatives in the FS. This objective has been further refined by the LWG to include two primary sub-objectives. The first sub-objective relates to understanding the future fish tissue chemical burdens under various remedial alternatives and the source contributions to those burdens (e.g., site sediments, upstream sources of chemicals, stormwater, groundwater). This is similar to Objective 1 above, but in this case, this is a prediction of future conditions after remedial alternatives are in place. The second sub-objective relates to predicting future sediment and water chemical concentrations as the river system reaches a new equilibrium after the disturbance of remediation. The time needed to reach this future equilibrium is an important factor in cleanup decisions that will also be evaluated. This sub-objective includes estimating the following:

- The effect of "background" sediment/water chemical concentrations on future sediment and water equilibrium conditions within the Site
- The decrease and rate of decrease in sediment/water chemical concentrations in areas that are not actively remediated due to processes of natural recovery

- Potential recontamination of remediated areas due to ongoing uncontrolled sources.

Objective 4 will be addressed primarily through use of the Hydrodynamic and Sediment Transport Model component. The model will be used to make predictions of sediment deposition and erosion under various potential future river flow conditions. This information will be used in two ways. One, areas predicted to be potentially susceptible to erosion will be evaluated to determine whether buried chemical concentrations of concern could be exposed to cause risk to the river ecosystem and people using it. This is primarily an RI risk assessment task. Two, for each remedial alternative evaluated in the FS, the model will be run to evaluate depositional/erosional effects on dredged and capped areas to understand the overall suitability and stability (particularly for caps) of these remedial alternatives.

7.3.2 Hybrid Model Components

Each component of the model is described very briefly below and more details can be found in the references noted above for each model component.

The Hydrodynamic and Sediment Transport Model is a numerical, depth-averaged, two dimensional model using EFDC with the following general model specifications:

- The model computation domain extends from the confluence with the Columbia River (RM 0) to the confluence with the Clackamas River (RM 24.1) and includes Multnomah Channel to its confluence with the Columbia River near St. Helens, Oregon. The upstream boundary of the Phase 2 recalibration model is approximately 2.4 miles downstream of Willamette Falls (RM 26.6), which was previously used as the upstream boundary in the Phase 1 model.
- The model includes five physical processes that may significantly affect sediment transport in the study area: tides, river flows, sediment inflows, sediment bed composition and dynamics (such as deposition and erosion), and wind. Density (salinity and temperature) and groundwater discharges are not included because these processes are not expected to have a significant effect on sediment transport.

The abiotic Fate and Transport Model is explicitly inked to the FWM. The abiotic model is dynamic (time-dependent) so that it is possible to track changes over time (in response to possible remedial alternatives) and to determine how long it will take the system to approach steady-state. The abiotic model incorporates daily and seasonally varying data (e.g., river flow rate, water temperature). A daily time period provides a reasonable balance between model resolution, the amount of data generated, and the units in which calculations typically occur. The FWM relies on the output from the abiotic model at each time step. Because of the half-life of some of the chemicals involved, it is expected to be run for periods of approximately 20 years, and possibly

longer. Depending on the specific scenarios eventually run for the FS, different time steps and modeling periods may be developed.

The abiotic model domain extends from RM 2 to RM 11. The model domain is divided into 37 relatively large segments, with individual segments along the right and left banks and central channel for approximately each river mile. A separate segment represents Swan Island Lagoon. The model calculates the movement of chemical mass associated with particulates and water into and between each model segment. At any given time step, the concentrations of chemicals in the sediment or water phase can be calculated by dividing the chemical mass present in the segment by the volume of sediment or water present within that same segment. The model does not explicitly simulate the movement of sediments and water through the system, but rather uses the outputs of the Hydrodynamic and Sediment Transport Model to estimate the movement of chemical masses associated with water and sediment through these model segments.

The FWM is known as TrophicTrace, which is an Excel® spreadsheet model that estimates concentrations in invertebrates and fish for a user-specified food web. Chemical concentrations in specific invertebrate prey species are assumed to be derived either entirely from sediment or entirely from water, depending on whether the user designates the invertebrate species as a deposit feeder or filter feeder, respectively. Chemical concentrations in fish tissue are calculated in this steady-state model based on the work of Gobas and others (as referenced in Windward 2004a,b). The model predicts the uptake of chemicals into various types of fish receptors from environmental media (e.g., direct sediment and water exposures) and diet (e.g., plankton, invertebrates, fish) appropriate for that type of fish. Chemical concentrations in invertebrates are predicted with a user-specified BSAF. TrophicTrace was developed for the USACE to use in its dredged material management program for sediment disposal decisions.

Originally, the LWG developed an independent version of the FWM for use in the RI to meet Objectives 1, 3, and 5 above. Simultaneously, EPA and its partners were developing a TrophicTrace model in conjunction with the abiotic Fate and Transport Model described above (Hope 2006). Subsequently, LWG, EPA, and partners conducted a series of technical discussions to resolve differences in the two versions of the FWM and identify a consistent approach. This process included determining the user-specified food web that is appropriate for this Site. This consensus version of TrophicTrace was also used in this report to calculate PRGs (objective 5) as discussed in Section 10.

7.3.3 Path Forward

A working version of the complete Hybrid Model ready for use in RI/FS evaluations is scheduled to be completed by February 2007.

EXECUTIVE SUMMARY

SECTION 8 – ROUND 2 HUMAN HEALTH RISK ASSESSMENT

Abstract

This Round 2 human health risk assessment (HHRA) presents an initial evaluation of potential risks to human health for the Study Area using the data available at the conclusion of Round 2 of the RI/FS. The Round 2 HHRA was conducted to identify those chemicals and exposure pathways that are predicted to have the highest contribution to the risks at the Study Area, to focus subsequent RI/FS tasks, and to identify the remaining data needs for the baseline HHRA. Because the Round 2 HHRA is not the baseline HHRA, the results are not intended for developing final cleanup levels or identifying areas in need of remediation. The Round 2 HHRA evaluated preliminary risks to human health resulting from exposure to COPCs through direct exposure to beach sediment, in-water sediment, surface water, and groundwater seeps and through fish and shellfish consumption.

Fish and shellfish consumption exposure scenarios result in estimated risks that exceed EPA target risk levels (cancer risk range of 10^{-4} to 10^{-6} or noncancer hazard index of one) and are generally orders of magnitude higher than the other exposure scenarios evaluated based on the conservative assumptions used in the preliminary risk evaluation. Because it is not known to what extent, if at all, shellfish consumption actually occurs at the Study Area and risks from fish consumption are higher than those from shellfish consumption, risks from fish consumption are considered the main risk driver for human health. For the fish consumption scenarios, approximately 85 percent of the estimated cancer risk is due to PCBs. Additionally, the PCB noncancer hazard for some fish consumption scenarios is 80 times higher than for any other chemical. While tissue concentrations within the Study Area are higher than upstream tissue concentrations, the Round 2 HHRA found that risks from consumption of fish collected upstream of the Study Area also exceed EPA target risk levels.

Uncertainties associated with the risk estimates were analyzed. Uncertainties that could impact the conclusions of the Round 2 HHRA and thus have significance to risk management decisions were identified. Those uncertainties were the focus of the data needs evaluation.

While existing data, particularly tissue data, and the exposure assumptions used to evaluate fish consumption risks will be evaluated further, the quantity and quality of the existing data set is adequate to complete the baseline HHRA. Therefore, no additional data collection is needed to complete the baseline HHRA.

Work Plan and Field Sampling Plan Directives

The Programmatic Work Plan established the overall approach for the Round 2 HHRA, and subsequent interim deliverables that were approved by EPA provided the detailed methods and values used in the risk calculations. The Round 2 HHRA was developed consistent with the Programmatic Work Plan and the interim deliverables, as well as numerous discussions among EPA, DEQ, ODHS, and Native American tribes on appropriate risk assessment techniques for

the Study Area. In addition, the Round 2 HHRA incorporated further requirements from EPA by including risks from consumption of clams and a screening evaluation of surface water and transition zone water against specified criteria. The screening evaluation was done to identify potential data gaps and does not indicate unacceptable risks or areas requiring remediation, nor should it be used to establish cleanup levels.

Data Collection Activities

Preliminary risks were estimated using beach sediment, in-water sediment, surface water, groundwater seep, shellfish tissue, and fish tissue data that resulted from the extensive data collection and compilation activities implemented through Round 2 of the RI. These data points can be broken down as approximately 1,200 sediment samples, 130 water samples, and 150 fish and shellfish samples. For fish, both whole body tissue samples and fillet tissue samples were included in the Round 2 HHRA. Samples were analyzed for nearly 300 chemicals, which included dioxins and furans, herbicides, metals, PAHs, PCBs, pesticides, petroleum, phenols, phthalates, and SVOCs.

Preliminary Assessment of Findings

The following findings are based on the conservative Round 2 HHRA preliminary evaluation:

- Risks from consumption of fish or shellfish are generally orders of magnitude higher than any of the other exposure scenarios.
- Risks from consumption of fish or shellfish are within or above the EPA target cancer risk range of 10^{-4} to 10^{-6} and exceed the target noncancer hazard index of one.
- Risks from consumption of upstream (Willamette Falls) fish also are within or above the EPA target cancer risk range of 10^{-4} to 10^{-6} and exceed the target noncancer hazard index of one.
- PCBs result in the highest cancer and noncancer risks from fish consumption.
- With the exception of a single in-water sediment exposure scenario at two ½-mile river segments, risks from direct exposure to beach sediment, in-water sediment, surface water, and groundwater seeps are within or below EPA's target cancer risk range of 10^{-4} to 10^{-6} and below the target noncancer hazard index of one.

Data Interpretation Methods

The Round 2 HHRA followed EPA and DEQ risk assessment guidance and incorporated the four steps of the baseline risk assessment process: data collection and evaluation, exposure assessment, toxicity assessment, and risk characterization, which included an uncertainty assessment.

The preliminary exposure assessment identified the potentially exposed populations, identified and characterized the exposure pathways, and estimated the amount and extent of exposure. A conceptual site model was developed for the Round 2 HHRA based on the current

understanding of the Study Area to depict the pathways through which human populations may be exposed to COPCs. Only those pathways that were found to be potentially complete and significant were evaluated quantitatively in the Round 2 HHRA.

The following populations and associated exposure scenarios were quantitatively evaluated in the Round 2 HHRA:

- Dockside worker - direct exposure to beach sediment;
- In-water worker - direct exposure to in-water sediment;
- Adult and child recreational beach user - direct exposure to beach sediment and surface water (for swimming scenarios);
- Transient - direct exposure to beach sediment, surface water (for bathing and drinking water scenarios), and groundwater seeps;
- Native American fisher - direct exposure to beach sediment or in-water sediment and fish consumption; and
- Non-tribal fisher - direct exposure to beach sediment or in-water sediment, fish consumption, and shellfish consumption.

As approved by EPA, a range of conservative values was used to estimate exposures and risks in order to incorporate reasonable maximum exposures, which are intended to be protective of highly exposed populations. Preliminary exposures and risks were estimated on a Study Area-wide basis as well as more localized spatial scales as appropriate for each exposure scenario, in accordance with EPA-approved methodologies. Toxicity values used in the Round 2 HHRA were obtained from EPA's recommended hierarchy of sources for Superfund sites. Toxicity values were evaluated for both cancer and noncancer endpoints of COPCs.

Preliminary noncancer risks were estimated using hazard indices and were compared to EPA's target hazard index of one, below which remedial action at a Superfund site is generally not warranted. Preliminary cancer risks were estimated by summing risks for each exposure area across all chemicals and were compared to EPA's target cancer risk range of 10^{-4} to 10^{-6}, which is the target range within which EPA strives to manage risk as part of the Superfund program. Preliminary risks were calculated for all of the above exposure scenarios. Chemicals that resulted in a cancer risk greater than $1x10^{-6}$ or a hazard quotient greater than one under any of the preliminary scenarios were identified as iCOCs. Uncertainties in the risk estimates included the exposure values used for the fish and shellfish consumption scenarios, the exposure point concentrations used in the maximum exposure scenarios, and consideration of background in the risk estimates. In most cases the noted uncertainties are counter-balanced by the conservative assumptions and factors utilized in the Round 2 HHRA.

In addition to the preliminary risk evaluation, the Round 2 HHRA also included a screening evaluation of surface water and transition zone water using criteria specified by EPA for exposure pathways not considered in the Round 2 HHRA. The screening evaluation was done to identify potential data gaps and does not indicate unacceptable risks nor should it be used to

establish cleanup levels. Even with the use of maximum detected concentrations at the locations anticipated to have the greatest impacts, only a few chemicals exceeded their respective screening levels and were retained as potential iCOCs following the screening evaluation. These chemicals had already been identified as iCOCs through the Round 2 HHRA for other exposure scenarios or are dependent on further policy decisions regarding the use of the Study Area as a drinking water source. Therefore, no additional data needs have been identified for surface water or transition zone water.

Next Steps

While additional data are not needed to complete the baseline HHRA, data collected during Round 3 that are appropriate for inclusion in the baseline HHRA will be used in the final risk estimates. In developing the baseline HHRA, efforts will focus on further evaluation of existing data, particularly tissue data, and refining the exposure factors used in the fish and shellfish consumption scenarios through further discussions with EPA and its partners.

8.0 ROUND 2 HUMAN HEALTH RISK ASSESSMENT SUMMARY

The overall objective of the Round 2 HHRA for the Portland Harbor Superfund Site is to identify chemicals and exposure pathways that may result in potential unacceptable risks and to focus on those that are predicted to have the highest contribution to the estimated risk at the Site. The results of the Round 2 HHRA were used in identifying iAOPCs and the RI/FS data needs for Round 3, as described in Sections 10 and 12.

The Round 2 HHRA for the Site is presented in Appendix F. This section presents a summary of the methods and results of the Round 2 HHRA, including the data evaluation, exposure assessment, toxicity assessment, risk characterization, uncertainty analysis, and conclusions. The approach of the Round 2 HHRA is based on EPA (1986; 1989a,b; 1991a, 2001b,d) and Region 10 EPA (2000b) guidance. The approach is also consistent with DEQ HHRA guidance (DEQ 2000). The Round 2 HHRA was conducted in accordance with the EPA-approved programmatic work plan (Integral et al. 2004b) and human health interim deliverables (Kennedy/Jenks 2004a,b,c; 2006).

8.1 DATA EVALUATION

The sources of data available for use at the time of the Round 2 HHRA are described in Section 2 of the Round 2 Report. The use and evaluation of those data for purposes of the Round 2 HHRA are described in Section 2 of Appendix F. Data from LWG and non-LWG sampling events were included in the SCRA database, a subset of which was used for the Round 2 HHRA. Only data of confirmed quality that met the data quality objectives (DQOs) for risk assessment were included in the SCRA database. The following summarizes the data used in the Round 2 HHRA:

- Beach sediment: Composite beach sediment samples that were collected from designated human use areas within the Study Area were included in the Round 2 HHRA data set.
- In-water sediment: In-water sediment (i.e., not beach sediment) samples that were collected from the top 30.5 cm in depth between the bank and the navigation channel and located within the Study Area were included in the Round 2 HHRA data set.
- Surface water: Round 2 surface water samples, which include samples collected from 23 locations and three sampling events, a subset of which were included in the Round 2 HHRA data set.
- Seep water: Data from Outfall 22B, which discharges in a human use area, were included in the Round 2 HHRA data set.
- Fish tissue: Composite samples, both whole body and fillet, of target resident fish species (smallmouth bass, brown bullhead, black crappie, and common carp) were included in the Round 2 HHRA data set. Composite samples of

adult salmon (whole body and fillet), adult lamprey (whole body only), and sturgeon (fillet only) were also included in the Round 2 HHRA data set.

- Shellfish tissue: Field-collected composite samples of crayfish and clam tissue were included in the Round 2 HHRA data set.

8.2 EXPOSURE ASSESSMENT

The objectives of the exposure assessment are to identify potentially exposed receptor populations, identify and characterize exposure pathways, and estimate the extent of exposure for pathways that are complete and significant. The exposure assessment for the Round 2 HHRA is found in Section 3 of Appendix F. Additionally, Map 8.2-1 shows the CSM for the Round 2 HHRA, which summarizes all of the exposure scenarios that were evaluated in the Round 2 HHRA.

Only potentially complete and significant exposure pathways are quantitatively evaluated for risk in the Round 2 HHRA (see Map 8.2-1). These pathways were identified in the Programmatic Work Plan (Integral et al. 2004b). The following are the populations and associated exposure scenarios that were quantitatively evaluated in the Round 2 HHRA:

- Dockside Worker—Direct exposure to beach sediment
- In-water Worker—Direct exposure to in-water sediment
- Adult and Child Recreational Beach User—Direct exposure to beach sediment and surface water
- Transient—Direct exposure to beach sediment, surface water, and groundwater seep
- Native American Fisher—Direct exposure to beach sediment or in-water sediment and fish consumption
- Non-tribal Fisher—Direct exposure to beach sediment or in-water sediment, fish consumption, and shellfish consumption.

Within the fish consumption exposure scenarios, pregnant and nursing women are a subgroup of potential concern due to potential exposures to fetuses and nursing infants. The breast milk exposure pathway is not evaluated in the Round 2 HHRA, but it will be incorporated in the baseline HHRA.

The exposure assessment incorporated the reasonable maximum exposure (RME) methods recommended by EPA. The RME is intended to be a conservative exposure level that is still within the range of possible exposures. The exposure assessment also used central tendency (CT) values, which better represent average exposures, for certain exposure assumptions. For the RME scenarios, the 95 percent upper confidence limit (UCL) on the mean or the maximum concentration was used in risk equations for the

EPC. For the CT scenarios, the mean was used in risk equations. For non-tribal fish consumption, a range of ingestion rates was used that represent high levels of fish consumption relative to average rates. A range of ingestion rates was also used for the shellfish consumption scenario. All of the fish and shellfish consumption scenarios were evaluated using both the UCL or maximum (UCL/max) and the mean tissue concentrations as the EPCs.

Exposures were evaluated on a site-wide basis as well as on more localized spatial scales as appropriate for each exposure scenario. The assumptions used to evaluate the exposure scenarios in the Round 2 HHRA were based on exposures that may generically occur throughout the Study Area and do not consider site-specific conditions that may reduce or eliminate exposure at a given location.

8.3 TOXICITY ASSESSMENT

Toxicity values provide a quantitative estimate of the potential for adverse effects resulting from exposure to a chemical. Toxicity values for both cancer and noncancer endpoints were evaluated. Toxicity values used for the HHRA are presented in Section 4 of Appendix F. The following hierarchy of sources of toxicity values is currently recommended for use at Superfund sites (EPA 2003), and was used for the Round 2 HHRA:

- Tier 1—EPA's Integrated Risk Information System (IRIS)
- Tier 2—EPA's Provisional Peer Reviewed Toxicity Values (PPRTVs)
- Tier 3—Additional EPA and non-EPA sources of toxicity information

Some toxicity values are based on exposure to chemical mixtures and not to individual chemicals. As a result, risks were evaluated for the combined exposure to the chemicals and not on an individual chemical basis for the following chemicals:

- Chlordane
- DDD, DDE, and DDT
- Endosulfan
- PCBs
- Dioxins and furans.

Toxic equivalency factors (TEFs) were used to evaluate carcinogenic effects of dioxin and furan congeners and dioxin-like PCB congeners. PCBs were also evaluated as total PCBs for both carcinogenic and non-carcinogenic effects.

8.4 RISK CHARACTERIZATION AND UNCERTAINTY ANALYSIS

The Round 2 HHRA risk characterization was performed according to EPA guidance (EPA 2003). The methods and results are described in detail in Section 5 of Appendix F.

Potential noncancer risks are estimated using hazard indices (HIs). Per EPA guidance (1989a), hazard quotients (HQs) should only be summed for chemicals with common toxicological endpoints. In this Round 2 HHRA, the HQs were summed regardless of the toxicological endpoint, resulting in a more conservative assessment. In the baseline HHRA, endpoint-specific HIs (e.g., neurological or immune system effects) will be calculated. Estimated HIs, which were not endpoint specific, were compared to a target HI of 1, below which remedial action at a Superfund site is generally not warranted (EPA 1991a; ORS 465.315[1][b][A]; OAR 340-122-0115[4]).

Estimated total cancer risks (summed across all chemicals) were compared to a 10^{-4} to 10^{-6} risk range, which is the "target range" within which EPA strives to manage risk as a part of the Superfund program (EPA 1991a). The DEQ acceptable risk levels are $1x10^{-6}$ for individual carcinogens and $1x10^{-5}$ for total cancer risks (ORS 465.315[1][b][A]; OAR 340-122-0115[2] and [3]).

8.4.1 Risk Characterization Results

The ranges of estimated potential risks resulting from the different exposure scenarios are summarized in Table 8.4-1. A summary of the risk characterization results is presented by exposure scenario.

8.4.1.1 Fish Consumption

Risks were calculated for the non-tribal adults and children who consume fish caught within the Study Area, based on three different ingestion rates representing a range of potential high-end consumption scenarios; for both single-species and multiple-species diet (crappie, bullhead, and smallmouth bass); and based on consumption of both whole body and fillet tissue. Risks were also evaluated for Native American adults and children who consume fish as a multi-species diet consisting of resident fish species (carp, crappie, bullhead, and smallmouth bass) as well as sturgeon, lamprey, and salmon; and on consumption of both whole body and fillet tissue. All risk estimates were made using both mean and UCL/max estimates of chemical concentrations in tissue. Consequently, minimum risk estimates represent the lowest consumption rate for the scenario and mean tissue concentrations, and maximum estimates represent the highest consumption rate and UCL/max tissue concentrations. In addition, spatial scales smaller than the Study Area were evaluated, so the minimum and maximum risk estimates typically reflect more localized exposures.

The cancer risks for all of the finfish consumption scenarios range from $3x10^{-6}$ to $2x10^{-2}$. HIs for cumulative noncarcinogenic risks for all of the fish consumption scenarios ranged from 0.5 to 1,000. For many of the fish consumption scenarios, the cancer risks and noncancer hazards exceed the EPA target cancer risk range and target HI. The highest risk estimates for fish consumption are associated with numerous conservative

assumptions that, when combined, result in unrealistic scenarios. The following summarizes the assumptions associated with the highest risk estimates:

- **Fish ingestion rate.** The highest ingestion rates for Native American and non-tribal consumers (175 and 142 g/day) are equivalent to 23 and 19 meals per month, respectively.
- **Exposure duration.** Fish consumption is assumed to occur at that same rate every month of every year for 30 years for non-tribal consumers and 70 years for Native American consumers.
- **Whole body tissue.** Only whole body tissue (i.e., the entire fish) is consumed.
- **Single species.** Only one species (i.e., carp) is consumed.
- **Source of fish.** 100 percent of the fish consumed is caught/harvested from the same location.
- **Possible effects of cooking methods.** Possible effects of cooking methods, which can reduce PCB concentrations from 10 to 87 percent (Wilson et al. 1998), were not considered.

The chemicals driving both cancer and noncancer risks for tissue are PCBs. Using the mean concentrations for the multiple species diet, PCBs, representing both total PCBs and PCB TEQ, contribute approximately 85 percent to overall cancer risk in tissue. Dioxin TEQ is the next highest contributor to cancer risk in tissue, but to a much smaller extent (approximately 10 percent). All other chemicals combined contribute to approximately 5 percent of the overall cancer risk. The noncancer HQ from PCBs is approximately 80 times higher than from mercury, which has the next highest noncancer HQ. While PCBs and dioxins/furans clearly have the greatest contribution to the overall cancer risk, other chemicals still result in unacceptable risks, especially with the higher ingestion rates and UCL/max concentrations.

While the tissue concentrations and associated risks within the Study Area appear elevated relative to upstream areas, cancer risks and noncancer hazards from consumption of upstream fish tissue also exceed the EPA target cancer risk range and target HI. Using the same ingestion rates and exposure assumptions as the adult non-tribal fish consumer, the cumulative cancer risks from consumption of upstream fish tissue ranged from $6x10^{-5}$ to $2x10^{-3}$, and the HIs, which were not endpoint specific, ranged from 0.6 to 40. The upstream risks suggest that the EPA target risk range and target HI may not be achievable at the Site, especially when considering the higher-end ingestion rates.

8.4.1.2 Shellfish Consumption

The consumption of shellfish was evaluated for adult non-tribal consumers based on two consumption rates representing a range of potential high-end consumption scenarios, assuming shellfish collection/consumption actually occurs within the Study Area. It is not known whether the collection actually occurs within the Study Area, and

if it does, whether those shellfish are consumed by humans on an ongoing basis. However, this exposure scenario was included in the Round 2 HHRA, as required by EPA in its comments on the PRG Technical Memorandum (dated June 30, 2006). The shellfish species evaluated for consumption risks were crayfish and clams. Cumulative cancer risks from consumption of shellfish ranged from $1x10^{-6}$ to $8x10^{-4}$. HIs for cumulative noncarcinogenic hazard ranged from 0.05 to 20 for consumption of shellfish. While the cancer risks and noncancer hazards exceed the EPA target cancer risk range and target HI, the ingestion rates and spatial scales used to quantify risks for this exposure scenario are highly uncertain.

8.4.1.3 Direct Exposure to Beach Sediment

Beaches were identified as potential human use areas associated with industrial upland sites (dockside workers), recreation (recreational users or fishers), or trespassing or transient use (transients). Beaches were associated with one or more of these uses (e.g., fishing and transient use). Even if such beach use occurs, the extent to which the beach is used and the nature of the contact with sediments/beach is uncertain. However, conservative assumptions were included in the risk analysis of this exposure pathway to provide an estimate of potential risks.

The RME scenarios for exposure to beach sediment for at least one beach area resulting in cumulative risks above 10^{-6} include: dockside worker, adult and child recreational beach user, Native American fisher, recreational fisher, and non-tribal non-recreational fisher. None of the RME scenarios resulted in risks greater than 10^{-4} or HIs exceeding 1. Only the dockside worker and Native American fisher had CT scenarios where the cancer risks were above 10^{-6}. The cumulative cancer risks for all of the CT scenarios were below 10^{-4}. Cumulative risks above 10^{-6} resulting from exposures to beach sediment are due in part to arsenic, which may be present at naturally occurring background concentrations. The contribution from arsenic to the cumulative risk varies by individual beach and generally ranges from approximately 40 to 99 percent of the total cancer risk.

8.4.1.4 Direct Exposure to In-Water Sediment

Risks from in-water sediment exposure were estimated separately for each of the ½-mile river segment exposure areas (east [E] and west [W]), and for site-wide exposure. In-water sediments within the navigation channel were not included in the risk evaluation because the majority of exposure is expected to occur in the nearshore areas (Kennedy/Jenks 2006). Risks from in-water sediment exposure were evaluated for exposures to in-water workers, Native American fishers, recreational fishers, and non-tribal non-recreational fishers.

Cumulative cancer risks were greater than 10^{-6} but were below or equal to 10^{-4}, with the exception of exposures to in-water sediment by a Native American fisher at exposure areas RM 4.5E (due primarily to PAHs) and RM 7W (due primarily to dioxins). The Native American fisher was the only CT scenario with cancer risks above 10^{-6}. The

cumulative risks for all of the CT scenarios were below 10^{-4}. None of the scenarios, RME or CT, resulted in an HI exceeding 1.

8.4.1.5 Direct Exposure to Surface Water

Risks from exposures to surface water were evaluated for exposures by transients and adult and child recreational beach users. None of the evaluated scenarios resulted in cumulative risks greater than 10^{-6} or HIs greater than 1.

8.4.1.6 Direct Exposure to Seeps

Risks from exposures to groundwater seeps were evaluated for the only seep identified as a human use area, which was designated for transient use only. The transient exposure scenario did not result in cumulative risks greater than 10^{-6} or HIs greater than 1.

8.4.1.7 Initial Chemicals of Concern

Chemicals were identified as iCOCs if they resulted in a cancer risk greater than $1x10^{-6}$ or an HQ greater than 1 under any of the exposure scenarios for any of the exposure point concentrations evaluated in this Round 2 HHRA, regardless of the uncertainties. The iCOCs are shown by medium and scenario in Table 8.4-2. A total of 24 chemicals were identified as iCOCs for various media and receptors for the Study Area.

8.4.2 Uncertainty Analysis

Uncertainty is associated with every step of a risk assessment, from the sampling and analysis of concentrations of chemicals in environmental media to the assessment of exposure and toxicity. In general, the approach and methodologies used in a risk assessment are designed to err on the side of conservatism, i.e., protection of human health.

A detailed analysis of the uncertainties associated with the Round 2 HHRA is found in Section 7 of Appendix F. Uncertainties were evaluated relative to their potential impact on the conclusions of the Round 2 HHRA and resulting significance to risk management decisions. The sources of uncertainty with the highest significance to risk management decisions include:

- **Conservatism of exposure parameters for fish and shellfish consumption exposure scenarios.** The exposure factors used in estimating potential human health risks were purposely selected to be conservative (e.g., protective), and the range of fish consumption rates varied by an order of magnitude to reflect the uncertainty. These exposure assumptions are likely to overestimate actual exposure conditions at the Study Area and, therefore, overestimate human health risks and hazards.
- **Using the maximum concentration to represent exposure.** In cases when there were fewer than five (5) samples with a detected concentration for a given analyte for a given exposure area, the sample size was not sufficient to calculate a UCL on the mean, so the maximum concentration detected was used as the EPC. Using maximum detected concentrations of infrequently detected

chemicals to represent individual exposure areas, and especially site-wide exposure, results in an extremely conservative estimate of risk for the Study Area. The use of the maximum detected concentration likely overestimates the actual human health risks.

- **Risks from Background.** The Round 2 HHRA risk estimates were calculated based on empirically derived data from the Portland Harbor. As such, the contribution of upstream and background concentrations of analytes was not explicitly accounted for in the estimates of potential human health risks. However, it is important to recognize that upstream tissue concentrations result in unacceptable risks from fish consumption based on the exposure assumptions used in this Round 2 HHRA. Therefore, the calculated potential human health risks likely overestimate actual risks that are a result of exposure to the Study Area.

The cumulative effects of the numerous conservative assumptions made during the Round 2 HHRA resulted in calculated risk estimates that are likely substantially higher than actual risks that may exist at the Study Area. As a result, the risk estimates presented in the Round 2 Report are not an appropriate basis for defining risk management or remedial actions. Completion of the baseline HHRA and FS are needed before these decisions can be made. As noted previously, the results of the Round 2 HHRA are used to identify the most significant exposure scenarios and which chemicals are contributing the highest percentage of the calculated risks, and to identify data needs for completing the HHRA and FS.

8.4.3 Data Needs Evaluation

To evaluate the data needs that may be necessary to complete the baseline HHRA, focus was placed those uncertainties above that were identified as having an impact on the conclusions of this Round 2 HHRA, and thus a potentially significant impact on risk management decisions.

- **Exposure parameters for fish consumption exposure scenarios.** The ingestion parameters used were negotiated with EPA and its partners, and EPA and its partners have been clear that conducting additional regional fish consumption studies would not be considered as a mechanism to adjust these parameters. As these parameters already provide a high degree of protectiveness to the exposure scenarios being evaluated, it does not appear that this uncertainty can be resolved through additional data collection and is not considered a data need for the baseline HHRA. Additional discussions with EPA and its partners are needed to assess whether the conservative assumptions used in this Round 2 HHRA should be refined for the baseline HHRA.
- **Using the maximum concentration in fish tissue to represent exposure when detection frequency was low.** The use of the maximum concentration to represent exposure is a highly health-protective assumption; therefore, the

concern that potential risks would be underestimated is not an issue. However, it is not certain that additional tissue collection would provide sufficient numbers of detected concentrations of a given chemical to allow for a calculation of an upper-bound estimate of the arithmetic mean. Instead, it is proposed that alternative statistical procedures be evaluated to handle limited data sets and estimate an appropriate exposure concentration for these exposure areas and scenarios.

- **Risks from Background.** Additional upstream sediment data collection along with surface water and sediment trap data collection is currently underway or being proposed. The upstream sediment, surface water, and sediment trap data will be used to account for background when establishing remedial goals. There are upstream fish tissue data available of adequate data quality that can be used to provide context for site risks for purposes of risk communication. Therefore, no additional data collection is recommended to address this uncertainty.

8.5 SCREENING OF SURFACE WATER AND TRANSITION ZONE WATER DATA

The Round 2 HHRA evaluated risks associated with the potentially complete and significant exposure pathways identified in the CSM. As agreed to by EPA, scenarios that were not evaluated in the Round 2 HHRA include: (1) surface water as source of contamination for biota that are consumed by humans, (2) surface water as a drinking water source, (3) TZW as source of contamination for biota that are consumed by humans, and (4) TZW as a potential source to surface water. In its comments on the PRG technical memorandum dated June 30, 2006, EPA required that surface water and TZW be screened against specific criteria. The screening evaluation of surface water and TZW data is presented in detail in Section 6 of Appendix F and is summarized here. The evaluation was performed to assist with identifying data gaps and does not indicate that these are potentially complete exposure pathways, nor does it indicate that unacceptable risks exist for these exposure pathways.

8.5.1 Screening of Surface Water Data

The complete surface water data set (i.e., all of the Round 2 surface water samples from the SCRA data set, including those not used in the Round 2 HHRA) was screened against human health based screening levels for drinking water and for the consumption of organisms.

To evaluate the biota consumption exposure pathway, the maximum concentrations of each chemical detected in surface water were compared against Human Health Ambient Water Quality Criteria for the Consumption of Organisms (human health AWQC) (EPA 2006f). Measured tissue concentrations are available for all chemicals that were detected in surface water at concentrations exceeding the human health AWQC, which allowed for the use of empirical data to calculate potential human health risks. Of the

list of chemicals detected in surface water at concentrations exceeding the human health AWQC, only chrysene was not identified as an iCOC for shellfish or fish tissue.

The LWR is not currently used as a public drinking water source, nor are there plans to develop a source of public drinking water from the LWR. Nonetheless, the maximum concentrations of each chemical detected in surface water were compared against EPA Region 9 tap water PRGs (EPA 2004d) and EPA Maximum Concentration Levels (MCLs). Chemicals that were detected at a frequency greater than 5 percent and at a maximum concentration exceeding the EPA Region 9 tap water PRG include: arsenic, several PAHs, and dioxin/furan compounds. No chemicals were detected at concentrations exceeding the respective MCL.

8.5.2 Screening of Transition Zone Water Data

There are no direct exposure pathways for human populations to TZW. However, in theory, chemicals present in TZW could accumulate in biota that are consumed by humans or could contribute to surface water concentrations.

In theory, shellfish could be exposed to TZW directly, so measured concentrations in TZW were evaluated with respect to the shellfish consumption exposure pathway. The direct comparison of TZW concentrations to human health AWQCs for surface water is a very conservative evaluation that does not account for differences in uptake of chemicals from TZW versus surface water by shellfish organisms. In addition, the human health exposure assumptions and acceptable risks levels used to derive the human health AWQC differ from those used in the Round 2 HHRA. As a result, an adjustment factor of 5,000 was applied to the maximum detected concentrations in TZW and the adjusted maximum TZW concentrations were compared against the human health AWQC. The chemicals identified as potential TZW iCOCs for biota consumption include total DDT and total DDD. Total DDT and total DDD were identified as iCOCs for consumption of fish and shellfish.

TZW data were also evaluated for protection of surface water. Conservative loading estimates and models were used to estimate surface water concentrations based on the maximum discharge flow of groundwater to the Willamette River. The estimated surface water concentrations were then compared against EPA Region 9 PRGs and MCLs, even though the LWR is not currently used as a public drinking water source, nor are there plans to develop a source of public drinking water from the LWR. Only the surface water concentration estimates for chloroform and trichloroethylene (TCE) exceed the respective Region 9 PRG for tap water. The magnitude of exceedance of the Region 9 PRG for tap water was 2.7 for chloroform and 1.7 for TCE. These chemicals were not detected at concentrations that would exceed MCLs. As described in Appendix D, the loading estimates for chloroform and trichloroethene are dominated by TZW sample concentrations from a single location for each chemical. For chloroform, more than 99 percent of the estimated load is associated with a TZW sample location AP03D offshore of the Arkema Acid Plant. For trichloroethene, 97 percent of the load is associated with a TZW sample location GP67 offshore of the Siltronic facility. Given

the conservatism in the approximations of upland groundwater plume loading to surface water, the uncertainty associated with loads that are dominated by individual TZW sample concentrations, and the small magnitude of the exceedances of the Region 9 PRGs for tap water, it is not likely the contribution from TZW to surface water leads to exceedances of human health based screening levels for drinking water.

8.5.3 Screening Evaluation Conclusions

Surface water and TZW data were compared against human-health-based screening levels, as required by EPA in its comments on the PRG technical memorandum (dated June 30, 2006). Based on the screening evaluation, the chemicals retained as potential TZW iCOCs include total DDT and total DDE, based on the biota consumption pathway. Though TCE and chloroform were retained as potential TZW iCOCs, based on slight exceedances of the EPA Region 9 tap water PRG, the assumptions used to model surface water concentrations from groundwater loading estimates were extremely conservative.

In conclusion, the results of this evaluation do not lead to the identification of data needs with respect to TZW and human health exposure pathways.

8.6 SUMMARY AND CONCLUSIONS

The following summarizes the results of the Round 2 HHRA:

- Fish consumption exposure scenarios result in estimated risks that are generally substantially higher than other exposure scenarios. The range of cumulative cancer risks from all fish consumption scenarios is $3x10^{-6}$ to $2x10^{-2}$, which are all within or above EPA's target cancer risk range. The majority of tissue ingestion scenarios also result in noncancer HIs that exceed the target HI of 1.
- The chemicals associated with the highest cancer risk and noncancer hazard for fish consumption were PCBs. Approximately 85 percent of the cancer risk is due to PCBs. The noncancer hazard from PCBs is 80 times higher than that from any other chemical.
- Estimated risks from direct exposure to beach sediment are within or below the target risk range of 10^{-6} to 10^{-4}. No noncancer HIs exceed the EPA target HI of 1.
- Estimated risks for most in-water sediment exposure scenarios are within or below the target risk range of 10^{-6} to 10^{-4}; two ½-mile river segments exceed an estimated risk of 10^{-4} for the Native American fisher receptor. No noncancer HIs exceed the EPA target HI of 1.
- Estimated risks and hazards from exposure to groundwater seeps or surface water are below EPA's target cancer risk range and do not exceed the EPA target HI of 1.
- Human health risks from fish tissue collected upstream of the Study Area exceed the EPA target cancer risk range and noncancer HI.

While additional data are not needed to complete the baseline HHRA, data collected during Round 3 that are relevant for human exposures will be used in refining risk estimates for those exposure scenarios. In developing the baseline HHRA, efforts will focus on further evaluation of existing data and refining the exposure factors of the consumption scenarios.

EXECUTIVE SUMMARY

SECTION 9 – ROUND 2 ECOLOGICAL RISK ASSESSMENT

Abstract

This Round 2 ecological risk assessment (ERA) presents an evaluation of potential risks to ecological receptors for the Study Area using the data available at the conclusion of Round 2 of the RI/FS. The term potential risk indicates exceedance of screening levels that identify chemicals warranting further evaluation in a baseline ecological risk assessment. The purpose of this Round 2 ERA is to help focus subsequent RI/FS tasks and identify remaining data needs for the baseline ERA.

Receptors addressed in this Round 2 ERA include benthic invertebrates, fish, wildlife, amphibians and reptiles, and aquatic plants. Multiple lines of evidence (LOEs) were used to assess risks to each receptor. This represents a screening-level ecological risk assessment (SLERA) per U.S. Environmental Protection Agency (EPA) 1997 guidelines (EPA 1997) and is consistent with EPA 1998 guidance (EPA 1998). The additional effort to identify initial chemicals of concern (iCOCs) was necessary to establish iPRGs and iAOPCs. This screening-level assessment was done to identify data gaps and to prepare for developing the Baseline ERA Problem Formulation; it is not intended to indicate unacceptable risks or areas requiring remediation, nor should it be used to establish cleanup levels.

The findings of this Round 2 ERA indicate:

- Much of the Study Area does not pose a significant risk to ecological receptors.
- A high percentage of sediment sampling stations were classified as nontoxic to benthic invertebrates despite extensive sampling near known or suspected potential sources of COPCs and in sediments with contamination levels characteristic of an urban harbor. Benthic invertebrate iCOCs included selected metals, PCBs, PAHs, and DDTs.
- It is not expected that the baseline ERA will conclude population-level effects on fish and wildlife, despite preliminary identification of iCOCs for fish and wildlife.
- No iCOCs were identified for amphibians, reptiles, and aquatic plants.

Uncertainties in the risk estimates and related conclusions of the Round 2 ERA that could have significance for risk management decisions were identified. Those uncertainties were the focus of the data needs evaluation. Data that are or will be collected as part of Round 3 sampling programs will supplement the existing data set and fulfill all data needs for the baseline ERA.

Work Plan and Field Sampling Plan Directives

Following development of the Work Plan (Appendix B: Ecological Risk Assessment Approach of the *Portland Harbor RI/FS Programmatic Work Plan*; Integral et al. 2004 and related documents listed in Appendix G) and preparation of the ecological preliminary risk evaluation

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(PRE) (Windward 2005), the LWG developed the *Portland Harbor Superfund Site Proposed Ecological Risk Assessment Decision Framework* (Windward 2006). This document describes the approach to spatial analysis and risk characterization in more detail than the Work Plan and outlines a weight of evidence approach to risk characterization. Subsequently, LWG worked with the U.S. Environmental Protection Agency (EPA) to develop the initial LOEs for the ERA. EPA directed LWG to use all of the proposed LOEs for the Round 2 ERA. LWG has coordinated with EPA to develop data analysis methods, exposure assumptions, and effects-based thresholds (e.g., toxicity reference values [TRVs], ecological screening levels [Eco SLs] in water) for the Round 2 ERA. While the Round 2 ERA is less conservative than the PRE (Windward 2005), it is still a screening-level assessment and the results are most useful for the intended purpose of defining data gaps, not for identifying areas definitely in need of remediation or for developing final cleanup levels.

Data Collection Activities

The project data set for surface sediment chemistry and toxicity, surface water chemistry, TZW chemistry, and fish and aquatic invertebrate tissue chemistry was used to assess ecological risks at the Study Area. See Section 2 of this Report for a summary of the sources of data and Section 6 for an overview of the distribution of Round 2 COPCs at the Study Area.

Data Interpretation Methods

Benthic community responses were used to evaluate Study Area-specific risks from exposure to sediment and its associated TZW. Ingestion of sediment or prey and direct contact with sediment, near-bottom surface water, and TZW were considered the primary routes of exposure for benthic invertebrates. Multiple LOEs were used to assess risks to benthic communities. Results of laboratory toxicity tests of surface sediment collected from 227 stations in the Study Area comprised the primary LOE. Predictive models derived from the toxicity responses in relation to sediment chemistry were applied to assess the potential toxicity of sediments at locations where sediment chemistry data were available but toxicity data were not. Risks to benthic invertebrates were also assessed by comparing empirical or predicted tissue chemical concentrations to aquatic tissue-based TRVs, and by comparing chemical concentrations in near-bottom surface water or TZW to Eco SLs for water developed based on ambient water quality criteria (AWQC) or other water screening benchmarks. A TZW framework was developed to further evaluate TZW risks to benthic invertebrates.

Risks to fish and wildlife receptors were assessed primarily by comparing tissue residue data or modeled estimates of ingested dietary dose of chemical to TRVs, either residue-based or dose-based toxicity benchmarks respectively. Risks to fish were also assessed by comparing surface water and TZW chemical concentrations to the Eco SLs. Risks to piscivorous birds were also assessed by comparing estimated concentrations of COPCs in bird egg tissue to bird egg-based TRVs.

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Risks to amphibians and aquatic plants were assessed by comparing surface water and/or TZW chemical concentrations to Eco SLs in water developed based on AWQC or other water screening benchmarks.

Preliminary Assessment of Findings

Benthic invertebrates

- Areas of potential risk to the benthic community were identified using benthic toxicity testing, predictive models of benthic toxicity and other lines of evidence. These areas are located primarily nearshore adjacent to known chemical sources.
- A high percentage (79 percent) of the sampled sites was classified as nontoxic to benthic invertebrates. Only 13 percent were classified as toxic, with the remaining stations (8 percent) either not evaluated due to limited chemistry data and no sediment toxicity data or identified as indeterminate.
- iCOCs for benthic invertebrates based on multiple LOEs include 3 metals, PCBs, 3 individual PAHs, total PAHs, and DDTs.
- Other, potential iCOCs for benthic invertebrates also were identified as those chemicals associated with high uncertainty or identified solely based on transition zone water exceedances of surface water screening levels, not supported by other LOEs, as posing risks to benthic invertebrates. These potential iCOCs are not expected to pose significant risks to benthic invertebrates because there is limited potential for exposure.

Fish

- Potential risks to fish were identified through the Round 2 ERA. The chemicals that have the greatest potential for posing risk to fish are PCBs.
- Other iCOCs for fish include DDTs, phthalates, mercury and tributyl tin.

Wildlife

- Potential risks to wildlife were identified through the Round 2 ERA. The iCOCs are PCBs, dioxins, mercury, DDTs and aldrin.
- Potential risks to most wildlife receptors were identified based on dietary exposure to PCBs, dioxins and furans, and DDE. DDE also represented a potential risk to osprey and bald eagle based on the bird egg tissue LOE.
- Potential localized risks to shorebirds (represented by spotted sandpiper) were associated with six specific foraging beach areas and based on dietary exposure to PCBs, dioxins and furans, sum DDD, and aldrin.

Amphibians, reptiles, and aquatic plants

- No iCOCs were identified for amphibians, reptiles, and aquatic plants; therefore, no data gaps were identified.

Next Steps

Most of the data needed to complete a baseline ERA have already been collected. The extensive site-specific data set already available for sediments, surface water, TZW, and biological tissues will provide most of the data needed to complete the baseline ERA. The remaining data needs have been identified and the sampling efforts are either underway or achievable through the Round 3 sampling program. Data collected during Round 3 – including sediment, surface water and stormwater chemistry data, lamprey and sturgeon tissue concentration data, lamprey toxicity data and potentially additional benthic toxicity data – will provide additional targeted data to augment the existing data set for assessing ecological risks in the baseline ERA. Further evaluation of data and discussions with EPA and its partners will be helpful in producing the baseline problem formulation, study design and determining final data needs.

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9.0 ROUND 2 ECOLOGICAL RISK ASSESSMENT SUMMARY

This section presents a summary of the ecological risk assessment for the Study Area. The overall objective of this Round 2 ERA is to identify chemicals and exposure pathways that have the potential to drive risks for ecological receptors within the Study Area. Receptors addressed in this Round 2 ERA include benthic invertebrates, fish, wildlife (i.e., fish-eating birds and mammals and shorebirds that feed on invertebrates in the sediment), amphibians and reptiles, and aquatic plants.

The specific objectives of the Round 2 ERA were to: 1) perform and document the results of a conservative screening-level risk assessment of COIs using Site data collected to date, 2) develop a list of Round 2 COPCs based on the conservative screening-level risk assessment assumptions for all receptor groups, 3) perform and document further assessment of the Round 2 COPCs using more realistic risk assessment assumptions and develop a list of iCOCs based on this additional evaluation.[42] The general process for identifying ecological iCOCs is presented in Figure 9.0-1). As with the Round 2 HHRA (Section 8), the results of the Round 2 ERA are used to identify iAOPCs (Section 10) and to identify data needs that must be filled in order to complete a baseline ecological risk assessment (BERA) (Section 12).

The Round 2 ERA (Appendix G) represents an interim phase of the BERA for the Study Area and presents preliminary risk analyses, including documentation of the screening-level ecological risk assessment (SLERA), consistent with EPA guidance (EPA 1989b; 1997a,b; 1998). The Round 2 ERA is consistent with Ecological Risk Assessment Guidance for Superfund (ERAGS) and includes a SLERA. However, the Round 2 ERA goes beyond ERAGS, per EPA Region 10 project-specific directives, because EPA Region 10 requested that iPRGs and iAOPCs be included as part of this Round 2 evaluation. The iPRGs and iAOPCs presented in this Round 2 evaluation are conservative (i.e., protective) because they are based on screening-level assumptions. Ecological exposure assumptions and risk threshold levels will be updated in the BERA using a refined baseline problem formulation and will lead to a final risk characterization based on a weight-of-evidence approach and final PRGs and AOPCs.

For several receptors (e.g., wildlife), this Round 2 evaluation is an update to the draft *Portland Harbor RI/FS Ecological Preliminary Risk Evaluation* (Windward 2005a). The Round 2 ERA was conducted in accordance with the EPA-approved Programmatic Work Plan (Integral et al. 2004b), and ERA interim deliverables (Windward 2004a,b; 2005a; 2006; Windward et al. 2006), and EPA's comments on those deliverables (EPA 2004a; 2006a,b,c,e).

[42]The identification of COCs is beyond the scope of the Comprehensive Round 2 Report. COCs will be identified in the BERA as part of the RI.

9.1 ERA DATA SET

The LWG sampling events and non-LWG sampling events included in the SCRA data set are described in detail in Section 2. The data set used in the Round 2 ERA (hereafter referred to as the ERA data set) is a subset of the data that comprise the SCRA data set. The ERA data set (including sediment, tissue, and water chemistry and sediment toxicity) used to conduct the Round 2 ERA are briefly summarized in Appendix G. Only those non-LWG data included in the SCRA database that are of acceptable data quality for risk evaluation (Category 1/QA2) were included in the ERA data set, as approved in the Programmatic Work Plan (Integral et al. 2004b). The ERA data set includes only those data relevant for ecological exposure pathways: surface (0 to 30.5 cm) sediment,[43] benthic invertebrate and fish tissue, surface water, and TZW collected from shallow (0 to 38 cm) water depths. Other data included in the SCRA data set (e.g., subsurface sediment and deep [90 to 150 cm] TZW samples) were not used in the Round 2 ERA. The following data were used in the Round 2 ERA:

- Surface sediment chemistry data were used to estimate exposure concentrations for relevant ecological receptors based on direct contact (i.e., benthic invertebrates and fish) and dietary exposure (i.e., fish and wildlife).
- Laboratory toxicity data (based on survival and growth) for amphipods (*Hyalella azteca*) and midge (*Chironomus tentans*) larvae were used to define areas of benthic risk and develop a model to predict benthic risks based on sediment chemical concentrations.
- Fish and invertebrate tissue chemistry data collected from the Study Area were used to estimate exposure concentrations (as tissue residues or diet) for appropriate species or groups of ecological receptors (i.e., benthic invertebrates, fish, and wildlife).
- Tissue chemistry data from worms (*Lumbriculus variegatus*) and clams (*Corbicula fluminea*) exposed to Study Area sediments in laboratory bioaccumulation tests were also used to estimate exposure concentrations (as tissue residues or diet) for appropriate species or groups of ecological receptors (i.e., benthic invertebrates, fish, and wildlife).
- Surface water chemistry data were used to estimate surface water exposure concentrations for aquatic receptors (i.e., benthic invertebrates, fish, amphibians, and aquatic plants).
- TZW chemistry data were used to estimate TZW exposure concentrations for benthic invertebrates and benthic fish (i.e., sculpin and lamprey ammocoetes).

[43]Ecological exposures to sediment deeper than 15 cm seldom occur; however, the inclusion of sediments from 0 to 30.5 cm in the surface sediment matrix for ecological receptors was agreed upon by LWG based on EPA's comments (EPA 2005a).

9.2 SELECTED RECEPTORS AND RISK ASSESSMENT APPROACH

Selected ecological receptors and potential chemical exposure pathways evaluated in the Round 2 ERA were identified in Appendix B of the Programmatic Work Plan (Integral et al. 2004b). Receptors may be exposed to chemicals in water or sediment, either directly through dermal contact with or the ingestion of sediments or water or indirectly through the ingestion of food. An ecological CSM was developed for the Programmatic Work Plan and is presented in Map 9.2-1. The CSM illustrates the exposure pathways that chemicals may follow from primary sources to the ecological receptors that were evaluated in the Round 2 ERA. The lines of evidence (LOEs) that were evaluated in this Round 2 ERA to assess risks to all ecological receptors were presented in Appendix B of the Programmatic Work Plan and were further refined based on discussions between LWG and EPA (EPA 2004a, 2005a).

Details on the selected receptors (i.e., benthic invertebrates, fish, wildlife, amphibians/reptiles, and aquatic plants), exposure pathways, and the LOEs used to assess risks are presented in Appendix G.

9.2.1 Benthic Invertebrates

Benthic receptors for the Round 2 ERA were selected to determine whether chemical concentrations in the Study Area are sufficient to cause adverse effects on the survival, growth, or reproduction of benthic invertebrates. The benthic invertebrate community was evaluated as an ecological receptor; shellfish (i.e., clams) and crayfish were also evaluated as separate receptors, per EPA's direction.

The LOEs evaluated to conduct the SLERA and assess risks to the benthic community in the Study Area included the following:

- Interpretation of site-specific sediment toxicity based on laboratory sediment exposures of *Hyalella azteca* and *Chironomus tentans*
- Development and interpretation of predicted sediment toxicity based on models (including the FPM and logistic regression model [LRM]) developed from site-specific toxicity tests and sediment chemistry
- Comparison of site-specific empirical and predicted[44] benthic invertebrate tissue (i.e., field-collected clam tissue, laboratory-exposed clam tissue, laboratory-

[44]Tissue concentrations of selected invertebrate species (i.e., clams [field-collected and laboratory-exposed], worms, and crayfish) were estimated using site-specific sediment concentrations and biota-sediment accumulation factors (BSAFs) or biota-sediment accumulation regressions (BSARs) developed using collocated site-specific data. High uncertainty is associated with predicting tissue concentrations from sediment concentrations. Predicted data are therefore of lower reliability than measured data.

exposed worm tissue, field-collected multiplate invertebrate tissue,[45] and field-collected crayfish tissue) chemical concentrations to tissue-based TRVs

- Comparison of chemical concentrations in near-bottom surface water to ecological screening levels (Eco SLs) developed based on AWQC or other water screening benchmarks
- Comparison of chemical concentrations in TZW to Eco SLs developed based on AWQC or other water screening benchmarks
- Comparison of sediment chemical concentrations to literature-based sediment quality values (SQVs), either consensus-based[46] or empirical[47] SQVs.

The weight-of-evidence approach for identifying Round 2 COPCs and iCOCs for the benthic community based on these LOEs is presented in Sections 9.3 and 9.4, respectively.

The LOEs evaluated to assess risks to the shellfish and crayfish in the Study Area included the following:

- Comparison of empirical and predicted[48] chemical concentrations in shellfish and crayfish tissue (i.e., field-collected clam tissue, laboratory-exposed tissue, and field-collected crayfish tissue) to tissue-based TRVs
- Comparison of chemical concentrations in near-bottom surface water to Eco SLs developed based on AWQC or other water screening benchmarks
- Comparison of chemical concentrations in TZW to Eco SLs developed based on AWQC or other water screening benchmarks.

In addition, the site-specific sediment toxicity tests were used in the risk evaluation for shellfish. The weight-of-evidence approach for identifying Round 2 COPCs and iCOCs for shellfish and crayfish based on these LOEs is presented in Sections 9.3 and 9.4, respectively.

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[45] Invertebrate tissue collected during Round 2 sampling on the multiplate samplers included epibenthic invertebrates and zooplankton.

[46] Consensus-based SQVs were developed to "combine" the wide variety of SQVs available in the literature. SQVs with similar narrative intent were grouped together.

[47] Empirical SQVs were developed based on relationships between sediment chemistry and toxicity.

[48] Tissue concentrations of shellfish (i.e., clams [field-collected and laboratory-exposed]) and crayfish were estimated using site-specific sediment concentrations and BSAFs or BSARs developed using collocated site-specific data.

9.2.2 Fish

Nine fish receptors were selected for the Round 2 ERA to determine whether chemical concentrations in the Study Area are sufficient to cause adverse effects on survival, growth, or reproduction of fish. Largescale sucker, carp,[49] and pre-breeding white sturgeon were selected to represent omnivorous and herbivorous fish; sculpin, peamouth, and juvenile Chinook salmon were selected to represent invertivorous fish; smallmouth bass and northern pikeminnow were selected to represent piscivorous fish; and Pacific lamprey ammocoetes were selected to represent detritivorous fish in the Study Area. Study-Area-wide risks were evaluated for all fish receptors, and a separate analysis was conducted for fish receptors with home ranges smaller than the Study Area (i.e., sculpin, smallmouth bass, and northern pikeminnow) to determine potential risks in localized areas.

The LOEs evaluated to conduct the SLERA and assess risks to fish in the Study Area included the following:

- Comparison of site-specific empirical and predicted[50] fish tissue chemical concentrations to tissue-based TRVs
- Comparison of estimated dietary doses of chemicals using fish receptor-specific parameters and assumptions to dietary dose-based TRVs
- Comparison of chemical concentrations in surface water to Eco SLs developed based on AWQC or other water screening benchmarks
- Comparison of chemical concentrations of dissolved metals (i.e., copper) in surface water compared to concentrations in water associated with olfactory function impairment in migrating adult Chinook salmon populations
- Comparison of chemical concentrations in TZW to Eco SLs developed based on AWQC or other water screening benchmarks
- Comparison of PAH sediment concentrations to literature-derived PAH concentrations in sediment associated with the occurrence of skin or liver lesions in fish.

The weight-of-evidence approach for identifying Round 2 COPCs and iCOCs for fish based on these LOEs is presented in Sections 9.3 and 9.4, respectively.

9.2.3 Wildlife

Six wildlife receptors were selected for the Round 2 ERA to determine whether chemical concentrations in the Study Area are sufficient to cause adverse effects on the survival, growth, or reproduction of wildlife. Spotted sandpiper was selected to

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[49]Carp were included as a surrogate receptor of concern for dioxin-like chemicals, including PCB congeners.

[50]Tissue concentrations of selected fish receptors (i.e., sculpin) were estimated using site-specific sediment concentrations and BSAFs or BSARs developed using collocated site-specific data.

represent sediment-probing invertivorous and omnivorous birds and as a surrogate receptor for herbivorous birds; hooded merganser was selected to represent diving carnivorous and omnivorous birds; bald eagle and osprey were selected to represent piscivorous birds; and mink and river otter were selected to represent carnivorous mammals in the Study Area. Localized risks to spotted sandpipers were evaluated at individual beaches where shorebirds may forage. For all other wildlife receptors, Study-Area-wide risks were evaluated.

The LOEs evaluated to conduct the SLERA and assess risks to wildlife in the Study Area included the following:

- Comparison of estimated dietary doses of chemicals using wildlife receptor-specific parameters and assumptions to dietary dose-based TRVs
- Comparison of estimated bird egg tissue concentrations for selected piscivorous bird receptors (i.e., bald eagle and osprey) to bird egg tissue-based TRVs

The weight-of-evidence approach for identifying Round 2 COPCs and iCOCs for wildlife based on these LOEs is presented in Sections 9.3 and 9.4, respectively.

9.2.4 Amphibians and Reptiles

Amphibian populations were evaluated in the Round 2 ERA to determine whether chemical concentrations in the Study Area are sufficient to cause adverse effects on the survival, growth, or reproduction of amphibians. Reptile populations were not evaluated, and the assessment of risks to amphibians was assumed to be protective of reptiles.

Only one LOE was evaluated to conduct the SLERA and assess risks to amphibians in the Study Area; in this LOE, chemical concentrations in surface water within quiescent habitat areas were compared to Eco SLs developed based on AWQC or other water screening benchmarks.

9.2.5 Aquatic Plants

Aquatic plants (including submergent plants, emergent herbaceous and woody plants, shrubs, and trees along the shoreline of the Study Area) were evaluated in the Round 2 ERA to determine whether chemical concentrations in the Study Area are sufficient to cause adverse effects on the survival, growth, or reproduction of the aquatic plant community.

The LOEs evaluated to conduct the SLERA and assess risks to aquatic plants in the Study Area included the following:

- Comparison of chemical concentrations in surface water within quiescent habitat areas to Eco SLs developed based on AWQC or other water screening benchmarks

- Comparison of chemical concentrations in TZW to Eco SLs developed based on AWQC or other water screening benchmarks.

A comparison of bulk sediment concentrations to relevant TRVs representing plant toxicity was proposed to assess aquatic plant exposure to chemicals in sediments; however, this LOE was not evaluated because no relevant toxicity data were available for the evaluation of the exposure of aquatic plants to chemicals in sediment.

9.3 RESULTS OF ROUND 2 COPC SCREENING ASSESSMENT

A SLERA was conducted for all receptor groups to identify Round 2 COPCs. The weight-of-evidence approach for Round 2 COPC identification was as follows:

- Round 2 COPCs were identified for each LOE.[51]
- Round 2 COPC lists were integrated across LOEs to determine the list of Round 2 COPCs for each receptor group (i.e., benthic invertebrates, fish, wildlife, amphibians/reptiles, and aquatic plants).

In the screening level approach, any chemical that screened in based on any one LOE was carried forward as a Round 2 COPC. All LOEs for all receptors (identified in Section 9.3) were used to identify Round 2 COPCs, with the exception of the SQV comparison LOE for benthic invertebrates, which was given a weight of zero because none of the SQVs in the literature could reliably predict toxicity to the benthic community in the Study Area based on 233 sediment toxicity tests. Therefore, this LOE was not carried forward in the Round 2 ERA.

The process for identifying Round 2 COPCs was consistent across all LOEs and all receptor groups, with the exception of the sediment toxicity LOEs for benthic invertebrates. For all LOEs other than the sediment toxicity LOEs, COIs were defined as those chemicals detected in the relevant media (i.e., tissue or water) for that LOE. Seven crustal elements (i.e., aluminum, beryllium, cobalt, iron, magnesium, manganese, and potassium) were not included as COIs because concentrations of these crustal elements in the Study Area were at or below regional background levels, and/or these elements are ubiquitous in environmental media because they occur naturally. To identify Round 2 COPCs, the maximum concentration of each COI (or maximum estimated exposure dose, for the dietary-dose LOEs) was compared to its respective screening-level toxicological threshold (e.g., Eco SL, TRV). If the maximum exposure concentration or exposure dose (for each LOE) was greater than the screening-level toxicological threshold, the chemical was identified as a Round 2 COPC. The identification of Round 2 COPCs by means of a conservative screen in which maximum concentrations in relevant media are used is consistent with EPA guidance (EPA

[51] The SQV comparison LOE for benthic invertebrates was the only LOE not used to identify Round 2 COPCs.

1997a,b) and an important step in narrowing the list of chemicals to only those chemicals that could potentially pose a risk to ecological receptors.

COIs in sediment for benthic invertebrates based on the predictive sediment toxicity models (FPM and LRM) were identified as those chemicals that were detected at sufficient frequencies to support model development. Round 2 COPCs were then identified as those chemicals associated with observed toxicity.

A summary of the Round 2 COPCs for each receptor group is presented in Table 9.3-1. Details of the evaluation and technical analyses of ecological receptors through the SLERA are presented in Appendix G. Screening-level toxicological thresholds (e.g., chronic Eco SLs, no-observed-adverse-effect-level [NOAEL] TRVs) were developed per EPA's direction to ensure that screening levels were adequately conservative thresholds for environmental protection.

9.4 RESULTS OF ROUND 2 ERA AND IDENTIFICATION OF iCOCS

A further assessment of Round 2 COPCs was conducted for all receptor groups to identify iCOCs that may potentially pose a risk to ecological receptors. iCOC identification relied on the same approach as that used for Round 2 COPC identification, differing only in level of conservatism. The iCOC identification used less-conservative assumptions and incorporated a weighted approach across LOEs in an effort to narrow the list of chemicals and identify the potential areas associated with risks to ecological receptors in the Study Area. A summary of the iCOCs for each receptor group is presented in Table 9.4-1. Final COCs will be identified as part of the BERA. iCOCs were used to identify potential data needs for the BERA and to identify areas that may pose risk to ecological receptors. These areas (i.e., iAOPCs) are presented in Section 10.

Details on the risk assessment analysis, including methods, exposure assumptions (e.g., statistical derivation of UCL exposure point concentrations [EPCs]), and toxicological thresholds (e.g., NOAEL and lowest-observed-adverse-effect-level [LOAEL] TRVs) used to identify iCOCs for all ecological receptors are presented in Appendix G.

9.4.1 Benthic Invertebrates

The FPM, in combination with toxicity testing, was identified as the LOE that best predicted risks to the benthic community and was used to identify iAOPCs (see Section 10) and potential iCOCs for benthic invertebrates. Potential iCOCs for benthic invertebrates based on the FPM were the same as the Round 2 COPCs identified by the FPM as those chemicals statistically associated with toxicity to the benthic community. Because the FPM cannot establish causality between chemicals and toxicity, the chemicals associated with toxicity are identified as potential iCOCs. The identification of potential iCOCs was based on *Chironomus tentans* mortality and growth endpoints, *Hyalella azteca* mortality endpoint, and two effects levels (Levels 2 and 3) defined as 80 and 70 percent, respectively, of the response observed in the control group. The

following potential iCOCs were identified using the FPM: arsenic, cadmium, lead, mercury, silver, zinc, DRH, RRH, total PCBs, alpha-HCH, beta-HCH, delta-HCH, dieldrin, endrin ketone, DDTs (including sum DDD, sum DDE, and sum DDT), and total chlordane, ammonia, and sulfides. In addition, percent fines was identified by the FPM as a physical condition that could affect the benthic community structure.

Benthic invertebrate iCOCs were identified based on the tissue, surface water, and TZW LOEs and included the following: cadmium, copper, zinc, total PAHs, three individual PAHs (BAP, chrysene, and pyrene), total PCBs, and DDTs (including 2,4′-DDD, 2,4′-DDT, 4,4′-DDD, 4,4′-DDE, and 4,4′-DDT). For the tissue LOE, iCOCs were identified as those Round 2 COPCs that exceeded the aquatic TRVs based on the UCL and not driven by outlier data points, indicating a highly limited spatial exposure. For the surface water LOE, potential iCOCs were identified as those Round 2 COPCs that exceeded the Eco SLs based on the UCL. For the TZW LOE, potential iCOCs were identified through the TZW framework.[52] For both the surface water and TZW LOEs, all potential iCOCs were included as iCOCs for benthic invertebrates, if supported by other LOEs. Cyanide, perchlorate, 13 individual PAHs,[53] TBT, and BEHP were retained as potential iCOCs for benthic invertebrates. Potential iCOCs for benthic invertebrates were those chemicals that were associated with high uncertainty or identified by the TZW LOE, but not supported by other LOEs, as posing risks to benthic invertebrates. These potential iCOCs are not expected to pose significant risks to benthic invertebrates because there is limited potential for exposure.

Several uncertainties are associated with the risk characterization of the benthic community based on the FPM; some are related to the structure of the model, and others are related to the data used for making predictions based on the model. Uncertainties associated with model structure include the mathematical assumption that the concentration of each chemical is independent of the concentrations of other chemicals and the summing methods of chemicals. Uncertainties associated with the data used in the model include lack of causality due to mixture of chemicals in the sediment samples, selection of toxicity tests and endpoints used in the model, and limitation in the suite of chemicals analyzed. The effect of these uncertainties on the risk estimate is unknown.

The selected TRVs and Eco SLs and relevance of the TZW pathway to benthic invertebrates are the primary uncertainties associated with the tissue, surface water, and TZW risk characterization for the benthic community. Because the majority of the

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[52]Potential iCOCs in TZW were identified as a subset of Round 2 COPCs in TZW based on an additional screening step using the TZW framework process, as described in detail in Appendix G, Section 3.0. Potential iCOCs were identified to narrow the list of chemicals in TZW to those that may actually pose risks to ecological receptors.

[53]The following PAHs were identified as iCOCs for benthic invertebrates: 2-methylnaphthalene, acenaphthene, anthracene, BAP, benzo[b]fluoranthene, benzo[g,h,i]perylene, benzo[k]fluoranthene, dibenzo[a,h]anthracene, fluoranthene, fluorene, indeno[1,2,3-cd]pyrene, naphthalene, and phenanthrene.

TRVs and Eco SLs were conservative screening values, the risk estimates based on these values are likely overestimated. There is uncertainty associated with the TZW assessment based on the selection of TZW sampling sites at potential source areas and whether TZW data represent appropriate ecological exposure for the benthic community, which may result in an overestimate of risk.

Using both measured toxicity data[54] and predicted toxicity based on the FPM, 79 percent of all sediment sampling locations with chemistry data were classified as non-toxic and 13 percent were classified as toxic. The remaining stations (8 percent) were either not evaluated by the FPM due to limited chemistry data or were identified as indeterminate. The high percentage of stations classified as non-toxic indicates that much of the Study Area does not pose a significant risk to the benthic community.

The areas identified as potentially causing toxicity, using either direct benthic toxicity or the FPM, will be evaluated in more detail in the BERA. Further analysis (i.e., cluster analysis) of the direct benthic toxicity results and FPM-predicted results is presented in Section 10 in order to identify iAOPCs for benthic invertebrates. Most of the areas identified by the FPM as potentially causing adverse effects on the benthic community were also identified through the tissue and water LOEs. Areas identified as indeterminate or with elevated tissue residues (Section 12) will also be evaluated in more detail in the BERA. In cases where benthic invertebrate laboratory-measured toxicity or FPM-predicted toxicity were not definitive, the potential for adverse effects as indicated by other LOEs (tissue or water) were used to identify potential data needs (Section 12).

9.4.2 Fish

For the tissue LOE, fish iCOCs were identified as those Round 2 COPCs (except for physiologically regulated metals) that exceeded the LOAEL TRVs based on the UCL EPC (for wide-ranging fish receptors) or any individual composite location EPC (for small-ranging receptors including sculpin, smallmouth bass, or northern pikeminnow). For the dietary dose LOEs, fish iCOCs were identified as those Round 2 COPCs that exceeded the LOAEL TRVs. For the surface water LOEs, fish iCOCs were identified as those Round 2 COPCs that exceeded the chronic Eco SLs and were supported by other LOEs as chemicals posing potential risk to fish. For the TZW LOE, fish iCOCs were those chemicals that were identified as potential iCOCs through the TZW framework[55] and supported by other LOEs as chemicals posing potential risk to fish.

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[54]The stations were classified as toxic if any of the endpoints from the tests conducted with the 227 sediment samples collected in the Study Area were classified as Effects Level 3 and as indeterminate if any of the endpoints were classified as Effects Level 2.

[55]Potential iCOCs in TZW were identified as a subset of Round 2 COPCs in TZW based on an additional screening step using the TZW framework process, as described in detail in Appendix G, Section 3.0. Potential iCOCs were identified to narrow the list of chemicals in TZW to those that may actually pose risks to ecological receptors.

The fish iCOCs were identified based on the tissue, dietary dose, surface water, and TZW LOEs and included the following: mercury, TBT, BEHP, total PCBs, and DDTs (including 2,4′-DDD, 2,4′-DDT, 4,4′-DDE, 4,4′-DDD, 4,4′-DDT, and total DDTs). Of these iCOCs, PCBs, DDTs, and BEHP are the most likely to pose risk based on an empirical analysis of individual tissue composites of sculpin and/or smallmouth bass. However, Study-Area-wide potential risk estimates based on the dietary dose LOE supported PCBs as potentially posing risks to fish. The potential for risks to northern pikeminnow from mercury was determined based on the empirical analysis of tissue residues. Estimates of Study-Area-wide risks based on the dietary dose LOE suggested that TBT might also pose a risk to fish. Finally, localized exposure to DDT in surface water and TZW and cyanide in TZW potentially pose risk to fish. Cyanide, perchlorate, and 16 individual PAHs[1] were retained as potential iCOCs for fish. Potential iCOCs for fish were identified as those chemicals that were identified by the TZW LOE, but not supported by other LOEs. These potential iCOCs are not expected to pose significant risks to fish because there is limited potential for exposure.The primary uncertainties associated with the risk characterization for all fish receptors are whether the assumptions used (including the relevant exposure scales evaluated and assigned dietary prey portions) and the selected TRVs are appropriate for the BERA. NOAEL TRVs that were extrapolated using uncertainty factors may overestimate risks to fish. Fish iCOCs (i.e., TBT) identified using TRVs selected from a limited toxicity data set are highly uncertain and may overestimate or underestimate risks to fish. Conservative assumptions used to evaluate fish receptors (e.g., use of single tissue composite concentrations to determine risks to selected fish species) may overestimate risks to fish; while other assumptions (i.e., assigned dietary prey portions) may overestimate or underestimate risks to fish. There is uncertainty associated with the TZW assessment based on the selection of TZW sampling sites at potential source areas and whether TZW data represent appropriate ecological exposure for fish, which may result in an overestimate of risk. No LWG-collected tissue data were available for assessing risks to lamprey ammocoetes or pre-breeding sturgeon in Round 1 or Round 2 sampling, and the risks to these selected fish receptors are unknown.

The spatial evaluation to identify areas potentially associated with risk (i.e., iAOPCs) to fish from the iCOCs is presented in Section 10.

9.4.3 Wildlife

iCOCs identified for wildlife were those Round 2 COPCs that exceeded LOAEL TRVs for at least one wildlife receptor (i.e., spotted sandpiper, hooded merganser, bald eagle, osprey, mink, and river otter) or where Round 2 COPCs exceeded a NOAEL TRV for bald eagles (a special-status species evaluated at the individual level) for either the dietary or bird egg tissue LOE.

The wildlife iCOCs identified in the Round 2 ERA are: PCBs (including total PCBs and dioxin-like PCBs expressed as PCB TEQ), dioxins, mercury, DDTs (including sum DDD and sum DDE), and aldrin. Dietary exposure to PCBs and dioxins and furans was identified as potentially posing risks to wildlife receptors. Predicted bird egg DDE concentrations exceeded screening values, indicating potential risk to osprey and bald eagle. Potential localized risks to shorebirds (represented by spotted sandpiper) were associated with six specific foraging beach areas and were based on dietary exposure to PCBs, dioxins and furans, sum DDD, and aldrin. The primary uncertainties associated with the risk characterization for wildlife are whether the dietary assumptions used (including site use factors [SUFs] and the spatial scale evaluation) and the selected TRVs are appropriate for the BERA. NOAEL TRVs that were extrapolated using uncertainty factors may overestimate risks to wildlife. Bird egg TRVs based on field studies and dietary dose TRVs extrapolated using uncertainty factors may overestimate risks to wildlife. Most of the assumptions used to evaluate wildlife receptors were highly conservative (e.g., spotted sandpipers forage and breed from within only the habitat beach areas; the sandpiper diet consists only of laboratory-exposed worms) and may overestimate risks to wildlife. However, the assumption that bald eagles consume only fish may underestimate risks from specific iCOCs (i.e., PCBs). There is additional uncertainty associated with the field-based biomagnification factors used to estimate bird egg tissue concentrations from fish tissue concentrations, which may overestimate or underestimate risks.

The spatial evaluation to identify areas potentially associated with risk (i.e., iAOPCs) to wildlife from the iCOCs is presented in Section 10.

9.4.4 Amphibians and Reptiles

No iCOCs were identified for amphibians and reptiles because risks are not expected at the population level based on the surface water LOE. No risks to amphibians and reptiles in the Study Area are expected because surface water Eco SLs were exceeded in limited areas, and surface water concentrations of Round 2 COPCs (2,4′-DDT, 4,4′-DDT, total PCBs, total DDTs) were never detected at concentrations greater than amphibian-specific toxicity thresholds. Details on the amphibian and reptile risk assessment are presented in Attachment G.

Amphibians and reptiles were not further evaluated. This receptor group will be summarized in the BERA; however, no further analysis will be conducted.

9.4.5 Aquatic Plants

No iCOCs were identified for aquatic plants because risks are not expected at the community level based on the surface water and TZW LOEs. No risks to aquatic plants in the Study Area are expected because TZW samples were often not located within the quiescent habitat areas identified for aquatic plants; surface water and TZW Eco SLs were exceeded in limited areas; and plant-specific toxicity data for the majority of the aquatic plant Round 2 COPCs and potential TZW iCOCs were greater than the Eco

SLs, which suggests that risks based on the Eco SLs are overestimated for aquatic plants. Furthermore, the LWR aquatic plant community consists of species that would be expected to exist in the habitat of an industrial harbor, providing additional evidence that risks to aquatic plants at the Study Area are not significant at the community level. Details on the aquatic plant risk assessment are presented in Attachment G.

Aquatic plants were not further evaluated. This receptor group will be summarized in the BERA; however, no further analysis will be conducted.

9.5 ERA DATA NEEDS AND FUTURE ANALYSES

Data needs affecting the risk evaluation results or ecological receptors and the significance of the spatial extent of ecological risks were identified as part of the Round 2 ERA. Data needs are discussed in Appendix G and Section 12. Data needs represent information or data required to complete the BERA. Filling those data needs will address key uncertainties that will affect the outcome of the BERA and the spatial scale over which risks need to be assessed to support remedy selection for the Portland Harbor Superfund Site.

Key uncertainties include those related to the data and assumptions used to assess risks. Data needs for the ERA are grouped into the following categories:

- Analytical data that can be addressed through the collection and analysis of additional samples
- Further analysis of existing data (e.g., development of predictive modeling)
- Additional review of existing literature, including regional data, toxicological data, and other information to refine exposure estimates, toxicological thresholds, and ultimately, risk estimates.

Table 9.5-1 presents the data needs identified from the Round 2 ERA. The extensive Round 1 and Round 2 sampling of sediment, surface water, TZW, and biological tissues will provide sufficient data for the BERA. Sampling during Round 3 will provide additional targeted data to meet limited data needs for benthic invertebrates and fish.

Data needs, identified by EPA and its partners, that will be filled during Round 3 sampling include:

- The extent of chemical contamination in lamprey ammocoete and pre-breeding sturgeon tissues
- Toxicity of selected chemicals in water to lamprey ammocoetes.

There is also a potential spatial data need regarding indeterminate areas of benthic risks. Additional surface water collected during Round 3 (currently being conducted) will be incorporated into an updated analysis for relevant aquatic receptors in the BERA to

better understand any influence of flow conditions on surface water concentrations for applicable receptor groups (e.g., fish, benthic invertebrates, amphibians/reptiles, and aquatic plants).

Re-evaluation of data during the BERA will determine whether:

- TPHs are appropriate for inclusion in the FPM benthic predictive model
- Exposure assumptions for fish and wildlife dietary models should be further refined
- Assessment of risks to fish and wildlife receptors at the population level can be further developed.

Review of additional literature for benthic invertebrate TRVs may be used to develop more reliable toxicity thresholds for evaluating benthic invertebrate receptors in the BERA.

EXECUTIVE SUMMARY

SECTION 10 – INITIAL AREAS OF POTENTIAL CONCERN

Abstract

Initial areas of potential concern (iAOPCs) were developed by integrating the results of the preliminary risk evaluations. These iAOPCs will be modified based upon the results of Round 3 sampling and, based on determinations made pursuant to the National Contingency Plan (NCP) evaluation criteria, SMAs in the FS. The human health and ecological preliminary risk evaluation results (a total of ten receptors/pathways combined) were translated into initial preliminary remediation goals (iPRGs). Areas within the Study Area with iPRG exceedances, areas that contributed to exceedance of site-wide iPRGs, or areas with other indicators of risk were identified and compiled, resulting in a total of 28 iAOPCs. These iAOPCs range from approximately 0.2 to 40 acres in size. Some iAOPCs exhibited overlapping risks for more than one pathway or receptor, typically in areas of higher iCOC concentrations.

Based on the results of the iAOPC analysis, the following conclusions were made and data gaps identified:

- Additional assessment of the surface water concentrations and inputs must be made in order to conclusively determine whether or not the surface water component will affect what is currently a sediment-based delineation of iAOPCs.
- Further evaluation of the potential iCOCs identified based on TZW is needed in the baseline risk assessment. Depending on the outcome of this evaluation, TZW information may be incorporated into the delineation of final AOPCs/SMAs.
- The issue of the most appropriate approach for addressing background concentration concerns associated with arsenic and PCBs should be addressed in risk management determinations made pursuant to NCP evaluation criteria in the FS and ROD phases of the project.

Additional surface water and sediment trap data are needed to address the first bullet (currently being collected as part of Round 3A). In addition, focused stormwater samples and sediment trap data from specific outfalls within the Study Area will also help with this analysis (this work is currently being scoped by LWG and EPA). Also, some additional data on the spatial and volume extent of contaminated sediments and benthic toxicity in and around some iAOPCs to assist in FS evaluations will be collected in Round 3B. Otherwise, the existing quantity and quality of data is adequate to complete the iAOPC evaluation.

Work Plan and Field Sampling Plan Directives

Numerous risk assessment related work plans and field sampling plan activities were followed in developing the risk assessment results that led to the development of the iAOPCs. These are described in the summaries of Sections 8 and 9. The Work Plan describes a general process of

developing Areas of Potential Concern that become SMAs. A Technical Memorandum on the development of PRGs was submitted to and commented on by EPA in 2005. This section was developed consistent with the Work Plan and the LWG responses to EPA's comments on the PRG Technical Memorandum.

Data Collection Activities

Although no data collection activities were conducted specifically for the purpose of iAOPC development, the identification of the iAOPCs is the culmination of extensive data collection activities implemented through Round 2 sampling for the RI.

Data Interpretation Methods

Two primary steps were involved in developing the iAOPCs. The first step is to develop chemical-specific iPRGs that are protective of both human health and ecological receptors . The first step in the process involves calculating a sediment-based iPRG. This step incorporates the food web model results and biota-sediment accumulation factors (BSAFs) to transition from tissue-based risks to sediment-based risks. Other risks, such as direct sediment contact/exposure, were more straightforward in terms of getting to a sediment-based iPRG and did not involve a food web model or use of BSAFs, and some risk evaluation information was used directly in the determination of iAOPCs.

Once iPRGs were developed, they were compared to the calculated side wide sediment concentrations to identify iAOPCs. Identification of iAOPCs integrates multiple constituents, multiple risk pathways, and multiple risk receptors identified in both the ecological and human health risks. In delineating the size of an iAOPC associated with risks to different receptors within the Willamette River, spatial scales are an important factor. Three basic scales were considered, a *site-wide scale* that was relevant for wide-ranging ecological receptors, an *area-specific scale* for receptors that did not encompass the entire Study Area, but were more wide-ranging than individual sediment stations, and *location-specific* scale for point specific exposures that were represented by an individual sediment station.

As a result of application of individual sediment-based iPRGs and other risk information, individual iAOPCs were developed for ten different pathway/receptor individual iAOPC maps (five human health and five ecological). The individual human health iAOPC delineations include beach sediment ingestion, in-water sediment ingestion, shellfish consumption, site-wide fish consumption, and area-specific fish consumption. The individual ecological iAOPC delineations included benthic community, sculpin, bass, otter, and shorebirds.

Using a process referred to as "hilltopping" and a GIS overlay process for site-wide and area-specific scales of risk as well as location-specific information, iAOPC areas were delineated that consisted of areas of overlapping and contiguous risk or areas that substantially contribute to site-wide scale or area-specific risks for all ten of these receptor/pathway groups and represented reasonably discrete iAOPCs. These iAOPCs represent areas that if a sediment remedial action were to occur, the overall risk for relevant receptors/pathways would be reduced to an acceptable level for area-specific risks and would potentially reduce site-area

wide risks that the area is contributing to. In doing the hilltopping procedure, it was assumed that areas targeted for hilltopping would be replaced with sediment concentrations that are consistent with preliminary current background levels measured upstream of the Study Area. This approach was acceptable for all constituents except arsenic (beach and in-water sediments) and PCBs (human health fish consumption). For these two constituents, preliminary background concentrations were so close to the iPRGs that replacing remediated areas with background results in only a negligible improvement in risk reduction (not to acceptable levels). A better understanding of background conditions for these chemicals will provide for appropriate risk management decisions pursuant to NCP evaluation criteria in the FS and ROD process.

iPRGs were not developed for surface water or transition zone water (TZW). Therefore, the iAOPCs that are delineated do not take into account these media/pathways. For the RI, surface water iPRGs will be developed using Round 3 information, but these iPRGs are not expected to provide substantial information for refining the spational delineation of the sediment AOPCs because of the transient and dynamic nature of surface water in river systems. For TZW, a spatial evaluation comparing the distribution of potential iCOCs based on TZW to the iAOPC locations was conducted.

Preliminary Assessment of Findings

It is important to note that there might be alternative methods to achieve site-wide iPRGs than actually remediating the hilltop areas identified by the process described above. Determining suitable remediation areas is part of the FS process the configuration/location of the iAOPCs that have been initially developed using the hilltopping procedure as the principle basis for some risks for delineating the areas to attain iPRGs will be refined and addressed in the FS using the NCP evaluation criteria. The following summary highlights the key findings of iAOPC delineation process.

- A total of 29 [including T4 and site-wide] iAOPCs were identified within the nine-mile Study Area
- The iAOPCs ranged in size from under 0.2 acres, to just over 40 acres
- Five of the iAOPCs were less than 1 acre; ten of the iAOPCs were between 1 and 10 acres; and thirteen of the iAOPCs were between 10 and 40 acres
- Generally, individual iAOPCs had two or more human health and/or ecological receptors/scenarios driving the risk within that iAOPC
- Typically, the more receptors/scenarios that drove the risk within the iAOPC, the higher the concentrations of iCOCs at that area
- While the use of background concentrations in the hilltopping procedures was effective for most chemicals, it was not effective for arsenic or PCBs because preliminary background concentrations are too high to effectively reduce risk via the "substitution method"

- Where two or more risk areas overlapped, the area was defined as iAOPC regardless of any other mitigating circumstances
- Stations exhibiting benthic toxicity that fell within statistical clusters were also defined as iAOPCs, even in those cases where it was the only line of evidence
- PCBs are the most wide-spread chemical causing the identification of iAOPCs, and PCBs risks are present in almost every iAOPC. In comparison, other chemicals sporadically contribute to iAOPC development in one or several areas
- The iAOPCs encompass all of the locations where TZW concentrations led to the identification of potential iCOCs based on TZW for human health; and all but three of the locations where TZW concentrations led to the identification of potential iCOCs based on TZW for benthic invertebrates.

Additional Data Needs

Round 3 data are needed to assess surface water contributions to potential human health and ecological risks, particularly from exposure to PCBs. Understanding surface water contributions will be helpful in defining preliminary remediation goals (PRGs) in the Remedial Investigation and in assessing the risks and benefits of remedial alternatives in the Feasibility Study. Further evaluation of the potential iCOCs identified based on TZW is needed in the baseline risk assessment. Depending on the outcome of this evaluation, TZW information may be incorporated into the delineation of final AOPCs/SMAs. Also, some additional data on the spatial and volume extent of contaminated sediments and benthic toxicity in and around some iAOPCs to assist in FS evaluations will be collected in Round 3B. The issue of the most appropriate approach for addressing background concentration concerns associated with arsenic and PCBs should be addressed in risk management determinations made in the FS and ROD phases of the project.

10.0 PRELIMINARY IDENTIFICATION OF IAOPCS

This section describes the process through which risk information presented in the previous two sections was evaluated to determine initial Areas of Potential Concern for the RI. These iAOPCs are one step in focusing additional data collection in Round 3B to ensure the data are sufficient to complete the RI/FS. The iAOPCs presented in this section are intended solely for the purposes of evaluating data collected to date and are not intended to represent SMAs[56] or remediation areas. This is because the iAOPCs only represent a partial analysis of information that has been and will be collected and evaluated in the RI. The RI will use the additional data evaluation and data gathering steps identified in Section 12 of this report to define AOPCs. Thus, the primary purpose of iAOPCs defined here is to facilitate the data gaps analysis so that the data necessary to complete the project are collected in Round 3B.

For data gaps identification, areas inside versus outside iAOPCs represent two categories of potential types of data collection or data evaluation needs. For example, areas inside iAOPCs are more likely to be subject to data needs regarding the accurate delineation of risk areas and volumes of sediments in and around the area. These areas are also used to identify data needs regarding potential sources, fate and transport processes, and other physical/chemical characterization in the context of the area-specific CSM development process in Section 11. Data collection or evaluation gaps for areas outside iAOPCs might focus on reducing uncertainties related to those areas, determining whether a site-specific CSM is needed to understand the reason for the area, and whether other types of risk have been accurately assessed and identified in these areas.

The iAOPCs developed for this report were developed based on information from preliminary Round 2 risk assessments presented in Sections 8 and 9 and Appendices F and G. After the risk information was evaluated, some consideration was given to basic physical information about the Study Area to help identify manageable iAOPCs that could be used in area-specific CSM development. Information on upstream (or "background[57]") concentrations of chemicals was also used in iAOPC development in a few limited and necessary instances.

The general approach for developing iAOPCs is described in Section 10.1. Section 10.2 discusses the limited use of background concentrations in the iAOPC development process. Section 10.3 summarizes the iPRGs used to map iAOPCs. Section 10.4 describes the mapping of risk information to help develop iAOPCs. Finally, Section 10.5 compiles the individual risk layers from Section 10.4 into overall iAOPCs.

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[56]SMAs are the areas where remediation alternatives are evaluated in the FS and where remediation is eventually implemented.

[57]Use of this term is not intended to imply any formal or informal definition of background conditions for the site, but rather identify when upstream information presented in Section 6 was used in iAOPC process.

10.1 APPROACH AND METHODS

10.1.1 General Approach

iAOPC development was a compilation and summary of areas within the Study Area associated with potential unacceptable risks due to direct exposure to or bioaccumulation from chemicals in surface sediments. The two primary steps of this process were: 1) iPRG development followed by 2) iAOPC development. These steps are discussed in general first, and then in detail for both human health and ecological risks.

iAOPCs were developed using a combination of risk information from the Round 2 human health and ecological risk assessments summarized in Sections 8 and 9 and detailed in Appendices F and G. These two sources of risk information were first mapped independently and then were "overlain" in a mapping process to generate combined iAOPCs that incorporate both types of risk information.

The Round 2 human health and ecological risk assessments used in the iAOPC development process estimated initial risks associated with surface sediment chemical concentrations. Thus, the iAOPCs presented in this document do not fully account for concentrations of chemicals in subsurface sediments. Such an analysis cannot yet be conducted because areas of subsurface sediment that may be potentially exposed through erosional events have not yet been determined. This erosional analysis is dependent on the findings of the hydrodynamic and sedimentation modeling currently underway. Once this analysis is complete, data gaps associated with subsurface sediments not associated with any current iAOPC can be identified. The process of modeling, identification of erosional areas, review of subsurface data in those areas, and preparation of a field sampling plan to address any data needs in those areas (as necessary) is planned for completion in time for Round 3B subsurface sediment sampling to take place in fall of 2007. Given this schedule, it appears that later identification of subsurface data needs will present no obstacle to timely completion of the RI/FS.

It should also be noted that existing subsurface data in and around each currently identified iAOPC were reviewed for the data gaps analysis in Section 12 to identify general subsurface data needs that may be related to understanding the volume extent in and around surface-sediment-derived iAOPCs.

10.1.1.1 iPRGs

Per the Programmatic Work Plan (Integral et al. 2004b), PRGs are numeric matrix-specific chemical concentrations that are consistent with the Remedial Action Objectives (RAOs) for the project. EPA guidance (EPA 1991a,b) indicates that PRGs are initially set based upon protection of human health and the environment (i.e., site-specific risk-based levels) and Applicable or Relevant and Appropriate Requirements (ARARs). The guidance also indicates that PRGs are modified during the RI/FS process based on "balancing" and "modifying" factors relating to uncertainty, exposure,

and technical feasibility (e.g., background concentrations and analytical practical quantitation limits). Therefore, the terms iPRG and PRG are used in this document to specifically recognize the iterative nature of this approach described in the guidance. Because of the preliminary nature of iPRGs, they can provide a useful tool for data needs and evaluation identification, but they are not considered applicable for identifying final issues and areas of potential concern. For this reason, iPRGs represent reasonable conservative approaches to avoid missing potential issues or areas, and may identify data needs that are later shown to not be critical to the completion of the RI.

Consistent with the Programmatic Work Plan (Integral et al. 2004b), risk-based protective concentrations of COCs, which are those chemicals identified in the Baseline Risk Assessment as posing unacceptable risk, will be used to set PRGs in sediments and water for use in the FS. Consequently, if no risks are found in the Baseline Risk Assessment for some chemicals (i.e., they are not COCs), PRGs are not necessary and are not developed for these chemicals. The list of iCOCs and resulting iPRGs presented in this Round 2 Report may change upon further evaluations for the RI, which will present final COCs and PRGs.

iPRGs for some ecological receptors were not developed due to the level of uncertainties associated with one or more lines of evidence used to assess risk for that particular receptor. That is, the lines of evidence in question were too uncertain to reliably determine an iPRG. In addition, the FWM was successfully applied to estimate iPRGs for human health and ecological iCOCs when a reduction in sediment chemical concentration alone was sufficient to achieve target tissue concentrations (i.e., no change in surface water chemical concentrations was assumed). For some chemicals, sediment iPRGs could not be determined because chemical exposure from surface water alone (i.e., sediment chemical concentration equaled zero) was sufficient to yield tissue chemical concentrations that exceeded target tissue concentrations. As discussed below, a relationship between sediment and water concentrations will be evaluated for the RI, and it may be possible to determine PRGs for these chemicals in future model iterations. The specifics of cases where iPRGs were not developed are discussed in Sections 10.1.2 and 10.1.3.

iPRGs for surface water and TZW are not presented in this report, and were not considered in the development of iAOPCs. One reason for this is that the water risk characterization conducted in Appendices F and G did not indicate unacceptable risks in some cases. Another reason for this is that surface water and TZW concentrations were only evaluated relative to preliminary water screening values. It has not yet been determined in coordination with EPA the appropriate ARARs for these media and which of these screening values would be suitable for use as iPRGs. As previously noted by the LWG (e.g., response to comments on the LWG PRG Technical Memorandum; Integral et al. 2006), at least some of these screening values are not ARARs with respect to some of the receptors and scenarios being evaluated, and are therefore not suitable as iPRGs. The evaluation of surface water and TZW relative to water screening values as required by EPA was conducted and is discussed in the

Round 2 human health (Appendix F) and ecological risk assessment sections (Appendix G).

The approach to evaluation of both surface water and TZW risks as they relate to potential iPRG and iAOPC development is discussed more in the following two subsections, followed by the iPRG and iAOPC development approach for surface sediments.

10.1.1.1.1 Approach for Surface Water

The relationship between sediment chemicals and surface water column chemicals (i.e., through resuspension of sediment into the water column) that results in observed fish tissue chemical concentrations is not yet fully understood, and is therefore a data need. Addressing this need is one of the primary purposes of ongoing Round 3A sediment trap, surface water, and fate and transport evaluations. Once this information is available, a goal for the RI will be to set PRGs for both surface water and sediment that recognize the contributions of COCs in both these matrices to fish tissue concentrations. These PRGs should represent a balanced approach in terms of sediment versus water remediation goals for meeting acceptable levels of those chemicals in fish.

Until the relationship between sediment and water chemicals is understood, assumptions must be made about one of the two matrices to derive an iPRG for the other matrix for this Round 2 Report. Thus, at this time, an iPRG can be derived for one but not both matrices. Given the transient and dynamic nature of surface water, it was much more useful at this stage in the project to make assumptions about surface water chemical concentrations in order to set sediment iPRGs that provide direct means to focus Round 3B investigations of the Study Area.

The assumptions made for surface water concentrations affected the determination of sediment iPRGs presented in this report for those sediment iPRGs calculated through the FWM. The FWM predicts risks to fish or via the consumption of fish (for either wildlife or people). For fish-tissue-related risks, the sediment iPRGs presented in this report were calculated assuming that the presently observed surface water concentrations remain constant (in terms of the Study-Area-wide average concentration used in the FWM). This assumption resulted in lower (more conservative) sediment iPRGs, because all the reduction in fish tissue concentrations must come from lower sediment concentrations and none from lower water concentrations. This assumption avoided overestimating (higher) sediment iPRGs, which might result in missing some iAOPCs, and better supported identifying all potential data needs.

Because of this conservative approach, it appears unlikely that any data needs related to sediment would be missed. In addition, data needs related to understanding surface water concentrations have already been identified and are currently being sampled in Round 3A. Consequently, it appears that there are few if any implications, in terms of timely and complete RI/FS development, caused by not having surface water iPRGs at this time.

10.1.1.1.2 Approach for TZW

The approach for human health and ecological risks are discussed in the following two subsections.

Human Health Evaluation of TZW

While there are no direct exposure pathways for human populations to TZW, a screening evaluation of TZW was conducted as part of the Round 2 HHRA at the request of EPA to assess whether chemicals present in TZW could accumulate in biota that are consumed by humans or could contribute to surface water concentrations. The screening evaluation did not indicate that these are potentially complete exposure pathways nor did it indicate that unacceptable risks exist for these exposure pathways. The human health evaluation of TZW is discussed in detail in Section 6 of Appendix F.

To evaluate accumulation in biota, an adjustment factor of 5,000 was applied to the maximum detected concentrations in TZW, and the adjusted maximum TZW concentrations were compared against the human health AWQC. The TZW adjustment factor was applied to detected concentrations to account for the water ventilation ratio for shellfish, the dietary fraction from a single location, and the target cancer risk level (see Section 6.2.1.3 of Appendix F). To evaluate contributions from TZW to surface water as a drinking water source, surface water concentrations in the river were estimated based on the maximum discharge flow of groundwater and minimum flow in the river and then compared against EPA Region 9 PRGs and MCLs, even though this portion of the river is not currently used as a public drinking water source, nor are there plans to develop a future source of public drinking water from the LWR.

The following chemicals were identified as potential TZW iCOCs through the screening evaluation:

- Total DDD and Total DDT for accumulation in biota
- Chloroform and TCE for contribution to surface water as a drinking water source

These chemicals were considered potential TZW iCOCs even though the Round 2 HHRA did not estimate risks based on TZW data. However, total DDT and total DDD were also identified as iCOCs based on fish and shellfish tissue data, which were used in estimating risks in the Round 2 HHRA. Because TZW was not evaluated as an exposure medium in the Round 2 HHRA and due to the uncertainties and conservatism of the TZW screening, iPRGs were not developed for TZW, and TZW data were not used in identifying iAOPCs for human health.

No further evaluation in the RI is planned for potential human health TZW iCOCs at this time because DDD and DDT are already addressed through tissue data and consideration of the LWR as a source of drinking water requires risk management and policy discussions. Although further evaluation of human health TZW iCOCs is not proposed, an evaluation of the relationship between locations where TZW iCOC

screening levels are exceeded and iAOPC locations identified for other reasons is discussed in Section 10.5, which presents the iAOPCs developed for this report.

The evaluation of locations where TZW iCOC screening levels were exceeded will identify any potential additional data needs related to TZW for the remainder of the RI/FS. Consequently, it appears that there are few, if any, implications in terms of timely and complete RI/FS development caused by not having human health TZW iPRGs.

Ecological Evaluation of TZW

The comparison of TZW concentrations to surface water screening levels (Eco SLs) was an LOE for six ecological receptors: the benthic community shellfish (bivalves), crayfish, sculpin, lamprey ammocoetes, and aquatic plants (Appendix G). The screening process was the same for all receptors. Maximum TZW concentrations for all COIs were compared to Eco SLs to identify Round 2 COPCs. Those chemicals that screened in as Round 2 COPCs were evaluated further based on magnitude, frequency, and spatial extent of Eco SL exceedances. The potential TZW iCOCs identified through this process are cyanide, perchlorate, 2-methylnaphthalene, acenaphthene, anthracene, BAA, BAP, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, fluoranthene, fluorene, indeno(1,2,3-cd)pyrene, naphthalene, phenanthrene, pyrene, 2,4'-DDD, 2,4'-DDT, 4,4'-DDD, 4,4'-DDE, 4,4'-DDT and total DDTs.

In addition to the iCOCs, 30 other Round 2 COPCs were identified based on TZW screening. These were barium, cadmium, copper, lead, nickel, silver, sodium, vanadium, zinc, 1,2-dichlorobenzene, 1,4-dichlorobenzene, dibenzofuran, dalapon, silvex, 1,1-dichloroethene, 1,2,4-trimethylbenzene, 1,3,5-trimethylbenzene, benzene, carbon disulfide, chlorobenzene, chloroethane, cis-1,2-dichloroethene, ethylbenzene, isopropylbenzene, m,p-xylene, o-xylene, total xylenes, toluene, TCE, and vinyl chloride. All the iCOCs and additional Round 2 COPCs will be re-evaluated in the BERA problem formulation, and some of them are likely to be carried forward into the analysis and risk characterization phases of the BERA.

An evaluation of the relationship between locations where ecological TZW iCOC screening levels were exceeded and iAOPC locations is discussed in Section 10.5.

The evaluation of locations where TZW iCOC screening levels are exceeded will identify any potential additional data needs related to TZW for the remainder of the RI/FS. Consequently, it appears that there are few, if any, implications in terms of timely and complete RI/FS development caused by not having ecological TZW iPRGs.

10.1.1.1.3 iPRGs for Surface Sediments

Because of the above considerations, the iPRGs presented in this section are developed for surface sediment and the resulting iAOPCs were identified based on sediment iPRGs and surface-sediment-related risk information. As noted above, surface water iPRGs will be developed using Round 3 information for the RI. Surface water iPRGs

will mainly fulfill the goal of identifying source inputs and acceptable risk levels in river water.

For some chemicals, BSAFs were used to determine iPRGs in sediments that are protective of fish-tissue-related risks. BSAFs attempt to relate all of the chemical concentration in fish tissue to sediment concentrations. Thus, no allowance was given for chemical contributions to fish tissue from other sources (e.g., water column, upstream, stormwater, groundwater, etc.). Again, this assumption will result in relatively lower sediment iPRGs where there are any other waterborne sources of the chemicals in fish tissue and is consistent with the above approach for setting lower sediment iPRGs to ensure that all potential data needs are assessed. iPRGs were developed from BSAFs only if the averaging approach could be applied; otherwise, iPRGs could not be developed for those chemicals (see Appendix E, Section 2.0).

The iPRG results based on the Round 2 human health and ecological risk assessments are discussed and presented in Section 10.3 after the methods discussions in the remainder of this section and Section 10.2.

10.1.1.2 iAOPCs

Depending on the risk receptor, the iPRGs were developed for a specific spatial scale and cannot necessarily be applied directly to individual sample results to identify sediment iAOPCs. Three general spatial scales were considered in the Round 2 ecological and human health risk assessments:

- *Site-wide spatial scale* refers to the entire Study Area and is applicable for wide-ranging ecological receptors (e.g., otter, northern pikeminnow, and osprey) and site-wide human exposures (i.e., ingestion of wide-ranging fish species).
- *Area-specific spatial scale* refers to an assumed exposure area that encompasses an area smaller than the entire Study Area (e.g., 1 river mile) but larger than the area represented by a specific sediment sampling station. Area-specific scales are relevant to defined exposure areas (i.e., human fishing areas and sediment foraging areas for large-home-range wildlife receptors) and to moving exposure areas (i.e., for smallmouth bass), which are smaller than the Study Area but not tied to a specific location.
- *Location-specific (or station-specific) scale* refers to point-specific exposures based on individual sediment sampling stations (i.e., benthos), to exposure areas that are represented by a single composite sample (i.e., human health and shorebird beach sediment stations), or where the home range of a receptor is represented by individual sediment samples (i.e., sculpin).

Table 10.1-1 presents the sediment spatial scales relevant for the use of iPRGs in the delineation of iAOPCs.

For some risks relevant to location-specific scales, information indicating areas of risk (e.g., HQ values for ecological receptors) were used directly to identify iAOPCs rather than using iPRGs (and these cases are noted in Table 10.1-1). Examples of this process include identification of beach areas found to pose unacceptable risk to human health in the Round 2 HHRA, benthic toxicity based on cluster analysis bioassay testing results (as well as toxicity/sediment chemistry correlations using the FPM), and beach areas posing unacceptable risk to shorebirds in the Round 2 ERA.

In all other cases, iPRGs were used to define iAOPCs where sediment concentrations contribute to the exceedance of that iPRG on the appropriate scale of the risk. This process was applied to all scales of risk as defined in Table 10.1-1. For area-specific and site-wide scales of risk, the iPRGs could not be applied on a station-by-station basis. However, the relationship between the individual station-specific sediment chemistry results and the overall sediment chemical concentrations across the appropriate spatial scale was assessed through a method termed "hill topping" (the term "iterative truncations" is also used).

The first step in this process was to compare the site-wide or area-wide average sediment chemical concentration to its corresponding iPRG value. If the "Spatially Weighted Average Concentration" (SWAC) was less than the calculated iPRG for the sediment in the defined exposure area, then surface sediment areas related to risk for this receptor/scenario are unlikely to exist and further analysis was not needed.[58] Otherwise, a hill-topping procedure was used, as well as other procedures to apply iPRGs for each spatial scale. Methods for each spatial scale are discussed in the following subsections.

10.1.1.2.1 Site-Wide Scale Method

Site-wide sediment iPRGs are risk-based concentration goals that should be applied to site-wide average concentrations. The site-wide sediment iPRGs are used as target sediment concentrations that are expected to result in target risk levels for the respective receptors. Site-wide sediment iPRGs were determined by back-calculation from protective chemical concentrations in fish tissue (i.e., protective of fish or people and ecological receptors consuming fish) to protective average sediment chemical concentrations (or sediment iPRGs) using the FWM or BSAFs.

Figure 10.1-1 presents an example of the hill-topping procedure for applying iPRGs at the site-wide scale. (Methods for the area-specific scale are discussed further below.) As shown in Figure 10.1-1, the first step in the hill topping for site-wide sediment

[58]While development of an iPRG typically indicates that a risk threshold is exceeded, there are several reasons why the SWAC might be less than the iPRG. For area-specific scales, a chemical that was identified as an iCOC for the Study Area may not exceed the risk threshold for a given area, so the SWAC would be less than the iPRG for that area. For scenarios where a risk threshold used to identify iAOPCs is different from that used to identify iCOCs, the SWACs may also be less than the iPRGs. Finally, for bioaccumulation, risks were calculated using empirical tissue data, which integrates both water and sediment contributions, so the sediment SWACs could be less than the iPRGs if tissue concentrations are not due entirely to sediment.

iPRGs was to map areas associated with each surface sediment station using an interpolation method known as Thiessen polygons[59]. The Thiessen polygon method utilizes code written into GIS, with boundary conditions (e.g., channel width) set by the GIS user. From this, a site-wide SWAC was calculated for each chemical posing unacceptable risks to human or ecological receptors. The surface sediment stations were then sorted by decreasing chemical concentration, and the highest stations were sequentially removed (in theory) until the recalculated SWAC is equal to or less than the site-wide sediment iPRG. For this "removal" process, some replacement concentration must be applied to the area that is "removed." Assuming no concentration (zero) was not realistic and results in an over-optimistic reduction in the recalculated SWAC with each new area removed. The replacement values were the preliminary "background" concentrations that are presented in Section 10.2.

Per the example graph in Figure 10.1-1, if areas with values greater than 97 parts per billion (ppb) are removed, the example site-wide sediment iPRG of 5 ppb will be achieved. Thus, 97 ppb becomes the hill-top target concentration for delineation of iAOPCs based on site-wide spatial scales. It should be noted that the SWAC and target concentration are dependent on the sediment data set. Therefore, as more sediment data are collected from the Site, the SWAC will change and thus the target concentration that achieves the iPRG will also change. Even if the iPRG does not change in later reports (such as the Baseline Risk Assessment) the target concentration for AOPC development may change due to the collection of more sediment data in Round 3B (if necessary).

It should also be noted that although this method provides a straightforward means to identify areas that contribute to site-wide risks, remediating the areas identified through hill topping is unlikely to be the actual method used to identify effective remedial alternatives in the FS. Rather, FS evaluations will examine ways to clean up Site sediments in the most cost effective manner. Thus, some iAOPCs developed by the above method (particularly where other types of risks do not exist) may not be targeted for remedial alternatives. These remedial alternatives may clean up more sediments in other areas to achieve the same overall goal. Similarly, marginal areas of iAOPCs that are present due to hill topping analyses may be either not subject to remedial alternatives or expanded to nearby areas for an overall remediation that more cost-effectively achieves site-wide goals. Also, the hill-topping method contains assumptions about exposure areas of species that may or may not be accurate to actual population exposures (e.g., no exposure within the river channel). Thus, these assumptions can be a key factor determining the locations that get hill topped, and making different exposure assumptions can result in relatively different hill-topped locations across the Study Area. Finally, other mathematical methods exist to identify areas of higher contribution to bioaccumulative risks that could be considered or used in

[59]Thiessen polygons are one of many interpolation tools that may be employed during the RI/FS to spatially map affected areas. This method has limitations in that chemical gradients or geomorphologic features are not accounted for during the interpolation. Therefore, polygons are used in this initial mapping process only to identify iAOPCs and other methods may be employed in the future.

the future. The assumptions of these methods can also alter the specific hill-topped areas identified.

10.1.1.2.2 Area-Specific Scale Methods

Area-specific sediment iPRGs are risk-based concentration goals that should be applied to area-wide average concentrations for defined exposure areas or home ranges that are smaller than the Study Area. For area-specific scales, two hill-topping methods were used to apply area-specific sediment iPRGs to identify iAOPCs.

Method 1 (Defined Exposure Areas)—The first method is similar to the conversion method described above. This method was used for human health scenarios with defined exposure areas that are smaller than the Study Area, including direct human contact with in-water sediment and ingestion of fish with home ranges smaller than the Study Area (i.e., ingestion of smallmouth bass). This method was not used for any ecological receptors. For this method, the hill-topping procedure was applied to Thiessen polygons across a defined exposure area. Area-specific sediment iPRGs were determined by back-calculation from target risk levels and sediment exposure assumptions. In this case, the SWAC was calculated for the defined exposure area, and stations were "removed" only within that defined area until the recalculated area-wide SWAC was equal to or less than the area-specific sediment iPRG. The area-wide SWAC and target concentration were dependent on the sediment data set for the exposure area. Consequently, the target concentration for iAOPC development was different for each exposure area and is only applicable to that particular portion of the Study Area.

At some locations it is possible for PCB concentrations to be higher outside iAOPCs than inside nearby iAOPCs. The primary reason for the differences in the ranges of PCBs included in iAOPCs is due to hill topping on a river-mile basis for human health area-specific fish consumption (i.e., bass). By establishing a data set for each river mile, the hill top target concentration (i.e., the lowest concentration removed by hill topping) will change by river mile. Anomalies such as these that exist in the iAOPCs will be considered when defining AOPCs and SMAs for the RI and FS.

Method 2 (Moving Exposure Area)—The second method for conversion of area-specific risks was used for ecological assessment of smallmouth bass. This method was not used for any human health scenarios. Like scenarios with defined exposure areas, the smallmouth bass has an assumed exposure area smaller than the Study Area. Unlike scenarios with defined exposure areas, the assumed exposure area for the smallmouth bass was not tied to a specific location (i.e., it can be centered anywhere in the Study Area, excluding the channel, thus the term "moving exposure area"). The moving exposure area for the smallmouth bass was a ¼-mile-radius circle clipped at the shoreline and edge of the navigational channel and is considered representative of the bass exposure area. The SWAC was calculated as the average sediment concentration in this moving exposure area. A moving SWAC was calculated starting at either shoreline ¼-mile below the upstream boundary of the Study Area, shifting the exposure

area 10 ft across the river (excluding the navigational channel) until the far shore was reached, at which point it was shifted 10 ft downstream; this was repeated until the moving SWAC had been calculated for the entire Study Area. The moving SWACs were compared to iPRGs, and the locations where the moving SWAC exceeded the iPRG were noted in a GIS layer. The hill-topping procedure as described in Section 10.1.1.2.1 was then applied to Thiessen polygons in the moving exposure areas where the SWACs exceeded the iPRG until the moving SWAC no longer exceeded the iPRG at any location across the Study Area. The hill-topped Thiessen polygons were highlighted on the Study Area map, and iAOPCs were identified based on the grouping of such highlighted areas. iAOPCs for bass represent polygons that were hill topped based on exceedances in the moving home range exercise.

10.1.1.2.3 Location-Specific Scale Methods

Location-specific sediment iPRGs are risk-based concentration goals that should be applied to individual sediment sampling stations due to either the scale of the exposure or the scale of the sediment data (i.e., composite samples for an exposure area). The location-specific sediment iPRGs were compared directly to individual sediment station concentrations for purposes of identifying initial iAOPCs. As a result, a hill-topping method was not applied for the location-specific scale.

As noted above, for some cases of location-specific risks (indicated with an asterisk in Table 10.1-1), iPRGs were either not developed (e.g., benthic toxicity) or not directly used (i.e., human health beach areas). In these cases the Round 2 risk assessment results were used directly to identify areas based on Thiessen polygons for benthic toxicity or defined usage areas for human health beach areas around the actual stations that pose risk. This approach was applied to reflect realistic exposure areas of ecological and human receptors. In the cases noted in Table 10.1-1, if the area or polygon associated with a sampling location was shown to pose risk through the Round 2 risk assessment process, that area or polygon was simply highlighted with no need for the intermediate step of iPRG development. For human health, this method was used for beach areas because even at naturally occurring concentrations of arsenic, unacceptable risks would still exist (see Section 10.1.2.2).

10.1.2 Human-Health-Specific Methods

The methods used to develop iAOPCs for human health varied depending on the exposure scenario. For the purposes of iAOPC development, the exposure scenarios fall into the following five categories:

- Direct exposure to beach sediment—station-specific scale
- Direct exposure to in-water sediment—area-specific scale
- Shellfish consumption—station-specific scale
- Area-wide fish consumption (i.e., smallmouth bass)—area-specific scale

- Site-wide fish consumption (i.e., black crappie, brown bullhead, carp)—site-wide scale.

The methods used to develop iAOPCs for human health deviated from the general approaches described above when the general approach was not feasible or useful in meeting the objectives of this Round 2 Report. In some cases, iPRGs were not developed for a particular iCOC for a particular exposure scenario, and in some cases iPRGs were developed, but not used to determine iAOPCs for a specific iCOC or scenario. The iPRGs developed for each scenario, and their use in iAOPC determination, are discussed below.

The Round 2 HHRA identified iCOCs that resulted in cancer risks greater than $1x10^{-6}$ or noncancer hazard quotients greater than 1 (see Section 5.3 and Table 5-61 of Appendix F). iPRGs were developed for those iCOCs for the exposure scenarios associated with cancer risks greater than $1x10^{-6}$ or noncancer hazard quotients greater than 1. According to EPA (1991a) guidance, 10^{-4} to 10^{-6} is the risk range used to manage risks as part of a Superfund cleanup. iPRGs were developed based on target cancer risk levels of 10^{-6}, 10^{-5}, and 10^{-4}, and for a target noncancer hazard quotient of 1.

Uncertainties associated with the Round 2 HHRA affected both the development of iPRGs and the ability to delineate human health iAOPCs. Uncertainty occurs at every stage in the Round 2 HHRA and, therefore was incorporated into the iPRGs based on that risk evaluation. Uncertainties associated with the Round 2 HHRA are discussed in Section 7 of Appendix F. In addition to the uncertainties in the Round 2 HHRA itself, there were further uncertainties in developing a relationship between concentrations of iCOCs in biota and sediment that are incorporated into the iPRGs for fish and shellfish consumption. In general, the Round 2 risk assessment approach and methodology were designed to err on the side of conservatism (i.e., protection of human health). Potentially significant sources of uncertainty that may affect the iPRGs and iAOPCs are discussed below within each subsection.

10.1.2.1 Human Health iPRGs

Human health iPRGs were developed for scenarios involving direct exposure to sediment and for fish and shellfish consumption. For the direct exposure scenarios, iPRGs were calculated based on target risk levels and hazard quotients and the intake equations in the Round 2 HHRA. For fish and shellfish consumption, target tissue levels were calculated based on target risk levels and hazard quotients and the intake equations in the Round 2 HHRA. Sediment iPRGs were derived from the target tissue levels using modeled sediment-tissue relationships.

As noted in Section 10.1.1.1, surface water concentrations were assumed to stay constant at the presently observed concentrations for the purposes of deriving relatively lower (more conservative) sediment iPRGs. However, in the case of PCBs for some human health scenarios, the contribution from existing surface water PCB concentrations was sufficient to exceed target risk levels even with zero contribution of

PCBs from surface sediments. Thus, an iPRG for PCBs in sediments cannot be derived for these human health scenarios. For this reason, a comparison to PCB concentrations upstream or downstream of the Study Area may be helpful in determining PRGs. Also, it is possible that iPRGs developed from some combination of sediment and surface water contributions could achieve target risk levels for PCBs under these human health scenarios, but until the relationship between sediment and surface water chemicals is better understood (a data need currently being assessed with Round 3A sampling), it is impossible to derive a sediment iPRG for PCBs based on target risk levels for some human health scenarios for this document.

The human health iPRGs that were used in iAOPC development are presented in tables discussed in Section 10.3.

10.1.2.1.1 Direct Exposure to Sediment

Risks resulting from potential direct exposure to sediment were evaluated in the Round 2 HHRA (Section 5, Appendix F). The scenarios quantified were for direct exposure to either beach sediment or in-water sediment. The risks were calculated using existing sediment data and the equations and exposure assumptions described in Appendix F. The scenarios and chemicals that resulted in risks greater than 10^{-6} or hazard quotients greater than 1 are presented in Table 10.1-2. iPRGs were back-calculated for those scenarios and chemicals based on a target cancer risk or noncancer hazard quotient and the same exposure assumptions as in the forward risk calculations. Target cancer risks of 10^{-6}, 10^{-5}, and 10^{-4}, and a target noncancer hazard quotient of 1, were used in calculating the iPRGs.

Beach Sediment—Beach areas that are accessible to the general public were identified as potential human use areas (see Map 2-1 and Section 2.1.1 in Appendix F). Uncertainties regarding the likelihood, frequency, and nature of beach use exist within the Study Area, but were not explicitly represented in iPRG estimates. Rather, to calculate iPRGs for beach sediment, specific assumptions were made about exposures to beach sediment that could potentially occur. For the recreational scenarios, it was assumed that exposure occurs at the same beach for 94 days (5 days per week in the summer, 1 day per week in the spring and fall, and 1 day per month in the winter) every year for an entire childhood or 30 years for an adult. For the fisher scenarios, it was assumed that exposure occurs at the same beach for 104 to 156 days per year for a minimum of 30 years (recreational and non-tribal high-consumption fishers), and for 260 days every year for 70 years (Native American fisher). For the dockside worker scenario, it was assumed exposure occurs at an individual beach 1 day per week for 50 weeks a year for 25 years. In addition to exposure frequency and duration assumptions, the intake that occurs during beach exposures is also an uncertainty. Default parameters for soil exposure were generally used; however, the adherence factor (dermal contact with sediment) for recreational children was more than 10 times greater than the defaults for soil (which results in more than a 10-fold lower iPRG). Exposure parameters used in the Round 2 HHRA are presented in Section 3 of Appendix F.

In-Water Sediment—As with beach sediment, scenarios for in-water sediment assume ongoing, repeated exposures with the same sediment areas. To calculate iPRGs for in-water sediment, assumptions were made about exposures to in-water sediment that could theoretically occur (see Section 3 of Appendix F). For the fisher scenarios, it was assumed that exposure occurs over the same ½-mile river segment, 25 percent of the time, for the:

- Non-tribal fisher: 104 to 156 days, every year for 30 years
- Native American fisher: 260 days per year, every year for 70 years.

As with beach sediment, the intake that occurs during in-water sediment exposures is an uncertainty.

10.1.2.1.2 Fish and Shellfish Consumption

Risks resulting from fish and shellfish consumption were also evaluated in the Round 2 HHRA (see Section 5 of Appendix F). The risks were calculated using existing tissue data and the equations and exposure assumptions described in Appendix F. The scenarios and chemicals that resulted in risks greater than 10^{-6} or hazard quotients greater than 1 are presented in Table 10.1-3. Target tissue levels were back-calculated for those scenarios and chemicals based on a target cancer risk or noncancer hazard quotient and the same exposure assumptions as in the forward risk calculations. Target cancer risks of 10^{-6}, 10^{-5}, and 10^{-4} and a target noncancer hazard quotient of 1 were used in calculating the target tissue levels. The target tissue levels are presented in Tables 10.1-4 through 10.1-7.

Site-specific fish consumption information is not available for the non-tribal scenarios. As a result, nationwide fish consumption data were used to calculate target fish tissue levels. A limited consumption study conducted for the Columbia Slough was also used (Adolfson 1996). The 99th percentile rate from the nationwide survey was used as the high ingestion rate, the 95th UCL rate from the Columbia Slough study was used as the medium ingestion rate, and the 90th percentile rate from the nationwide survey was used as the low ingestion rate. All three of these rates represent high levels of fish consumption relative to average ingestion rates reported from the respective studies. Fish consumption was assumed to occur at the same ingestion rate every day of every year for 30 years for the non-tribal scenarios. Furthermore, 100 percent of the fish consumed were assumed to be caught at the same location over 30 years, the entire fish was assumed to be consumed, and no reduction in concentrations of contaminants during food preparation and cooking was assumed.

For the Native American fish consumption scenario, the 95th percentile rate from the Columbia River Inter-Tribal Fish Commission (CRITFC) Fish Consumption Study (CRITFC 1994) was used. Fish consumption was assumed to occur at the same rate every day of every year for 70 years. As with the non-tribal scenarios, it was assumed that 100 percent of the fish consumed were caught at the same location for 70 years, the

entire fish was consumed, and no reduction in concentration of contaminants during food preparation or cooking occurred.

There is only anecdotal, unconfirmed information suggesting that shellfish consumption may occur within the Study Area, and Site-specific shellfish ingestion rates are not available. As a result, nationwide shellfish consumption data were used to calculate target tissue levels for clams and crayfish. The 95th percentile rate from the nationwide survey was used as the high ingestion rate and the mean rate from the nationwide survey was used as the low ingestion rate. In the nationwide survey, shrimp, which are not found at the Study Area, accounted for more than 80 percent of the shellfish consumed. Crayfish accounted for less than 1 percent of the shellfish consumed and freshwater clams were not even included in the nationwide survey. Shellfish consumption was assumed to occur at the same rate every day of every year for 30 years. As with fish, 100 percent of the shellfish were assumed to be caught from the same area for the 30 years and no reductions in contaminant concentration were assumed from food preparation or cooking.

Sediment iPRGs were developed using the target tissue levels and sediment-tissue relationships. The sediment-tissue relationship was established through use of the FWM for PCBs; dioxins and furans; and DDD, DDE, and DDT. For other chemicals, BSAFs based on statistically significant regressions were used to establish the sediment-tissue relationships. Because it is not technically defensible to use a tissue-sediment relationship for metals and because metals are naturally occurring, metals were evaluated relative to upstream concentrations, as described below.

Food Web Model—The FWM was used to establish relationships between sediment and tissue for PCBs; dioxins and furans; and DDD, DDE, and DDT. The FWM development and methodology for developing iPRGs are described in detail in Appendix E. The FWM was run iteratively by changing the sediment input concentration until the target tissue level was achieved. At that point, the sediment input concentration was identified as the iPRG.

The predictive accuracy of the FWM was evaluated based on comparison of empirical and modeled tissue concentrations. Overestimating tissue concentrations results in an overly conservative iPRG. For bullhead, crappie, and carp, the predictive accuracy of the FWM ranged from 1.1 to 3.3. In some cases, the model underestimated tissue concentrations, and in other cases it overestimated them. The predictive accuracy of the FWM for bass always overestimated and the predictive accuracy ranged from 1.3 to 11.2, which involves significantly more uncertainty than for the other fish species modeled. The predictive accuracy of the FWM ranged from 1.1 to 5.6 for shellfish. The model consistently underestimated tissue concentrations for clams and always overestimated them for crayfish. The most conservative iPRGs for finfish and shellfish were used in the development of iAOPCs.

Biota-Sediment Accumulation Factors—For the other organic iCOCs not evaluated with the FWM, BSAFs, based on statistically significant regressions, were used to establish the sediment-tissue relationships. The development and methodology of BSAFs for developing iPRGs are described in detail in Appendix E.

BSAFs were developed for fish based on the same trophic levels used in the FWM. The BSAFs used for the four trophic levels were: forage fish for black crappie; benthivore for brown bullhead; piscivore for smallmouth bass; and omnivore for carp. The BSAFs are simply a ratio of the average tissue concentration for a given trophic level to the average sediment concentration for the Study Area. The BSAFs do not account for water or related food web contributions, which, as demonstrated by the FWM, may be significant.

The BSAFs were developed on a sediment organic carbon basis. As a result, the target tissue concentrations for the fish consumption iCOCs were lipid-normalized on a dry weight basis using the average measured lipid and water content concentrations for the trophic level. The lipid-normalized target tissue concentrations were then divided by the BSAF for the respective trophic level and multiplied by the site-wide average TOC concentration. For the mixed-diet iPRGs, the target tissue concentrations were normalized by applying weighted (25 percent for each of the target species) lipid and water content concentrations and multiplying by a weighted BSAF.

For shellfish, data for collocated sediment and benthic invertebrate tissue samples were used to develop sediment-tissue relationships. For crayfish, there were no statistically significant relationships between the tissue and sediment concentrations. Because the organic iCOCs for crayfish were detected in only one or two samples (with the exception of those chemicals evaluated using the FWM), it is not surprising that a relationship could not be established. Due to the limited frequency of detection, iPRGs were not developed for crayfish for chemicals not evaluated in the FWM.

For clams, statistically significant relationships did exist for aldrin, BAA , BAP , benzo(b)fluoranthene, and benzo(k)fluoranthene. Relationships were developed between lipid-normalized tissue, on a wet weight basis, and organic-carbon-normalized sediment, on a dry weight basis. To develop the iPRG, the target tissue concentration was lipid-normalized using the average lipid concentration for field-collected clams. The relationship was then applied to the target tissue concentration and the result was multiplied by the site-wide average TOC concentration to derive the iPRG. Because statistically significant relationships did not exist for all iCOCs, the relationship for aldrin was used for dieldrin and heptachlor epoxide, and the relationship for BAP was used for dibenzo(a,h)anthracene and indeno(1,2,3-cd)pyrene.

The minimum and maximum tissue and sediment concentrations in the data sets were used to develop the relationships. The relationship is most applicable within these concentration ranges. Outside of these concentration ranges there is considerable uncertainty associated with the use of the relationship to predict tissue or sediment

concentrations. The target tissue levels used in developing iAOPCs for shellfish were outside the concentration ranges used to develop the relationships.

Metals—Arsenic, mercury, and zinc were identified as iCOCs for fish consumption. Arsenic was also identified as an iCOC for shellfish consumption. Metals are bioregulated chemicals, so it is not technically defensible to develop sediment-tissue relationships. Metals are also naturally occurring chemicals and may be present in tissue due to background concentrations. For these reasons, the concentrations of arsenic, mercury, and zinc in fish tissue samples collected within the Study Area were compared with concentrations in fish tissue samples collected at upstream locations. As shown in Table 10.1-8, the concentrations within the Study Area are similar to those detected in upstream samples. Because a sediment-tissue relationship cannot be established for metals and because tissue concentrations do not appear elevated over background concentrations, iPRGs were not developed for metal iCOCs for fish or shellfish consumption. As a result, metals were not used in identifying iAOPCs based on fish or shellfish consumption.

10.1.2.2 Human Health iAOPCs

Human health iAOPCs were identified using the sediment iPRGs and the exposure areas evaluated in the Round 2 HHRA (see Appendix F). The human health iAOPCs represent the initial delineation of sediment areas that were used in area-specific CSM development and evaluation of data needs based on potential human health effects. Due to naturally occurring concentrations of arsenic and water-column contributions of PCBs, a target risk level of 10^{-6}, or even 10^{-5} for many exposure scenarios, cannot be achieved through changes in surface sediment concentrations. For example, even if it is assumed that all sediments have concentrations of zero for PCBs or are at background levels for arsenic, unacceptable risks would still exist at these levels for some scenarios. Thus, sediment iPRGs for PCBs cannot be derived for some scenarios due to the water column contributions to fish tissue alone. In the absence of any iPRG for PCBs, iAOPCs based on PCBs in sediment cannot be delineated at this time and a site-wide iAOPC has been identified for those scenarios.

The following sections describe the approaches used to develop iAOPCs for each of the exposure scenarios (i.e., sediment ingestion and fish/shellfish consumption).

10.1.2.2.1 Direct Exposure to Beach Sediment

Beach iAOPCs were identified for individual beaches. Because each beach is represented by a single composite sample, the results for that sample were used to determine whether a beach was identified as an iAOPC.

iPRGs for beaches were initially calculated for a target risk level of 10^{-6} (for carcinogenic iCOCs). However, exposure to naturally occurring concentrations of arsenic in regional soils typically results in risks greater than 10^{-6} for all of the beach use scenarios. Therefore, a target cancer risk level of 10^{-6} cannot be achieved due to the presence of naturally occurring concentrations of arsenic. As a result, the risk for the arsenic concentration in soil recognized by DEQ to represent background levels in

Oregon (7 mg/kg; based on an Ecology study in 1994) was calculated for each of the beach sediment exposure scenarios (Table 10.1-9). The default for arsenic in soil was used for beaches because the range of concentrations of arsenic in the beach sediment samples suggests it is appropriate in the absence of Site-specific background data for soil. Beaches were identified as an iAOPC if the risk for the beach exceeded the risk for the default background arsenic concentration.

10.1.2.2.2 Direct Exposure to In-Water Sediment

The exposure areas for in-water sediment direct exposure scenarios are ½-mile river segments on either shore of the river, excluding the navigation channel. Therefore, iAOPCs for direct exposure to in-water sediment were identified based on ½-mile river segments. SWACs were calculated for each iCOC in each ½-mile river segment. If the SWAC for a segment exceeded the iPRG, hill topping was performed for that segment, as described in Section 10.1.1.

iPRGs for in-water sediment were calculated for a target risk level of 10^{-6}. The iPRG for arsenic for the Native American fisher is below the background value for arsenic for upstream in-water sediment, which indicates that a target risk of 10^{-6} is not achievable for the Native American fisher. Furthermore, the Native American fisher scenario is based on highly conservative exposure assumptions that are not considered realistic for purposes of identifying iAOPCs. As a result, possible iAOPCs for direct exposure to in-water sediment were instead identified based on the non-tribal, recreational fisher scenario, which is the next most conservative scenario (i.e., has the lowest iPRGs of the remaining scenarios). The iPRGs for the non-tribal, recreational fisher are less than an order of magnitude greater than the iPRGs for the Native American fisher, so achieving the iPRGs for the non-tribal fisher would result in risks less than 10^{-5} for the Native American fisher.

10.1.2.2.3 Site-Wide (Carp, Crappie, Bullhead) Fish Consumption

The exposure areas (or home ranges) for carp, crappie, and bullhead may be as large as the Study Area and possibly even larger. In addition, given the exposure durations and ingestion rates used in developing the target tissue levels, it is assumed that fish are caught throughout the Study Area. As a result, iAOPCs for consumption of carp, crappie, and bullhead were identified based on exposure over the entire Study Area. SWACs were calculated for each iCOC for the Study Area. If the site-wide SWAC exceeded the iPRG[60], hill topping was performed across the entire Study Area, as described in Section 10.1.1.

iPRGs were developed for target risk levels of 10^{-6} and 10^{-4} for adults and for a hazard quotient of 1 for children based on ingestion of single species, and based on a mixed

[60] As noted previously, risks related to bioaccumulation were determined in the risk evaluation empirically, through direct evaluation of fish tissue chemical concentrations. Consequently, iCOCs identified in tissue as potentially posing risks using this method may not necessarily be present in sediments at SWACs above the derived sediment iPRG.

diet (in other words, assuming fish consumption consists of 25 percent carp, 25 percent crappie, 25 percent bullhead, and 25 percent bass). Because the mixed diet represents risks from consumption of all species and is more realistic for higher ingestion rates where it may not be possible to consume a single species from the Study Area, the iPRGs for the mixed diet were used to identify iAOPCs. For PCBs, which were evaluated using the FWM, sediment iPRGs could not be developed for the target risk level of 10^{-6} or for the high and medium consumption rates at a target risk level of 10^{-4} or for the hazard quotient of 1 due to water column contributions, for reasons described previously in Sections 10.1.2.1 and 10.1.2.2. The only scenario and target risk level for which a sediment PCB iPRG could be derived based on current water column contributions is the low consumption rate with a 10^{-4} risk. As a result, the PCB iPRGs that were used to identify possible iAOPCs for site-wide fish consumption were developed for the low consumption rate at a 10^{-4} risk.

10.1.2.2.4 Area-specific (Bass) Fish Consumption

While it is still assumed that bass are caught throughout the Study Area, bass may have an exposure area (i.e., home range) smaller than the Study Area. Therefore, iAOPCs for consumption of bass were identified based on the smallest exposure area evaluated in the Round 2 HHRA, which is a single river mile. Furthermore, EPA has commented that bass may not cross the navigation channel, so the navigation channel was excluded from the identification of iAOPCs for consumption of bass. However, based on the City of Portland/ODFW study (Friesen 2005), these assumptions are not valid for all bass and are overly conservative as the home range can be much greater and can span both sides of the river. SWACs were calculated for each iCOC for each river mile. If the river mile SWAC exceeded the iPRG, hill topping was performed across the river mile, as described in Section 10.1.1.

The iPRGs used for bass consumption iAOPCs were the same as for the site-wide species, as the iPRGs are based on a mixed-species diet consisting of carp, crappie, bullhead, and bass. For the same reasons related to water column concentrations discussed for the site-wide species, the iPRGs used to identify possible iAOPCs for bass consumption were developed for the low consumption rate at a 10^{-4} risk.

10.1.2.2.5 Shellfish Consumption

Shellfish consumption, if it occurs, is assumed to occur across the entire Study Area, especially given the ingestion rates used in the Round 2 HHRA. That is, it is highly unlikely that there is enough biomass of shellfish at individual sample locations to support the hypothetical ingestion rates. However, shellfish tissue concentrations may not be accurately predicted based on site-wide averages, as shellfish have a localized home range and the sediment-tissue relationships are not always linear. Therefore, as a highly conservative and health-protective approach, iAOPCs for shellfish consumption were identified based on individual sample locations. In other words, if the result for a given sample exceeded the iPRG, that location was identified as an iAOPC. The navigation channel was excluded from iAOPCs for shellfish consumption due to harvesting difficulties within the channel. It is important to note that iAOPCs were

identified solely based on the exceedance of an iPRG and do not consider whether shellfish are actually present at that location or even theoretically could be present based on habitat suitability.

iPRGs were developed for target risk levels of 10^{-6} and 10^{-4} for both high and low ingestion rates. Because iAOPCs were to be identified based on individual sample exceedances, iPRGs for the high ingestion rate were not used for identifying iAOPCs because that is not a realistic or even possible scenario given the available biomass at the Study Area. Even for the low ingestion rate, identifying the iAOPCs based on individual sample exceedances is an extremely conservative and unlikely scenario given the exposure frequency and duration. At the 10^{-6} risk level, most of the stations across the Study Area exceed the iPRG for PCBs. Therefore, this is not a realistic target risk level and given the numerous uncertainties associated with this scenario, only the 10^{-4} target risk level was used to identify iAOPCs for shellfish consumption.

10.1.2.2.6 Summary of Information Used in iAOPC Development

As mentioned previously, the approach to identifying iAOPCs depended on what would theoretically be achievable through sediment remediation as well as the uncertainties associated with the iPRGs. Consequently, iAOPCs were not developed for every iPRG for every exposure scenario. iPRG development and use in iAOPC determination is summarized in Tables 10.1-10 and 10.1-11. For beach sediment, iAOPCs were developed based on risks greater than risk from background arsenic in soil, so the iPRGs were not used in identifying the beach iAOPCs. For in-water sediment, iPRGs for the non-tribal, recreational fisher were used to develop iAOPCs for in-water sediment based on a risk level of 10^{-6}. For site-wide and area-specific fish consumption, iPRGs for the adult, multi-species diet, low consumption rate, 10^{-4} risk scenario were used in developing iAOPCs. The iAOPCs for both direct exposure to in-water sediment and fish consumption were developed through hill topping. For some chemicals, the iCOCs were not considered in identifying iAOPCs because the SWACs were already less than the iPRGs. Finally, for shellfish consumption, iPRGs for the low consumption rate, 10^{-4} risk scenario were used in developing iAOPCs. The iPRGs for the low consumption rate, 10^{-4} risk scenario were less than detected concentrations for some chemicals and were not used to identify iAOPCs.

10.1.3 Ecological-Specific Methods

The methods used to develop iAOPCs for ecological receptors varied depending on the receptor. For the purposes of iAOPC development, the receptors fall into five categories:

- Benthic community—station/area-specific scale
- Sculpin—station-specific scale
- Smallmouth bass—area-specific scale
- Shorebirds—area-specific scale

- Ecological receptors with site-wide exposure scales (largescale sucker, juvenile chinook salmon, peamouth, hooded merganser, bald eagle, osprey, mink, and river otter).

The Round 2 ERA goes beyond the requirements for such evaluations in ERAGS, per EPA Region 10 project-specific directives, because EPA Region 10 requested that iPRGs and iAOPCs be included as part of this Round 2 Report, which would not normally be done for this level of evaluation. The iPRGs and iAOPCs presented in this Round 2 evaluation are conservative (i.e., protective) because they are based on screening-level assumptions. Ecological exposure assumptions and risk threshold levels will be updated in the BERA using a refined baseline problem formulation and will lead to a final risk characterization based on a weight of evidence approach and final PRGs and AOPCs.

10.1.3.1 Ecological iPRGs

The iCOCs were identified through the Round 2 risk assessment process by receptor group as described in the ERA (Section 9 and Appendix G). iCOCs were identified for each fish and wildlife (includes birds and mammals) receptor. Where an iCOC posed an unacceptable risk to a receptor, an iPRG was developed (i.e., where an iCOC-receptor pair was identified) except where noted in Table 10.1-1 and where unacceptable tissue-related risks occurred due to water column contributions alone (as described above for human health scenarios in Section 10.1.2.1). iPRGs were not developed for mercury, aldrin, TBT and BEHP because BSAF relationships could not be developed for these contaminants (Appendix E). The specific receptor/iCOC pairs where this occurred are detailed below. Additional details on the development of ecological iPRGs are contained in the FWM/BSAF Appendix E. In addition, sediment thresholds for benthos based on the Round 2 ERA were developed for these receptors (as detailed in Appendix G). The contents of these appendices are summarized and placed in the context of overall ecological iPRG and iAOPC development below.

As noted in Table 10.1-1, iPRGs were not derived for benthos and shorebird location-specific scale risk measures. For benthos, benthic toxicity test results and the FPM were used directly in a statistical analysis of station clusters to identify iAOPCs as discussed below. Benthic toxicity test results cannot be used to derive iPRGs because each sediment sample used in toxicity testing contained a mixture of chemicals and, therefore, the FPM cannot predict causality. Individual chemicals apparently associated with the observed toxicity may be indicators of the chemical(s) or physical conditions actually causing the toxicity. Therefore, results of the toxicity tests may be due to a combination of chemical(s) and/or physical conditions. Further, the FPM sediment values obtained cannot necessarily be applied on a point-by-point basis because a point exceedance of this value may not be ecologically significant, even if it is assumed that some causality does exist between that chemical concentration and toxicity. For shorebirds, iAOPCs were developed using an HQ approach, rather than applying iPRGs to Thiessen polygons.

To develop iPRGs for tissue-based measurement endpoints a predictive relationship between chemical concentrations in sediment and tissue was needed. An FWM is preferred over a statistical model because it describes chemical movement and retention between organisms and abiotic media and across trophic levels. The LWR FWM was designed for hydrophobic organic chemicals, so it was used to develop iPRGs for these general types of chemicals: PCBs, DDx, and dioxin-like chemicals (Appendix E).

The Round 2 ERA identified iCOCs for which iPRGs needed to be developed. For the above iCOCs the FWM was applied to derive a relationship between water, sediment, and tissue concentrations. Some uncertainty is associated with FWM-calculated iPRGs because the model's predictive capability is limited. The FWM included representative trophic groups for ecological receptors and were assumed to represent the species of interest, if the particular receptor was not the same as the representative trophic group. iPRGs were developed for the following specific chemicals for iAOPC evaluation:

- Total PCBs
- PCB TEQ—Birds
- PCB TEQ—Mammals
- Dioxin TEQ—Birds
- Dioxin TEQ—Mammals
- 4,4'-DDD
- 4,4'-DDT
- Sum DDT
- Total DDTs.

iPRGs were not developed for the following ecological iCOCs: aldrin, TBT, BEHP, and mercury. With the exception of aldrin, the remaining chemicals are iCOCs for fish. An iPRG for aldrin was developed using the FWM; however, shorebird iAOPCs were based on beach-specific forward-based risk calculations that represent a more appropriate exposure scale. No iPRGs were developed for TBT because risks from TBT to fish were from the dietary dose model and highly uncertain. Additionally, TBT was not analyzed in fish tissues used in the BSAF/FWM analysis and were not mapped in the iAOPC process. High uncertainty exists in both the BEHP data (low detection frequency) and its TRV; therefore, no iPRGs and iAOPCs were developed based on these uncertain data. Mercury is a river-wide contaminant (beyond the Study Area), and therefore no individual iAOPCs were developed (Appendix G).

Numerous FWM runs were used to generate ecological iPRGs. Table 10.1-12 provides the ecological target tissue concentrations, sediment concentrations evaluated, and number of model runs. The methodology for determining the range of sediment concentrations and number of model runs was the same as for the estimation of

ecological and human health iPRGs. All estimated ecological iPRGs fell within the target tissue concentration range.

10.1.3.2 Ecological iAOPCs

iCOC-receptor pairs were identified through risk calculations that identified iCOCs based on tissue or dietary models. iAOPCs were developed based on the primary line of evidence for each receptor group. The primary lines of evidence for each group consist of the following:

- Benthic community—toxicity test results and the FPM
- Wildlife—diet
- Fish—tissue and dietary dose.

All iCOC-receptor pairs were considered for mapping iAOPCs. However, where there was no relationship between sediment and tissue concentrations to calculate an iPRG (e.g., metals) these iCOC-receptor pairs were not mapped. These chemicals will be further evaluated in the BERA and they cannot be mapped with any certainty at this time. A summary of SWAC calculations for ecological receptors is presented in Table 10.1-13. The table shows the summary statistics for each iCOC, the SWAC value, and whether the chemical was included in ecological iAOPC development.

Maps of iAOPCs (presented in Section 10.4) were developed using sediment-based iPRGs through methods appropriate for the risk scale in question as discussed in Section 10.1.1. In cases where the SWAC was less than the iPRG, an iAOPC map was not generated as the existing sediment concentration is lower than the preliminary sediment goal. iAOPCs were identified through the hill-topping process for site-wide receptors and using area- or location-specific methods for receptors whose exposure area is less than the Study Area (as described above). A summary of iAOPC maps developed and iCOC-receptor pairs is presented in Table 10.1-14.

This table also identifies and explains those instances where:

- Sediment iPRGs were developed but not used in iAOPC development (e.g., because the SWAC was less than the iPRG)
- An iAOPC was not developed (e.g., due to uncertainty in the TRV or Round 2 risk assessment approach used).

10.1.3.2.1 Smaller than Site-Wide Exposure Areas

Benthic community, sculpin, smallmouth bass, and spotted sandpiper have exposure areas smaller than the Study Area. iAOPCs were generated for these receptors using various methods depending on the primary line of evidence:

- Benthic community was evaluated through a statistical cluster analysis of the results of the toxicity tests and FPM.

- Smallmouth bass were evaluated using the moving exposure area hill-topping method described above.
- Sculpin iAOPCs were identified where any Thiessen polygon exceeded the iPRG.
- Shorebirds were evaluated based on empirical data at each individual shorebird beach area where the HQ was greater than 1. Where empirical tissue data were not available, tissue data were modeled using the FWM.

Each of these receptors is described in greater detail below.

Benthic Community—Toxicity test results were mapped with the FPM to identify iAOPCs. Toxicity test results and the FPM are the primary lines of evidence for the benthic community; therefore, they were used to develop iAOPCs. Also, for TBT, an LWG-recommended TRV was used to identify potential iAOPCs. TBT exceeded this TRV at one location that is already defined as an iAOPC for other receptors. Chemicals that are statistically associated with toxicity by the FPM are summarized in Table 10.1-15. Concentrations of these chemicals associated with toxicity in the FPM are listed in Appendix G, Section 3, Table 3-33.

The FPM was used for iAOPC identification because, to date, the LWG has not been able to reproduce the results of the LRM (Appendix G, Section 3). iAOPCs were determined for the benthic community by performing a cluster analysis on the Effects Level 3 toxicity results and predictions of toxicity in the FPM. In order to convert the point features of toxicity test results and the FPM into iAOPCs, a statistical cluster analysis called the Gi* statistic was performed. The Gi* statistic, a common tool available in ArcGIS 9.0, identifies the location and significance of clusters of high or low point values by comparing each value to those of its neighbors and calculating a z-score for that value. The z-score determines how alike or dissimilar each point is to its neighboring points based on its significance level. The Gi* statistic was calculated using the FPM and toxicity test ranking values. The neighborhood was defined as 300 ft around each point. Neighborhood size was iteratively tested in increments of 50 ft until the number of points identified for each cluster leveled off. The 300 ft neighborhood was the area at which cluster number stabilized. The weight of each point was standardized by row, meaning that a point within the 300-ft neighborhood has equal weight with any other point in the neighborhood, while a point outside the 300-ft band has a weight of zero. Standardizing the weights ensures that all of the z-scores are comparable among all of the points. This process identifies spatially significant clusters of points for development of benthic iAOPCs. The map of spatially significant station clusters resulting from this analysis is shown in Appendix H. The area of the Thiessen polygon associated with any station falling within a cluster was then mapped to derive iAOPCs associated with spatially significant benthic station clusters.

Sculpin—Total PCBs, Total DDTs, and BEHP were identified as iCOCs for sculpin. No iAOPCs were developed for BEHP due to uncertainty of TRVs and BSAFs.

Furthermore, the site-wide SWAC was less than the iPRG for BEHP and sculpin tissue data had one location with an HQ greater than 1. iAOPCs for sculpin-Total PCBs and sculpin-Total DDTs were identified by comparing surface sediment concentrations to iPRGs. Any polygon that exceeded the iPRG for Total PCBs or Total DDTs was identified as an iAOPC. This approach was developed to reflect sculpin's high site fidelity and small home range.

Smallmouth Bass—Smallmouth bass iAOPCs were evaluated by applying a modified hill-topping method called the "moving exposure area" as described above. This method reflects the smallmouth bass' nearshore habitat in the Study Area by excluding the navigation channel in the hill topping exercise. The exposure area for bass is not tied to a specific location; it can be centered anywhere on the Study Area (excluding the navigation channel).

Two chemicals were identified as iCOCs for smallmouth bass: BEHP and total PCBs. iAOPCs were not developed for BEHP because of uncertainty of the TRVs and BSAFs due to low detection frequency in tissue and sediment. No relationship between tissue and sediment could be developed for BEHP based on the low detection frequency in tissue and sediment. Total PCBs were evaluated applying an iPRG based on an LWG-recommended LOAEL TRV for fish (Fisher et al. 1994).

Spotted Sandpiper—The following iCOCs were evaluated for spotted sandpiper: Dioxin TEQ, PCB TEQ, Total PCBs, Sum DDD, and aldrin. iAOPCs were identified for spotted sandpiper based on empirical data at each individual shorebird beach area. Each area with a LOAEL HQ greater than1 for a given iCOC was identified as an iAOPC.

10.1.3.2.2 Site-Wide Receptors

Receptors evaluated on a site-wide basis, including the navigation channel, consist of largescale sucker, juvenile Chinook salmon, peamouth, northern pikeminnow, hooded merganser, bald eagle, osprey, mink, and river otter. Site-wide receptors were evaluated applying the hill-topping method, as described above.

Largescale sucker—No iAOPC maps for largescale sucker were developed because the iPRG for total PCBs is higher than the SWAC. The target fish tissue concentration (4,020 µg/kg) is based on an LWG-recommended LOAEL TRV for fish.

Juvenile Chinook salmon—No iCOCs were identified for juvenile Chinook salmon in the Round 2 risk assessment procedure and therefore no iAOPC figures were created.

Peamouth—No iCOCs were identified for peamouth in the Round 2 risk assessment process; therefore, no iAOPC figures were created for peamouth.

Northern pikeminnow—No iAOPC figure for northern pikeminnow-total PCBs was generated because the iPRG for total PCBs is greater than the SWAC. The target fish

tissue concentration (4,020 µg/kg) is based on an LWG-recommended LOAEL TRV for fish.

Hooded merganser—No iCOCs were identified for hooded merganser in the Round 2 risk assessment and therefore no iAOPC figures were created.

Eagle and osprey—iAOPC maps for eagle and osprey were not developed because of high uncertainty of bird egg TRVs and the egg modeling Round 2 risk assessment approach.

Mink—Mink iCOCs included dioxin TEQ, PCB TEQ, and Total PCBs. The iPRG for dioxin TEQ is greater than the SWAC; therefore, this iCOC-receptor pair was not mapped. The iPRGs for PCB TEQ and Total PCBs are more conservative for river otter; therefore, the river otter iAOPCs are considered protective of mink.

River otter—iCOCs identified for river otter are PCB TEQ and Total PCBs. iAOPC maps for these chemical-receptor pairs were created and are considered protective of mink.

10.1.4 Compilation of iAOPCs

Information used in generating potential iAOPCs from both Round 2 human health and ecological risk assessments were mapped separately. The final step in the development of iAOPCs was to combine information generated from human health and ecological evaluations into one map of combined iAOPCs. This was a GIS map overlay process, where areas of overlapping and contiguous risks were evaluated to define reasonable individual areas along the river that can be examined further as relatively discrete units for the purposes of CSM development (Section 11) and data needs analysis (Section 12). The methods of this process are described further in Sections 10.4 and 10.5 in the context of results to help better illustrate this mapping process.

10.2 BACKGROUND INFORMATION

In order to support the evaluation and identification of the final data needs for the RI/FS, EPA and the LWG agreed it was necessary to employ the concept of "background" in many of the Round 2 Report analyses. However, it is understood by all parties that the final designation of background conditions for each media has yet to be established for the Study Area. The LWG will work collaboratively with EPA and its partners to establish the final definition(s) of "background," which will be presented in the final RI.

As noted above, information on upstream or background concentrations of chemicals was evaluated and developed for several steps in the iAOPC development process. The primary purpose of evaluation was to provide replacement values for the hill-topping process. This method avoids making the assumption of "zero" replacement

concentration during hill topping, which would be overly optimistic (i.e., results in smaller delineation of iAOPCs) and unrealistic.

EPA has required that background information not be included in iPRGs for the Round 2 Report. The concern expressed is that risks should be summarized such that chemicals are not eliminated due to background issues, and that iPRGs should not be adjusted based on background concentrations until later in the process as a part of risk management in the FS and ROD. In all cases, the iPRGs developed and presented in this document were not adjusted to account for background levels. However, in a few cases of human health exposures to metals, it was impossible to develop meaningful iAOPCs for some scenarios based on such iPRGs. For example, these analyses showed that the entire river (not just the entire Study Area) would be shown to be an iAOPC based on exposure to very low levels of naturally occurring arsenic. These individual exposure scenarios are described more in Section 10.2.2.

10.2.1 Source and Derivation of Background Values

The source and statistical derivation of the preliminary background values used in the hill-topping process for iAOPC development are detailed in Section 6.1.3. Table 10.2-1 lists the preliminary values used for each iCOC. It is important to emphasize that for most iCOCs, these values were based solely on an upriver (RM 15.3 to 26) surface sediment data set that is limited in sample size for many analytes. The determination of final background values for the RI/FS will consist of a weight-of-evidence approach that will evolve from this preliminary approach through Round 3 data collection and the final RI data evaluation. This determination will include an evaluation of multiple data types. These will likely include upstream surface water, sediment trap, and additional bedded sediment data to be collected in Round 3.

10.2.2 Use of Background Values in AOPC Development

As described above, the primary use of background values was in the hill-topping process, which is described in Section 10.1.1.2. Background values for some metals, which are naturally occurring chemicals, were also used in a few additional ways to assist in identifying human health iAOPCs, as described below.

The default background soil concentration of arsenic in soil recognized by DEQ to represent background levels in Oregon (7 mg/kg; based on an Ecology study in 1994) was used as the background concentration of arsenic in beach sediment. This concentration was considered representative of arsenic background in beach sediment based on the range of concentrations detected in beach sediment samples and because human use beach areas include soil as well as in-water sediment. The background concentration of arsenic results in risks greater than 10^{-6} for all of the beach exposure scenarios evaluated in the Round 2 HHRA. Therefore, instead of using a target risk level of 10^{-6}, risks for each of the beach sediment exposure scenarios were calculated at the arsenic background concentration. Beaches where the cumulative risks exceed the risk from background arsenic were identified as iAOPCs.

For in-water sediment, upstream bedded sediment concentrations of arsenic were used to determine the background concentration (Table 10.2-1). The iPRG for the Native American fisher scenario based on the target risk level of 10^{-6} was less than the preliminary background concentration for arsenic. The arsenic iPRGs for all of the other in-water sediment direct exposure scenarios were above this background concentration. The exposure scenario with the lowest iPRGs that was above background (the non-tribal, recreational fisher) was used to identify the iAOPCs for direct exposure to in-water sediment.

For reasons discussed above, it is not technically defensible to establish sediment-tissue relationships for metals. For the fish and shellfish consumption scenarios, upstream concentrations of metals in tissue were compared with concentrations in tissue from the Study Area to determine whether concentrations in tissue are elevated relative to upstream (see Attachment F1). The results from smallmouth bass and brown bullhead tissue samples collected during Round 1 at RMs 20 and 28 were used as the upstream tissue concentrations. For the tissue iCOCs (arsenic and mercury), the tissue concentrations in samples collected upstream were similar to those in samples collected within the Study Area. Therefore, it was concluded that tissue concentrations of metals in the Study Area were not elevated over upstream conditions and iPRGs for metals were not needed for fish and shellfish consumption. Upstream tissue concentrations for all fish tissue iCOCs are presented in Attachment F1.

10.2.3 Background and RI/FS

It should also be noted that, for a number of chemicals evaluated in the hill-topping process, the existing sediment SWAC was very close to the background value used as the replacement value. This means that the theoretical "removal" of each polygon only minimally reduces the overall average concentration toward the iPRG using the hill-topping approach. The result is that very large areas of sediment have to be removed to attain a very small incremental decrease in site-wide sediment chemical concentrations.

Similarly, in the case of PCBs for human health fish consumption, the background replacement value was only slightly below the iPRG itself, which means, regardless of the existing SWAC, large areas have to be replaced in order to attain the iPRGs. For example, the range of PCB values for human health site-wide fish consumption for the SWAC (72 ppb), iPRG (17 ppb), and replacement value (13 ppb) was less than an order of magnitude.

In these cases, a thorough understanding of background conditions (including anthropogenic sources outside the Study Area within the definition of background) is indicated as a primary data need. A better understanding of background conditions for these key chemicals will allow better risk management decisions in the FS and ROD process including addressing such issues as:

- What is the incremental risk benefit of remediation of large areas that results in small changes in the site-wide chemical concentrations?

- What is the potential for background upstream chemical inputs to return remediated areas to levels at or above conservatively derived iPRGs?

Data needs associated with background conditions are identified and discussed in Section 12.

10.3 SUMMARY OF iPRGs

The methods for developing sediment iPRGs are discussed in Section 10.1. The results of those iPRG evaluations for human health scenarios and ecological receptors are presented in the following tables:

Human Health Risk

- Beach sediment iPRGs: Table 10.3-1
- In-water sediment iPRGs: Table 10.3-2
- Fish iPRGs
  - Non-Tribal Adult: Table 10.3-3
  - Non-Tribal Child: Table 10.3-4
  - Native American Adult and Child: Table 10.3-5
- Shellfish iPRGs: Table 10.3-6

Ecological Risk

- Fish iPRGs: Table 10.3-7
- Wildlife iPRGs: Table 10.3-8.

For comparative purposes, the ecological iPRG tables also show the target tissue or dose levels, SWACs, and background replacement values used in the hill topping analysis.

10.4 SUMMARY OF POTENTIAL RISK AREAS

Risk information, primarily in the form of iPRGs, was used to develop iAOPCs using the methods described in Section 10.1. This section describes the results of those evaluations for both human health and ecological risks.

Throughout most of this report, the separate development of areas associated with both human health and ecological risks are referred to as "iAOPCs." However, the actual delineation of iAOPCs needs to encompass both human health and ecological risk areas in a consistent and logical fashion. Consequently, to be clear, for the remainder of this section, the term "risk areas" will be used when referring to human health risks or

ecological risks alone, and "iAOPCs" will refer to the combination of these areas, which are discussed in Section 10.5.

10.4.1 Human Health Risk

Human health risk areas were defined for each of the human health scenarios including:

- Beach sediment direct contact
- In-water sediment direct contact
- Shellfish consumption
- Site-wide fish consumption (i.e., carp, black crappie, brown bullhead)
- Area-specific fish consumption (i.e., smallmouth bass).

Individual maps for the entire Study Area for each of these scenarios are presented in Appendix H. These areas were combined into one map of human health risk areas as shown in Map 10.4-1.

The process of combining these layers was a simple GIS mapping process, where each of the five individual layers above was added to the map, and areas of overlap were assigned colors based on the number of layers overlapping at that point. There was the potential for a combination of up to four human health risk layers to occur in one location because beach areas and in-water sediment exposure areas do not overlap by definition.

The approach of overlapping risk scenarios was used because, where more risk scenarios are expected to occur, there is a greater potential need for risk management and for area-specific CSM development. Also, data needs in these areas of overlapping risks should be evaluated to ensure those important risk areas are fully assessed in the RI. The overlapping scenario approach provides a reasonable surrogate for prioritizing risk areas based on the magnitude of chemical concentrations, which is one potential alternate approach. A general visual review of sediment chemical distribution maps in Section 6 in comparison to Map 10.4-1 (and the similar ecological figure discussed below) reveals that higher chemical concentrations generally occur in areas of the greatest overlapping scenarios for those chemicals found to pose risk (i.e., iCOCs). Thus, as the chemical concentrations in sediment increase, that chemical becomes more likely to exceed a wider range of iPRGs representing more human health scenarios (and ecological receptors).

The need for evaluating chemical concentrations in conjunction with areas of overlapping risk scenarios will be further evaluated in the RI to identify the importance of particular risk areas and to determine whether additional data analysis and presentation techniques are warranted.

10.4.2 Ecological Risk

Ecological risk areas were defined for each of the following ecological receptors based on the Round 2 ERA (except where substantial uncertainty issues occurred as discussed in Section 10.1):

- Benthic community
- Sculpin
- Bass
- Otter (which is protective of mink)
- Shorebirds.

Individual maps for the entire Study Area for each of these receptors are presented in Appendix H. These areas were combined into one map of ecological risk areas as shown in Map 10.4-2.

The process for combining the maps into the final figure was the same as that described for human health risk areas. In this case, areas of multiple overlapping receptors were a general indication of areas that are potentially important for area-specific CSM development and data needs to understand risks for the RI/FS. As discussed above, these overlapping areas tended to occur in areas of higher chemical concentrations of iCOCs.

10.5 OVERALL iAOPCs

As noted above, the individual risk areas, represented by the human health risk and the ecological risk (Maps 10.4-1 and 10.4-2), were combined to create a map for delineation of iAOPCs that considers both these types of risk. The following sections discuss the methods and results of this analysis.

10.5.1 Overall iAOPC Methods

The first step in this process was to simply combine the two figures into one GIS figure showing the 10 layers (five from human health risk and five from ecological risk). Using this combined map, areas of overlapping and contiguous risk were evaluated to obtain a set of reasonably discrete iAOPCs as shown in Map 10.5-1. Not every potential risk area identified on either the human health or ecological risk area maps was necessarily defined as an iAOPC in the combined map. To help facilitate CSM development in Section 11 and data needs identification in Section 12, iAOPC borders were generally drawn around contiguous areas of overlapping potential risks. This process, which is discussed in detail below, differentiated these types of areas from relatively isolated risk areas that were identified through just one line of evidence and where there is little or no corroborating evidence from other measures to suggest the presence of risks at this location.

Such an approach was useful for identifying areas that require CSM development and evaluation at this time, as compared to areas where limited indications of risk may exist and may not warrant full-scale CSM development or remedial scenario evaluation in the future. For data needs identification, areas inside versus outside iAOPCs represent two useful categories of potential types of data collection or data evaluation needs. For example, areas ***inside*** iAOPCs with multiple and overlapping potential risks are more likely, where sample density is not already adequate, to be subject to data needs regarding the accurate characterization of risk areas and volumes of sediments in and around this area. These areas were also used to identify data needs regarding potential sources, fate and transport processes, and other physical/chemical characterization through the area-specific CSM development process in Section 11. Data collection or evaluation gaps for areas ***outside*** iAOPCs might focus on understanding why the area is present, reducing uncertainties related to those areas, whether a CSM is needed to understand the reason for the iAOPC, and whether other types of risk have been accurately assessed and identified in these areas.

The types of data needs relevant to both these types of areas as well as other categories of data needs are presented in Section 12.

The iAOPC identification process followed a relatively simple set of rules discussed below. These rules are an extension of the overall risk process concepts of elevating the importance of areas with multiple lines of risk evidence and reflect the level of certainty associated with the Round 2 risk assessment process for each line of evidence. The rules also consider potential artifacts of the process of extrapolation from site-wide or area-wide risks to station-specific areas as discussed in Section 10.1.

1. ***Where two or more risk areas overlapped, this area was defined as an iAOPC.*** The general concept behind this rule is that an area with multiple lines of evidence indicating potential risks warrants area-specific CSM development and falls within the category of potential data needs related to iAOPCs (as defined above).
2. ***Multiple stations exhibiting benthic toxicity that fell within statistically determined clusters (as discussed in Section 10.1) were defined as iAOPCs.*** The cluster analysis evaluates when groups of benthic stations exhibiting toxicity are spatially significant using the results of bioassay tests, which was one of the strongest and most direct lines of evidence in the Round 2 ERA. Therefore, this line of evidence by itself was considered sufficiently significant to warrant CSM development and place it in the category of data needs related to iAOPCs.
3. ***Human health area-specific fish consumption areas that were not coincident with other risks were not included in iAOPCs.*** These areas occur sporadically throughout the Study Area and are often isolated with respect to other lines of evidence. (Section 10.5.2 discusses more about where and how often this issue occurred.) The reasons for this result were examined and appear to be largely

driven by the area-specific hill-topping approach used for bass. There were considerable assumptions in this approach, including the length of shoreline (i.e., 1 river mile) over which the bass exposure would take place and the affinity of the bass for this segment of shoreline. Further, the hill-topping process identified specific areas based simply on rank order concentrations, and other methods for identifying iAOPCs exist that would potentially result in identification of different areas within each river mile. In summary, the risk information indicated a potential risk is present from exposure to tissue that was composited for that river mile, but it was difficult to associate that risk with specific sediment stations in a limited river mile segment assumed to represent the bass home range. Consequently, these areas did not appear to warrant area-specific CSM development at this time and fall into the category of data needs more closely associated with the conditions outside iAOPCs (as defined above).

4. ***For human health area-specific fish consumption areas (bass) that are contiguous to iAOPCs where multiple other issues are present, the iAOPC was expanded into the bass risk area unless such an expansion radically expanded the iAOPC's footprint.*** This rule is corollary to Rule No. 3 in that other lines of evidence, while not overlapping with these bass risk areas, might indicate continuing but decreasing risks with distance from the center of the iAOPC. A strict rule for limiting this expansion of an iAOPC into nearby bass areas was not adopted, but in general, if the iAOPC would double or more in size by such expansion, these outlying bass areas were treated consistent with Rule No. 3. Also, if the bass risk area was contiguous to an iAOPC that had only one or two risk issues, the iAOPC was not extended into the bass area. In general, there were few iAOPCs where this rule was applied.

5. ***Where human health beach areas were the only risk present, these were not included as an iAOPC (except when directly contiguous with another area of multiple risks, per the previous example)***. As noted in the Round 2 HHRA, the risks present at many of these beach sites were similar to metals background risks. Consequently, these areas appeared not to warrant CSM development and were better categorized with data needs outside iAOPCs. This condition only occurred in two beach areas of the Site, as discussed in Section 10.5.2.

6. ***Where human health direct ingestion of sediment was the only risk present, these were not included as an iAOPC (except when directly contiguous with area of multiple risks, per the previous example).*** This rule was adopted because of issues about risk assumptions and background levels discussed in the human health risk section. These uncertainties indicate these areas (by themselves) did not warrant CSM development at this time and were better categorized with data needs outside iAOPCs. Upon final analysis of the risk areas, this condition did not occur anywhere, and this rule ultimately did not need to be applied.

7. ***Ecological wildlife risks for otter that did not overlap with any other risk area, occurred in the navigation channel, and were entirely isolated from any other***

area of risk were not included as an iAOPC. The condition associated with this rule occurred twice in the river channel (one in the middle of the channel at RM 8 and the other in the middle of the channel at RM 10.5). Including these isolated areas as two additional iAOPCs was inconsistent with all other risk information available for these areas. These areas appeared to be the product of the hill-topping process and the assumptions behind it, including the fact that the large polygon sizes were determined by limited sampling station density in these areas. Consequently, these areas did not appear to warrant CSM development at this time and were better categorized with data needs outside iAOPCs for the same reasons noted in Rule No. 3.

10.5.2 Overall iAOPC Results

Map 10.5-1 illustrates the category of areas that fell outside of iAOPCs (as well as the iAOPCs themselves) using the above rules. There were 37 identified risk areas that were not included within an iAOPC or were not identified as an iAOPC. In all cases, these 37 areas were caused by the individual presence of one of the following four types of risk information:

- Human health beach exposures only (various chemicals)
- Human health area-specific fish consumption (PCBs)
- Ecological otter fish consumption exposures (PCBs)
- Ecological benthic toxicity at one station (uncertain chemicals).

A total of 32 of these 37 areas were present due to the human health area-specific fish consumption risk scenario for PCBs. Thus, this human health scenario was responsible for the vast majority of risk areas categorized outside iAOPCs. Specific PCB risk areas appeared to be present within each river mile, but this was mostly an artifact of using the area-specific hill-topping approach by river mile. Because of the widespread and scattered pattern of these 32 specific areas, those risks appear to be more a function of the same widespread presence of relatively low levels of PCBs throughout the Study Area that was found for site-wide-ranging fish evaluations. Thus, these 32 human health area-specific fish areas appear to be more related to the concept of a site-wide iAOPC for PCBs as discussed further below.

Map 10.5-2 presents the 27 iAOPCs as defined above without showing the risk areas outside iAOPCs to illustrate where area-specific CSMs were developed for Section 11. Table 10.5-1 summarizes the human health scenarios and ecological receptors at risk and iCOCs posing risk in each of these iAOPCs. Also, a site-wide iAOPC (iAOPC 28) is shown at the end of Table 10.5-1 for human health site-wide fish consumption for PCBs for cancer risks at the higher non-tribal and Native American ingestion rates and for noncancer hazards. In these cases, the target cancer risk level of 10^{-4} or hazard index of 1 cannot be achieved through sediment remediation due to water column contributions. Consequently, no discrete areas associated with this risk can be defined

and mapped. There are no other risk drivers or iCOCs in this site-wide iAOPC. If human health area-specific bass consumption were evaluated on a site-wide basis instead, it would fall into this site-wide iAOPC as well.

In addition to the above risk-related rules, other elements of the physical environment, chemical distribution, and general chemical source information were considered when delineating the shapes of iAOPCs. Such factors are useful for delineating logical and manageable sized areas for the purposes of area-specific CSM development in Section 11. These factors were considered only after the risk based delineation was completed and were applied when iAOPCs tended to potentially abut or overlap each other, and/or when large contiguous risk areas were present. Important considerations included splitting large risk areas:

- Within the navigation channel and away from some shoreline iAOPCs because of the very different physical environments
- Across long segments of shoreline where shoreline features such as coves, bends, or inlets existed
- The list of chemicals contributing to risks in different areas
- Where two or more upland areas with relatively well known and different source histories exist.

Map 10.5-3 presents each iAOPC with additional insets depicting the individual layers making up each of the iAOPCs. These maps illustrate the elements combined to develop each iAOPC and are informative for area-specific CSMs (Section 11) as well as identifying potential data needs (Section 12).

Similar to the situation discussed for Rule No. 3 above, a number of iAOPCs (e.g., iAOPCs 2, 8, 25, and 27) are based on a few stations and were present due to hill topping analyses for human health bass consumption and ecological otter risks only. Thus, these iAOPCs were entirely a product of the PCB hill topping analyses at one or two stations without regard to potential artifacts of that process as described above.

10.5.3 Spatial Evaluation of TZW Screening Exceedances

For reasons noted in Section 10.1.1, iPRGs for TZW were not developed for this report, and therefore were not included in the above iAOPC development. However, a comparative analysis of the locations where any TZW screening levels were exceeded and the above iAOPCs was conducted to understand whether any areas of potential interest might lie outside the identified iAOPCs, and thus, to assist in the development of any data needs for Round 3B. This evaluation is described in the next two subsections, first for human health scenarios and then ecological receptors. This evaluation is then used in Section 12 to identify data needs related to TZW.

10.5.3.1 Human Health

As discussed in Section 10.1.1, DDD, DDT, chloroform, and TCE exceeded human health TZW screening levels at select locations. Because total DDT and total DDD were identified as iCOCs for fish and shellfish consumption, iAOPCs were identified using sediment iPRGs for those chemicals derived using the FWM. An iAOPC was identified adjacent to Arkema in part due to total DDT. The Arkema Acid Plant is the only location where the TZW screening levels for total DDT and total DDD were exceeded.

Chloroform and TCE were also identified as potential TZW iCOCs. Based on the loading calculations presented in Appendix D, the vast majority of chloroform loading (> 99 percent) and TCE loading (97 percent) are from TZW discharges offshore of the Arkema Acid Plant and Siltronic, respectively. However, because the LWR is not currently used as a public drinking water source, nor are there plans to develop a future source of public drinking water from the LWR, instances where EPA Region 9 tap water PRGs were exceeded were not considered in identifying iAOPCs.

10.5.3.2 Ecological Receptor TZW

As noted in Section 10.1.1, several iCOCs exceeded TZW screening levels (Appendix G, Section 3). All TZW sampling sites fall within the above iAOPCs with the following three exceptions:

1. Kinder Morgan, where the TZW sampling area is across from iAOPC 5 but not in it. In that area, one PAH exceeded a chronic Eco SL for TZW by a factor of ~3 at one sampling station, and there are two toxic, two predicted indeterminate, three measured indeterminate, and eleven non-toxic locations for benthic toxicity in this area.
2. ARCO, where the middle of the TZW sampling area is in the iAOPC and the edges are outside of it. All stations that exceeded TZW screening levels at ARCO were within the iAOPC.

ExxonMobil (RM 5), where the TZW sampling area does not fall within an iAOPC. Numerous PAH screening levels were exceeded in TZW at this site. Also in this area, there are two measured toxic, one predicted indeterminate, one measured indeterminate, four measured non-toxic, and three predicted non-toxic locations for benthic toxicity.

EXECUTIVE SUMMARY

SECTION 11 – CONCEPTUAL SITE MODEL

Abstract

The CSM describes the current understanding of chemical sources, pathways and receptors in the Lower Willamette River. The analysis consists of two parts, a preliminary evaluation of the relative importance of both historical and current potential loading terms on a site-wide scale and a comparison of the spatial distribution of iCOCs in sediment to known or potential sources on an iAOPC-specific scale. This analysis serves to identify additional data needed to complete the in-water RI/FS and to help inform the DEQ source control program.

Estimates of contaminant mass loading to the Study Area were developed to refine the CSM on a site-wide basis, provide a preliminary assessment of the relative importance of historical and current potential sources to the Study Area, and identify areas of uncertainty.

The iAOPC-specific analysis of relative contributions is primarily a comparison of the spatial distribution of iCOCs in sediment to known or potential sources. The results of the iAOPC-specific CSMs indicate:

- In-water sampling has been conducted at areas of known or likely discharges from upland pathways
- At many iAOPCs, patterns of contamination in in-water media provide preliminary evidence of current and historical upland sources and transport pathways
- The LWG will work closely with DEQ to identify potential on-going sources of iCOCs at the iAOPCs, which may result in the need for additional source control investigation at some upland sites under the DEQ source control program
- iAOPCs that eventually become Sediment Management Areas (SMAs) may require additional in-water sampling during the post-ROD, RD/RA phase to define final remediation areas and volumes and/or evaluate recontamination potential.

Work Plan and Field Sampling Plan Directives

Development and refinement of a CSM is a critical part of the RI/FS process, according to EPA guidance (Principles for Managing Contaminated Sediment Risks at Hazardous Waste Sites [Office of Solid Waste and Emergency Response (OSWER) Directive 9285.6-08 (EPA 2002b)]. A CSM portrays the relationship among sources, chemicals, transport mechanisms), receptors, and other parameters that are determined to be relevant for the site. Per the Programmatic Work Plan, the purpose of the Round 2 CSM is to:

- Focus sampling and other investigations;
- Gain an understanding of potential contaminant loadings from upland sources (including direct discharge, overland transport, groundwater, and bank erosion) and the

scale and relative importance of the various pathways by which contaminants are transported to the river

- Identify where there may be continuing sources of contamination and pathways to the river (including persistent bioaccumulative toxins) based on historical site use, current site information, and analytical data
- Identify and determine the relative importance of historical sources of contamination and pathways to the river
- Identify areas of the river where recontamination of sediments is likely
- Gain insight regarding upland source control strategies and help DEQ identify where additional work must be done by responsible parties and DEQ on upland sites.

The primary function of this CSM is threefold: to structure an initial evaluation of sources of iCOCs to the Study Area and individual iAOPCs, to assess the relative contribution of those sources and pathways, and to identify data gaps for completion of the RI/FS. This information will also be used to help inform the DEQ source control program. The CSM builds on information presented in the previous sections of this report, the Programmatic Work Plan (Integral et al. 2004) and earlier CSM updates (Integral 2004). The CSM will be refined further in the RI/FS, as additional data and other information become available.

Data Collection Activities

Information used to refine the CSM included sediment, water, and biota data collected during Rounds 1 and 2, the Round 2 human health and ecological risk assessments, models and calculations developed for the site, data from the literature, upland site summaries prepared by the LWG and its members (Integral 2004, 2006), and professional judgment.

Preliminary, qualitative to semi-quantitative chemical loading rates for iCOCs entering the Study Area were estimated for upstream surface water, stormwater runoff, upland groundwater plumes, and atmospheric deposition. Rate estimates for the transfer of sediment contamination to the water column by groundwater flow were also generated. No estimates of loading from upstream sediment, bank erosion, permitted wastewater discharges, or historical releases by any loading mechanism (e.g., spills, industrial discharge, stormwater runoff, etc.) were made. A preliminary assessment of the potential relevance of each loading term, including historical contributions, was generated, based on available loading estimates and an understanding of chemical properties for each iCOC.

Surface water loading rates were estimated from high volume/high resolution chemistry data collected from the upstream transect at RM 11 during three sampling events between November 2004 and July 2005. Land use information for the Willamette River basin and stormwater chemical characteristics from published studies provided the basis of stormwater loading estimates. Upland groundwater plume contribution estimates relied on site-specific TZW chemistry and seepage meter data. Groundwater advective transport estimates were based on area-weighted sediment chemistry, estimates of average groundwater flux through the river bottom, and assumed partitioning between the sediment solids and the porewater, based

on literature partitioning constants. Atmospheric deposition to the river surface was derived primarily from literature-reported, regional air quality data and deposition rates (either measured or modeled). A range of estimates was produced for each loading term, reflecting uncertainty in input parameters.

No loading estimates were made for site-specific iAOPCs. Rather, current and historical information about adjacent facility activities, chemical processes or use, waste disposal practices, stormwater management, and chemistry of upland media were used to assess the potential links between the adjacent upland facilities and in the in-river environment for individual iAOPCs.

Preliminary Assessment of Findings

CSM Overview for the Study Area

Receptors, exposure scenarios, and associated iCOCs and potential iCOCs were identified in the Round 2 preliminary risk evaluations and are integrated into the revised CSM for the Study Area. The loading, fate, and transport assessment for the Study Area found that the relative importance of the various external loading terms and fate and transport processes varied by iCOC. In general, however, historical loading from direct discharges of industrial process wastes and wastewater, overwater releases, upstream surface water, upstream sediment, and stormwater runoff are expected to be the most significant loading terms for many of the iCOCs. Current loads from these sources are anticipated to be substantially lower than historical levels.

Among the current loads, upstream surface water loading is expected to be significant. Upstream sediment loading is uncertain and will be assessed following completion of planned Round 3 work, including surface water sampling, sediment grab collection, sediment trap sampling, and additional modeling. Stormwater loading is also a highly uncertain term that will be addressed by planned Round 3 sampling (stormwater sampling at 31 basins around the Study Area). In contrast, current permitted wastewater discharges are expected to be an insignificant current contributor. Upland groundwater plume loading is expected to be locally important for a subset of iCOCs (e.g., LPAHs and DDx pesticides) and potential iCOCs (i.e., cyanide, chloroform, perchlorate, TCE). Current bank erosion is a highly uncertain loading term; however, estimation of this term is not considered necessary for the purposes of the RI/FS and will instead be evaluated on an area-specific basis, as needed, as a part of the remedial design process for each SMA. Finally, atmospheric deposition is expected to be a minor contributor for most iCOCs.

Site-Wide iAOPC CSM

Risks to people eating fish contaminated with PCBs resulted in identification of an iAOPC that encompasses the entire Study Area. PCBs were detected in all media sampled: sediment, tissue, and surface water. (Note: TZW was not sampled for PCBs because PCBs were not identified as upland groundwater chemical of interest). Based on the spatial distribution of PCBs in sediment and the current understanding of current and historical sources, the majority of PCBs in sediment are likely a result of historical overwater releases, upstream releases,

waste and wastewater discharges, and overland transport via stormwater runoff. Ongoing releases of PCBs from stormwater discharge will be evaluated in Round 3 to determine the significance of this pathway. Additional ongoing sources to the Study Area include sediment transport and riverbank erosion at certain sites. Sediment transport will be evaluated in the final RI Report. Atmospheric deposition to the water surface is considered a minor source to the river and will not be evaluated further.

Individual iAOPC CSMs

Twenty-seven individual iAOPCs have been identified throughout the Study Area based on initial human health and ecological risk estimates. Two others are Terminal 4 and the side-wide iAOPC for PCBs. Other iCOCs associated with iAOPC-specific risks varied by location and may have included metals (e.g., arsenic, cadmium, mercury, and zinc), pesticides (e.g., DDD, DDT, and delta-BHC), dioxins, PAHs (e.g., benzo(a)pyrene), and phthalates (bis(2-ethylhexyl)phthalate). Potential iCOCs were also identified at some iAOPCs based on less certain and/or less rigorous evaluations including the floating percentile model (FPM) or other highly uncertain lines of evidence.

As with the site-wide iAOPC, iCOCs in the sediment appear to be primarily related to releases from historical nearshore and upland sources. Overwater activities (including spills), stormwater runoff (including CSOs), waste disposal practices (including in-river disposal or process waste discharge) were potentially the most significant pathways linking upland activities and sources with in-river receptors (sediment and biota). Groundwater discharges from adjacent upland facilities may also have been historically significant for some iAOPCs; however, in most cases the contribution is low compared to releases from associated or concurrent operations. Stormwater discharges are likely the most significant current pathway, but are expected to be significantly less than historical contributions. Sediment transport of contaminants has and continues to redistribute contaminants within the river. The relative contribution of these potential current sources and pathways within the individual iAOPCs will be further quantified in the RI Report.

Next Steps

Refined estimates of physical/chemical fate and transport processes will be developed based on the results of planned Round 3 surface water, sediment, and stormwater sampling and completion of the fate and transport model. Details of these next steps are presented in Sections 7 and 12 of this report.

The understanding of biotic fate and transport will be further developed based on refinements to the food web model that was used to develop iPRGs that defined the iAOPCs. The FWM will be linked to the physical/chemical fate and transport model to assess the relative risk reductions associated with various alternative evaluated in the FS.

11.0 CONCEPTUAL SITE MODEL

The purpose of the Round 2 CSM presented in this section is to describe the current understanding of iCOC loading mechanisms, in-river fate and transport processes, and exposure pathways for human and ecological receptors at the Portland Harbor site. The section presents the Round 2 evaluation of sources of iCOCs to the Study Area to support identification of additional information needs to be addressed in Round 3B of the RI or through coordinated DEQ-led information-gathering efforts. This section builds on information presented in the previous sections of this report, including identification of sources (Section 5), distribution of chemicals in the Study Area (Section 6), overview and estimation of loading, fate and transport terms (Section 7), identification of iCOCs (Sections 8 and 9), and identification of iAOPCs (Section 10). Additionally, this section builds on the CSM previously presented in the Programmatic Work Plan (Integral et al. 2004b) and updated in the CSM Update (Integral and GSI 2004).

Figure 11.0-1 presents a general conceptualization of the iCOC sources, release mechanisms, transport media, and exposure media. The human health and ecological CSMs for the Portland Harbor site are summarized in Map 8.2-1 and 9.2-1, respectively, which illustrate the general relationships between sources, release mechanisms, exposure media and routes, and potential receptors.

The information presented in this CSM focuses on the current understanding of iCOC sources (loading terms), migration pathways, and fate and transport processes based on information available at the completion of Round 2 of the RI/FS process. The loading estimates that were completed are qualitative to semi-quantitative, and are therefore considered very preliminary tools for identification of the historical and ongoing sources and migration pathways at both the harbor-wide scale (Section 11.1) and the individual iAOPC scale (Sections 11.2 and 11.3). The purpose of presentation and discussion of this loading analysis at this stage in the RI/FS process is to examine the information available to-date to allow for relative comparison of the loading terms, with careful consideration to the associated uncertainty and unknowns. This analysis supports the advancement of the CSM and the identification of key uncertainties. This information, in turn, supports identification of remaining data needs for the RI/FS.

The specific objectives of this CSM include the following:

- Identify the key historical and ongoing sources and migration pathways contributing to risk at the harbor-wide and iAOPC-specific scales
- Qualitatively assess the relative magnitude of current and historical sources and migration pathways at the harbor-wide and iAOPC-specific scales.

The CSM is presented in three main subsections. Section 11.1 presents an integrated understanding of how iCOCs and potential iCOCs[61] enter the Study Area (loading) and how they move, transform, and attenuate within the Study Area (fate and transport). Section 11.2 presents the CSM for the site-wide iAOPC. Section 11.3 presents the CSM discussions for the remaining iAOPCs. For each iAOPC, including the site-wide iAOPC, the key processes that contribute to loading of iCOCs and potential iCOCs to in-water media are described based on the distribution of iCOCs and potential iCOCs and current information on sources and pathways. Data gaps and information needs related to refining the understanding of iCOC and potential iCOC sources, loading, fate, and transport—at both the harbor-wide and iAOPC-specific scale and as they affect RI/FS objectives—are identified in Section 12.

11.1 CONCEPTUAL SITE MODEL OVERVIEW FOR THE ENTIRE STUDY AREA

This section provides an overview of the CSM at the scale of the entire Study Area. Section 11.1.1 summarizes the iCOCs and potential iCOCs identified in the Study Area for individual receptors and exposure scenarios in the human health and ecological risk evaluations. Section 11.1.2 briefly reviews the conceptual understanding of individual, loading terms and the important physical, chemical, and biological processes that govern the loading, fate, and transport of iCOCs to the Study Area. These processes are described in greater detail in Section 7 and Appendix D. Finally, Section 11.1.3 addresses the individual iCOCs and potential iCOCs (or group of chemically-related iCOCs and/or potential iCOCs), describing their potential sources; chemical and environmental properties; and loading, fate, and transport behavior at the scale of the entire Study Area. Each of these iCOC-specific subsections concludes with a discussion of the planned path forward for refining the evaluation of iCOC loading, fate, and transport in the remainder of the RI/FS process.

11.1.1 iCOCs and Potential iCOCs

This section presents the combined list of iCOCs and potential iCOCs identified in the human health and ecological risk assessment evaluations (see Sections 8 and 9, respectively). Table 11.1-1 summarizes these iCOCs and potential iCOCs, identifying the risk scenario(s) that resulted in their inclusion.

Categories of iCOCs include:

- Human health iCOCs for fish consumption
- Human health iCOCs for shellfish consumption
- Human health iCOCs for direct sediment contact

[61]Potential iCOCs are differentiated from iCOCs because they were identified through less certain and/or less rigorous evaluations based on fewer lines of evidence.

- Ecological iCOCs for benthic invertebrates
- Ecological iCOCs for fish
- Ecological iCOCs for wildlife.

Categories of potential iCOCs[62] include:

- Potential human health iCOCs in TZW for drinking water scenarios
- Potential human health iCOCs in TZW for consumption of fish/shellfish
- Potential ecological iCOCs for benthic invertebrates (based on the TZW LOE, the floating percentile model (FPM) LOE, or other highly uncertain LOEs)
- Potential ecological iCOCs for fish (based on dietary and bird egg LOEs).

Six chemicals (ammonia, sulfides, lead, silver, diesel-range hydrocarbons, and residual-range hydrocarbons) are identified as potential iCOCs for ecological risk based exclusively on the FPM. Because the FPM only statistically associates chemicals with toxicity and does not establish causality, the identification of these chemicals as potential iCOCs is considered highly uncertain.

As presented in Table 11.1-1, the resulting set of iCOCs and potential iCOCs includes the following chemicals:

- Dioxins/furans expressed as toxic equivalents of 2,3,7,8-TCDD (Dioxin TEQ)
- PCBs (Total PCBs as Aroclors and expressed as toxic equivalents of 2,3,7,8-TCDD—PCB TEQ)
- DDx Pesticides (2,4'-DDD, 2,4'-DDT, 4,4'-DDD, 4,4'-DDE, 4,4'-DDT, total DDD, total DDE, total DDT, and total DDx)
- Non-DDx Pesticides (aldrin, alpha-hexachlorocyclohexane, beta-hexachlorocyclohexane, delta- hexachlorocyclohexane, gamma-hexachlorocyclohexane, dieldrin, endrin, endrin ketone, heptachlor, heptachlor epoxide, total chlordanes)
- Individual LPAHs (2-methylnaphthalene, acenaphthene, anthracene, fluorene, naphthalene, phenanthrene)
- Individual HPAHs (benzo[a]anthracene, benzo[a]pyrene, benzo[b]fluoranthene, benzo[g,h,i]perylene, benzo[k]fluoranthene, chrysene, dibenzo[a,h]anthracene, fluoranthene, indeno[1,2,3-cd]pyrene, and pyrene)
- Total PAHs

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[62]Selection of human health potential iCOCs for drinking water scenarios and consumption of fish/shellfish is described in Appendix F, and summarized in Section 8. The selection of potential ecological iCOCs is described in detail in Appendix G and in Section 9.

- Phthalate esters (bis[2-ethylhexyl] phthalate and dibutyl phthalate)
- SVOCs (pentachlorophenol and hexachlorobenzene)
- Tributyltin (TBT)
- Metals (arsenic, cadmium, copper, lead [based exclusively on the FPM], mercury, silver [based exclusively on the FPM], and zinc)
- Perchlorate
- Cyanide
- VOCs (chloroform, trichloroethene)
- Total petroleum hydrocarbons – based exclusively on the FPM - (diesel- and residual-range)
- Conventional analytes – based exclusively on the FPM – (ammonia and sulfides).

11.1.2 Loading, Fate, and Transport Processes

This section summarizes the external loading terms and the important processes that govern the fate, and transport of iCOCs within the Study Area. This information, which is presented in greater detail in Section 7, is summarized here to provide a concise introduction to the iCOC-specific loading, fate, and transport discussions in Section 11.1.3.

The loading estimates developed in Section 7 and Appendix D include a large range of certainty, from quantitative and empirically based estimates, to semi-quantitative literature-based estimates, to wholly unestimated terms and no estimates of historical contributions for each term. It is recognized that each loading term has a corresponding historical component that may be very significant to the Study Area; however, limited quantitative data are available to support estimates of these historical terms. Therefore, historical loading is discussed only qualitatively in this CSM. Section 5 provides additional qualitative discussion of some historical sources.

Section 11.1.2.1 briefly reviews the definition of each loading term identified in LWG's Response to EPA CSM Questions (Integral et al. 2006) and the status and degree of certainty of its assessment, noting current and historical aspects of each term. Section 11.1.2.2 reviews the important physical, chemical, and biological processes that govern the subsequent fate and transport of iCOCs within the Study Area, along with the assessment methods used in this report (or later in the RI/FS process).

11.1.2.1 External Loading Terms

The potential external loading terms for iCOCs to the Study Area were identified in LWG's Response to EPA CSM Questions (Integral et al. 2006). Each is considered both a potential historical and current loading term. Historical loading for each term could be related to a variety of historical activities in the area, with long histories of operation

over periods of less strict regulation. These activities include wartime shipbuilding and dismantling, chemical and metals manufacturing, utilities, freight distribution, etc. The loading terms, status of assessment, and path forward for further assessment in the RI/FS process are described briefly below:

- **Upstream Surface Water and Sediment Loading:** iCOCs may be released to surface water and sediment upstream of the Study Area from a variety of possible sources, including current and historical activities in the basin. These may include commercial, industrial, private, urban, agricultural, mining, or public sources. iCOCs may enter the river upstream of the Study Area through outfalls, runoff, overwater releases, or by atmospheric deposition. These iCOCs can be transported to the Study Area by surface water flow and bed load sediment transport. For this report, the upstream sediment and surface water loading terms are defined as the mass loading rate passing RM 11 into the Study Area. Semi-quantitative estimates of current upstream loading via surface water are presented in Appendix D, and discussed in detail in the chemical-specific subsections that follow. The surface water loading estimates are considered to be the most accurate and precise of the current loading estimates, though the small range of flow rates reflected in the available Round 2 surface water chemistry data set is a recognized limitation that will be address in Round 3[63].

  Estimates of upstream sediment loading and revised estimates of upstream surface water loading will be generated following planned Round 3 sampling events and completion of the Fate and Transport Model. Historical loading from upstream surface water and sediment may also have been a source of iCOCs currently present in the Study Area. At this time, the historical loading term cannot be quantified, but is recognized as a component of the CSM.

- **Stormwater:** iCOCs present in soils and deposited from the air and human activities onto pavement, roofs, and other impervious or semi-pervious surfaces can be transported to the Study Area by stormwater. Stormwater-related iCOCs are transported mostly via conveyance systems and through over 300 outfalls that discharge to the river in the Study Area. Overland flow of stormwater to the river also occurs in some relatively limited areas. Qualitative estimates of stormwater loading rates, presented in Appendix D, were generated for a subset of relevant iCOCs using a range of literature concentrations supplemented with limited site-specific information and runoff estimates. These Round 2 loading estimates for stormwater are considered highly uncertain due to the necessary reliance on literature values to estimate runoff concentrations at this point in the RI/FS process. Therefore, as part of Round 3, the LWG will undertake collection of stormwater samples at 31 basins around the Study Area drainage.

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[63]While the Round 2 surface water sampling program was designed to evaluate flows for different seasons, flow rates at the time of sampling were all low, ranging from 7,000 to 17,000 cfs. As such, no clear concentration trends as a function of river flow rate can be discerned. Additional sampling is planned in Round 3 to address this issue.

Historical loading of iCOCs from stormwater runoff may also be responsible for iCOCs currently present in the Study Area. It is likely that historical stormwater loading rates of iCOCs, prior to implementation of upland stormwater runoff controls in some areas, were higher than current loading rates. At this time, the historical loading term cannot be quantified, but is recognized as a component of the CSM. As stated above, stormwater sampling will be performed as part of Round 3 to provide a better understanding of current stormwater loading term.

- **Upland Groundwater Plume Discharge:** Upland groundwater plumes flowing toward the river are a possible source of chemicals to in-river sediments, TZW, and surface water in the Study Area. The upland groundwater plume loading term is distinguished from the mechanism of groundwater as an advective force for transport of contamination originating in sediment to the water column (termed advection through sediment). Advection through sediment is considered a transport process within the Study Area, as opposed to an external loading term. Semi-quantitative estimates of current upland groundwater plume discharge rates are presented in Appendix D, based on empirical data. These loading estimates are expected to be conservatively high, due to the assumptions and calculation approach, as discussed in detail in Appendix D.4.1.3.

  Overall groundwater loading to the transition zone may have been more significant historically, prior to institution of groundwater controls at several upland sites. However, the time delay in transport of chemicals released to upland groundwater to the river can be significant, making it difficult to predict or generalize about the duration of migration or the timing of the peak concentrations. At this time, the historical loading term cannot be assessed, but is recognized as a component of the CSM. No additional investigation of the upland groundwater plume discharge term is planned for the RI/FS.

- **Groundwater Advection through Sediments:** Advective transport of iCOCs in the sediment-porewater environment refers to the aggregate movement of chemicals by flow of porewater through the sediments. Flow through the sediments to the water column occurs in the form of groundwater discharge. This mechanism is a transport process for chemicals in the sediment-porewater environment to migrate to the water column. The analysis of advective transport focuses on iCOCs that are generally widespread throughout the sediment in the Study Area and not necessarily associated with areas of upland groundwater plume discharge. Qualitative estimates of loading to surface water from advection through sediments are presented in Appendix D. These estimates generally cover a large range and are considered uncertain, reflecting the large range of published equilibrium partitioning values, but adequate for the purposes of general comparison with other terms.

  Historical transport of chemicals to the water column by this mechanism may have played a small role in the current distribution of iCOCs in the Study Area; however, quantification of this historical process is not needed for completion of

the RI/FS. No additional investigation of the current or historical groundwater advection term is needed for completion of the RI/FS.

- **Atmospheric Deposition:** Air pollution (e.g., vehicle and industrial emissions, other combustion products, fugitive dust, etc.) can enter the river directly through the processes of dry and wet deposition. This term is defined here as deposition directly to the river surface over the Study Area. Air deposition to the Study Area watershed, which subsequently reaches the river by runoff, is considered separately in the stormwater loading term. Likewise, air deposition to the upstream watershed and water surface is considered in the upstream loading terms. Qualitative estimates of direct air deposition loading rates were generated in Appendix D for a subset of relevant iCOCs, using literature values for air concentrations and for deposition velocities. These estimates for air deposition are considered highly uncertain due to the necessary reliance on literature values for concentrations and deposition rates, but adequate for the purposes of general comparison with other terms.

  It is possible that overall atmospheric loading to the Study Area may have been more significant historically, prior to widespread adoption of emissions controls and cessation of the production and use of certain chemicals (e.g., pesticides and PCBs). No additional investigation of the current or historical atmospheric deposition term is needed for completion of the RI/FS.

- **Permitted Wastewater Discharges:** Wastewater from commercial, industrial, private, or public outfalls may be directly discharged to the Study Area. These wastewater discharges may contain iCOCs, and are required to be permitted under the National Pollutant Discharge Elimination System (NPDES), and many of these waste streams undergo pretreatment prior to discharge. It should be noted that, because these are regulated discharges, it is assumed that significant exceedences of permit standards or limits are likely rare, and it is expected that loading estimates for permitted wastewater discharge would be minor compared to other loading terms.

  It is generally understood that loading to the Study Area from industrial discharge was more significant historically, prior to adoption and regulation of discharge permits and controls, and may have been a significant historical source of iCOCs that currently remain in the Study Area. Estimates of current loading rates from wastewater discharges were not developed for this report, but will be included in the RI report as needed. Estimates of historical loading terms cannot be generated due to limited information; however, this information is not considered necessary for the RI/FS.

- **Riverbank Erosion:** Erosion of bank soils by stormwater runoff or river flows is a potential source of iCOCs to the in-water portion of the Study Area. Wind erosion, shoreline construction, other human activities, activities of animals, etc. are also possible erosion mechanisms. (Note: Construction is considered a minor contributor because such projects are regulated and permitted to minimize erosion of soils into surface waters.) Sporadic mass wasting or slumping events

can also occur as bank slopes become over steepened or otherwise unstable. No loading rate estimates for riverbank erosion were generated for this report due to extremely limited available riverbank soil chemistry data and bank condition information.

Bank erosion to the Study Area is likely to have been more significant historically, prior to installation of erosion controls in many areas, including riprap and sea walls. The composition of bank soils historically is highly uncertain; therefore, the overall impact of historical bank erosion is uncertain. Collection of upland data to evaluate riverbank erosion may be necessary, in the context of recontamination potential, to support development of the remedial design; however, quantification of current and historical riverbank erosion is not considered necessary for the RI/FS.

- **Overwater Releases:** Chemicals released by historical overwater activities (e.g., sandblasting, painting, material transfer, maintenance, repair, and operations at riverside docks, wharves, or piers), discharges from vessels (e.g., gray, bilge, or ballast water), fuel releases, and spills likely affected the Portland Harbor Superfund Site. These releases from overwater activities are categorized as historical and are not considered quantifiable; however, these releases are considered a significant source of the existing contamination in the Study Area, and therefore important in the overall CSM. While improved BMPs are likely to significantly reduce the occurrence of overwater releases, it is acknowledged that future releases could occur. No attempt is made in this report to predict and quantify such releases as a "current" loading term. To evaluate the expected importance of overall historical loading (for all historical loading terms combined, including overwater releases), simple, stratigraphy-based comparisons of sediment concentration were conducted. The results of these comparisons are presented in the chemical-specific discussions of loading, fate, and transport later in this section to support general assessment of the relative significance of overall historical loading to sediments. No additional analysis of this term is needed for the RI/FS.

Comparison of the relative contributions from the loading terms is presented in the chemical-specific discussions later in Section 11.1.3, incorporating consideration of chemical properties and fate and transport processes within the system.

11.1.2.2 In-River Fate and Transport Processes

The fate and transport processes relevant to iCOCs and potential iCOCs in the Study Area can be grouped into four main categories: surface water transport, sediment transport, uptake into biota, and abiotic and biotic transformation/degradation. Each of these is described generally below:

11.1.2.2.1 Surface Water Transport

Advection, the flow of river water in response to gravitational forces, is the primary mechanism for transport of surface water and its load of dissolved and particle-bound

iCOCs. Lateral and vertical movement of iCOCs in surface water occurs primarily as a result of turbulent (eddy) dispersion (mechanical mixing), and to a far lesser extent as a result of mixing/diffusion resulting from chemical, thermal, and density gradients. Suspended particles provide an important vehicle for transport of iCOCs in the water column and exchange of iCOCs between the sediment and the surface water. The sediment-carrying capacity of river water increases with increasing stream flow and turbulence, which varies spatially as well as temporally. Stream flow, turbulence, and total suspended solids (TSS) loads are greater in areas where the river is narrower (e.g., upstream of RM 10), and throughout the river during high-flow events. Semi-quantitative estimates of dissolved and particulate iCOC transport via surface water are presented in Appendix D. Refined estimates will be developed based on the results of planned Round 3 surface water and sediment sampling and completion of the Fate and Transport Model.

11.1.2.2.2 Sediment Transport

Many of the Portland Harbor iCOCs are hydrophobic chemicals associated with sediment particles; therefore, the physical transport of sediments within the Study Area greatly influences chemical distribution and fate. Sediment transport processes (described in greater detail in Section 7.2.12)—including deposition, erosion/resuspension, mixed-layer turbation, long-term burial, and ingestion/uptake by biota—are not evaluated in this report. These processes will be evaluated later in the RI/FS process using the numerical hydrodynamic/sediment transport model (WEST Consultants 2004; 2005a,b; 2006), which is still being refined and will eventually be linked to the Fate and Transport Model. Empirical data collection planned for Round 3 (sediment trap sampling, bathymetric survey of Multnomah Channel, additional surface water sampling) will further support the modeling efforts. Following evaluation of results of the site-wide fate and transport modeling, alternative combinations and applications of empirical data and additional localized modeling efforts (e.g., propwash resuspension models) may be used to address location-specific RI/FS issues, as needed. The need to invoke these alternative approaches will be assessed following evaluation of the site-wide fate and transport model in early 2007.

11.1.2.2.3 Uptake into Biota

A number of processes govern how organisms living in the lower Willamette River (LWR) are exposed to chemicals and how chemicals are transformed, excreted, or stored in tissue. Organisms living in the LWR take up chemicals through physical (e.g., diffusion), chemical, and biological processes, including transfer of water-borne chemicals across gill structures or other tissues, consumption of prey, or ingestion of sediment. Organisms can modify the chemical burden in their tissues through growth, reproduction, excretion, metabolic transformation, or sequestration. Chemicals are transferred among organisms through trophic interactions, resulting in increases in concentrations of some chemicals at higher trophic levels.

11.1.2.2.4 Abiotic and Biotic Transformation/Degradation

Several abiotic and biotic processes can result in the transformation and/or degradation of chemicals in the environment. Among these are partitioning between the solid and aqueous phases, oxidation/reduction reactions, abiotic degradation/transformation reactions (e.g., hydrolysis, dehalogenation, oxidation, reduction), and biotic degradation/transformation reactions. Biodegradation involves the metabolic oxidation or reduction of organic compounds and is carried out predominantly by bacteria in aqueous environments, but yeasts and fungi may also contribute to biodegradation. In general, oxidation of organic compounds occurs under aerobic conditions and reduction under anaerobic conditions, although both processes can occur under both conditions. No quantification of these processes, beyond the geochemical analysis presented in Appendix D, Section 7, is presented in this report. The fate and transport processes for iCOCs will be evaluated further as part of the Fate and Transport Model (described in Section 7.3) and will be presented in the RI Report.

11.1.3 Loading, Fate, and Transport of iCOCs and Potential iCOCs

This discussion of loading, fate, and transport is organized by chemical or chemical group, for the combined list of iCOCs and potential iCOCs identified in the human health and ecological risk assessment evaluations (see Sections 8 and 9, respectively). Each subsection begins with a summary of the potential sources and distribution of the chemical (or group of chemicals), followed by a discussion of chemical properties and general behavior in environmental media. Next, external loading sources are discussed. Estimated loads in surface water across the Study Area (RM 11, RM 6.3, and RM 4) are described, followed by a discussion of the qualitative to semi-quantitative estimates of the loading terms[64] for upstream surface water, stormwater, upland groundwater plumes (using unfiltered results), advection through sediments[65] (using the outside-navigation-channel assumption, as described in Appendix D), and air deposition. Additionally, the current conceptual understanding of historical sources is discussed in general terms for each iCOC (or iCOC group), citing stratigraphy-based comparisons of sediment concentration statistics to support the discussions. Finally, where relevant, uptake into biota and chemical transformation/degradation processes in the environment are also described.

11.1.3.1 Dioxins/Furans

Polychlorinated dibenzo-*p*-dioxins and dibenzofurans, expressed as TEQ for 2,3,7,8-TCDD, were identified as iCOCs for both human health and ecological risk (Table 11.1-1).

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[64]A summary of chemicals for which current loading rate estimates were prepared is presented in Tables 7.1-1 through 7.1-7, for each assessed loading term.

[65]Though advection through sediments is considered a transport mechanism, as opposed to an external loading term, it will be included in discussions in Section 11.1.1.2 to allow for comparison of relative significance to other estimated loading terms, including surface water loads across the Study Area.

11.1.3.1.1 Potential Sources and Distribution in the Study Area

As a group, polychlorinated dibenzo-*p*-dioxins (dioxins) represent 75 different positional isomers, while polychlorinated dibenzofurans (furans) comprise over 135 compounds (Eisler 1986). These two chemical classes are generally referred to as dioxins. The toxicity of dioxins and furans is frequently expressed using a toxicity equivalency procedure, in which the toxicities of individual congeners (expressed relative to the toxicity of 2,3,7,8-TCDD) are summed to yield the 2,3,7,8-TCDD dioxin toxic equivalent (TEQ). This procedure involves applying toxicity equivalency factors (TEFs) to the analytical results for individual dioxins/furans and calculating the 2,3,7,8-TCDD TEQ for each sample. TEFs developed by the World Health Organization (Van den Berg et al. 1998) for 7 dioxin congeners and 10 furan congeners were applied to calculate dioxin TEQs for this RI/FS. The TEQ expresses the assumed combined contribution of the individual congeners to total dioxin/furan toxicity, expressed in terms of the toxicity of 2,3,7,8-TCDD.

Dioxins have never been purposely manufactured. They can be anthropogenically and naturally produced through combustion, bleached paper production, or as trace impurities or incidental byproducts in chlorophenols, chlorinated herbicides, and commercial Aroclor (PCB) mixtures (ASTDR 1998). When released into the air, some dioxins may be transported long distances, even around the globe. In the atmosphere, it has been estimated that 20 to 60 percent of 2,3,7,8-TCDD in the air is in the vapor phase. Sunlight and atmospheric chemicals will break down a very small portion of the dioxins, but most dioxins will be deposited on land or water (ATSDR 1998).

Specific potential sources and release mechanisms of dioxins/furans to the Study Area are discussed in Section 11.3 below for individual iAOPCs. The distribution of dioxins in sediment, TZW, surface water, and biota is summarized in Section 6. Dioxin TEQ was identified as an iCOC in sediment for the following iAOPCs: T4, 13, 14, 15, 17 (see Section 10 for details).

11.1.3.1.2 Chemical Properties and Behavior in the Environment

Dioxins and furans are characterized by extremely low vapor pressures, high octanol-water and organic carbon partitioning coefficients (K_{ow}s and K_{oc}s, respectively), and extremely low water solubilities. These factors indicate a strong affinity for sediments, particularly sediments with high organic content. Some dioxins deposited on or near the water surface will be broken down by sunlight, and a very small portion will evaporate to air; the vast majority will sorb strongly to particulate matter, including organic matter, and eventually settle to the sediment bed, where they will be subject to sediment transport processes. Once sorbed to particulate matter or bound in the sediment organic phase, they exhibit little potential for leaching or volatilization. They are highly stable in all environmental media, with persistence measured in decades. The only environmentally significant transformation process for these congeners is believed to be photodegradation of chemicals not bound to particles in the gaseous phase or at the soil-air or water-air interface (EPA 1994). Chemical degradation of

dioxins and furans through reductive chlorination can also occur, but it is a very slow process.

Dioxins and furans have been shown to biomagnify in aquatic food webs and associated avian and mammalian species (ATSDR 1998).

11.1.3.1.3 Loading, Fate, and Transport in the Study Area

Loading rate estimates of dioxin TEQ to the Study Area were only prepared for surface water (semi-quantitative) and air deposition (qualitative).[66] Figure 11.1-1 presents the estimated load of dioxin TEQ in surface water at RM 11, RM 6.3, and RM 4 for the three Round 2 surface water sampling events. Dioxin TEQ loads are similar at all three transects in two of the three Round 2 surface water sampling events. In contrast, the July 2005 event shows an increase between RM 6.3 and RM 4. At this time, there is no clear explanation for this observed increase. In general, however, the majority of dioxin TEQ loading estimates in surface water at RM 4 are similar to or slightly higher than the load estimated to flow into the Study Area with surface water at RM 11, indicating that the current surface water data set does not allow for identification/location of other source terms of dioxins by difference on a gross scale. Additional planned Round 3 surface water sampling may provide more information.

The estimated air deposition loading rate of dioxin TEQ to the Study Area is presented relative to upstream surface water (RM 11) in Figure 11.1-2. The air deposition loading rate estimate has a large range, varying by 3 orders of magnitude. The low end of the estimate is 3 orders of magnitude below the estimated surface water load, while the upper end of the estimate is comparable to the total surface water load estimate. These qualitative air deposition estimates for dioxins are highly uncertain due to the lack of available local data (deposition velocities were based on measurements from Japan, and ambient concentrations were based on values from California). The absence of a consistent load increase in surface water across the Study Area, as shown in Figure 11.1-3, may indicate that the air deposition term is not a significant contributor (and therefore the lower end of air deposition estimates may be more representative of the conditions in Portland).

TZW was not sampled to evaluate upland groundwater plume loading of dioxins to the Study Area, with the exception of two TZW samples collected offshore of the Rhone Poulenc site. Dioxins have been observed in upland groundwater at Time Oil's NW Terminal, and Rhone Poulenc has documented dioxin as being present in the 2,4,5-T and 2,4-D manufactured at its Portland plant; however, there is no reason to expect that conditions exist that would facilitate transport of these highly hydrophobic chemicals to the transition zone via groundwater. Transport from groundwater advection through sediments was also not quantified, considering the highly hydrophobic nature of

[66]Note: Dioxin TEQ is a toxicity-based weighted sum of dioxin compounds. As such, the generation and comparison of loading estimates of dioxin TEQ is problematic. It should be understood that the loading values cannot be truly compared as dioxin loads. Instead the comparisons are of rough relative toxicity contributions.

dioxins/furans and because application of the equilibrium partitioning approach to chemical concentrations expressed as a TEQ (weighted sum of 17 congeners) is problematic, due to the varying partitioning characteristics of the individual congeners. Because of the highly hydrophobic nature of dioxins and furans, both upland groundwater plume discharge and groundwater advection through sediments are expected to be insignificant for this iCOC.

In contrast, considering the high hydrophobicity of dioxins and corresponding tendency to be associated with particulate material and organic matter, stormwater and sediment transport from upstream may be significant loading terms. For similar reasons, bank erosion may also be relevant. Insufficient information is currently available to estimate the potential magnitude of these loading and transport terms. Additional information to develop improved estimates of dioxin loading and transport will be obtained from Round 3 upstream sediment and surface water sampling, Round 3 and/or DEQ-led stormwater evaluations, Round 3 and/or DEQ-led bank erosion studies, and ongoing modeling efforts (hydrodynamic model and the fate and transport model).

Given the long-term generation of dioxins as manufacturing byproducts around the world, atmospheric transport, and the general recalcitrance of the molecules, it is expected that loading of dioxins to the Study Area has occurred for many years, and this historical loading is a significant source of the dioxins currently present in the system. Historically loaded dioxins still present in the Study Area would be expected to be sorbed to sediments. A review of the Round 2A sediment data set reveals that average concentrations of dioxins in subsurface sediments (interval B[67]) are very similar to average observed concentrations in the surface sediments (interval A[68]). This may suggest that loading rates for dioxins have remained fairly unchanged, or possibly that sediments are well-mixed through hydrodynamic processes, though this is not consistent with observations of concentration trends with depth for other recalcitrant compounds. Additional analysis of historical loading may be performed as part of the RI to better understand this term. Any such additional analysis will not involve collection of additional data unless specified as a data gap in Section 12.

Dioxins and furans were detected in all tissues except juvenile Chinook stomach contents, large scale sucker, northern pike minnow, and peamouth tissue, which were not analyzed for dioxins/furans (Appendix G). Because dioxins are highly hydrophobic, all trophic levels would be expected to primarily take up dioxins and furans via dietary exposure, including ingestion of sediment. However, dioxins were detected in some water samples, making them readily available for biological uptake, even at very low concentrations. Storage sites within biota are mainly those tissues and organs with high lipid content. Given their resistance to degradation, dioxins would be

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[67]The Round 2A subsurface sediment sampling interval B is defined as the interval extending from 30 cm bml to anywhere from 60 cm to 190 cm bml.

[68]Round 2A surface sediment sampling interval A is defined as the interval extending from 0 to 30 cm bml.

expected (and were predicted) to both bioaccumulate and biomagnify within Willamette River food webs and would also transfer from maternal reproductive tissue to offspring.

11.1.3.2 PCBs

Total PCBs were identified as human health and ecological iCOCs (Table 11.1-1).

11.1.3.2.1 Potential Sources and Distribution in the Study Area

PCBs are a general class of chemically inert, non-polar, synthetic, halogenated hydrocarbons, of which there are 209 different compounds (congeners) (Eisler and Belisle 1996). Congeners differ based on the number of chlorine atoms substituted on the biphenyl nucleus and the pattern of substitution; substitutions can occur in any of 10 positions on the biphenyl nucleus in any combination. PCBs were manufactured in the United States from 1929 until 1977 for many uses, including dielectric fluids in transformers and capacitors, cutting oils, fire retardants in building materials, hydraulic oils, heat transfer fluids, and microscope oils. They were also used as additives to pesticides, paints, copy paper, adhesives, and sealants, and as plasticizers. A variety of commercial blends of PCBs were sold and used under the trade name Aroclor® and were identified with four-digit codes (1221 through 1268). The last two digits indicate the percentage of chlorine in the mixture. Aroclor 1016, containing 41.5 percent chlorine, was also produced (ATSDR 2000).

Total PCB TEQ is the toxicity-weighted sum of 12 individual PCB congeners that are believed to exhibit dioxin-like toxicity. Toxicity of these individual congeners (relative to the toxicity of 2,3,7,8-TCDD) is expressed using a TEF-weighting procedure as described above in Section 11.1.3.1.1.

Because PCBs are no longer produced and sold, significant new releases to the environment are uncommon. Releases continue to occur, however, from uncontrolled landfills, hazardous waste sites, combustion of PCB-bearing wastes, releases from older electrical equipment, and improper disposal/spills (ATSDR 2000). PCBs can also be introduced to aquatic environments by stormwater runoff, wastewater discharges, atmospheric deposition, accidental spillage of hydraulic fluids and other PCB-bearing oils, bilge water discharge, and other sources.

Specific potential sources and release mechanisms of PCBs to the Study Area are discussed for the site-wide iAOPC in Section 11.2. The distribution of PCBs in sediment, surface water, and biota is summarized in Section 6. (PCBs were not analyzed in TZW.) Total PCB Aroclors and/or total PCB TEQs were identified as iCOCs in surface sediment for all iAOPCs except iAOPC 6 and iAOPC 15 (see Section 10 for details). Based on bioaccumulation studies and food web modeling conducted for this RI/FS, PCBs in surface water are thought to contribute significantly to bioaccumulation and subsequent biomagnification of PCBs in the food web (see Sections 8 and 9 and Appendices B, C, and H).

11.1.3.2.2 Chemical Properties and Behavior in the Environment

As a group, PCBs in the environment are insoluble, stable, persistent, and lipophilic with log K_{ow}s that range from 4.15 to 9.60 (Eisler and Belisle 1996). Generally, log K_{ow} values increase with increasing chlorination, and higher log Kow values indicate higher hydrophobicity and binding affinity. In aquatic environments, PCBs strongly partition to organic carbon phases in the water column and sediment, and lipid fractions in biota. Only a very small fraction of PCBs present in sediment porewaters or groundwater are in the freely dissolved state[69]. Some organic carbon present in sediments, such as anthropogenic sources of black soot-like carbon, have been shown to have even higher aqueous partitioning coefficient values (K_{oc}) and lower bioavailability than is often observed for natural organic matter (Jonkers et al. 2004). Among PCBs, the more chlorinated congeners exhibit lower solubility and a stronger tendency to sorb compared to the less chlorinated congeners. The small fraction of less chlorinated congeners present in the dissolved form are also subject to volatilization out of the water column, depending primarily on wind speed and water column concentration. PCBs bound to sediment particles are persistent; however, minor transformation processes such as volatilization, photooxidation, hydrolysis and metabolism (dechlorination) by both aerobic and anaerobic microorganisms do occur.

Aquatic organisms can be exposed to PCBs through gill ventilation, ingestion of sediments (and associated organic matter), and consumption of prey. Invertebrate concentrations are mostly dependent on sediment and water concentrations, while concentrations in fish and wildlife are dependent on PCB concentrations in prey. Biological uptake of PCBs by aquatic organisms appears to be species-specific. Rates of accumulation vary depending on species, age, sex, and size.

11.1.3.2.3 Loading, Fate, and Transport in the Study Area

Figure 11.1-3 presents the estimates of the total PCB (Aroclors) and PCB TEQ[70] loads observed in surface water during the three Round 2 surface water sampling events at each of the three sampling transects, RM 11, RM 6.3, and RM 4. For both total PCBs and PCB TEQ, different general concentrations trends were observed across the Study Area for each of the three sampling events. Loads increased from upstream to downstream across the Study Area during the July 2005 sampling event, decreased from upstream to downstream during the November 2004 event, and showed little change over the length of the Study Area during the March 2005 event. The upstream (RM 11) sample from November 2004 was collected during a storm event, and the higher PCB levels may reflect stormwater discharges and/or resuspension of bedded sediments.

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[69]In surface water, where the mass ratio of water to solids (suspended) is much higher than in groundwater or sediment, partitioning theory still holds; however, the total chemical mass in the dissolved state can be comparable to or greater than the total chemical mass in the sorbed state, depending on the concentrations of suspended solids.

[70]Note: PCB TEQ is a toxicity-based weighted sum of PCB compounds. As such, the generation and comparison of loading estimates of PCB TEQ is problematic. It should be understood that the loading values cannot be truly compared as PCB loads. Instead the comparisons are of rough relative toxicity contributions.

Samples collected from RM 6.3 and RM 4 during this sampling event were not during a comparable storm event. The observed variability (60-percent decrease to >300-percent increase) during very similar (low flow) sampling events suggests variable loading conditions and/or challenges with representative sampling and load estimation.

The estimated ranges of loading to the water column from stormwater, advection through contaminated sediments, and air deposition are presented relative to upstream surface water (RM 11) in Figure 11.1-4. The estimated loads from groundwater advection through sediment are much lower than the observed water column loads. Air deposition estimates for total PCBs are from concentration modeling for Multnomah County, and are expected to be reasonably representative. These estimates show air deposition to constitute a small fraction of the total PCB load to the water column. In contrast, air deposition estimates for PCB TEQ and stormwater estimates for total PCBs range from well below the observed water column loads to higher than observed surface water loads across the length of the Study Area. Both of these estimates are based on non-local literature information. The PCB TEQ air deposition estimates are based on measurements in California, and the stormwater estimates are based on information from a study in Switzerland, as described in Appendix D. Consequently, these estimates are considered highly uncertain.

Loading from upland groundwater plumes was not estimated. PCBs were not identified as upland groundwater COIs at any of the TZW study sites, are not expected migrate significantly in groundwater (based on their strong tendency to sorb to particulate matter and associated organic material), and therefore were not sampled in TZW. Upland groundwater transport of PCBs is not considered a relevant loading term to the Study Area.

In summary, based on these estimates, air deposition and groundwater advection through sediments may be contributing to the total PCB load in the water column, but these contributions are minor compared to upstream surface water loading. Stormwater loads are uncertain but may be locally significant where upland sources of PCBs are present. Though loading terms from upstream sediment transport and bank erosion are not available, these terms also may be important sources of PCBs, given the relatively widespread distribution and highly hydrophobic nature of these chemicals. Additional information to develop improved estimates of PCB loading and transport will be obtained from Round 3 upstream sediment and surface water sampling, Round 3 and/or DEQ-led stormwater evaluations, Round 3 and/or DEQ-led bank erosion studies, and ongoing modeling efforts (hydrodynamic model and the fate and transport model).

Given the discontinuation of production of PCBs in the United States in 1977 and their resistance to transformation/degradation, it is expected that historical loading of PCBs to the Study Area is the predominant source of the PCBs currently present in the system. Historically loaded PCBs still present in the Study Area would be expected to be sorbed to sediments. A review of the Round 2A sediment data set reveals that average concentrations of PCBs in subsurface sediments (interval B[67]) are more than 55

percent higher than the average observed PCB concentrations in the surface sediments (interval A[68]). This may suggest that loading rates for PCBs were higher historically. Additional analysis of historical loading may be performed as part of the RI to better understand this term. Any such additional analysis will not involve collection of additional data unless specified as a data gap in Section 12.

PCBs (as Aroclors) were detected in all fish and invertebrate tissues except crayfish, where Aroclors were detected in fewer than half the samples analyzed (Appendix G). PCB congeners (used to calculate TEQs) were detected in all tissues except one laboratory-exposed clam. PCBs are highly hydrophobic; all trophic levels would be expected to primarily take up PCBs via dietary exposure, including ingestion of sediment. However, PCBs were detected in water samples, which would be highly bioavailable, even at low concentrations. The significance of this potential contribution is currently unknown; however, the food web model can be used to estimate the relative contribution of different pathways and media in future model runs. Storage sites within biota are mainly those tissues and organs with high lipid content. Given their resistance to degradation, PCBs would be expected (and are predicted) to both bioaccumulate and biomagnify within Willamette River food webs and would also transfer from maternal reproductive tissue to offspring.

11.1.3.3 Pesticides

Several DDx and non-DDx pesticides were identified as iCOCs and/or potential iCOCs for human health and ecological risk (Table 11.1-1).

11.1.3.3.1 Potential Sources and Distribution in the Study Area

DDT (1,1,1-trichloro-2,2-bis[*p*-chlorophenyl]ethane) was used as insecticide until it was banned for use in the United States in 1972 because of toxicity to wildlife. DDE (1,1-dichloro-2,2-bis[*p*-chlorophenyl]ethylene) and DDD (1,1-dichloro-2,2-bis[*p*-chlorophenyl]ethane) are the primary metabolites of DDT, but technical-grade DDT may also contain DDE and DDD as impurities (ATSDR 2002d). DDT was released historically to air and soil through widespread spraying of crops and forests, and for mosquito control. Releases also occurred at local scales at pesticide manufacturing and storage facilities. Ongoing releases occur in countries where its use is not banned, and some of these releases can be transported globally through the atmosphere.

The non-DDx pesticides identified as iCOCs can be released to the environment from similar sources and mechanisms. Pesticides can be transported to aqueous environments from stormwater runoff, soil erosion, wastewater discharge, accidental spills and releases, and atmospheric deposition.

Specific potential sources and release mechanisms of pesticides to the Study Area are discussed in Section 11.3 for individual iAOPCs. The distribution of pesticides in sediment, transition zone water, surface water, and biota is summarized in Section 6. Pesticides were identified as iCOCs in sediment for the following iAOPCs: 3, 9, 11, 13, 14, 17, and 19 (see Section 10 for details). DDx pesticides were also identified as human health potential iCOCs in TZW in iAOPC 14 for consumption of aquatic life,

and as potential ecological iCOCs for benthic invertebrates based on the FPM, TZW, and/or other highly uncertain lines of evidence (Table 11.1-1).

11.1.3.3.2 Chemical Properties and Behavior in the Environment

DDT and its principal metabolites (DDD and DDE) are organochlorine compounds that are very persistent in the environment due to low vapor pressure, high fat solubility, and resistance to degradation and photooxidation. Both DDD and DDE are stable and biologically active, although DDE is non-insecticidal (Montgomery 1996). Similar to the DDx pesticides, the non-DDx pesticide iCOCs are characterized by high log K_{ow}s and high K_{oc}s, resulting in a strong tendency to sorb to sediments.

Generally, pesticides are subject to three types of degradation: microbial, chemical, and photodegradation. One of the most common pesticide degradation reactions is hydrolysis, a breakdown process wherein the pesticide reacts with water. Depending on the pesticide, this may occur under both acidic and alkaline conditions. DDT degrades slowly to DDE under aerobic conditions and to DDD in anoxic systems (EPA 2000b). All of the non-DDx pesticides on the iCOC list also tend to degrade and transform very slowly, except aldrin, which can be degraded to dieldrin by sunlight or bacteria, and heptachlor, which can be transformed to heptachlor epoxide by hydrolysis or biodegradation. Additionally, endrin can photodegrade to endrin ketone; however, this process is slow (ATSDR 1996). The non-DDx pesticides on the iCOC list are also subject to very slow volatilization from water or saturated soils (ATSDR 1995b, 1996, 2002b, 2005b,c).

The behavior (fate and transport) of pesticides in the water column is largely a function of the highly hydrophobic nature of these molecules. Pesticides have a strong tendency to be associated with particulate matter, especially particulate matter coated with organic matter. As such, the large majority of pesticides in the water column are associated with suspended solids of all size fractions, including colloidal sizes. Some particles may settle out, transferring pesticides to the sediment. In sediments, DDT strongly adheres to suspended sediment particles, but once metabolized, DDE is the primary product that is very slightly soluble in water (Montgomery 1996).

Laboratory studies have shown that DDx compounds are readily bioconcentrated in aquatic organisms, with reported log BCFs for DDT ranging from 3.08 to 6.65 and for DDE ranging from 4.80 to 5.26 (EPA 2000a). The non-DDx pesticides can also bioaccumulate in tissue, except aldrin, which is rapidly transformed to dieldrin in plants and animals (ASTDR 2002b).

11.1.3.3.3 Loading, Fate, and Transport in the Study Area

Figures 11.1-5a–c present the estimated pesticide loads in surface water during the three Round 2 surface water sampling events at RM 11, RM 6.3, and RM 4. For DDx compounds, estimated surface water loads generally increase through the Study Area to RM 6.3. A similar, though less pronounced, trend is shown in Figure 11.1-5c for the non-DDx pesticides, aldrin, dieldrin, heptachlor, heptachlor epoxide, and total chlordanes. The remaining non-DDx pesticides, endrin, endrin ketone, and the

hexachlorocyclohexanes, show no consistent trends in measured surface water load across the Study Area. The average load increase for DDx compounds between RM 11 and RM 4 was 40 percent, ranging from a 90-percent decrease for α-hexachlorocyclohexane in the July 2005 sampling event to a 260-percent increase for total DDD in the December 2004 sampling event.

The estimated ranges of loading to the water column from other terms (stormwater, groundwater plume discharge, advection through sediments, and air deposition), where they could be calculated, are presented relative to upstream surface water (RM 11) for each of the DDx iCOCs in Figure 11.1-6a. Figure 11.1-6b presents the estimated loads for the non-DDx pesticides. For the DDx compounds, the groundwater plume and advection through sediment terms are generally somewhat lower than the surface water upstream load, but are comparable in magnitude. Stormwater contribution estimates for DDT are extremely uncertain, as discussed in Appendix D, and cover a very wide range that extends from values comparable to the observed upstream surface water load to values more than 20 times the estimated surface water load. Finally, the air deposition estimates for total DDE and total DDT suggest that this could be an important loading term to the Study Area; however, the results span a very large range of estimates for both DDE and DDT (both estimates extend down to a value more than 2 orders of magnitude below the lowest observed surface water load). Additionally, the air deposition loading rate estimates for DDE and DDT were not based on any local air quality information; instead, these values were derived from the maximum observed values at six Michigan stations (all assumptions for loading estimates are presented in detail in Appendix D).

Based on these estimates, upland groundwater plumes and groundwater advection through sediment may be contributing to the observed increase in pesticide concentrations in the water column across the Study Area. (Pesticides in TZW were analyzed only in samples collected in and around iAOPC 14.) The magnitude of the groundwater advection term is more uncertain due to the qualitative nature of the estimates and varies primarily as a function of the large range of applied literature K_{oc} values. The stormwater contribution is highly uncertain given the large loading estimate range relative to the observed surface water loads, as well as the lack of site-specific stormwater runoff information and surface water sampling data during runoff events. Further, considering the hydrophobic nature of these pesticides, a number of potentially important loading terms to the water column have not yet been estimated, including upstream sediment loading. Bank erosion may also contribute some pesticides to the Study Area. Additional information to develop improved estimates of pesticide loading and transport will be obtained from Round 3 upstream sediment and surface water sampling, Round 3 and/or DEQ-led stormwater evaluations, Round 3 and/or DEQ-led bank erosion studies, and ongoing modeling efforts (hydrodynamic model and the Fate and Transport Model).

Given the prohibition of DDT use in the United States in 1972, and the slow degradation rates of DDT pesticides, it is expected that historical loading of DDT

pesticides to the Study Area is a significant source of the DDT pesticides currently present in the system. In contrast with expectations, a review of the Round 2A sediment data set reveals that average concentrations of DDT pesticides in subsurface sediments (interval B[67]) are actually 25 to 30 percent *lower* than the average observed DDT pesticide concentrations in the surface sediments (interval A[68]). A closer review of the data reveals that this finding is the result of very high surface concentrations in the area of AOPC 14. Further investigation into the data indicates that sediment samples below segment B in this area exhibit higher DDT concentrations than the surface sediments, reflecting the pathway for the upland source DDT source at this site. Round 2A sediment data for all other pesticides[71] listed as iCOCs show higher average subsurface sediment (interval B[67]) concentrations, as compared to average concentrations in the surface sediments (interval A[68]), ranging from 40 to 85 percent higher, which may suggest that loading rates for pesticides were higher historically. Additional analysis of historical loading may be performed as part of the RI to better understand this term. Any such additional analysis will not involve collection of additional data unless specified as a data gap in Section 12.

Total DDx was detected in all tissues analyzed within the Study Area. Other pesticides were much less frequently detected. Chlorinated pesticides tend to be hydrophobic; all trophic levels would be expected to primarily take up DDx and other pesticides via dietary exposure, including ingestion of sediment. However, DDx was detected in the water column in the LWR; dissolved pesticides would be very bioavailable and could represent a significant source to all trophic levels even at low concentrations. Storage sites within biota are mainly those tissues and organs with high lipid content. Given their resistance to degradation, chlorinated pesticides would be expected (and are predicted) to both bioaccumulate and biomagnify within Willamette River food webs and would also transfer from maternal reproductive tissue to offspring.

11.1.3.4 PAHs

Sixteen individual PAHs were identified as iCOCs and/or potential iCOCs for human health and ecological risk (Table 11.1-1). Total PAHs were identified as an ecological iCOC (Appendix G).

11.1.3.4.1 Potential Sources and Distribution in the Study Area

PAHs comprise a group of more than 100 chemicals that are formed during the incomplete burning of coal, oil, gas, wood, garbage, or other organic substances, such as tobacco. Natural sources include volcanoes and forest fires. PAHs are also constituents of crude oil, shale oil, coal tar, and creosote. Anthropogenic releases to the environment are far greater than natural ones (ATSDR 1997b). Globally, the largest source of PAHs to the environment is emissions to the atmosphere; however, the largest sources of PAHs for the Study Area are releases, such as historical industrial

[71]Note: This is not the case for heptachlor epoxide, which showed 35 percent higher concentrations in the surface relative to the subsurface; however, this is not considered a strong comparison because it is based on only a handful of detections (3 in the surface and 10 in the subsurface).

discharges, from facilities along the Study Area that formerly or currently use, manufacture, and/or store products and waste materials containing PAHs (e.g., petroleum oils and coal-based products).

Specific potential sources and release mechanisms of PAHs to the Study Area are discussed in Section 11.3 for individual iAOPCs. The distribution of PAHs in sediment, transition zone water, surface water, and biota is summarized in Section 6. PAHs were identified as an iCOC in sediment for the following iAOPCs: T4 and 11 (see Section 10 for details). PAHs were identified as potential iCOCs for the benthic community based on the TZW and tissue-residue lines of evidence.

11.1.3.4.2 Chemical Properties and Behavior in the Environment

PAHs are composed of hydrogen and carbon arranged in the form of two or more fused benzene rings in linear, angular, or cluster arrangements, which may or may not have substituted groups attached to one or more rings (Eisler 1987b). Low–molecular-weight PAHs are more mobile in the environment than the HPAHs. Higher-molecular-weight PAHs are relatively immobile because of their large molecular volumes and their extremely low volatility and solubility. Primarily, the fate of PAHs in aquatic environments is to become sorbed to suspended particles or sediments. The degree of sorption depends on the organic carbon content and particle size (ATSDR 1997b). Sorption of PAHs to particulates increases with increasing organic carbon content of the particles and increasing molecular weight of the PAHs. Low- and medium-molecular-weight PAHs are more likely to be transported through sediments by leaching or to be resuspended into the water column. At low humic acid concentrations (below 0.1 percent), hydrocarbons are adsorbed onto the hydrophobic portions of humic particles (Eisler 1987b). This sorption increases as the humic acid concentration increases. Above humic concentrations of 0.1 percent, solubilization of PAHs into humic acid aggregates sharply increases. This solubility is also pH-dependent. At a humic acid concentration of 0.05 percent, higher pH levels favor PAH solubilization. The dissolved fraction of PAHs is expected to degrade rapidly through photooxidation.

Microbial metabolism is the major degradation process for PAHs in sediments. Sorption of PAHs to organic matter and sediment particles influences their bioavailability[72] and hence metabolism (ATSDR 1997b). Biodegradation is affected by environmental inputs, characteristics of the microbial population, and the physical and chemical properties of the PAHs. Environmental inputs that may affect the rate of biodegradation include temperature, pH, dissolved oxygen, PAH concentrations, sediment type, moisture content, nutrients, and other substances that may act as substrate co-metabolites. The size and composition of microbial populations are also affected by these factors. The rate of biodegradation is also altered by the presence of other chemical stressors that may be toxic to biodegrading microorganisms. PAHs can be very persistent under low oxygen or anoxic conditions (Eisler 1987b).

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[72]Bioavailability of PAHs varies significantly with the type of organic matter in the sediment and tends to be low where organic matter is related to MGP residuals (Khalil et al.,in press).

PAHs may accumulate in benthic organisms, fish, and other organisms that consume sediments while feeding. Although food-chain transfer of PAHs to higher trophic levels can occur, biomagnification is likely to be minimal due to the high rate of PAH metabolism in fish, mammals, and birds. In general, bioaccumulation potential is greater for the higher-molecular-weight compounds than for the lower-molecular-weight compounds.

11.1.3.4.3 Loading, Fate, and Transport in the Study Area

Figure 11.1-7a,b present the estimated PAH loads in surface water for the three Round 2 surface water sampling events at RM 11, RM 6.3, and RM 4. Seven individual HPAHs and total PAHs are shown on Figure 11.1-7a,b because only these PAHs were identified as iCOCs for scenarios/receptors involving exposure to surface water. (The remaining seven LPAHs were identified as potential TZW iCOCs for the benthic community [Appendix G].) Figure 11.1-7a,b shows that PAH loads in surface water generally increased between RM 11 and RM 4, often peaking at RM 6.3. Total PAHs in the water column show an overall increase through the Study Area in two of the three sampling events, and a decrease in the third event. The trends in total PAH loads parallel the LPAH loads (not shown), which constitute the large majority of the total PAHs in surface water. This pattern suggests a significant external load of PAHs or resuspension of contaminated sediment within the site.

Estimated PAH loading estimates from stormwater, groundwater plume discharge, advection through sediments, and air deposition are presented relative to upstream surface water (RM 11) in Figures 11.1-8a,b. (Note: loads are presented on a logarithmic scale.) These figures present individual PAHs ordered by increasing molecular weight. For total PAHs, the stormwater estimate spans more than 4 orders of magnitude, confounding any interpretation of its relative importance as a loading term. The groundwater plume estimates are similar in magnitude to the upper end of the range of upstream surface water load estimates. These loads are attributable primarily to TZW from the area around and including AOPC 11 and may be significantly influenced by effects of in-water sources of PAHs on TZW concentrations. As expected, the relative contribution of individual PAHs to groundwater plume loading decreases with increasing molecular weight. Estimated loading from groundwater advection through sediment is lower than the observed surface water load across the Study Area (Figure 11.1-7a,b). Air deposition loading estimates, which are available only for a few of the higher-molecular-weight PAHs, are generally comparable in magnitude to the observed upstream surface water loading rate estimates.

In summary, PAH loading estimates suggest that upstream surface water, upland groundwater plumes, stormwater, and air deposition could be important external loading terms to the water column, with current estimates of air deposition and stormwater being highly uncertain. Additionally, within the Study Area, resuspension of PAH-contaminated sediment from the areas such as AOPC 11 likely explains the observed increase in PAH load in the water column at RM 6.3 (see Figure 11.1-7a,b). Sediment transport from upstream areas and bank erosion, which have not yet been quantified,

may also provide PAHs to the Study Area; however, these terms are expected to be small relative to the significant loading terms and transport processes that have been identified. Additional information to develop improved estimates of PAH loading and transport will be obtained from Round 3 upstream sediment and surface water sampling, Round 3 and/or DEQ-led stormwater evaluations, Round 3 and/or DEQ-led bank erosion studies, and ongoing modeling efforts (hydrodynamic model and the Fate and Transport Model).

Historical loading terms are expected to be a significant source of the PAHs currently present in the system. A review of the Round 2A sediment data set reveals that average concentrations of total PAHs in subsurface sediments (interval B[67]) are ~65 percent higher than average observed concentrations in the surface sediments (interval A[68]). For individual PAHs, the same trend is observed, ranging from 40 to 85 percent. This term may be somewhat confounded by data from the area of AOPC 11, including the tar body. Additional analysis of historical loading may be performed as part of the RI to better understand this term. Any such additional analysis will not involve collection of additional data unless specified as a data gap in Section 12.

Benzo(a)pyrene and total PAHs were used as surrogates to represent the distribution of PAHs in tissues in the Study Area. One or more PAHs (including benzo[a]pyrene) were detected in invertebrate tissues, with the exception of crayfish, where PAHs were infrequently detected. PAHs were also infrequently detected (and benzo[a]pyrene was never detected) in fish tissues. Invertebrate and fish exposure pathways within the Study Area are similar and include respiration (i.e., diffusion across gill surfaces) of porewater or surface water, ingestion of sediment, and ingestion of invertebrate prey. All of the pathways would be expected to contribute to tissue burdens in aquatic biota in varying degrees depending on the compound; however, the models and equations used to evaluate the relationship between site-specific sediment and tissue do not distinguish between aqueous and sediment contributions. Detected concentrations of PAHs in invertebrate tissues demonstrate that exposure has occurred. Given lower invertebrates' inability to rapidly metabolize these compounds, they likely act as a source of PAHs to their predators. However, fish and other vertebrates can rapidly metabolize PAHs, which makes the magnitude of exposure of these organisms less apparent and biomagnification of these compounds unlikely.

11.1.3.5 Phthalate Esters

Bis(2-ethylhexyl)phthalate (BEHP) was identified as a human health and ecological iCOC (Table 11.1-1). Dibutyl phthalate was identified as a potential ecological iCOC for benthic invertebrates (Appendix G).

11.1.3.5.1 Potential Sources and Distribution in the Study Area

Both BEHP and dibutyl phthalate are manufactured, colorless liquids with little or no odor and low vapor pressures. They are commonly added to plastics and paint to make the finished product more flexible (ATSDR 2001a, 2002c). Releases to the environment can occur as direct spills from industrial facilities that manufacture or use

these chemicals. More commonly, releases occur by leaching of low volumes of phthalates from the wide variety of products that contain them (ATSDR 2001a, 2002c). Despite their low vapor pressures, BEHP and dibutyl phthalate are both ubiquitous in the atmosphere due to their widespread use in plastics. They are present in the atmosphere in both the vapor phase and associated with particulates, and are subject to both wet (rain and snow) and dry (wind and settling) deposition on the earth's surface (ATSDR 2001a, 2002c). Releases to the environment also occur directly to soil and water.

Specific potential sources and release mechanisms of BEHP and dibutyl phthalate to the Study Area are discussed in Section 11.3 for individual iAOPCs. The distribution of BEHP and dibutyl phthalate in sediment and biota is summarized in Section 6. Neither BEHP nor dibutyl phthalate was sampled in TZW, and BEHP only was sampled in surface water. Dibutyl phthalate was identified as an iCOC in iAOPCs 1, 3, 14,19, and 21.

11.1.3.5.2 Chemical Properties and Behavior in the Environment

Both BEHP and dibutyl phthalate have high K_{ow}s and low solubilities; therefore, both chemicals have a strong tendency to sorb to solids and organic matter in the aqueous environment. Neither would be expected to migrate significantly with groundwater or volatilize significantly from the Study Area once in the river or associated with sediment particles. Both of these phthalate esters are subject to fairly rapid chemical degradation in the atmosphere, and relatively slower biodegradation in soil and water under aerobic conditions (HSDB 2006; ATSDR 2001a).

HSDB (2006) indicates that BEHP would be expected to bioconcentrate in aquatic organisms; however, sampling results described below suggest that BEHP is readily metabolized. In contrast, for dibutyl phthalate, ATSDR (2001a) indicates that there is no evidence that it builds up in the food chain and that accumulation potential in tissue is limited due to biotransformation reactions.

11.1.3.5.3 Loading, Fate, and Transport in the Study Area

Dibutyl phthalate loading estimates in the water column are presented in Figure 11.1-9 for the July 2005 surface water sampling event at each of the three sampling transects, RM 11, RM 6.3, and RM 4. Sampling results in the water column show fairly consistent concentrations across the Study Area between RM 11 and RM 4, with a small peak in concentrations at RM 6.3. Estimated ranges of BEHP loading rates to the water column from air deposition are presented relative to estimated upstream surface water loads (RM 11) in Figure 11.1-10. The air deposition estimate is several orders of magnitude higher than the estimated load from upstream surface water.

Dibutyl phthalate is not an upland groundwater COI and was not sampled in TZW, and adequate literature information for stormwater loading estimates was not found. Therefore, no estimates of dibutyl phthalate loading from upland groundwater plumes or stormwater were generated for this report.

BEHP loading estimates in the water column are presented in Figure 11.1-9 for the July 2005 surface water sampling event at each of the three sampling transects. Sampling results for BEHP were below detection limits at all transect locations in the November 2004 and March 2005 sampling events. The estimated July 2005 BEHP load in the water column decreased by more than 50 percent between RM 11 and RM 4. BEHP is hydrophobic and subject to biodegradation in water and soil under aerobic conditions (HSBD 2006); therefore, the observed decrease over the 7-river-mile stretch could reflect sorption to solids and settling and/or biodegradation.

Estimated ranges of BEHP loading rates to the water column for stormwater, advection through sediments, and air deposition are presented relative to estimated upstream surface water loads (RM 11) in Figure 11.1-10. Estimated BEHP loads from advection through sediments are much lower than the estimated surface water column loads from July 2005. In contrast, the highly uncertain literature-value-based estimates of air deposition and stormwater loading rates span a range of values comparable to or substantially higher than the estimated water column loads. The uncertainty associated with these estimates, however, limits their usefulness in understanding the relative loading contribution of these terms to the Study Area.

In summary, based on the understood behavior and environmental distribution of BEHP and dibutyl phthalate, air deposition loading, upstream sediment loading, and stormwater could be important terms for BEHP loading to the Study Area. Bank erosion is also a possible, though highly uncertain, source. Upland groundwater plume loading is not expected to contribute these chemicals to the Study Area because they are not upland groundwater COIs and would not be expected to migrate to the Study Area in groundwater. Within the Study Area, sediment transport mechanisms are likely to be the most important transport mechanisms for phthalates. Additional information to develop improved estimates of BEHP loading and transport will be obtained from Round 3 upstream sediment and surface water sampling, Round 3 and/or DEQ-led stormwater evaluations, Round 3 and/or DEQ-led bank erosion studies, and ongoing modeling efforts (hydrodynamic model and the fate and transport model).

Historical loading is potentially a significant source of the phthalate esters currently present in the system. Historically loaded phthalate esters still present in the Study Area would be expected to be sorbed to sediments. A review of the Round 2A sediment data set reveals that average concentrations of dibutyl phthalate in subsurface sediments (interval B[67]) are ~60 percent higher than the average observed concentrations in the surface sediments (interval A[68]). This could reflect higher historical loading rates and/or better conditions for degradation in shallow sediment zones. In contrast, average concentrations of BEHP in subsurface sediments (interval B[67]) are ~60 percent *lower* than the average observed concentrations in the surface sediments (interval A[68]), reflecting several very high surface sediment concentrations at RM 7.4 and between RM 3.8 and RM 4. Additional analysis of historical loading may be performed as part of the RI to better understand this term. Any such additional analysis will not involve collection of additional data unless specified as a data gap in Section 12.

Phthalates were infrequently detected in fish and invertebrates. Invertebrate and fish exposure pathways within the Study Area are similar and include respiration (i.e., diffusion across gill surfaces) of porewater or surface water, ingestion of sediment, and ingestion of invertebrate prey. All of the pathways would be expected to contribute to tissue burdens in aquatic biota, with sediment or prey ingestion potentially being the most significant due to the hydrophobic nature of these compounds; however, the models and equations used to evaluate the relationship between site-specific sediment and tissue do not distinguish between aqueous and sediment contributions. Detected concentrations of phthalates in invertebrate tissues demonstrate that limited exposure has occurred. Given lower invertebrates' inability to rapidly metabolize these compounds, they likely act as a source of phthalates to their predators. However, fish and other vertebrates can metabolize phthalates, which makes the biomagnification of these compounds unlikely. Site-specific data suggest that BEHP may be less readily metabolically degraded that dibutyl phthalate, in that concentrations in fish tissues were higher than those in invertebrate tissues, whereas dibutylphthalate was rarely detected in fish tissue but was detected in most invertebrate tissue.

11.1.3.6 SVOCs

Hexachlorobenzene and pentachlorophenol (PCP) were identified as human health iCOCs. Hexachlorobenzene was also identified as an ecological potential iCOC for benthic invertebrates (Appendix G). No other SVOCs were identified as iCOCs or potential iCOCs (Table 11.1-1).

11.1.3.6.1 Potential Sources and Distribution in the Study Area

Hexachlorobenzene is a white crystalline solid formed as an industrial byproduct from the manufacture of solvents, other chlorine compounds, and pesticides. It also occurs in waste streams from chlor-alkali and wood-treating facilities, and combustion processes can produce hexachlorobenzene in small amounts. Historically, hexachlorobenzene was used as a fungicide, but its use was suspended in 1984 (ATSDR 2002e). Hexachlorobenzene is released to the environment from industrial facilities, waste processing facilities, incineration, and from the use of pesticides that contain hexachlorobenzene as an impurity. It can also be transported to aqueous environments from stormwater runoff, soil erosion, wastewater discharge, accidental spills and releases. Atmospheric deposition is considered a major transport pathway for hexachlorobenzene released to the atmosphere (ATSDR 2002e).

PCP is a colorless crystalline solid that was formerly in widespread general use as a wood preservative. Its use in the United States is currently restricted to certified applicators, but it is still used industrially for utility poles, railroad ties, and wharf pilings. PCP is usually applied to wood products after dilution in solvents such as mineral spirits, No. 2 fuel oil, or kerosene. PCP can be released to air, water, and soil. It enters the environment through evaporation from treated wood surfaces, industrial spills, and disposal at uncontrolled hazardous waste sites (ATSDR 2001b). Because of its widespread use, PCP is ubiquitous in the environment. Important sources to the aquatic environment include soil runoff and leaching, wood-treating facility effluent

discharges, direct leaching from treated wood products, atmospheric deposition, and historical water discharges from cooling towers in which PCP was used as a biocide (ATSDR 2001b).

Specific potential sources and release mechanisms of hexachlorobenzene and PCP to the Study Area are discussed in Section 11.3 for individual iAOPCs. The distribution of these chemicals in sediment, surface water, and biota is summarized in Section 6. TZW was not analyzed for hexachlorobenzene or PCP.. For the reasons discussed in Section 10.1.3 and Appendix G, sediment concentrations of hexachlorobenzene and PCP did not influence the mapping of iAOPCs.

11.1.3.6.2 Chemical Properties and Behavior in the Environment

PCP is practically insoluble in water (Eisler 1989), and its sorption and related mobility is controlled primarily by pH (ATSDR 2001b). Maximum adsorption has been reported at pH values of 4.6–5.1, with no adsorption above pH 6.8. Hexachlorobenzene also has very low aqueous solubility, and it has a high tendency to sorb to solids and organic matter in the aqueous environment (ATSDR 2002e).

PCP readily degrades in sediment and soil by chemical (reductive dehalogenation), microbiological, and photochemical processes (Eisler 1989). Biodegradation is considered the major transformation mechanism for PCP in soil, with half-lives usually on the order of 2–4 weeks (ATSDR 2001b). Hydrolysis, oxidation, and volatilization do not, however, significantly affect surface water PCP concentrations. In contrast, hexachlorobenzene breaks down very slowly, exhibiting a half-life of 2.7 to 5.7 years in lakes, rivers, and streams (ATSDR 2002e).

PCP is found in fish and other aquatic organisms, but tissue levels are usually low, and biomagnification of PCP in terrestrial or aquatic food chains has not been observed (ATSDR 2001b). Hexachlorobenzene can bioaccumulate in aquatic and terrestrial organisms. The ability of hexachlorobenzene to biomagnify in the food web, however, is uncertain, and further study is needed (ATSDR 2002e).

11.1.3.6.3 Loading, Fate, and Transport in the Study Area

Hexachlorobenzene loading estimates in the water column are presented in Figure 11.1-11 for each of the three Round 2 surface water sampling events at RM 11, RM 6.3, and RM 4. The water column loading estimates indicate that, for the three low-flow events sampled, hexachlorobenzene loads did not vary much over the Study Area between RM 11 and RM 4, increasing slightly in the November 2004 event, and decreasing slightly in the March and July 2005 sampling events.

Estimated ranges of hexachlorobenzene loading to the water column from advection through sediments and air deposition are presented relative to estimated upstream surface water loads (RM 11) in Figure 11.1-12. Both the air deposition (from Multnomah County ambient air concentrations) and the estimated advection through sediment loading rates to the water column are low compared to the estimated water column load. Upland groundwater plume estimates were not generated because

hexachlorobenzene is not an upland groundwater COI at any site with an expected pathway to the river, and therefore it was not analyzed for in TZW samples. Because hexachlorobenzene is hydrophobic, tends to sorb strongly to solids, and is not easily degraded, upstream sediment loading, stormwater loading, and bank erosion could be significant loading terms to the Study Area.

For PCP, loading estimates were generated for surface water only. As indicated on Figure 11.1-11, all surface water transect sample results for PCP were below detection limits for all three events; the detection limits ranged from 0.03 to 0.06 µg/L. Therefore, the estimated PCP loads are uncertain and are likely to be biased high. Upland groundwater plume estimates were not generated because PCP is not an upland groundwater COI at TZW study sites, and therefore it was not analyzed for in TZW samples. Literature data for stormwater loading and atmospheric deposition were unavailable to estimate loading terms. Groundwater advection through sediments was not estimated due to the relatively low frequency of PCP detection in surface sediments (14.2 percent) in the Study Area (see Section 6.1). PCP is subject to rapid photodegradation, chemical degradation, and microbial degradation; therefore, sediment transport from upstream areas, stormwater transport, atmospheric deposition, and bank erosion are not expected to be significant loading sources.

Additional information to develop improved estimates of hexachlorobenzene and PCP loading and transport will be obtained from Round 3 upstream sediment and surface water sampling, Round 3 and/or DEQ-led stormwater evaluations, Round 3 and/or DEQ-led bank erosion studies, and ongoing modeling efforts (hydrodynamic model and the fate and transport model).

Historical loading is potentially a significant source of hexachlorobenzene currently present in the system. Historically loaded hexachlorobenzene still present in the Study Area would be expected to be largely sorbed to sediments. A review of the Round 2A sediment data set reveals that average concentrations of hexachlorobenzene in subsurface sediments (interval B^{67}) are approximately 40 percent higher than the average observed hexachlorobenzene concentrations in the surface sediments (interval A^{68}). This could reflect higher historical loading rates. In contrast, historical loading is not expected to be significant for PCP, which degrades fairly rapidly. This is reflected in comparison of average PCP concentrations in subsurface (segment B^{67}) and surface (segment A^{68}) sediments, which show consistently higher surface sediment concentrations by approximately40 percent. Additional analysis of historical loading for hexachlorobenzene may be performed as part of the RI to better understand this term. Any such additional analysis will not involve collection of additional data unless specified as a data gap in Section 12.

The distribution of hexachlorobenzene and PCP in biota from the Study Area was assessed through the direct measurement in invertebrate (except PCP in epibenthic invertebrates and juvenile Chinook stomach contents) and fish tissues (except for PCP in black crappie, northern pikeminnow, and peamouth) (see Section 6.4 and

Appendix C, Sections 3 and 4). Uptake in fish and wildlife via dietary exposure was not evaluated. Hexachlorobenzene and PCP bioaccumulation was evaluated using site-specific relationships between sediment and tissue (Appendix H).

Hexaclorobenzene was frequently detected in invertebrate tissue (except crayfish) and was infrequently detected in fish; PCP was rarely detected in any tissue. Hexachlorobenzene concentrations, when detected, were typically higher in fish tissue (several times to several orders of magnitude) compared to invertebrate tissue, suggesting possible biomagnification. Exposure pathways for PCP and hexachlorobenzene are expected to be different: PCP exposure for both fish and invertebrates would likely be via aqueous pathways; hexachlorobenzene exposure for fish and invertebrates would more likely be via sediment or prey ingestion due to its hydrophobic nature. Based on data collected from the Study Area, PCP was not detected in surface water samples (hexachlorobenzene was detected); both PCP and hexachlorobenzene were infrequently detected in surface sediment (14 and 30 percent, respectively). As noted above, hexachlorobenzene was frequently detected in invertebrates that may be preyed upon by fish.

11.1.3.7 Tributyltin

As shown in Table 11.1-1, tributyltin (TBT) was identified as an iCOC for ecological risk for fish and as a potential iCOC for ecological risk to benthic invertebrates (Appendix G).

11.1.3.7.1 Potential Sources and Distribution in the Study Area

TBT has been used as an antifouling agent in paints on the immersed portions of boats and floating structures since the mid-1950s. Antifouling paints represent the largest source of TBT in coastal environments, and nationally, concentrations in shipyards, harbors, and marinas tend to be elevated relative to background conditions. Use of TBT compounds as slimicides on masonry, disinfectants, and biocides for various industrial processes also may result in their release to the environment.

Specific potential sources and release mechanisms of TBT to the Study Area are discussed in Section 11.3 for individual iAOPCs. The distribution of TBT in sediment, surface water, and biota is summarized in Section 6 (only a limited number of tissue samples were analyzed for TBT, and no TZW samples were analyzed for TBT). For the reasons discussed in Section 10.1.3, sediment concentrations of TBT did not influence the mapping of iAOPCs.

11.1.3.7.2 Chemical Properties and Behavior in the Environment

TBT is a strongly hydrophobic organotin compound that partitions preferentially to particulate and dissolved organic matter. The ORNL Risk Assessment Information System (RAIS) reports a very strong tendency to partition to organic matter (K_{oc} of 3.75 x 10^7 L/kg) for TBT oxide (ORNL 2006). TBT also partitions strongly into lipids of plants and animals (ORNL RAIS specifies a log K_{ow} for TBT of 3.84). While accumulation of TBT from water into organisms appears to be a significant process that

can result in elevated tissue concentrations, subsequent biomagnification through the food web is reportedly minor (ATSDR 2005f).

ATSDR (2005f) also offers the following summary of abiotic and biotic degradation processes for organotin compounds:

> Degradation of organotin compounds involves the breaking of the tin-carbon bond, which may occur by UV irradiation, or by biological or chemical cleavage (Blunden et al. 1984). In water, tributyltin can be degraded by photochemical and biological processes relatively rapidly; however, adsorption onto suspended particulate material in water followed by sedimentation is a key removal process (De Mora and Pelletier 1997). The half-life of tributyltin in seawater varies, depending on pH, temperature, turbidity, and light; it is generally estimated to be in the range of 1 day to a few weeks (Alzieu 1998). Biodegradation is the major process in seawaters rich in suspended solids, but photolysis, in surface waters, exceeds biodegradation in clean seawater. Calculated half-lives range from 6 days in summertime waters rich in suspended particles to 127 days in clean winter waters (Watanabe et al. 1992). Tributyltin can be degraded by microbial, microalgal, and fungal populations, as well as by some higher organisms, such as fish (Anderson et al. 2002). Cleavage of the tin-carbon bond by hydrolysis is not an important fate process under environmental conditions (WHO 1990).
>
> Degradation of organotin compounds in sediments is much slower than in water, and half-lives have been estimated to be several years (Alzieu 1998). In addition to dealkylation of organotin compounds, methylation of tin and organotin compounds by chemical and/or biological means may occur. The contribution of methylation by biotic and abiotic mechanisms is not clear. This pathway may result in fully substituted and volatile tin compounds. Methylated butyltin compounds, such as tributylmethyltin and dibutyldimethyltin, have been found in contaminated harbor sediments and in surface waters (Amouroux et al. 2000; Cooney 1988). Methylation of tin in sediments was found to be positively correlated with increasing organic content in sediment and to follow predominately [sic] a biotic pathway (Hadjispyrou et al. 1998).

11.1.3.7.3 Loading, Fate, and Transport in the Study Area

Estimated TBT loads to and within the Study Area were quantified for surface water only. Figure 11.1-1 presents the estimated TBT load in surface water at RM 11, RM 6.3, and RM 4 for the three Round 2 surface water sampling events. TBT concentrations in all surface water transect samples were below detection limits.

Literature data were not sufficient to develop estimates of TBT loading from stormwater. TBT is not a COI in upland groundwater at any of the nine sites evaluated as part of the Round 2 groundwater pathway evaluation; therefore, TBT was not

sampled in TZW, and loading of TBT from upland groundwater plume discharge was not evaluated. Transport from sediment and porewater to surface water from groundwater advection was not quantified because TBT was not identified as an iCOC for surface water receptors and because of the highly hydrophobic nature of TBT. As a result, advective transport of TBT from sediment and porewater to surface water is expected to be insignificant. TBT can be present in the atmosphere as gases/fumes and/or attached to dust particles. Atmospheric deposition, however, is not expected to be an important source of TBT due to its low vapor pressure and rapid photodegradation (ATSDR 2005f). TBT tends to sorb to solids; therefore, sediment transport from upstream areas may be an important TBT loading term to the Study Area. Additional information to develop improved estimates of TBT loading will be obtained from Round 3 upstream sediment and surface water sampling, Round 3 and/or DEQ-led stormwater evaluations, Round 3 and/or DEQ-led bank erosion studies, and ongoing modeling efforts (hydrodynamic model and the fate and transport model).

It is expected, given long-term shipping activities in Portland Harbor, that historical loading of TBT to the Study Area is a significant source of the TBT currently present in the system. Given the chemical properties of TBT, historically loaded TBT would be expected to be sorbed to sediments and subject to fairly slow transformation/ degradation processes. A review of the Round 2A sediment data set reveals that average concentrations of TBT in subsurface sediments (interval B[67]) are approximately 50 percent higher than the average observed concentrations in the surface sediments (interval A[68]). This suggests that loading rates for TBT were historically higher than current average loading rates across the Study Area.

TBT was detected in over half the tissue samples analyzed for this compound; concentrations were higher in invertebrates than fish, reflecting the ability of vertebrates to metabolize butyltins. Invertebrate uptake of TBT is expected to come from exposure to or ingestion of sediment; TBT was not detected in surface water. Chinook and shorebirds accumulate TBT primarily from ingestion of invertebrate prey (with incidental ingestion of sediment by shorebirds). Uptake of TBT was not evaluated for any other receptors, either by direct measurement or estimation of tissue concentrations, or modeled concentrations.

11.1.3.8 Metals

Seven metals were identified as iCOCs or potential iCOCs (Table 11.1-1): arsenic was identified as a human health iCOC and as an ecological potential iCOC for benthic invertebrates (Appendix G); cadmium, copper, and zinc were identified as ecological iCOCs; mercury was identified as both a human health and an ecological iCOC; and silver and lead were identified as ecological potential iCOCs based on the FPM (Appendix G).

11.1.3.8.1 Potential Sources and Distribution in the Study Area

Arsenic is a naturally occurring metal that occurs widely in natural minerals, including realgar ($As_4S_{4(s)}$), orpiment ($As_2S_{3(s)}$), and arsenolite (As_2O_3) (ATSDR 2005a). Arsenic

occurs naturally in soil, water, and air as a result of mineral weathering, leaching, volcanic eruptions, and wind-blown dirt. Anthropogenic activities, including smelting activities, pesticide use, combustion of wood and coal, waste incineration, and the production and use of treated wood products that utilize soluble chromium copper arsenate (CCA) can also release arsenic into the air, soil, water, and sediments.

Cadmium is also a naturally occurring rare earth metal; the large majority of cadmium released to the environment, however, results from anthropogenic activities, including mining and smelting, fuel combustion, disposal of metal-bearing wastes, and fertilizer use (ATSDR 1999a).

Copper, in contrast, is an abundant element in the earth's crust, and natural releases to environmental media can be significant. Mining operations, agriculture, wastewater sludge, municipal and industrial solid waste, and other industrial processes can also result in environmental releases of copper (ATSDR 2004b).

Lead occurs naturally in small amounts in the earth's crust, and is released to air, soil, water, and sediments by human activities, including burning fossil fuels, mining, and manufacturing. Lead is also commonly used in a variety of products including batteries; however, in response to health concerns, lead use in gasoline, paints, and pipe solder has been dramatically reduced in recent years (ATSDR 2005d).

Mercury sources are also both natural and anthropogenic; primary human activities resulting in releases to the environment are mining and smelting; industrial processes involving the use of mercury, including chlor-alkali production facilities; combustion of fossil fuels, primarily coal; production of cement; and medical and municipal waste incinerators and industrial/commercial boilers (ATSDR 1999b).

Silver is a rare but naturally occurring metal, often found in mineral ores in association with other elements. Emissions from smelting operations, manufacture and disposal of certain photographic and electrical supplies, coal combustion, and cloud seeding are some of the anthropogenic sources of silver in the biosphere. Silver is used to make jewelry, silverware, electronic equipment, dental fillings, photographs, and solders. Silver is also used as an antibacterial agent (ATSDR 1990).

Zinc is a common element in the earth's crust and is released to the environment from both natural and anthropogenic sources. Mining and metallurgical processing are the primary anthropogenic sources, along with use of commercial products such as fertilizers and wood preservatives that contain zinc (ATSDR 1997c). Zinc is also used in galvanizing steel and in soldering formulas.

Specific potential sources and release mechanisms of metals to the Study Area are discussed in Section 11.3 for individual iAOPCs. The distribution of metals in sediment, TZW, surface water, and biota is summarized in Section 6. One or more metals were identified as iCOCs or potential iCOCs in sediment for the following iAOPCs: 1, 3, T4, 6, 7, 10, 13, 14, 15, 19, and 21 (see Section 10 for details).

11.1.3.8.2 Chemical Properties and Behavior in the Environment

Arsenic: Arsenic is a redox-sensitive species, existing at the +3 and +5 oxidation states in aqueous environmental conditions. Under oxidizing conditions the As(V) species (H_3AsO_4, $H_2AsO_4^-$, $H_2AsO_4^-$, $HAsO_4^{2-}$, AsO_4^{3-}) predominate, while under reducing conditions the As(III) species (H_3AsO_3, $H_2AsO_3^-$, $HAsO_3^{2-}$, AsO_3^{3-}) predominate (EPRI 1986). Arsenic is generally highly soluble, with few mineral phases exerting controls on aqueous arsenic concentrations under typical environmental conditions. Arsenic sulfide minerals, such as orpiment ($As_2S_{3(s)}$) and realgar ($As_4S_{4(s)}$) can be important under reducing and acidic conditions. Although arsenic minerals are generally highly soluble, adsorption reactions to sediment/aquifer mineral grain surfaces frequently limit dissolved arsenic concentrations (Kabata-Pendias and Pendias 1992). Arsenic is particularly strongly adsorbed to iron oxide minerals, with the As(V) species having a greater affinity for the oxide surface than the As(III) species. Because arsenic is frequently present as an anion under typical environmental conditions, its sorption to oxide surfaces is favored at pH < 9 (Stumm 1992).

In aquatic environments, bioaccumulation of arsenic occurs primarily in algae and lower invertebrates (ATSDR 2005a). Fish and shellfish can also accumulate arsenic, mainly in the exoskeleton of invertebrates and in the livers of fish. While biomagnification in aquatic food chains is not generally considered significant, predatory fish may biomagnify arsenic through the consumption of prey species (especially bottom dwellers) (ATSDR 2005a).

Cadmium: Cadmium is a divalent, naturally occurring, rare earth metal. Cadmium exists in the elemental (Cd^0) state or the Cd^{2+} valance state. The 2+ form dominates between pH 4.0 and 7.0 (EPA 2000a). In aquatic environments, cadmium is relatively insoluble in water and is not affected by photolysis, volatilization, or biological methylation (EPA 1999b). Although chloride and sulfate cadmium salts are freely soluble, precipitation and sorption to mineral surfaces and organic materials are dominant processes for cadmium compounds. This favors the deposition and retention of cadmium in sediment. The bioavailability of cadmium is dependent on several factors, including sorption and desorption rates, pH, Eh, chemical speciation, and many other modifiers. The concentration of acid-volatile sulfides (AVS) is known to be an important factor controlling the toxicity and bioaccumulation of cadmium in sediments (EPA 2000a).

Freshwater organisms can readily accumulate cadmium from water; however, there is considerable variation in the degree of accumulation between tissues. The evidence for cadmium transfer through various trophic levels suggests that only the lower trophic levels exhibit biomagnification. Most studies reviewed suggest that cadmium is not a highly mobile element in aquatic food webs, and there appears to be little evidence to support the general occurrence of biomagnification of cadmium within freshwater food webs (EPA 2000a).

Copper: Copper exists in four oxidation states: Cu^0, Cu^{+1}, Cu^{+2}, and Cu^{+3} (Eisler 1998). The cupric ion (Cu+2) is the one generally encountered in water and it is the most readily available and toxic inorganic species of copper. However, the free ion concentration is sensitive to complexation with numerous compounds normally found in natural waters, or partitioning to dissolved and particulate organic carbon. Both processes result in reduced bioavailability to aquatic organisms (Eisler 1998; EPA 2000a). The amounts of the various copper compounds and complexes present in solution in freshwater depend on water pH, temperature, hardness, and alkalinity; concentrations of bicarbonate, sulfide, and organic ligands; size and density of suspended materials; and rates of coagulation and sedimentation of particulates. Up to 29 different species of copper can be present in aqueous solution in the pH range from 6 to 9. The majority of copper in freshwater from pH 6.0 to 9.3 is in the form of carbonate species ($CuHCO_3^+$, $CuCO_3$, $Cu[CO3]_2^{-2}$) which have low toxicity (Eisler 1998). Cupric ions account for less than 1 percent of the total dissolved copper in freshwater. Copper carbonate, cupric hydroxide, cupric oxide, and cupric sulfide will precipitate from solution or form colloidal suspensions when excess cupric ions are present (Eisler 1998). The majority of copper released to surface waters settles out or adsorbs to sediments (EPA 1999b; Eisler 1998). Bioavailability of copper in sediments is controlled by the degree of complexation with AVS and adsorption to organic matter (EPA 2000a).

Copper is taken up by aquatic organisms primarily through dietary exposure and is an essential micronutrient for animals as a component of a number of essential enzymes (EPA 2000a). Most organisms retain only a small proportion of the copper ingested with their diet. Copper bioconcentrates in aquatic organisms but does not bioaccumulate in mammals or biomagnify in aquatic food chains (EPA 1999b).

Lead: Lead occurs in four valence states: elemental (Pb^0), monovalent (Pb^+), divalent (Pb^{2+}), and tetravalent (Pb^{4+}); all forms are environmentally important, except possibly Pb^+ (Eisler 1988). In nature, lead occurs mainly as Pb^{2+}; it is oxidized to Pb^{4+} only under strong oxidizing conditions, and few simple compounds of Pb^{4+} other than PbO_2 are stable. Some lead salts are comparatively soluble in water (lead acetate, 443 g/L; lead nitrate, 565 g/L; lead chloride, 9.9 g/L), whereas others are only sparingly soluble (lead sulfate, 42.5 mg/L; lead oxide, 17 mg/L; lead sulfide, 0.86 mg/L). Of the organoleads, tetraethyllead and tetramethyllead are the most stable and the most important because of their widespread use as antiknock fuel additives. Both are clear, colorless, volatile liquids, highly soluble in many organic solvents; however, solubility in water is only 0.18 mg/L for tetraethyllead, and 18.0 mg/L for tetramethyllead. Both undergo photochemical degradation in the atmosphere to elemental Pb and free organic radicals, although the fate of automotive organoleads has yet to be fully evaluated (Eisler 1988). In general, organolead compounds are more toxic than inorganic Pb compounds, food chain biomagnification of Pb is negligible, and younger organisms are most susceptible (Eisler 1988)

Mercury: Mercury may be present in the environment in a number of forms and can exist in three oxidation states: elemental mercury (Hg^0), mercurous ion (Hg_2^{2+}), and mercuric ion (Hg^{2+}). Mercury compounds in aqueous solution are chemically complex. Depending on pH, alkalinity, redox, and other variables, a wide variety of chemical species may be formed. Nonvolatile inorganic forms of mercury compounds sorb readily to sediments, particularly those containing high organic carbon and reduced sulfur levels (EPA 2000a). Mobilization of sorbed mercury can be caused by bioreduction to elemental mercury and bioconversion to more volatile and soluble forms, such as methylmercury. Methylmercury is the most hazardous mercury species due to its high stability, its lipid solubility, and its possession of ionic properties that allow it to readily pass through cellular membranes (Eisler 1987a).

Mercury discharged into rivers, bays, or estuaries can be converted into methylmercury compounds by natural biological (bacterial microorganisms) or chemical processes (Eisler 1987a). Mercury methylation process depends on mercury loadings, microbial activity, nutrient content, pH and redox condition, suspended sediment load, sedimentation rates, and other variables; anaerobic conditions favor methylmercury formation more than aerobic conditions (Eisler 1987a). Bacterial microbes are also responsible for methylmercury decomposition (demethylation). They are widespread in the environment and have been isolated from water, sediments, soils, and from the gastrointestinal tract of mammals, including humans.

Mercury is accumulated by all trophic levels, with biomagnification occurring through the food web (EPA 2000a). The transfer efficiency of mercury through the food web is affected by the form of mercury. Although inorganic mercury is the dominant form in the environment and is easily accumulated, it is also depurated quickly. Methylmercury accumulates quickly and depurates very slowly, and therefore has a greater potential to biomagnify in higher-trophic-level species.

Silver: In nature, silver occurs primarily in the form of the sulfide (Ag_2S) or is associated with other metal sulfides, especially those of lead, copper, iron, and gold, which are all essentially insoluble (ATSDR 1990). Monovalent silver ion (Ag^+) is rare or negligible in the natural environment. Metallic silver is insoluble in water, but many silver salts, such as silver nitrate ($AgNO_3$) are soluble. Most of the silver released to the environment from human activities enters terrestrial ecosystems, where it is immobilized in insoluble species (Smith and Carson 1977). Silver does not appear to biomagnify significantly in aquatic animals (ATSDR 1990).

Zinc: In nature, zinc occurs as a sulfide, oxide, or carbonate. Because zinc ligands are soluble in neutral and acidic solutions, zinc is readily transported in most natural waters (Eisler 1993). Zinc mobility in aquatic ecosystems is a function of the composition of suspended and bed sediments, dissolved and particulate iron and manganese concentrations, pH, salinity, concentrations of complexing ligands, and the concentration of zinc (Eisler 1993). In freshwater, zinc is most soluble at low pH and low alkalinity: 10 mg Zn/L of solution at pH 6 that declines to 6.5 mg Zn/L at pH 7,

0.65 mg Zn/L at pH 8, and 0.01 mg/L at pH 9 (Eisler 1993). In water, the free zinc ion is thought to coordinate with six water molecules to form the octahedral aquo ion $(Zn(H2O)_6)^{2+}$ in the absence of other complexing or adsorbing agents (Eisler 1993). In freshwater, zinc exists almost exclusively as the aquo ion at pH >4 and <7 (Eisler 1993). In freshwater at pH 6, the dominant forms of dissolved zinc are the free ion (98 percent) and zinc sulfate (2 percent); at pH 9 the dominant forms are the monohydroxide ion (78 percent), zinc carbonate (16 percent), and the free ion (6 percent). In typical river waters, 90% of the zinc is present as aquo ion, and the remainder consists of ZnHCO3+, ZnCO3, and ZnSO4 (Eisler 1993).

Most of the zinc introduced into aquatic environments eventually is partitioned into the sediments (Eisler 1993). Zinc in the water column can partition to dissolved and particulate organic carbon. Water hardness (i.e., calcium concentration), pH, and metal speciation are important factors in controlling the water column concentrations of zinc since the divalent zinc ion is believed to be responsible for observed biological effects (EPA 2000a). Bioavailability of zinc in sediments is controlled by the AVS concentration. Zinc released from sediments is enhanced under conditions of high dissolved oxygen, low salinity, and low pH (Eisler 1993).

Zinc is an essential trace element for all living organisms. As a constituent of more than 200 metalloenzymes and other metabolic compounds, zinc ensures stability of biological molecules such as DNA and of biological structures such as membranes and ribosomes (Eisler 1993). Most studies reviewed contained data that suggest that zinc is not a highly mobile element in aquatic food webs, and there appears to be little evidence to support the general occurrence of biomagnification of zinc within marine or freshwater food webs (EPA 2000a).

11.1.3.8.3 Loading, Fate, and Transport in the Study Area

Figure 11.1-13 presents the estimated load of the seven metals in surface water at the three sampling transects of the three Round 2 surface water sampling events (RM 11, RM 6.3 and RM 4). Arsenic, copper, lead, and zinc were detected in all surface water samples. Copper loads did not vary substantially between the RM 11, RM 6.3 and RM 4 transects. Lead loads showed a slight increase over the Study Area for the November 2004 event, but limited change during the other two sampling events. Arsenic showed a slight increase over the Study Area for all three sampling events, whereas the spatial trends in zinc loads through the Study Area were different for each sampling event (decreasing from upstream to downstream transects in November 2004; not changing in March 2005; and increasing from the upstream to downstream transects in July 2005). Cadmium was detected only at RM 6.3 and RM 4 in two of the three sampling events; these detections were very close to the detection limits (detected concentrations ranged from 0.02 to 0.03 µg/L, while detection limits ranged from 0.02 to 0.05 µg/L); based on this information, cadmium loads are fairly consistent across the to the Study Area. Mercury concentrations in all surface water transect samples were below detection limits. Silver was only detected in the RM 4 sample from November 2004.

The estimated metals loads to the water column from stormwater, groundwater plume discharge, advection through sediments, and air deposition are presented relative to upstream surface water (RM 11) in Figure 11.1-14. For arsenic and cadmium, the contribution to the Study Area from upstream surface water loading greatly exceeds the other estimated terms, and is expected to be the primary source of these metals in the water column. This interpretation matches the observation of consistent cadmium loads[73] and minimally increasing arsenic loads in surface water across the Study Area.

Surface water upstream loading estimates for lead are also significantly higher than estimates for the groundwater plume loading term and the air deposition term. The stormwater loading estimates for lead span nearly three orders of magnitude, indicating significant uncertainty associated with this term, and confounding comparison to other terms. Collection of additional stormwater data is planned for Round 3, as described in Section 12.

The relative estimated loading rates for copper and zinc show similar patterns. The upstream surface water load dominates, with only the upper end of the stormwater estimate exceeding the observed water column load estimate. There is significant uncertainty in these stormwater loading rates, as reflected by the large range of the estimates (3 to 4 orders of magnitude).

For mercury, both the stormwater and air deposition loading estimates span more than 2 orders of magnitude, and each is significantly higher than the groundwater plume estimate. While the estimated surface water load for mercury is zero, due to non-detect results for all samples, estimates based on the detection limit correspond to a loading rate range of 300 to 575 kg/yr, which greatly exceeds the other loading terms. Greater resolution in the surface water concentrations would be needed (lower detection limits or samples collected during periods of higher concentrations) to further evaluate the relative importance of the upstream surface water loading term.

For silver, upstream surface water loading estimates were zero because all samples at RM 11 were below detections limits. Loading from TZW was low, at less than 0.2 kg/yr. It should be noted that silver is included in the potential iCOC list exclusively due to FPM results, which only correlate chemicals with observed risk and do not demonstrate causality of risk. Therefore, the risk, if any, attributable to silver is uncertain. Additional analysis will be performed in the baseline risk assessment to further assess this analyte.

In summary, for most of these metals, the upstream surface water loading term appears to be the primary source of metals to the water column under the low-flow conditions reflected in the Round 2 surface water sampling. With the possible exception of

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[73]This assumes that the cadmium surface water samples below detection limits were actually similar to the detected concentrations, which were very close to the detection limits. Additional insight into water column loads for cadmium metals should be provided by planned Round 3 surface water sampling.

arsenic, which can be relatively soluble under some environmental conditions, these metals tend to form mineral precipitates or partition onto solids. Consequently, loading mechanisms that transport solids into the Study Area, such as upstream sediment loading and stormwater, and to a lesser degree bank erosion and air deposition,[74] might be expected to be contributing loading terms. Additional information to develop improved estimates of metals loading and transport will be obtained from Round 3 upstream sediment and surface water sampling, Round 3 and/or DEQ-led stormwater evaluations, Round 3 and/or DEQ-led bank erosion studies, and ongoing modeling efforts (hydrodynamic model and the fate and transport model).

The relative importance of historical loading of metals to the Study Area is uncertain. A review of the Round 2A sediment data set reveals that average concentrations of arsenic, cadmium, copper, and zinc are slightly higher (no more than 20 percent higher) in subsurface sediments (interval B[67]) than the average observed concentrations in the surface sediments (interval A[68]). In contrast, mercury shows a slightly stronger trend, with the average subsurface concentration 50 percent higher than the average surface concentration. This change may reflect long term reductions in anthropogenic releases of mercury on a large spatial scale.

Arsenic, cadmium, copper, mercury, and zinc were detected in all invertebrate tissues analyzed, except for mercury in one laboratory-exposed worm sample where it was not detected. Similarly, arsenic, copper, mercury, and zinc were detected in all fish tissues; cadmium had slightly lower frequencies of detection, depending on the species analyzed. Exposure of invertebrates and fish in the Study Area to metals occurs from a variety of pathways including respiration (i.e., diffusion across gill surfaces) of porewater or surface water, ingestion of sediment, and ingestion of prey. Several metals (e.g., copper) are physiological requirements and would be expected to be found in tissues at some baseline concentration. Invertebrates are also able to sequester some metals in their shell or exoskeleton and thus may accumulate metals; fish may similarly sequester some metals in bone. Metals are regulated by vertebrates; whole-body tissue residues will vary based on the duration of exposure, the exposure or uptake route (dietary versus aqueous), whether the animal was pre-exposed to metals, and the rate at which the metal is regulated. Site-specific predictions of metals uptake do not account for how these processes might modify tissue concentrations once an individual organism is exposed; however, the predicted relationship should reflect the generalized result of these processes. Mercury in its organic form would be expected to be taken up and magnified in organisms feeding at higher trophic levels; maternal transfer to offspring would also be anticipated. As noted, silver and lead were included on the potential iCOC list exclusively due to FPM results, and were not identified based on tissue concentrations.

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[74]This statement is based on the definition of atmospheric deposition applied to this evaluation. Atmospheric deposition is limited to deposition to Study Area water surface. Atmospheric deposition to the upland watershed is included in the stormwater loading term. Atmospheric deposition to the upstream watershed is included in the upstream surface water loading term.

As described previously, metals are subject to a variety of abiotic and biotic processes that may influence their speciation, solubility, partitioning behavior, and bioavailability in the environment. These processes will be considered further, as appropriate, in subsequent RI/FS fate and transport evaluations.

11.1.3.9 Perchlorate

As shown in Table 11.1-1, perchlorate is a TZW potential iCOC for ecological risk (Appendix G). Perchlorate was not identified as an iCOC for any other receptors or scenarios.

11.1.3.9.1 Potential Sources and Distribution in the Study Area

Detections of perchlorate in TZW were limited to samples collected in the area of iAOPC 14. The source of the observed perchlorate in this area is believed to be historical upland and overwater releases of perchlorate salts used in manufacturing processes at the former Arkema site. As described in Section 6 of this report, perchlorate was detected in TZW at iAOPC 14 at concentrations ranging from 105 to 177,000 µg/L.

11.1.3.9.2 Chemical Properties and Behavior in the Environment

There are five perchlorate salts that are manufactured in large amounts: magnesium perchlorate, potassium perchlorate, ammonium perchlorate, sodium perchlorate, and lithium perchlorate (ATSDR 2005e). Perchlorate salts are solids that dissolve easily in water. Due to its high solubility, perchlorate tends to migrate with water, including groundwater. The degradation rate of perchlorate is uncertain, but perchlorate is known to be generally resistant to degradation, lasting for many years (ATSDR 2005e). Bioaccumulation of perchlorate is not expected given its high solubility; however, perchlorates have been found in milk and food (ATSDR 2005e).

11.1.3.9.3 Loading, Fate, and Transport in the Study Area

Because perchlorate was identified as a potential TZW iCOC only, the calculation of external loads to the Study Area considers only upland groundwater plume loading. Upland groundwater plume loading estimates for perchlorate range from 2,100 to 4,700 kg/yr (Appendix D). These loading estimates came from TZW sample results offshore of the Arkema site. Other current loading terms are not expected to be significant contributors of perchlorate to the Study Area. Historical releases of perchlorate, including upland releases to groundwater and overwater releases are expected to be the primary source of the observed load currently in the Study Area.

Because perchlorate is a potential iCOC for TZW only, in-river fate and transport processes were not evaluated. No further evaluation of perchlorate loading, fate, and transport is planned as part of the RI/FS.

11.1.3.10 Cyanide

As indicated in Table 11.1-1, cyanide is a TZW potential iCOC for ecological risk (Appendix G). Cyanide was not identified as an iCOC for any other receptors or scenarios.

11.1.3.10.1 Potential Sources and Distribution in the Study Area

Detections of cyanide in TZW at concentrations that triggered the identification of this chemical as a potential TZW iCOC were limited to samples collected within iAOPC 11. The source of cyanide is believed to be associated with the historical use of oxide reactors for purifying manufactured gas and the storage of spent oxide materials at the Gasco site. As described in Section 6 of this report, cyanide was detected in TZW at iAOPC 11 at concentrations ranging from 0.006 µg/L to 23.1 µg/L.

11.1.3.10.2 Chemical Properties and Behavior in the Environment

Cyanide occurs in aqueous environmental systems most commonly as hydrogen cyanide (HCN), but can also be present as free cyanide ion (CN^-) at higher pHs and as numerous complexes with metals and other cations. Cyanides are highly mobile in the environment and sorb only weakly to solid substrates such as clay minerals, biological solids, and sediments (ATSDR 2006a). The predominant removal mechanism for hydrogen cyanide in water is volatilization. Biodegradation is also an important loss mechanism for cyanide (ATSDR 2006a). There is no evidence to indicate that cyanides bioconcentrate in aquatic organisms or biomagnify through the food web.

11.1.3.10.3 Loading, Fate, and Transport in the Study Area

Because cyanide was identified as a potential TZW iCOC only, the calculation of external loads to the Study Area considers only upland groundwater plume loading. Upland groundwater plume loading estimates for cyanide range from 380 to 630 kg/yr (Appendix D). The large majority of this load estimate came from TZW sample results offshore of the Gasco site, with a small contribution from the area offshore of the Siltronic site. In surface water and soils, cyanide readily forms HCN and evaporates; therefore, the other current loading terms are not expected to be significant contributors of cyanide to the Study Area. Given the mobility, volatility, and biodegradability of cyanide, historical loading is not expected to be a significant source of the observed load currently in the Study Area, except inasmuch as the upland groundwater proportion of cyanide loading is related to historical upland releases.

Because cyanide is a potential iCOC for TZW only, in-river fate and transport processes were not evaluated for this report. No further evaluation of cyanide loading, fate, and transport is planned as part of the RI/FS.

11.1.3.11 VOCs

As indicated in Table 11.1-1, chloroform and trichloroethene (TCE) were identified as human health potential TZW iCOCs for drinking water scenarios based on concentrations measured in TZW in and around iAOPCs 11 and 14. No other VOCs were identified as iCOCs or potential iCOCs.

11.1.3.11.1 Potential Sources and Distribution in the Study Area

Detections of chloroform and TCE in TZW at concentrations that triggered their identification as potential TZW iCOCs were limited to samples collected in the offshore areas around and including iAOPCs 11 and 14. The sources of these VOCs are assumed to be associated with the historical use and subsequent release of chlorinated

solvents to upland groundwater. Specific potential sources and release mechanisms of these VOCs to the Study Area are discussed in Section 11.3 for individual iAOPCs. The distribution of chloroform and TCE in TZW is summarized in Section 6.

11.1.3.11.2 Chemical Properties and Behavior in the Environment

Both chloroform and TCE quickly evaporate from surface water. In groundwater or the transition zone environment, chloroform has a fairly high solubility and can migrate in water. In contrast, TCE has a lower solubility and tends to sorb more strongly to soil or sediment particles. Both TCE and chloroform are subject to chemical degradation by dehalogenation, producing dichloroethene and methylene chloride, respectively. Neither chloroform nor TCE tend to significantly bioaccumulate in plants and animals (ATSDR 1997a; ATSDR 2003).

11.1.3.11.3 Loading, Fate, and Transport in the Study Area

Chloroform and TCE loading estimates were prepared only for the upland groundwater plume loading term, which is expected to be the primary loading term to the Study Area for these analytes. VOCs were not sampled in surface water and were not sampled extensively in sediment; therefore, VOC loading estimates in surface water and from groundwater advection through sediments were not generated. For chloroform, the upland groundwater plume load (the loading rate to the Study Area was estimated between 3.5 and 2,800 kg/yr) comes almost exclusively from the area around and including iAOPC 14. For TCE, the large majority of the estimated load (the loading rate to the Study Area was estimated between 3.7 and 280 kg/yr) was measured in the offshore area near iAOPC 11, with a small contribution from the area around and including iAOPC 14. These large ranges are indicative of the high uncertainty associated with the upland groundwater plume loading rate estimates for these compounds. For both chloroform and TCE, the upper end range of the estimate is dominated by the concentration at a single TZW sampling point, which was more than 3 orders of magnitude higher in concentration than the next highest result in that area. Additional discussion of the approach and consideration taken in developing these loading estimates is presented in Appendix D (Section D.4.1.2.1).

Other loading terms are not expected to be significant contributors of chloroform and TCE. Neither chloroform nor TCE is expected to be transported to the Study Area in significant amounts from upstream sediments, upstream surface water, riverbank sediments, or stormwater. While atmospheric deposition is a source of VOCs to the water surface, literature data for atmospheric deposition of chloroform and TCE could not be identified. Any VOCs deposited to the water surface by atmospheric deposition are likely to volatilize rapidly soon after deposition (see discussion in Appendix D, Section D.5).

Accumulation of VOCs was not evaluated in fish and invertebrate tissues from the Study Area. Exposures, if they occur, are expected to be associated with localized releases to TZW or surface water. The exposures tend to result in a narcotic effect (with potential death), but not in uptake or biomagnification.

11.1.3.12 Ammonia, Sulfides, DRH, and RRH

As indicated in Table 11.1-1, ammonia, sulfides, DRH, and RRH were identified as ecological potential TZW iCOCs for benthic invertebrates. These chemicals were identified as potential iCOCs based only on the FPM, which does not demonstrate causality of risk. Recognizing this high level of uncertainty, discussion of potential sources and chemical properties are provided here; however, these chemicals were not included in the loading analysis. These chemicals will be evaluated further in the baseline ecological risk assessment.

11.1.3.12.1 Potential Sources and Distribution in the Study Area

Ammonia was identified as a potential iCOC based on the FPM at iAOPCs 11, 18, and 19. Ammonia is found throughout the environment in air, water, soil, animals, and plants. Ammonia occurs naturally and is an important source of nitrogen for plants and animals. It is also produced anthropogenically and used in household cleaners and fertilizers (ATSDR 2004a).

Sulfides were identified as a potential iCOC based on the FPM at iAOPCs 11 and 14. Sulfides occur naturally and are also produced anthropogenically. Hydrogen sulfide (H_2S) occurs naturally in crude petroleum, natural gas, volcanic gases, and hot springs. It can also result from bacterial breakdown of organic matter. It is also produced by human and animal wastes. Hydrogen sulfide can also be released from industrial sources, such as food processing, coke ovens, kraft paper mills, tanneries, and petroleum refineries (ATSDR 2006b).

DRH was identified as a potential iCOC based on the FPM at iAOPCs 3, T4, 6, 7, 11, 13, 19, and 21. RRH was identified as a potential iCOC based on the FPM at iAOPCs 3, 11, 13, 19. Total petroleum hydrocarbons (TPH) is a term used to describe a large family of several hundred organic chemical compounds that originally come from crude oil (ATSDR 1999c). Diesel range and residual range are fractions of TPH. Some chemicals that may be found in TPH are hexane, jet fuels, mineral oils, benzene, toluene, xylenes, naphthalene, and fluorene, as well as other petroleum products and gasoline components; however, it is likely that sources of TPH will contain only some, or varying mixtures, of these chemicals (ATSDR 1999c). TPH may enter the environment through accidental spills, from industrial releases, or as byproducts from commercial or private uses (ATSDR 1999c).

11.1.3.12.2 Chemical Properties and Behavior in the Environment

Ammonia gas can be dissolved in water (aqueous ammonia), but will quickly volatilize when exposed to air. Ammonia does not last very long in the environment and is metabolized rapidly by plants, bacteria, and animals (ATSDR 2004a). As a nutrient, ammonia does not bioaccumulate (ATSDR 2004a).

In an aqueous environment, sulfides are divalent anions that form a wide variety of compounds with metals, the solubility of which is largely influenced by redox conditions. Hydrogen sulfide can react to form sulfur dioxide and sulfuric acid under certain conditions (ASTDR 2006b). Sulfide is not expected to bioaccumulate.

It is difficult to generalize about the chemical properties and behavior of petroleum hydrocarbons because the classification includes such a large number of chemicals, with a correspondingly large range of chemical properties. Individual petroleum hydrocarbon chemicals vary in their aqueous solubility and in their affinity for sorption to organic matter. Degradation rates in the environment vary significantly and depend on the conditions, with many petroleum hydrocarbon chemicals remaining in the environment for very long periods of time. Due to the diversity of chemicals represented by this group, generalizations about toxicity are not possible. Please refer to Section 11.1.3.4 for a discussion of chemical properties and behavior of PAH compounds, which are an environmentally relevant component of many petroleum hydrocarbon mixtures.

11.2 SITE-WIDE IAOPC

This section provides the Round 2 CSM for the site-wide iAOPC, which includes the entire Portland Harbor Study Area, extending from approximately RM 2 to RM 11 (Map 11.2.1). The site-wide iAOPC is based only on total PCBs as the iCOC, as described in Table 10.5-1 of Section 10. The risk scenario defining this iAOPC is human health fish consumption for PCBs at the 10^{-4} cancer risk level for the higher ingestion rates and for a hazard quotient of 1. For these scenarios, PCB contributions from the water column alone result in tissue concentrations that exceed target risk levels. In other words, due to the water column contributions, even with a sediment concentration of zero the target risk levels would be exceeded. Because reduction of sediment concentrations will not achieve target risk levels, individual iAOPCs cannot be identified for these scenarios. As a result, the site-wide iAOPC was identified due to risks from the water column.

This CSM is summarized as follows: The major sources of PCBs were evaluated based on examination of the chemical distribution of total PCBs in in-water media, fate and transport processes, and the current understanding of historical and current potential sources within the Study Area. The majority of PCBs in sediment are the result of historical overwater releases, historical stormwater and wastewater discharges, and historical overland transport via stormwater runoff. Ongoing releases of PCBs are considerably lower in magnitude and are primarily associated with stormwater discharge, and to a lesser extent, local riverbank erosion. Sediment transport from upstream of and within the Study Area plays a role in the observed distribution of PCBs in the Study Area.

11.2.1 Physical Setting, Infrastructure, and Operational History

Previous sections in this document describe the physical setting, infrastructure, and operational history of the Study Area, which corresponds to this site-wide iAOPC. To avoid redundancy within this report, these sections are referenced and the information is not reproduced in this section. In-river physical characteristics, infrastructure, and operational history relevant to the site-wide iAOPC are described in Section 4.

Descriptions of potential upland sources are summarized in Section 5 and are included in the CSM summaries for each individual iAOPC (Section 11.3) and in the LWG site summaries (Integral and GSI 2004; Integral 2005a,b,c) and updates (Integral 2007).

11.2.2 Chemical Distribution of PCBs in the Site-wide iAOPC

This section describes the distribution of total PCBs in abiotic and biotic media for the site-wide iAOPC. Sampling locations are presented in Section 2. All iCOC data for the site-wide iAOPC are provided in Appendix C.

11.2.2.1 Sediment

The distribution of total PCBs in sediment throughout the Study Area is described in Section 6.1.1.5. Summary statistics of the total PCB analytical results for sediment are listed in Table 11.2-1. Maps 6.1-5a and b present surface and subsurface sediment sampling results for total PCB Aroclors, and Maps 6.1-6a and b present surface and subsurface sediment sampling results for total PCB congeners. The sediment PCB discussion from Section 6 is briefly summarized here.

Two types of PCB analyses were conducted for the sediment samples collected in the Study Area: PCB Aroclors for most of the samples, and PCB congeners for a subset of the samples. In surface sediment samples, total Aroclor concentrations were as high as 27,400 µg/kg, while total PCB congener values were as high as 35,400 µg/kg. In the subsurface samples, total Aroclor concentrations were as high as 26,000 µg/kg and total congener concentrations were as high as 36,800 µg/kg. The spatially weighted average concentration for total PCBs across the Study Area in surface sediment is 72.1 µg/kg. With few exceptions, total PCB Aroclor concentrations are relatively low throughout the navigation channel and higher in the nearshore zones, in both surface and subsurface samples.

As expected, the detected total PCB concentrations based on congeners show a strong, statistically significant correlation with the total PCB concentrations based on Aroclors in both the surface (correlation coefficient, $r = 0.88$) and subsurface ($r = 0.90$) data.

Aroclors 1248, 1254, and 1260 were identified throughout the Study Area. Aroclors 1221, 1242, and 1268 were identified locally but were not widespread (Maps 6.1-48 and 6.1-49), suggesting specific sources may be contributors in these areas. Aroclors 1232 and 1016 were each identified at only one location, and Aroclor 1262 was not identified in any sample. The relative abundance of Aroclors 1248, 1254, and 1260 varied from area to area, indicating there may be unique sources contributing PCBs in certain areas of the site.

A detailed description of PCB Aroclor distributions in areas with high PCB concentrations and in areas with unusual PCB Aroclor identifications (i.e., Aroclors 1221, 1232, 1016, and 1268) is provided in Section 6.1.1.5.3. Following are examples of several broad spatial patterns of Aroclor composition in surface sediment that illustrate the varying nature of PCBs in Study Area sediment and reflect the many

different sources of PCBs (Map 6.1-48). The dominant Aroclor patterns are described below, but additional Aroclors are also present in most locations:

- At RM 8.8, the western nearshore zone is dominated by Aroclor 1248. Aroclor 1242 is present at a single location. Surrounding areas contain Aroclors 1254 and 1260, although Aroclor 1248 is also present in sediment downriver from this area.
- Aroclor 1254 dominates the PCB profile at the mouth of Swan Island Lagoon (RM 8.2), with secondary concentrations of Aroclor 1260. Additional Aroclors present in isolated locations in Swan Island Lagoon appear to reflect discrete sources.
- Aroclor 1248 is prevalent in the western nearshore area near RM 7.5 and again near RM 6.7. Aroclor 1260 dominates in surrounding areas and across the river in Willamette Cove.
- A relatively small area with Aroclor 1268 is present in the eastern nearshore zone near RM 5.5. Aroclors 1248, 1254, and 1260 are also identified in this area. Surrounding areas are dominated by Aroclor 1260.
- Aroclor 1248 is present inside the T4 area, and Aroclor 1242 is identified just downriver of this area in the eastern nearshore area near RM 4. Both areas also contain Aroclor 1260. Aroclor 1260 is present at low concentrations in the navigation channel adjacent to these areas.
- Aroclor 1254 dominates the PCB profile at the head of the International Terminals Slip at RM 3.7.
- Aroclor 1248 dominates the PCB profile in eastern nearshore area at RM 2-2.5.

Aroclors 1254 and 1260 are present in varying proportions throughout the Study Area, including the areas described above, and Aroclor 1248 is also prevalent in some areas. Numerous smaller areas with different PCB composition are present between the areas summarized above, indicating the influence of additional sources.

Within the Study Area, Aroclor 1260 was most prevalent in areas with PCB levels similar to preliminary background levels. As described in Section 6.1.3.1 and Section 10, the primary use of preliminary background levels in the Round 2 data evaluation is to support the definition of iAOPCs as replacement values in the GIS "hilltopping" process. They also serve as a basis for an indirect comparison to Study Area data. Preliminary background concentrations for total PCBs (Aroclors) of 13.5 µg/kg (with non-detects set at one half the detection limit) were determined as described in Section 6.1.3. PCBs are ubiquitous in the environment, and these preliminary "background" levels may represent general anthropogenic input. Additional analysis is necessary to determine contributions from sources in the Study Area. Aroclor 1260, identified in 83 percent of samples from areas with total PCB concentrations below 10 µg/kg, was the predominant Aroclor in "background-level" samples. Aroclor 1254 was of secondary importance, identified in 20 percent of samples with less than 10 µg/kg total PCBs.

Aroclor 1248 was identified in fewer than 5 percent of background-level samples in the Study Area.

11.2.2.2 Surface Water

The distribution of total PCBs in surface water throughout the Study Area is described in detail in Section 6.3.3.2. Summary statistics of the total PCB analytical results for surface water are listed in Table 11.2-2. Total PCB concentrations in Round 2A surface water samples are depicted in Figure 6.3-8 and Map 6.3-3. A brief summary of the surface water PCB discussion from Section 6 is provided here.

For the three transect samples located within the site-wide iAOPC, the total PCB congener concentration ranged from a low of 171 pg/L (March, upriver transect [W023]) to a high of 609 pg/L (November, upriver transect). Excluding Station W013 in Willamette Cove, the near-bottom samples produced total PCB congener concentrations ranging from 201 to 1,290 pg/L in the XAD filters, and from 137 to 639 pg/L in the XAD columns. Total PCB congener concentrations at Station W013 were generally an order of magnitude higher, ranging from 3,340 to 12,000 pg/L.

At all sampling locations within the site-wide iAOPC, PCBs in the particulate fraction consistently exhibited a more highly chlorinated pattern than PCBs in the dissolved phase. This PCB distribution reflects the greater solubility and lower partitioning coefficients of the less chlorinated congeners, as described in Section 7. Pie charts depicting total PCB congener concentrations and PCB homolog distributions for the Round 2A surface water XAD column and filter samples are presented in Map 6.3-14, and are discussed in greater detail in Section 6.3.3.2.

11.2.2.3 Transition Zone Water

The Round 2 TZW sampling effort did not include the collection of TZW samples for PCB analysis because PCBs were not upland groundwater COIs at the locations sampled and are not expected to significantly migrate in groundwater due to their highly hydrophobic characteristics.

11.2.2.4 Biota

The distribution of total PCBs in biota collected within the Study Area is described in Section 6.4.2.6. Summary statistics of the total PCB analytical results for biota are listed in Tables 11.2-3 and 11.2-4. Total PCB concentrations in biota samples are depicted in Maps 6.4.2a–c, 6.4.3a–c, 6.4.4a–c, and 6.4.5a–c. A brief summary of the biota PCB discussion from Section 6 is provided here.

The biota data set for the site-wide iAOPC includes analyses of fishes, benthic invertebrates, and epibenthic communities conducted by the LWG as part of Rounds 1 and 2 of the Portland Harbor RI/FS, as well as recent data collected by other parties. Nine fish species are represented: brown bullhead, black crappie, carp, juvenile and adult Chinook, largescale sucker, northern pikeminnow, peamouth, sculpin, and smallmouth bass. The types of tissue examined were whole-body fish and fillets (skinless and skin on). Tissues from three invertebrate species were analyzed: the

Asiatic clam, mudworm, and crayfish. Both field and laboratory exposures were considered for the clam and mudworm. Epibenthic communities from multiplate samplers were composited for analysis. Prey (primarily aquatic organisms and terrestrial insects) found in the stomachs of juvenile Chinook was also analyzed and discussed as part of the invertebrate data.

One or more Aroclors were detected in all fish species. Across species, average total Aroclor concentrations in whole-body tissues ranged from 55.8 to 1,640 µg/kg. The maximum concentration (6,500 µg/kg) was measured in carp. Average congener totals in whole-body samples ranged from 147 to 1,920 µg/kg; again the highest individual concentration occurred in a carp sample.

At least one Aroclor was detected in every invertebrate species. In whole-body tissues, average across-species total Aroclors ranged from 9.17 to 438 µg/kg. The maximum concentration (3,230 µg/kg) was measured in mudworms. In comparison, total congener averages by species ranged from 44.2 to 635 µg/kg. The maximum congener sum (4,310 µg/kg) also was measured in mudworms.

Total PCB Aroclors measured in juvenile Chinook whole-body tissues averaged 15.9 µg/kg (with a range of 12.1 to 20.4 µg/kg) and total PCB congeners averaged 16.7 µg/kg (with a range of 12.8 to 21.6 µg/kg). The total Aroclor concentration reported for the single juvenile Chinook stomach contents composite sample was 9.17 µg/kg.

For comparison, total PCB Aroclors in adult Chinook whole-body samples from the Clackamas River averaged 14.8 µg/kg (maximum of 20 µg/kg) and fillets averaged 16.8 µg/kg (maximum of 19 µg/kg). Total PCB congeners averaged 13.1 µg/kg in Clackamas River whole-body adults (with a range of 6.89 to 17.1 µg/kg) and fillets averaged 12.6 µg/kg (with a range of 8.71 to 15.3 µg/kg).

11.2.2.5 Patterns of Aroclor Distribution in the Study Area

Map 11.2-1 shows Thiessen polygons representing PCB concentrations for each sample location. PCB concentrations in 74 percent of the Study Area are below 34 µg/kg, similar in magnitude but slightly higher than the preliminary background concentrations (see Section 6.1.3). Total PCBs were highest in surface sediment offshore of OSM (iAOPC 1), Schnitzer Steel (iAOPCs 3 and 5), Willamette Cove (iAOPC 13), Gunderson and Equilon (iAOPC 19), and Cascade General (iAOPCs 21 and 22).[75] Subsurface PCB concentrations were also high in these areas (Maps 6.1-28a–c).

Different patterns of PCB Aroclors and homologs (see Section 6) are evident in various parts of the Study Area, often corresponding with areas of elevated PCB concentrations. These conditions indicate that different areas of Portland Harbor are influenced by different PCB sources. The distinct delineations between some areas with different

[75]Although a portion of iAOPC 14 (offshore of Arkema) has high PCB concentrations in surface sediment, this area is not included here because the highest concentrations reflect extremely elevated values for non-detects.

PCB composition suggest that large-scale movement of sediment-bound PCBs in certain parts of the Study Area is limited. The Round 3 sediment transport study (described in Section 7.3), currently in progress, will be used to evaluate transport of sediment-sorbed iCOCs (including PCBs) in the Study Area to help identify the sediment transport contribution to the sitewide contamination.

PCB patterns in suspended solids at near-bottom surface water sampling locations are similar to nearby PCB patterns in bed sediment, which indicates that PCBs in sediment may influence the near-bottom suspended sediment composition. During Round 2, near-bottom suspended solids samples were collected at four locations within the Study Area and analyzed for PCB congeners, allowing comparison to the Aroclor signatures of adjacent bed sediment (see Maps 6.1.48a–i and 6.3-4). In Willamette Cove (RM 6.8, location W014, iAOPC 13), Aroclor 1260 was prevalent in surface sediment, and the PCB homolog pattern in both surface sediment and suspended solids was consistent with Aroclor 1260. In Swan Island Lagoon (RM 8.3, location W018, iAOPC 22), the PCB homolog pattern in suspended solids was consistent with a mixture of Aroclors 1260 and 1254. Only Aroclor 1260 was identified in bed sediment at location W018, but Aroclor 1254 was identified at adjacent sediment sampling locations. Particulate-phase PCB patterns at both of these locations differed somewhat from the pattern found at the surface water transect sampling locations.

Surface water sampling locations W015 and W016 are situated in AOPC 14 on the western side of the river at RM 6.9 and 7.3, respectively. Particulate-phase PCBs at location W015 varied somewhat in composition between sampling events. Suspended particles contained higher proportions of tetraCBs than were found in the transect samples, consistent with the Aroclor composition of the nearest sediment. The PCB composition in sediment in this area also exhibited a degree of variability. The spatial and temporal PCB patterns in surface water and sediment at both of these locations may reflect the presence and intermingling of several different PCB sources, including an intermittent source such as stormwater.

PCB concentrations in subsurface sediment are somewhat higher overall than in surface sediment throughout most of the Study Area (Maps 6.1-5a and b). This pattern is consistent with the historical use and release of PCBs and the depositional nature of nearshore areas in much of the Study Area (see Section 4.5.2 and Map 4.4-2). Exceptions to this pattern were noted for iAOPCs 2, 4, 5, 12, 13, 17, 19, 20, and 25; surface sediment in these iAOPCs generally has higher PCB concentrations than subsurface sediment.

Aroclor and PCB homolog distributions are fairly similar in surface and subsurface sediment in parts of the Study Area, which may indicate PCBs in both surface and subsurface sediment originate from the same sources in these areas. In these cases, PCBs in surface sediment may be attributed to ongoing upland or upstream sources that are similar to historical sources, or to vertical mixing of subsurface sediment into the accumulating surface sediment as a result of turbation. The PCB composition in surface

and subsurface sediment appeared substantially different at iAOPCs 1, 2, 5, 7, 17, 18, and 19, where PCB composition was found to be stratified. Current and historical PCB sources may be different in these areas.

The PCB mass in surface sediment (i.e., the upper 30 cm of sediment) was calculated[76] for the individual iAOPCs and for the non-iAOPC areas within the Study Area to provide a general indication of the relative importance of the PCB distribution in the different iAOPCs, which were categorized to facilitate discussion. PCB mass calculation results are shown in Table 11.2-6. Based on these approximations, Category 1 iAOPCs each contain more than 5 percent of the total PCB mass present in surface sediment in the Study Area; category 2 iAOPCs contain 1 to 5 percent; and category 3 iAOPCs contain less than 1 percent. When PCBs were not detected, half the detection limit was used as the PCB concentration for the purpose of calculating total PCB content in the sediment contained in the Thiessen polygon. The calculated PCB mass is likely overestimated in areas where PCBs were undetected at high detection limits, notably at iAOPC 14.[77]

The 27 iAOPCs are estimated to collectively contain approximately 70 percent of the PCBs found in Study Area surface sediment. Additionally, the eight iAOPCs with the highest PCB mass (category 1) account for approximately 70 percent of PCBs in surface sediments within the 27 iAOPCs and 50 percent of PCBs in the Study Area.

11.2.3 Potential Sources of iCOCs

This section presents a summary of the current understanding of potential historical and current sources of PCBs to the site-wide iAOPC, including available loading estimates from Section 11.1.

PCBs have low flammability and a high resistance to electrical currents. They are good insulators and remain stable even in conditions of high heat and pressure. Due to these characteristics, PCBs were widely used for a variety of purposes from the 1930s to the 1970s, including dielectric fluids in transformers and capacitors, cutting oils, hydraulic oils, and heat transfer fluids. Additionally, PCBs were used as plasticizers and as flame

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[76]PCB mass was determined by using Thiessen polygons to represent PCB concentrations for each sample location. ArcGIS was used to calculate the area of each polygon. The PCB concentration of each sample was assigned to the entire polygon. The sediment mass in each polygon was calculated and multiplied by the concentration of PCBs (on a wet-weight basis) in the sample to determine the total mass of PCBs. When a specific gravity value was not available for a sample (e.g., for non-LWG samples), the average specific gravity for Study Area surface sediment of 1.5 was used. Non-detects for total PCBs were evaluated at half the detection limit. Sample duplicates were averaged prior to generating Thiessen polygons, but replicates were not averaged since they have different x and y coordinates. Thiessen polygons were generated using the ET Geowizards toolset for ArcView 9.1.

[77]The maximum detected PCB Aroclor concentration at iAOPC 14 was 322 µg/kg and the maximum detected total PCB congener concentration was 972 µg/kg, but undetected PCBs were reported with detection limits up to 4,000 µg/kg.

retardants, additives to pesticides, paints, carbonless copy paper, adhesives, sealants, and for dust suppression. Although PCBs are ubiquitous in the environment, commercial PCB production in the United States ended in 1977. The Toxic Substances Control Act (TSCA), which became law in 1976, bans the manufacture of PCBs, controls the phase-out of their use, and regulates safe disposal. The law, regulated under 40 CFR Part 761, contains provisions for equipment contaminated with PCBs, PCB inspection and recordkeeping in use or in storage, PCB spill prevention and cleanup, waste PCB packaging, labeling, and storage, and disposal.

PCBs were associated with materials used in manufacturing processes and, during WWII, to build ships and tankers. A considerable number of Liberty ships, minesweepers, and T-2 tankers were built at shipyards located in the LWR. Following WWII, a few of the shipbuilding facilities were repurposed for scrapping the military's surplus and obsolete vessels. In addition to shipbuilding, scrapping, and repair, land uses in the Study Area have included lumber and steel mills, fuel facilities, rail yards, and manufacturing facilities. However, historical PCB uses and releases in the Study Area are generally not documented. Identified upland sources account for only a fraction of all PCB sources to the Study Area.

Map 11.2-2 shows historical shipyards observable on aerial photographs taken between 1936 and 1969 and superimposes these on a map depicting PCB concentrations in surface sediment. A relatively high degree of spatial correlation is observed between the historical shipyard locations and high PCB concentrations in nearshore sediment.

Known potential sources are summarized in Table 11.2-5. Many of these sources are not definitive and likely comprise only a portion of the PCB sources to the Study Area. Known or suspected PCB contributions are summarized in the following sections.

11.2.3.1 Stormwater/Overland Transport

Overland transport was likely to have been more important historically, prior to the development of extensive stormwater conveyance systems. Stormwater loads have likely decreased substantially since implementation of regulations in the 1970s. There is little specific information in the record on the relative historical contribution of these pathways as compared to overwater discharges and contributions associated with fill placement and subsequent erosion, which were also major contributors to the Study Area.

Stormwater runoff to the Study Area is currently discharged mostly via stormwater outfalls that are connected to stormwater conveyance systems. Overland flow of stormwater to the river occurs at some locations immediately adjacent to the river, as discussed in Section 4.1.4. Because the area drained by overland flow is small relative to the entire watershed for the Study Area (e.g., area discharged via outfalls), the transport of PCBs to the Study Area by overland transport is expected to be a less important current PCB pathway than stormwater discharge via outfalls.

Stormwater loading of total PCB Aroclors to the Study Area is discussed in Section 11.1. No site-specific PCB data were available to support these estimates; therefore, the estimates were based on a study from Switzerland. Consequently, the estimates are highly uncertain, as indicated by the 3-order-of-magnitude range in the estimates (0.02 to 13 kg/yr loading rate). For context, these estimates range from well below to slightly above the observed upstream surface water load (upstream surface water load estimates range from 1.0 to 8.1 kg/yr). Stormwater sampling to refine these estimates has been identified as a data need for Round 3.

11.2.3.2 Wastewater

Many waste management practices in the past were not regulated and were generally based solely on economic considerations. Common practices included discharging or dumping wastes directly into the river, storing wastes in unlined holding ponds, and dumping wastes onto the ground. Practices such as these likely resulted in historical releases to river sediment and surface water that may not have been documented and are difficult or impossible to reconstruct at the present time. The relative contribution of PCBs to the Study Area via wastewater discharge is not quantifiable, but is not considered a significant site-wide source compared to other historical pathways.

Industrial process wastewater is generated from several sources in the Study Area, as described in Section 5.1.3.2. Currently, wastewater generally enters the Study Area via constructed conveyance systems and outfalls. Wastewater discharge requires a permit under the NPDES. None of the wastewater generators have been identified as a current PCB source.

11.2.3.3 Overwater Discharge

Overwater discharges of PCB-containing materials are likely to have occurred historically, but are not a significant current or recent pathway except, possibly, at sites where continuous overwater construction activities occur, such as Cascade General Shipyard and Gunderson, and sites where waste materials are handled overwater, such as Schnitzer at International Terminal. Most detailed spill records of overwater discharges, as summarized in Table 5.1-6 relate to discharges that occurred in the past two decades. Some general evidence of historical overwater discharges also exists (e.g., EPA 1997c), although the exact nature of the discharge and quantities released are undocumented. As noted above, the relative importance of historical overwater discharge is difficult to distinguish from concurrent releases to stormwater and overland transport.

11.2.3.4 Groundwater Discharge

Upland groundwater plumes flowing toward the river are unlikely to be a source of PCBs to sediments, TZW, and surface water in the Study Area, given the highly hydrophobic nature of PCBs and the limited presence of PCBs in upland groundwater. Maps 5.1-1a–j provide a river-mile-scale view of the areas of affected groundwater in the vicinity of the Study Area. Groundwater as a source of iCOCs to the Study Area is also discussed in Section 5.1.2.

PCBs have, however, been detected in upland groundwater at four sites (Table 11.2-5):

- Front Avenue LP Properties (CMI NW, Hampton, Lonestar NW/Glacier NW, Tube Forging)
- Gunderson
- Sulzer Bingham Pumps
- Triangle Park.

PCBs are hydrophobic chemicals with a strong affinity for organic carbon associated with soil particles. This chemical characteristic limits their mobility in groundwater. PCBs were not identified as upland groundwater COIs for any of the TZW study sites; consequently no TZW samples were collected for PCB analysis, and no loading estimates were generated for PCB "plumes."

Groundwater may remobilize PCBs present in river sediment via groundwater advection through these sediments and into the surface water column, as described in Section 11.1.1.1. Because this transport process requires partitioning of the highly hydrophobic PCB molecules into the TZW, the resulting estimated PCB loading rates to the water column from advection through contaminated sediments are extremely low. The estimated advection loads are all well below the observed water column loads, as described in Section 11.1.2.6.3. Remobilization of PCBs by groundwater advection is not considered a significant pathway at the Study Area.

At all iAOPCs, including the four sites listed above, groundwater is considered a very small relative contributor of PCBs to the river.

11.2.3.5 Riverbank Erosion

The shoreline of the Study Area has been modified extensively over the last century (Section 4). Most of the modification consisted of filling and advancing the shoreline toward the river. Fill materials included both dredge material from the shipping channel and imported fill from known and unknown sources. In some cases, it is reasonable to expect that contaminated dredge material was used as nearshore fill material. Again, in some cases, these contaminants may have re-entered the in-water environment during placement and, to a lesser extent, subsequent bank erosion.

Riverbank erosion is not anticipated to be a major ongoing release mechanism in areas that are currently armored (Map 5.1-3), although it may be locally significant in some areas and was likely more significant in the past.

PCBs have been detected in exposed riverbank soils at five sites where data are available (Table 11.2-5), including the following:

- Crawford Street Corp.
- Gunderson

- Oregon Steel Mills
- Triangle Park
- Willamette Cove.

Additional detail is provided in the site summaries for these facilities. PCBs are likely to be present in eroding riverbank soil in areas other than those identified above. Due to limited riverbank soil data and limited detail on bank armoring, loading estimates of PCBs to the Study Area from riverbank erosion could not be prepared.

11.2.3.6 Atmospheric Deposition

Air pollution (e.g., vehicle emissions, industrial smokestacks, fugitive dust) can be a source of chemicals to the Study Area through the processes of wet and dry deposition. A semi-quantitative preliminary estimate of the annual loading rate of PCBs to the Study Area via atmospheric deposition was made based on literature information. The results are discussed in Section 11.1.2.6. This estimation accounts only for loading to the river surface and does not take into account atmospheric loading to the drainage basin. The atmospheric loading to the basin as a whole contributes to the overall loads from the stormwater and upstream inputs, which are included here as part of those source loads.

The atmospheric deposition loading rate of total PCBs to the river surface within the Study Area was estimated from literature values of modeled nearby conditions (Multnomah County) to be approximately 0.22 to 0.80 kg/year, as described in Section 11.1.2.6. This estimated loading rate, although significant, is small relative to the estimated upstream surface water loading.

11.2.3.7 Upriver Sources

Potential sources of chemicals, including PCBs, outside the Study Area may include point and non-point sources related to agricultural, industrial, and general urban activities. Upstream sources of contaminants are described in Section 5.2. PCBs may be carried into the Study Area from upstream sources dissolved in the surface water, adsorbed to suspended particles in the surface water, or as part of the sediment bed load, as described in Section 7.1.1.

Section 11.1.2.6.3 presents a preliminary quantitative estimate of PCBs entering the Study Area at RM 11 based on the concentrations of PCBs in the dissolved and particulate phases of surface water collected during three sampling events from November 2004 to July 2005. The estimated loading rates of dissolved PCBs entering the Study Area from upstream sources ranged from 0.40 to 0.90 kg/yr, and the estimated loading rate of particle-sorbed PCBs ranged from 0.47 to 7.7 kg/yr. Upstream surface water is a significant source of PCBs to Study Area surface water relative to other calculated and estimated PCB loading rates (Section 11.1.2.6).

A Round 3 sediment transport study is currently in progress, as described in Section 7.1.1.2. This study will be used to model bed sediment transport and to estimate a PCB

load to the Study Area via bedload transport. Additional surface water data collected during Round 3 will be used to refine upstream loading estimates.

11.2.4 Relationship of Upland Sources to the Distribution of iCOCs

This section provides a preliminary assessment of how the observed distribution of PCBs within the river relates to the various current and historical potential sources and migration pathways. This assessment will be augmented for the RI with Round 3 data.

The most significant pathways for PCBs to migrate to the Study Area are historical and include overwater releases, stormwater, wastewater, and overland transport (Table 11.2-7). Bank erosion and sediment transport from upstream areas were likely of additional, but secondary, importance. The historical releases from these pathways are not quantifiable and, in many cases, are difficult to distinguish; in the case of shipbuilding and dismantling operations, it is likely that overwater and stormwater releases occurred concurrently. The locations of high PCB concentrations in surface and subsurface sediment coincide in many cases with historical shipyards.

Current PCB inputs to the Study Area are much lower than historical inputs because PCBs are no longer used and because waste management practices have been greatly improved.

Important current pathways include stormwater, riverbank erosion, and sediment transport from upstream areas. Stormwater transport is expected to be the most significant current pathway for PCBs to enter the Study Area from upland sites. Stormwater is identified as a likely pathway for PCBs to enter the Study Area at many individual iAOPCs.

Locally, bank erosion is an important current pathway in some areas. Current PCB contributions to individual iAOPCs via bank erosion were considered of high or medium importance relative to other pathways at six iAOPCs overall, including four of the eight iAOPCs with the highest surface sediment PCB content. Bank erosion is also a potential pathway for PCBs to enter the Study Area in areas outside of the iAOPCs. No loading rate estimates for riverbank erosion could be generated due to extremely limited riverbank soil chemistry data and bank condition information.

Current overwater releases may be locally important at sites with continuous waste handling or construction activities, but are considered a minor current pathway overall.

Groundwater is unlikely to be a significant historical or current pathway for PCB migration into the Study Area. The relative contribution of PCBs via groundwater was considered low at all of the iAOPCs in the Study Area.

The loading rates for atmospheric deposition of PCBs onto the river surface are estimated to be low compared to other sources.

A preliminary evaluation of the relationship between sources, pathways, and iCOCs in the site-wide iAOPC is summarized in Figure 11.2-1. A preliminary assessment of the relative contributions of the current and historical relative contributions of each source is summarized Table 11.2-7.

11.3 CSM FOR iAOCs

This section provides Round 2 conceptual site models (CSMs) for the iAOPCs identified in Section 10. Each CSM describes the physical setting, distribution of iCOCs, and potential sources of iCOCs, and discusses the relationship of upland sources to the distribution of iCOCs.

The list of iCOCs for some iAOPCs is extensive (e.g., iAOPCs 14 and 19). In these cases, a subset of iCOCs was carried forward into the distribution and relationship sections of the CSMs. The iCOCs chosen for discussion were based on a number of factors, including representativeness of known or potential complete pathways, representativeness of a chemical group, frequency of detection, and distribution in the iAOPC.

The information presented on upland sources comes primarily from the site summaries. (Integral and GSI 2004; 2005a,b,c and Integral 2007). Pertinent information on upland sites that was available through the late fall of 2006 is included to the extent possible. Many of the upland sites addressed in the site summaries are in various stages of source control investigations and very recent data may not be included.

In addition, site summaries have not been prepared for all properties and systems that potentially discharge or have discharged to the river. Site summaries are not available for non-ECSI sites that primarily discharge to the river via the stormwater pathway, for unpermitted historical stormwater and wastewater discharges, for historical spills that may not be associated with a specific upland facility, or for the City of Portland's conveyance systems. Many of these potential sources have not been systematically evaluated by the LWG.

The relationship of upland sources to the distribution of iCOCs that is presented in this report is a preliminary evaluation. Each CSM contains a discussion and a table that identifies, to the extent possible, historical and current sources and pathways. These pathways are ranked relative to other pathways to the iAOPC. The discussion and table evaluates the existing data quality and quantity. A CSM figure is also provided illustrating the relative contributions (historical or current) of pathways. In many cases, the existing data quality and quantity are low and the evaluation of relative contribution can be subjective in these cases.

The rankings of pathway contributions presented for the individual iAOPCs do not reflect the relative inputs to the Study Area as a whole. The CSM for the site-wide

iAOPC (Section 11.2) provides a relative ranking of PCB sources and pathways for the entire Study Area.

11.3.1 CSM for iAOPC 1

This section describes the preliminary CSM for iAOPC 1, which includes a 19.13-acre area extending from approximately RM 2.0 to 2.6 along the eastern shore of the river, adjacent to the Oregon Steel Mills (OSM) and J.R. Simplot properties (Map 11.3.1-1). This CSM examines the physical setting of the iAOPC and adjacent upland properties, the chemical distribution of iCOCs in in-water media, and potential sources of the iCOCs.

The following iCOCs have been identified for this iAOPC:

- Total PCBs.

Potential iCOCs include:

- Zinc
- Dibutlyl phthalate (DBP).

The potential iCOCs are identified through less certain and/or less rigorous evaluations based on fewer lines of evidence, FPM results, or other high uncertainty lines of evidence (see Sections 8 and 9).

Map 10.5-3a–j shows the areas where this preliminary analysis identified the potential for risk for individual exposure scenarios that were considered in iAOPC development, and Table 10.5-1 identifies the iCOCs associated with the exposure scenarios. PCBs are an iCOC at all areas within the iAOPC. The area identified for DBP and zinc is relatively small and downstream of the OSM dock.

Riverbank erosion and stormwater runoff, which function as both present and historical pathways to the river, appear to be substantial contributors of iCOCs to in-water media. PCBs and metals, including zinc, have been detected at OSM in riverbank fill soils, upland surface soils, and catch basin solids. Groundwater and current overwater operations do not appear to be significant sources of iCOCs, although historical overwater operations may have been a likely source. In addition, iAOPC 1 lies at the downstream end of the Study Area and likely receives some sediment contribution from upstream sources.

Concentrations of PCBs in surface sediment were generally lower that those in underlying core samples suggesting that historical sources to the iAOPC were more substantial than current sources. Conversely, concentrations of DBP and zinc in surface sediment were generally higher than those in underlying core samples, suggesting that the sources to the iAOPC are relatively recent.

11.3.1.1 Physical Setting, Infrastructure, and Operational History

In-river and upland physical characteristics, infrastructure, and operational history relevant to iAOPC 1 are briefly described in this subsection. Information on adjacent upland sites was obtained from the LWG site summaries (Integral and GSI 2004; 2005a,b,c) and updates (Integral 2007) unless otherwise noted.

11.3.1.1.1 In-River

iAOPC 1 is located along the eastern side of the LWR where the river broadens and bends north-northeast toward the Columbia (Map 11.3.1-1). iAOPC 1 is situated on the inside of a bend in the river. From 0 to approximately -30 ft NAVD88 (the outer edge of the offshore dock structures), the riverbank is relatively steep-sloped. From the dock face to the navigation channel approximately 500 ft farther offshore there is a broad shelf extending down toward -40 ft NAVD88. The outer boundary of the iAOPC generally runs well inshore of the navigation channel edge.

Multnomah Channel intersects the Willamette on the west side of the river about 0.5 miles upstream of iAOPC 1 at RM 3. As detailed in Section 4.3.3.2, surface water always flows from the LWR down Multnomah Channel; depending on tidal stage and the relative stage heights of the Columbia and Willamette, anywhere from 25 to 100 percent of the LWR downstream discharge volume flows down Multnomah Channel. Higher percentages of the LWR downstream discharge flow down the Multnomah Channel on incoming tides during low flow periods (e.g., late summer) when Columbia River water flows upstream into the LWR (see Figure 4.3-9a). As a result of this hydrology and the channel morphology, the LWR is much more depositional below Multnomah Channel than just upstream, and iAOPC 1 is located on the landward side of a large area of persistent sediment deposition along the east side of the river known as the "Post Office Bar." Although river flow is upstream in this reach at times, bottom scour and significant sediment transport are not likely during these upstream flows. Any bottom scour is likely limited and restricted to the higher energy downstream flow periods. However, water and associated suspended sediments may move upstream at times, particularly during Willamette low-flow conditions.

The time-series bathymetric change data over the 25-month period from January 2002 through February 2004 illustrate multi-year sediment transport patterns in this reach. No or very little bathymetric change data are available for the narrow bank areas above 0 ft NAVD88 because of shallow water depths and obstructions such as docks. Areas of no observed elevation change and accretion up to 1.0 ft dominate the relatively steep nearshore areas from 0 to -30 ft NAVD88 throughout most of the iAOPC (RM 2.0 to 2.6 (Map 11.3.1-1). Offshore of this iAOPC, areas of considerable sediment accretion (up to 2 ft) alternate with smaller areas of no net bed elevation change. Areas on the far (west) side of the river across from this iAOPC deepened on the order of 0.25 - 2.0 ft over the 25-month bathymetric time-series period. The overall pattern of sediment deposition and erosion in this reach of the river suggests that the river channel is trying to migrate westward.

Upland geologic cross-sections and in-river subsurface sediment core data (Figure 11.3.1-1) indicate that material within and adjacent to the nearshore portions of the iAOPC is generally dredge fill and native sand overlaying sandy silt to silty clay. Approximately 200 ft offshore, the sediments consist of sand to fine sand overlaying sandy silt to silty clay (Map 11.3.1-2a,b).

11.3.1.1.2 River Shoreline Area

The majority of the western property boundary of OSM adjacent to the Willamette River consists of a historically filled riverbank and beach. The riverbank off OSM includes three features from bottom to top: 1) a gently sloping sand to boulder beach consisting of fill and naturally deposited material, intermittently vegetated with grasses; 2) a steep or near-vertical riverbank face consisting of slag-soil fill extending four to twelve feet above the beach in the central portion of the property and a more gently sloping heavily vegetated bank near the north and south property boundaries; and 3) a constructed soil berm at the top of the riverbank face. The soil berm was constructed from excavation soils from the construction of the combination mill. The toe of the riverbank, at the base of the riverbank face, is vegetated with mature trees and undergrowth. Stormwater outfalls WR-22 and WR-24 discharge on the beach near the toe of the riverbank. Information regarding riverbank conditions for this iAOPC is limited to that provided in the OSM CSM site summary (Integral 2007), which is based on a riverbank source control evaluation performed for DEQ. This evaluation reports a potential for riverbank erosion. OSM and DEQ are currently developing a stabilization plan for the riverbank.

The riverbank off of the J.R. Simplot property appears on aerial photos to be generally similar in nature to that along the southern portion of OSM.

Significant in-water facilities/structures adjacent to the iAOPC and their associated uses are as follows (Map 11.3.1-1):

- Historical dock/trestle—Prior to OSM ownership, from approximately 1942 until the 1960s, a pipe was used to convey bilge water and oily material from ships and barges to the "oil sump" on the property. The historical dock/trestle was located south of the current OSM dock.
- OSM dock – dock is currently not in use for moorage, although it has occasionally been used in the past for temporary moorage.
- J.R. Simplot dock structure – anhydrous ammonia (compressed gas), urea, and diesel fuel are transferred between barges and the dock.
- Private stormwater outfalls WR-22, WR-24, WR-367 (abandoned), WR-368 (abandoned), and WR-17 (immediately upstream of the iAOPC).
- Private outfall WR-23 – a permitted NPDES-IW discharge for contact cooling water.

11.3.1.1.3 Upland

Upland sites adjacent to iAOPC 1 include OSM and the northern portion of J.R. Simplot. Upland conditions at these sites are described in the site summaries prepared by LWG and are summarized in this subsection. Land use zoning for properties within the stormwater pipesheds draining into iAOPC 1 is industrial (Map 4-1-4a–d). Historical and current operations and predevelopment features (when available) for the OSM and J.R. Simplot properties are provided below.

The northern area of the upland sites (RM 2.0 to 2.5) is characterized as a historical floodplain between the Willamette and Columbia Rivers and is located approximately 2 miles southwest of the confluence of the two rivers. The terrain at the site is relatively flat, with elevations of 33-38 ft NAVD88 in the main plant and storage areas. In the northern portion of the upland sites, the reconfigured landfills reach elevations up to 88 ft NAVD88. A narrow portion of the upland sites (RM 2.0 to 2.5) on the north immediately adjacent to the Willamette River (on OSM property) falls within the City of Portland Greenway zone.

The southern area of the upland sites is generally flat, except near the river where the land slopes toward the site on the inland side of the berm, and toward the river at the riverbank itself. The upland sites are bordered by Ashgrove Cement on the south; Union Chemical, Consolidated Metco, and railroad spurs on the east; the Willamette River to the west; and Port of Portland Terminal 5 on the north.

Oregon Steel Mills

The OSM site (ECSI #141) consists of approximately 145 acres where the western edge of the property is adjacent to the Willamette River. The majority of the property has been developed for facility operations. The only undeveloped area of the site is a limited portion along the northwest property boundary that includes a small seasonal wetland. Historical and current operations for OSM facility are summarized below.

Filling of the Rivergate Area, including the current OSM property, began in the early 1940s. Fill soils (hydraulically placed dredged material) were placed in the area over an extended time from the 1940s through the 1960s. A dredge fill map compiled from Army Corps data shows that dredged material from the Post Office Bar, a depositional bar historically offshore of OSM, were placed on and/or near the OSM property in 1952, 1953 and 1960. Between approximately 1942 and 1960 bilge water, slop oil and other waste materials from ships and industries in the area were disposed of into pits commonly referred to as the "Ramsey Lake" sump (the "sump") dug on filled land in an area of what became the southwest portion of the OSM property. The waste materials were pumped or otherwise transferred from vessels on the Willamette River to the sump. In approximately 1960, the sump was dewatered. Radial trenches were dug around the sump and the water was drained over the surrounding property. An attempt was then made to burn the remaining material in the sump before it was filled. OSM bought the property in 1967 after the sump had been closed and filled, and completed construction of its steel mill in 1969. In the 1970s, fill was placed in the riverbank area of the property, using slag generated from its processes and soil from the site.

Industrial operations at the site since 1969 have been limited to steel production, steel processing, and related ancillary operations.

A dock extends over-water near the center of iAOPC 1. The dock was used from approximately 1969-80 to transfer an iron ore slurry through steel pipes directly from ship holds into the asphalt lined-direct reduction division (DRD) pond. From 1980 until recently, OSM has occasionally leased the dock space to ships in need of temporary moorage.

J.R. Simplot

J.R. Simplot (ECSI #3343) is one of many tenants of the South Rivergate Industrial Park (ECSI #2980), part of the 2,800-acre Rivergate Industrial District. Other tenants in the industrial park include HB Fuller Co./Union Chemical (ECSI #329), Ash Grove Cement (ECSI #4696), Port/Georgia Pacific (no ECSI#), Douglas Walters/T&G Trucking (no ECSI#), and PG&E (no ECSI#). Of these industrial sites, only the J.R. Simplot facility is adjacent to iAOPC 1. Current and historical operations for the J.R. Simplot facility are summarized below.

The J.R. Simplot Company's Rivergate Terminal occupies 31.38 acres south of OSM. It is bounded on the west by the Willamette River and on the east by HB Fuller Co. The site currently distributes anhydrous ammonia (compressed gas) and solid urea. Both compounds are manufactured offsite and transported to the terminal by ships and barges. The materials are also transported out of the facility by barge, truck and rail. In the past, sulfur, nitrogen, sodium hydroxide, and sulfuric acid were also handled at the site.

11.3.1.1.4 Upland Hydrogeology

Subsurface environmental site investigations have been conducted at the OSM facility. No geologic or hydrogeologic data were obtained or reviewed for the South Rivergate Industrial site – J.R. Simplot.

OSM

Three fill units are present in near-surface soils of the OSM facility: 1) soils (sand and silt) used to construct the berm at the top of the shoreline riverbank, 2) a surficial layer of slag-soil fill, and 3) dredge-fill (predominantly sand and silty sand) used to achieve development grades for the site prior to industrial manufacturing operations. The slag-fill deposits cover a majority of the upland OSM plant area and are typically 2 to 6 ft thick; however, along the riverbank area, the slag-fill unit appears to be wedge-shaped, with a maximum thickness of approximately 12 ft that forms the steep riverbank face above the beach in the central portion of the riverbank.

In some or all of the facility, the base of the dredge fill unit is underlain by a sand unit of native alluvium, similar in appearance and texture to the dredge fill. This undifferentiated sand extends to an approximate depth of 20 to 35 ft bgs (an elevation of 13.2 to -1.8 ft NAVD88 in the uplands and 1.2 to -16.8 ft NAVD88 along river) and is underlain by a predominantly silt unit.

The silt unit is laterally continuous and fine grained, consisting of sandy silt to silty clay with minor fine sand interbeds. Geotechnical logs from boreholes completed in 1967 indicate that the silt unit extends laterally under the beach, with the top of the silt at approximately -15.8 ft NAVD88 south of the dock and 1.2 ft NAVD88 north of the dock. The silt unit is encountered at a depth of approximately 20 to 35 ft bgs (13.2 to -1.8 ft NAVD88) in the uplands and ranges in thickness from approximately 30 to 70 ft. A generalized geologic cross section is provided in Figure 11.3.1-1.

The upper water-bearing unit of the OSM site consists of undifferentiated sand (dredge fill and native alluvium). The sand is underlain by a silt aquitard exhibiting low permeability 30 to 70 ft thick, which is continuous across the OSM facility. Shallow groundwater generally flows toward the west-southwest across the eastern portion of the OSM facility and then shifts slightly toward the west-northwest across the western portion of the facility as it approaches the river. In the immediate vicinity of the river, flow is generally perpendicular to the river. Water level measurements indicate that two groundwater mounds exist and locally affect groundwater flow. The first mound is located near the southwest edge of the former Ramsey Lake Sump Area and the second groundwater mound exists primarily on the Port's Terminal 5 (to the north of the OSM facility) and on the north easternmost corner of the OSM facility, in the former Blue Lagoon area. Both groundwater mounds are likely related to perching associated with lower permeability soil/fill layers in these areas.

The December 2005 gauging event suggests that a groundwater divide exists east of the OSM property boundary. Groundwater flow east of the OSM property and east of the divide flows towards the Columbia Slough. The location of this divide upgradient of the OSM property may be influenced by the presence of the groundwater mound in the vicinity of the former Blue Lagoon.

Groundwater elevations range from 27.2 ft NAVD88 in the central portions of the site to 7.22 ft NAVD88 in the beach wells. The groundwater mounds typically reach 26.2 - 27.2 ft NAVD88 where the surrounding groundwater is typically 23.2 ft NAVD88.

During low river-stage conditions, the silt unit outcrops along the beach near the southwest corner of the OSM property. Seasonally, shallow groundwater has been observed to seep along the top of silt in this area.

11.3.1.2 Chemical Distribution of iCOCs

This section describes the distribution of iCOCs and potential iCOCs in environmental media at iAOPC 1. Map 11.3.1-1 presents sampling locations. Tables 11.3.1-1a–c provide a statistical summary of iCOCs for sampled media in the iAOPC. All iCOC data for the iAOPC are provided in Appendix I.

11.3.1.2.1 Sediments

The sediment data for iAOPC 1 are from 36 surface samples (including beach samples) and 10 subsurface cores (30 subsurface samples). This section describes the distribution of the iCOCs in surface and subsurface sediments within the iAOPC.

PCBs

Two types of PCB analyses were conducted for the sediment samples collected in this iAOPC: PCB Aroclors for all of the samples and PCB congeners for a subset of the samples. PCB Aroclors were detected in 32 of 34 surface sediment samples (Map 11.3.1-3). PCB congeners were detected in all nine samples where analyzed (Map 11.3.1-4). Detected concentrations of total PCB Aroclors in surface sediment ranged from 58 to 9,300 µg/kg with a mean value of 1,060 µg/kg.

Total PCB congeners ranged from 9.46 to 9,780 µg/kg, with a mean value of 1,620 µg/kg. The highest PCB Aroclor concentrations in surface sediment within the iAOPC were detected in nearshore areas: offshore of outfalls WR-24 and WR-367 (abandoned), behind the main dock offshore of outfall WR-22, immediately upstream (south) of the dock in the vicinity of the historical dock/trestle for the former sump, and along the beach between the main OSM dock and the J.R. Simplot dock.

All subsurface sediment samples were analyzed for Aroclors and two were also analyzed for congeners. PCB Aroclors were detected in 23 of the 30 samples analyzed. Detected total Aroclor concentrations ranged from 1.8 to 7,900 µg/kg, with a mean value of 1,460 µg/kg (Map 11.3.1-5); maximum subsurface concentrations were generally higher than surface concentrations. Total PCB congeners were detected in both subsurface samples at 162 and 1,100 µg/kg, with a mean value of 631 µg/kg (Map 11.3.1-6). The highest concentrations of subsurface total Aroclors were detected in the same areas as the surface maxima. The highest Aroclor concentrations (>1,000 µg/kg) extended to a maximum depth of 2.3 m below mud level.

The relative proportions of individual Aroclors in iAOPC 1 surface sediment differ from those in samples collected above RM 2.7 and those collected across the river (Map 6.1-48a–i), which tended to be dominated by Aroclors 1260 and 1254. Surface sediment samples within iAOPC 1 include a higher percentage of Aroclor 1248.

Many subsurface samples at iAOPC 1, however, contained substantial proportions of Aroclor 1260 (Map 6.1-49a–i), and Aroclor 1254 was present. In general, the PCB homolog distributions in the surface sediment samples analyzed for PCB congeners (Map 6.1-50a–i) support the Aroclor 1248 identifications, with relatively high proportions of trichlorobiphenyl, tetrachlorobiphenyl, and pentachlorobiphenyl homologs. Additional discussion of the Aroclor patterns and the relationship between Aroclors and homologues throughout the Study Area is provided in Section 6.1.1.5.3.

Zinc

Zinc was detected in all 34 of the iAOPC 1 surface sediment samples analyzed for metals (Map 11.3.1-7). Concentrations in surface sediment ranged from 43.1 to 823 mg/kg, with a mean of 282 mg/kg. The highest concentrations in surface sediment were detected in nearshore areas: offshore of outfalls WR-24 and WR-367, and behind the main dock offshore of outfall WR-22.

Zinc was detected in all 25 of the subsurface samples analyzed for metals. Concentrations ranged from 65.4 to 479 mg/kg, with a mean of 147 mg/kg (Map 11.3.1-8). The highest concentrations of subsurface zinc were detected behind the main dock at its northern end and near outfall WR-22. The maximum subsurface concentration (479 mg/kg) was lower than the surface concentration (703 mg/kg) from the same core. Zinc concentrations in the subsurface intervals of sediment cores were lower than the overlying surface sample at almost all locations.

DBP

DBP was detected in 8 of the 34 surface sediment samples analyzed for this iCOC (Map 11.3.1-9). Detected concentrations in surface sediment ranged from 3.5 to 180 µg/kg, with a mean value of 33.4 µg/kg. The highest concentration was located behind the main dock.

DBP was detected in only 2 of the 27 subsurface samples analyzed for this iCOC (7.1 and 11 µg/kg) (Map 11.3.1-10). At this very low frequency of detection in surface and subsurface samples, vertical trends for DBP could not be determined due to variation in detection limits.

11.3.1.2.2 Surface Water

Surface water samples were collected at one location within the iAOPC during sampling events of November 2004, March 2005, and July 2005 (Integral 2006l). Station W001, located near the north end of the iAOPC (RM 2), downstream of the OSM outfalls and dock, falls within in a nearshore amphibian habitat area (Map 11.3.1-1). Near-bottom water samples were collected using a peristaltic pump at depths of approximately 0.9 to 4 ft below the water surface. Analytical results are reported in Appendix I.

PCB Aroclors were not detected at a detection limit of 0.0025 µg/L in November 2004 or March 2005. Aroclor 1248 (0.00358 µg/L) and Aroclor 1254 (0.00272 µg/L) were detected at estimated concentrations during the July 2005 sampling event. Total zinc was detected in all three sampling events (0.0014 to 0.00347 mg/L), and dissolved zinc was detected in November 2004 and March 2005 (0.0014 mg/L). Potential iCOC DBP was not detected in any of the three Round 2A sampling events at Station W001, at detection limits of 0.084-0.15 µg/L.

11.3.1.2.3 Transition Zone Water

No transition zone water samples were analyzed for the iAOPC-specific iCOCs at this iAOPC.

11.3.1.2.4 Biota

Limited fish and invertebrate tissue data for clams (field-collected and laboratory-exposed), worms (laboratory-exposed), crayfish, epibenthic organisms (sampled from artificial substrates), and sculpin are available to represent exposure of biota to iAOPC 1 sources. Crayfish were sampled from two locations within the iAOPC, and epibenthic samples from one. Clams and sculpin represent two separate composites collected over

several transects or nearshore areas within the iAOPC. Additional clams and worms were exposed in the laboratory to a single sediment composite from several transects along the shoreline north of the dock.

All iCOCs were detected in fish and invertebrate tissue, except for potential iCOC DBP, which was not detected in any fish or invertebrate organisms sampled and analyzed for phthalates from this iAOPC.

PCBs

PCB congener analyses were conducted on all biological samples from this iAOPC. Aroclors were also reported for all samples, although they were quantified by the analytical laboratory from the congener analyses for the clam and worm samples.

PCBs were detected in all tissues. The highest concentrations of total PCB Aroclors were measured in sculpin (3,360 µg/kg) and laboratory-exposed worms (2,120 µg/kg); these concentrations exceeded other measured tissue PCB concentrations by several orders of magnitude. Crayfish and epibenthic organisms exhibited the lowest concentrations of total PCB Aroclors (< 40 µg/kg) in whole-body tissue. A similar range in magnitude for specific tissues was also seen in total PCB congeners; however, for the clam and worm tissue data, Aroclors were calculated from congener results and not analyzed for Aroclors separately.

Aroclor 1260 was detected in all fish and invertebrate tissues, albeit in typically low proportions relative to other Aroclors; crayfish represent an exception in that Aroclor 1260 was the only Aroclor detected. By relative percent, the dominant Aroclors varied with species: Aroclor 1254 in clams and worms (although Aroclor 1242 was also represented), and Aroclor 1248 in epibenthic and sculpin tissues. PCB homolog distributions were not entirely consistent with the Aroclor data; however, some of the Aroclor identifications are considered presumptive only and should not be viewed as definitive.

A number of homolog groups, ranging from tetra- to hepta-chlorobiphenyls, were present in most samples, including crayfish tissue where only Aroclor 1260 was quantified. However, dichlorobiphenyl and trichlorbiphenyl (predominant constituents of Aroclor 1242) were present in clam tissues where Aroclor 1242 was detected. Additional discussion of the Aroclor patterns and the relationship between Aroclors and homologues in tissue is provided in Section 6.4.2.6.

Zinc

Zinc was detected in all fish and invertebrate tissues sampled from this iAOPC. Sample concentrations were relatively similar across species, ranging from 12.6 to 40.3 mg/kg. The highest concentrations were found in field-collected clams and laboratory-exposed worms associated with the nearshore transect between the dock and the northern boundary of the iAOPC.

DBP
DBP was not detected in tissue sampled from this iAOPC that was analyzed for phthalates.

11.3.1.3 Potential Sources of iCOCs

This section presents a summary of the current understanding of potential sources of iCOCs to the iAOPC. This iAOPC is adjacent to several parcels in the South Rivergate Industrial Park (ECSI #2980). Site summaries have been prepared for Oregon Steel Mills (ECSI #141) and J.R Simplot (ECSI #3343).

Information presented is this section was obtained from site summaries unless otherwise noted. In addition to iCOCs, COIs associated with nearby upland areas are also discussed in this section. COIs are presented to provide a comprehensive understanding of the upland issues and to support the identification of potential sources to the iAOPC. The relevance of the pathway to iCOCs is summarized at the end of each pathway discussion. Potential sources, COIs and pathways are summarized in Table 11.3.1-2. A site-wide remedial investigation and source control evaluations for stormwater, riverbank erosion, and TPH and metals in groundwater have been conducted at the OSM site. No comprehensive investigations have been conducted for the other South Rivergate Industrial parcels.

11.3.1.3.1 Upland Releases

Documented upland releases have occurred at both the OSM and J.R. Simplot sites. These releases are listed in Table 11.3.1-2 and summarized below. Impacted soil and groundwater have been associated with historical waste disposal activities at the former Ramsey Lake sump in the southwest portion of the OSM property. Releases include onsite spills of fuels (gasoline and diesel) from both above-ground and underground storage tanks, leaks or spills of hydraulic and transformer oils, and loss of materials during historical over-water transfer. A cooling water pond and permitted contact cooling water discharge exists at the OSM facility. No releases have been recorded from these facilities. In addition, portions of the OSM site, including portions of the riverbank, have been filled with a slag-soil mixture that, in at least some areas, has been found to contain PCBs and some metals.

Upland areas of the South Rivergate Industrial Park, including the property currently owned by OSM, were created with fill from dredged material beginning in the early 1940s. Originally, the land was used by various parties, with permission from the Port of Portland, to dispose of oily bilge water, slop oil and other waste materials into a series of earthen pits commonly referred to as the Ramsey Lake sump in the southwestern portion of what is now the OSM property. The waste materials were pumped or otherwise transferred from vessels on the Willamette River to the sump until approximately 1960, when the Port of Portland closed it. The sump was trenched, with drainage routed onto the surrounding property, and then filled. Core samples collected as part of the RI and other studies indicate that subsurface soils remain affected by petroleum hydrocarbons.

Industrial operations at the site since the OSM (formerly Gilmore Steel Mills) purchase in 1967 have been related to steel production, steel processing, and related ancillary operations. The original facility included the melt shop, the DRD facility (operating through approximately 1981), the rolling mill, and surface processing. Other facilities (ladle metallurgy furnace, vacuum degasser, additional pressure caster components, combination rolling mill, and cut-to-length facility) were added intermittently through 2001.

The OSM facility also includes a cooling pond, slab scarfing area, parking lots, and several gravel storage and staging areas. Slag, which was used as fill material within the site, is present in the majority of the surface soils across the upland plant area. Data collected for the RI show metals and PCBs in the slag-soil fill layer, locally elevated concentrations of PCBs at some former or current transformer areas, and arsenic, chromium, and lead in the eastern portion of the site and near the former sump.

According to OSM, the furnace at OSM has always operated at temperatures in excess of 1650 ^{o}C (ranging from 1693-1704 ^{o}C). Published information suggests that if PCBs were present they would be destroyed at this temperature. PCBs present in the slag-soil fill layer are presumed to have introduced after the formation of the slag in the furnace (e.g., from soil mixed with the slag that had been contaminated from PCBs present in soil from other releases). Low levels of Aroclor 1248 were also detected in soils in the area of the sump (up to 79 µg/kg).

Approximately 27 spills associated with leaking underground storage tanks, above-ground storage tanks, and handling of waste materials have been recorded for the OSM facility, typically small quantities of gasoline, diesel, hydraulic fluids, transformer oils, or in one case, sludge water from de-gasser refining process. There is no evidence that any spill reached the river (they have typically been of low volume and short duration, with rapid containment). However, four upland spills entered stormwater catch basins before being contained. These spills, which occurred in December 1977, December 1997, February 2000, and December 2005, resulted in visible sheen on the river and/or shoreline soils. Two other spills (North Fence AST gasoline spill and the Rolling Mill UST release) resulted in localized groundwater impacts; DEQ has not required further action because of the low concentrations of petroleum and the stable nature of the impacted area (i.e., future migration and release to the Willamette River is not anticipated). Soil contaminated with hydraulic oils from an additional spill in the southeast corner of the site (Mosely Shear area) was removed as part of an early action because of the contaminants' potential mobility.

OSM is permitted to discharge process water (contact cooling water) to the Willamette River via a newly constructed outfall 001, which discharges along the dock in-water. The original process water discharge outfall WR-23, which discharges offshore of the beach at RM 2.3, is maintained as an emergency overflow. Oil and grease, copper, iron, manganese, and zinc have been detected in discharge water, but generally within permit limits. Analyses of other organic chemicals have not been routinely

conducted in the process water discharge except during the permit application process. A second permitted discharge, at the process water intake pipe on the dock, returns river water after intake water has been centrifuged to remove larger material.

The J.R. Simplot facility distributes anhydrous ammonia (compressed gas) and solid forms of urea for use in the production of inks and resins, water treatment, and fertilizer; both products are manufactured offsite. Materials are delivered to the site in ships and barges, offloaded by pipe or conveyor from the dock to onsite storage tanks and facilities, and then redistributed via marine vessel, truck, and rail car. Other substances handled onsite included nitrogen, sulfur, sodium hydroxide, and sulfuric acid. As part of daily operations, barges are also refueled from onsite fuel tanks. Liquid ammonia, solid urea, lubrication oils, and diesel are known to have spilled between 1982 and 2002. Ammonia gas has also been released to the atmosphere. No spills or leaks from onsite storage tanks have been recorded, but soils previously contaminated with diesel fuel were encountered during construction excavation activities in 2002. Information on releases prior to 1982 is not available.

11.3.1.3.2 Stormwater/Overland Transport

Low concentrations of PCBs and metals have been detected in near-surface soils across much of the OSM site. Sheet flow during storm events and point discharges of stormwater provide two possible mechanisms for release of upland contaminants. Sheet flow from the site was eliminated in 1995 by the construction of an earthen berm along the top of the riverbank. Historical sheet flow runoff is unlikely to have been significant because of the facility's relatively flat topography.

Stormwater outfall and basin characteristic for discharges to or near iAOPC 1 are summarized in Table 5.1-3. Outfall basins are shown on Figure 4.1-1. The stormwater control system at the OSM facility consists of three main trunk lines. Two trunk lines drain the main process areas of approximately 80 acres, discharging stormwater to the iAOPC via private outfalls located at the toe of the bank at RM 2.3 (outfall WR-22) and RM 2.1 (outfall WR-24). Two abandoned outfalls (WR-367 and WR-368) are also located along the bank; their former drainage basins are unknown. A third stormwater trunk line drains the southeastern portion of the site. It joins the City of Portland's stormwater system within the South Rivergate Industrial Park and ultimately discharges at RM 2.7 through Outfall 53A. In stormwater samples from private outfalls WR-22 and WR-24 collected under NPDES permit requirements, there have been infrequent exceedances of permit benchmarks for pH, total suspended solids, copper, lead and zinc (Jurries 2006, pers. comm.). Organic chemical analyses are not required as part of the NPDES monitoring.

Large areas of the OSM facility are unpaved. Surface soils at the facility have historically included dredge fill, and PCB-containing oils and materials have been released onsite during operation of the steel mill. Surface soils may also have included oily materials spread during closure of the sump. Catch basin data indicates that some surface soils have been mobilized and transported into catch basins via overland flow.

Contaminants that have been detected in catch basin solids include metals, PAHs, and PCBs. PCB Aroclors 1248 and/or 1254 have been detected in all catch basin solids sampled in the Phase I Remedial Investigation. Sampling has focused on the outfalls and, with three exceptions, total Aroclor PCBs concentrations in surface sediment greater than 1,000 µg/kg have been detected in river sediments in the immediate vicinity of the outfalls. In its Milestone Report, DEQ (2006c) reports that stormwater is a complete pathway from this site and that stormwater source control is a high priority. OSM is currently working with DEQ to implement stormwater source controls.

Stormwater from the J.R. Simplot site is directed from four onsite drainage basins to private storm drains that discharge along the riverbank at RM 2.6 (WR-17) and RM 2.7 (WR-18) or to the municipal stormwater system within the South Rivergate Industrial Park that discharges at RM 2.7 (Outfall 53A). All three outfalls discharge upstream of iAOPC 1. Except for the drainage area discharging through WR-18, the system catch basins currently include an oil/sediment insert. A fifth drainage basin in the eastern portion of the site appears to percolate through the soil. Stormwater quality data from 1200-Z permitting may be available to characterize the discharge, but have not been reviewed. Urea could be entrained into the stormwater system from normal operations. Currently, sheet flow runoff from the site is considered unlikely given the stormwater system configuration. Historical drainage is unknown and surface soils at the facility may also have included oily materials spread during closure of the sump. Concentrations of PCBs in sediment offshore of J.R. Simplot are an order of magnitude less than the mean concentrations for the iAOPC. Whether stormwater from J.R. Simplot is a significant source of PCBs or other iCOCs to the iAOPC is a current data gap.

11.3.1.3.3 Overwater Discharge

As described above, from approximately 1942 until the 1960s, bilge waters and oily materials were offloaded to the Ramsey Lake sump from vessels on the Willamette. According to historical records, pipe breaks and breaches of the sump berms resulted in releases to the river, including overflows from the sump directly into the river documented in Coast Guard records. General spills during historical offloading of bilge waters and oily materials to the Ramsey Lake sump were also likely, given the presence of petroleum hydrocarbons in cores collected offshore of the sump area and what appeared to be Bunker C oil identified in dredged material removed near the process water intake downstream of the old dock/trestle used for offloading to the sump.

Since that time, minimal overwater activities have occurred at the OSM facility. Prior to 1980, OSM piped iron ore slurries from ships to the DRD ponds; however, no over-water spills have been reported as part of OSM operations. Anhydrous ammonia, solid urea, and diesel fuels are transferred over the water at the J.R. Simplot facility. According to site spill records available from 1982 to 2002, all of these materials have been released to the river; however, data regarding duration, concentrations, and volumes have not been identified.

Three surface sediment samples had PCB concentrations greater than 1,000 µg/kg on either side of the pier leading to the OSM dock. The relationship of these samples to overwater operations, if any, is not apparent. Based on the available information on materials transferred at the current OSM and Simplot docks, it does not appear that over-water releases from these areas are or were a likely substantial source of iCOCs to the iAOPC. Overwater spills from offloading of bilge waters and oily materials at the former barge offloading area may be a historical source of iCOCs to the iAOPC.

11.3.1.3.4 Groundwater Discharge

A plume of dissolved-phase petroleum hydrocarbons (primarily diesel-range but also residual-range) associated with the former sump was identified in the shallow water-bearing zone in the southwest portion of the OSM site. The nature and upland extent of the petroleum hydrocarbon plume associated with the former sump has been evaluated, and groundwater sampling data indicate that the plume is confined to the former sump location and groundwater immediately downgradient, and does not extend to the river. In the area of the former sump, groundwater in the shallow-water bearing zone contains volatile and semivolatile organic compounds, TPH including aliphatic hydrocarbons in the C6 to C8 range and both aliphatic and aromatic hydrocarbons in the C10 to C21 range.

Closer to the river, in the shallow groundwater beneath the beach, VOC and SVOC concentrations were below JSCS screening level values, with the exception of acenaphthalene during one sampling event. TPH was not detected in beach wells when using extractable/volatile petroleum hydrocarbon analysis. No current or historical preferential groundwater pathways have been identified from the former sump to the river, and nonaqueous phase liquids have not been identified downgradient of the former sump footprint. In communications with OSM and in the Milestone Report (DEQ 2006c), DEQ has indicated that the groundwater pathway for hydrocarbons is insignificant and no action is required.

Selected metals (i.e., arsenic, cadmium, lead, nickel and manganese) have been detected above JSCS screening levels in the shallow groundwater at various locations at the OSM facility; however, metals do not form a discrete plume and their distribution appears to be controlled largely by the nature of the fill material and the geochemistry of the groundwater at any given location. The concentrations of metals in the beach groundwater are consistent with transition zone water concentrations observed at other sites in EPA's Portland Harbor groundwater pathway assessment program or at site background conditions. In communications with OSM and in the Milestone Report (DEQ 2006c), DEQ has indicated that the need for further evaluation and action for the manganese in groundwater will be determined after additional assessment of river-wide conditions as part of the Portland Harbor Superfund Site RI/FS.

Of the sediment iCOCs for iAOPC 1, two have been detected in groundwater at the OSM site: PCBs (two initial low-level detections out of 42 samples analyzed, but none in subsequent sampling events) and zinc. Zinc has not been detected in OSM

groundwater above JSCS screening levels, suggesting that it is not a significant source of impact to the river.

No groundwater investigations have been conducted at the J.R. Simplot facility, and therefore, the potential for a J.R. Simplot to be a groundwater source of iCOCs is not known.

11.3.1.3.5 Riverbank Erosion

The western boundary of the OSM facility is composed of steep banks fronting the Willamette River, topped by a soil berm. Soils within the riverbank are composed of sandy dredged material and a slag-soil mixed fill. Central riverbank soils are contaminated with PCBs and some metals. Samples collected within the slag-soil fill typically had higher PCB concentrations (mean concentrations of 7,710 µg/kg; maximum and minimum concentration of 34,000 µg/kg and 20 µg/kg, respectively) than other areas of the riverbank, with Aroclor 1248 predominant. The slag-soil fill also had higher concentrations of chromium and manganese, and in some locations, zinc. Sandy fill within the bank also contained PCBs and metals. The horizontal distribution of PCBs and metals at concentrations above JSCS screening values generally extends from about 400 feet south of the northern property boundary (RM 2.1) to about 50 ft from the southern property boundary (RM 2.5). The spatial distribution of PCBs and metals in slag-soil fill, beach sediment, and river sediment fits a concentration gradient that decreases offshore away from the riverbank along the majority of the OSM facility. According to OSM, DEQ has concluded that erosion of riverbank soils represents a complete pathway requiring source control, and is evaluating a source control action that will include bank stabilization and capping.

Riverbank soil has not been sampled at J.R. Simplot. PCBs have been detected in sediment offshore of J.R. Simplot. Concentrations of PCBs in sediment are an order of magnitude less than the mean concentrations for the iAOPC, and therefore, if the J.R. Simplot bank is a source, the concentrations in this bank are likely less than in other areas of the iAOPC. J.R. Simplot executes an erosion control plan by maintaining the lawn and riprap along the shoreline.

11.3.1.3.6 Sediment Transport

iAOPC 1 is located in a broad area of the river known as Post Office Bar; the nearshore area (less than -35 ft NAVD88) comprising the iAOPC is characterized as an area of dynamic equilibrium (no net change) over a 25-month period based on Sediment Trend Analysis®. Historical records indicate that Post Office Bar has been a dominant feature in the river since at least the early 1900s, requiring periodic dredging. Time-series bathymetric data collected from January 2002 to February 2004 suggest that the broadly depositional conditions that created the Post Office Bar persist today. The potential for sediment transport of iCOCs is a data gap that will be further addressed in the RI.

11.3.1.4 Relationship of Upland Sources to the Distribution of iCOCs

The in-water distribution of PCBs and the foregoing evaluation of chemical sources and pathways constitute evidence of a potential link between this iCOC in the upland and

those in sediment and biota from the iAOPC. The data also suggest a possible link between zinc in the upland and in sediment and biota. Both of these iCOCs are also present in up-river sediments, and therefore up-river sources will also be further evaluated. Further assessment of these potential links will be performed in the RI. A comparable link for DBP cannot be established, as this potential iCOC was detected in only a few iAOPC sediment samples and in none of the biota samples that were analyzed for phthalates.

Riverbank erosion and stormwater runoff, which function as both present and historical pathways to the river, appear to be likely contributors of iCOCs to in-water media. PCBs and metals, including zinc, have been detected at OSM in riverbank fill soils, upland surface soils, and catch basin solids. PCB and zinc concentrations in surface and subsurface river sediment within the iAOPC are relatively high offshore of OSM outfalls; however, elevated concentrations of these iCOCs also occur in a broad area off of OSM. The relative proportions of individual Aroclors in surface sediment in iAOPC 1 differ from those farther upstream and downstream. The majority of sediment samples collected upstream and downstream of the iAOPC are dominated by Aroclors 1260 and 1254. Surface sediment samples within the iAOPC are dominated by Aroclor 1248 but do include Aroclor 1260 and 1254.

Judging from the spatial distribution of PCB and metals concentrations and from the Aroclor distributions within the samples, historical overwater sources, riverbank erosion and stormwater from OSM appear to be significant sources of iCOCs to the river at this iAOPC. Concentrations of zinc and DBP in surface sediment were generally higher than those in underlying core samples, suggesting these sources to the iAOPC may have been related to more recent processes. However, for PCBs, subsurface concentrations were generally higher than surface concentrations and have different Aroclor and congener distributions, suggesting that historical PCB sources were different and more substantial than current sources. However, interpretation of Aroclor patterns is not a definitive method for differentiating among PCBs sources. Further evaluation of congener distribution and/or evaluation of raw laboratory results would be necessary to confirm differences in PCB composition among sampling locations.

Because the reported concentrations of PCBs in upland soil and catch basin solids have been relatively low compared to those in riverbank fill soils and nearshore river sediment, it may be that stormwater is a less substantial source of iCOCs than riverbank erosion. Loading rates for riverbank erosion and stormwater are not yet available on an iAOPC-specific basis, and will be provided in the RI report.

Historical overwater activities may have been a significant historical source of iCOCs to the iAOPC as bilge water and oily materials pumped from vessels to the Ramsey Lake sump from the 1940s to approximately 1960, as well as upland releases of PCB-containing oils and waste materials during operation of the steel mill, may have impacted sediments with PCBs and metals.

Due to the low mobility of PCBs and relatively low concentrations of other upland COIs in groundwater, this matrix is not likely to be a significant pathway for iCOCs.

A preliminary evaluation of the relationship between sources, pathways, and iCOCs in the iAOPC is summarized in Figure 11.3.1-2. Preliminary assessments of the current and historical relative contributions of each source for iAOPC 1 are summarized in Table 11.3.1-3.

11.3.2 CSM for iAOPC 2

This section describes the preliminary Round 2 CSM for iAOPC 2, a small (0.87 acres) area of potential concern located near Outfall 53A (Map 11.3.2-1). This CSM examines the physical setting of the iAOPC and adjacent upland properties, the chemical distribution of iCOCs in in-water media, and potential sources of the iCOCs.

One iCOC has been identified for this iAOPC:

- Total PCBs.

Map 10.5-3a–j shows the areas where this preliminary analysis identified the potential for risk for individual exposure scenarios that were considered in iAOPC development, and Table 10.5-3 identifies the iCOCs associated with the exposure scenarios. PCBs are an iCOC at all areas within the iAOPC.

The CSM can be summarized as follows: iAOPC 2 receives discharge from an industrial stormwater drainage basin (Outfall 53A). Stormwater data for the majority of the drainage area are not available. PCBs have been detected in catch basin solids and in-line sediments draining a portion of Oregon Steel Mills (OSM), which currently comprises 10 percent and previously comprised 18 percent of the drainage basin. PCB detections in the OSM 2005 in-line sediments sample (City of Portland 2005) were approximately half the concentration measured in the river sediment. Other PCB sources to the stormwater system are probable, considering the wide-ranging industrial applications of these compounds (e.g., paints, sealants, coolants, lubricants, hydraulic and dielectric fluids).

11.3.2.1 Physical Setting, Infrastructure, and Operational History

In-river and upland physical characteristics, infrastructure, and operational history relevant to this iAOPC are briefly described in this subsection. Information on adjacent upland sites was obtained from the LWG site summaries (Integral and GSI 2004; 2005a,b,c) and updates (Integral 2007) unless otherwise noted.

Upland properties adjacent to iAOPC 2 include Ash Grove Cement (ECSI #4696) and a Port of Portland right-of-way located between Ash Grove Cement and J.R. Simplot (ECSI #3343). The only outfall that discharges to iAOPC 2 is Outfall 53A, which was installed by the Port of Portland in 1970. Outfall 53A drains stormwater from an 82-acre basin in the South Rivergate Industrial Area. Approximately 83 percent of the

basin consists of industrial facilities. Several ECSI sites lie within the drainage area: OSM (ECSI #141; see iAOPC 1, Section 11.3.1), Union Chemical (ECSI #329, aka H.B. Fuller Company), J.R. Simplot, Ash Grove Cement Co., and Consolidated Metco (#3295); all but OSM are also part of ECSI #2980. Ash Grove Cement does not discharge stormwater to Outfall 53A; stormwater is generally used for irrigation, but may be discharged to the river through a small ditch during periods of heavy rainfall.

11.3.2.1.1 In-River

iAOPC 2 is located along the eastern side of the LWR at approximately RM 2.7, where the river broadens and bends north-northeast toward the Columbia River. Multnomah Channel branches from the LWR on the west side of the river across from this area. As noted in Section 4.5.1, this reach is largely depositional, characterized by relatively low flows and bottom shear stresses (see Map 4.5-1). In this vicinity, the bathymetric change data from 2002 to 2004 show a patchwork of areas of no change, net accretion, and net erosion (about 1 ft loss or gain) along the channel slope, and large areas of deposition and no change in the offshore channel. This iAOPC is the upstream edge of the depositional area known as Post Office Bar.

Limited geologic data have been collected at the South Rivergate Industrial Park. Upland geologic cross sections and in-river subsurface sediment core data from the adjacent OSM site indicate that material within and adjacent to the nearshore is generally dredge fill and native sand overlying sandy silt to silty clay. Offshore surface sediments are dominated by fine-grained material (Map 11.3.2-2a,b). The shoreline adjacent to iAOPC 2 (Ash Grove Cement and Port of Portland right-of-way) appears vegetated and undisturbed. At the adjacent J.R. Simplot Co. site, the shoreline is made of up maintained lawn and riprap.

Significant in-water facilities/structures adjacent to the iAOPC and their associated uses are as follows (Map 11.3.2-1):

- Downstream end of the Ash Grove Cement dock (just upstream)—an overwater conveyor belt system is used for loading barges with lime products
- J.R. Simplot dock structure (just downstream)—anhydrous ammonia (compressed gas), urea, and diesel fuel are transferred between barges and the dock
- One stormwater outfall (Outfall 53A).

11.3.2.1.2 Upland

Two upland properties are immediately adjacent to iAOPC 2: Ash Grove Cement and a Port of Portland right-of-way. The J.R. Simplot facility lies immediately northeast of the iAOPC, adjacent to the Port of Portland right-of-way and the river. Industrial properties in the 81.8-acre stormwater drainage basin of Outfall 53A include:

- Southeastern portion of OSM (previously reported by the City as 14.6 acres, but reduced to approximately 8 acres after 2006 plant construction) (City of Portland 2006b; RETEC 2006)
- J.R. Simplot (14.3 acres)
- Bay Valley Foods (formerly known as Steinfelds) (13.3 acres)
- Consolidated Metco (13.4 acres)
- Port of Portland (vacant; 6 acres)
- Union Chemical (5.3 acres).

The remaining 15 acres includes right of ways, some industrial frontage drainage, and some small commercial areas (e.g., credit union). Upland conditions at these sites are described in the site summaries prepared by LWG for OSM and the South Rivergate Industrial Park parcels and are summarized in this subsection. Land use zoning for properties within the stormwater basin draining into iAOPC 2 is industrial. Historical and current operations and pre-development features (when available) for the properties are provided below.

Ash Grove Cement

The Ash Grove Cement Plant occupies 29.61 acres. The site is generally flat, except near the river where the land slopes toward the site on the inland side of the levee, and toward the river at the riverbank itself. A paved parking lot area is situated on the northeast end of the site. A railroad track enters the site from the east side at the midpoint of the property and ends at a series of buildings at the north-central area. The site contains an active underground storage tank and two decommissioned USTs. No information confirming the removal of the two decommissioned tanks was available for this review. The site also contains aboveground storage tanks for waste oil (500,000 gal), propane (500 gal), diesel #2 (10,000 gal), quicklime (5,000,000 lb), and hydrated lime (750,000 gal). Stormwater at Ash Grove Cement does not drain to Outfall 53A, but some stormwater discharge to the river may occur through a ditch during heavy rain.

The dock is currently permitted with the Oregon Department of State Lands (DSL). A public notice to perform annual maintenance dredging of up to 2,500 yd^3 of sediment offshore from the existing docking structures of the Ash Grove Cement Plant was published by the USACE on May 20, 2005. All dredged material would be placed in an approved upland disposal site.

Oregon Steel Mills

The terrain at OSM is relatively flat in the main plant and storage areas. The land draining to the city's stormwater system is in the southeast corner of the mill property, where their administrative and storage areas are located. Prior to facility improvement

at OSM, 14.6 acres in the southeastern portion of OSM (including 12 acres of building and pavement and 2.6 acres unpaved) drained to the city storm drain and was discharged to Outfall 53A. During construction activities at OSM in 2006, the drainage basin size was reduced to approximately 8 acres (6.8 acres of building and pavement, and 1.2 acres unpaved) and treatment (sand filters and swales) was added prior to discharge. Additional information on OSM can be found in the CSM for iAOPC 1 (Section 11.3.1). Information on the upgraded stormwater system is included in OSM's Source Control Evaluation Report for Stormwater (RETEC 2006).

J.R.Simplot

The site is generally flat, with slopes less than 3 percent. The southern property line is adjacent to a Port of Portland right-of-way, with Ash Grove Cement located on the south side of the right-of-way. Railroad tracks border the west and north sides of the site. The company distributes its products (anhydrous ammonia and solid and granular urea) to the Pacific Northwest via the terminal at the industrial park. Each compound is stored separately in insulated tanks or enclosed warehouses. Diesel fuel in a 300-gal storage tank onsite is used for the facility's equipment and barges. The J.R. Simplot site contains five drainage basins. City records indicate that 14.3 acres of the J.R. Simplot facility drain to Outfall 53A. Simplot indicates that its stormwater in Basins 3 and 5 (approximately 7-8 acres combined) drains via three possible catch basins through the City of Portland storm sewer (Outfall 53A).

Consolidated Metco

The ConMet facility is located 0.25 miles inland from the Willamette River (RM 2.5). Its 19.9-acre property is zoned for industrial and commercial uses and is encircled by other industrial businesses such as Ash Grove Cement to the west. Operations at the site primarily include a process to recover aluminum shavings from the cutting fluid used to manufacture aluminum casting.

Subsurface material at the site consists of well-drained alluvium or sandy dredge spoils, overlying fine- to medium-grained sands to depths of approximately 5 to 10 ft bgs. Underlying these overburden deposits and fill material are dark gray to orange silty clays. Aerial photographs indicate that fill was being placed onsite to create uplands as recently as the early 1980s. Approximately 80 percent of the facility is covered by steel pads, concrete pads, or asphalt.

Union Chemical

The site is located inland from the Willamette River and is adjacent to the eastern boundary of J.R. Simplot. It was the site of an anhydrous ammonia spill in 1982. City records indicate 5.3 acres of this facility drain to Outfall 53A. No other information is currently available.

11.3.2.1.3 Upland Hydrogeology

The only substantial subsurface environmental site investigations known have been conducted at the OSM facility. No geologic or hydrogeologic data have been collected for the South Rivergate Industrial parcels.

Ash Grove Cement
Two seeps were identified along the shoreline of Ash Grove Cement Company during the seep reconnaissance survey (GSI 2003b): one near the southern corner of the property and the other near the northern corner of the property. Both seeps are highlighted by iron (ferric hydroxide) staining. The seep at the southern corner occurs along a line of clayey soil at the base of the slope. The seep at the northern corner occurs where silty/clayey soil crops out below overlying gravel and cobbles.

J.R. Simplot
One groundwater discharge seep was identified along shoreline of J.R. Simplot Co. during the seep reconnaissance survey (GSI 2003b). The seep occurs at the base of the beach near the water line where silty/clayey soil crops out below overlying sand.

Consolidated Metco
Site borings indicate that the shallow groundwater system contains relatively thin, locally elevated perched aquifers (samples collected as shallow as 1 ft bgs) with the water table generally found between 6 and 20 ft bgs. Groundwater flow has not been evaluated.

Oregon Steel Mills
Hydrogeologic conditions for OSM are described in the CSM for iAOPC 1 (Section 11.3.1).

11.3.2.2 Chemical Distribution of iCOCs
This section describes the distribution of PCBs (the only iCOC) in iAOPC 2. Sediment sampling locations are shown in Map 11.3.2-1, and all iCOC data for the iAOPC can be found in Appendix I.

11.3.2.2.1 Sediments
Table 11.3.2-1 provides a statistical summary of iCOCs for sediment in iAOPC 2. One surface sample and three subsurface samples (collected from a single core) were analyzed for PCBs. The surface and subsurface sampling locations were quite close to one another.

The iAOPC is defined based on one surface sediment sample with PCB concentrations of 163 µg/kg (Map 11.3.2-3) for total Aroclors and 62 µg/kg (Map 11.3.2-4) for total congeners. The predominant Aroclor in the sample was Aroclor 1242. The surface sediment sampling location was on the nearshore slope offshore and slightly downstream of Outfall 53A. Upstream concentrations were an order of magnitude lower than that measured within the iAOPC; concentrations appear to decrease downstream of the outfall.

PCBs (Aroclors) were detected in only the shallowest of the three subsurface samples analyzed (1 to 5 ft bml). The detected total Aroclor concentration was 49.4 µg/kg (Map 11.3.2-5). The predominant subsurface Aroclors included 1248, 1254 and 1260. PCB congener analyses were not conducted.

11.3.2.2.2 Surface Water
Surface water samples were not collected within iAOPC 2.

11.3.2.2.3 Transition Zone Water
No porewater or TZW samples were collected within iAOPC 2.

11.3.2.2.4 Biota
No biota samples were collected within iAOPC 2.

11.3.2.3 Potential Sources of iCOCs
This section presents a summary of the current understanding of potential sources of iCOCs to iAOPC 2. The upland parcels adjacent to the iAOPC have been the site of industrial activities since the mid 1960s. Investigations of COIs in parcels draining to the City's stormwater system have not included PCB analyses, except at the OSM facility. Soils, bank sediment, groundwater, and stormwater catch basin solids at the OSM property have been analyzed for PCBs.

11.3.2.3.1 Upland Releases
The CSM for iAOPC 1 describes information currently available on upland releases and waste disposal practices at OSM (see Section 11.3.1). Very little sampling has been conducted at other facilities within the drainage basin associated with Outfall 53A.

11.3.2.3.2 Stormwater/Overland Transport
Except for OSM, little information is available to describe current or historical stormwater discharges from industrial facilities that drain through Outfall 53A. The stormwater control system at OSM consists of three main trunk lines, one of which (southeastern basin draining 7.14 acres) connects to the City's stormwater collection system at the entrance of the facility. Metals, PAHs, and PCBs have been detected in catch basin solids throughout the facility. Samples collected in three onsite catch basins draining to the outfall in 2003 had Aroclor 1248 and 1254 concentrations of 35 to 570 µg/kg (Exponent 2004). In 2006 OSM implemented several BMPs for the onsite portion of the Outfall 53A drainage basin (segregated roof drainage and swale/sand filter treatment system). Prior to implementing these BMPs, in-line sediments were collected in June 2005 from the City's stormwater system within the OSM line and were analyzed for PCBs as part of a municipal source control investigation (City of Portland 2005). Total PCBs consisting of Aroclors 1254 and 1260 were reported at a estimated concentrations of 85 µg/kg.

11.3.2.3.3 Overwater Discharge
The nearest docks present upstream of the iAOPC are at the Ash Grove Cement Company and appear to be used to load barges with lime products. An overwater gasoline spill of unknown quantity was reported in 1990. No information is available to document overwater release of PCBs in the vicinity of the iAOPC.

11.3.2.3.4 Groundwater Discharge

Groundwater monitoring in the vicinity of the iAOPC 2 has been conducted at only the OSM facility. No other information is available to assess groundwater quality within the drainage basin associated with Outfall 53A or nearby sites (i.e., South Rivergate Industrial Park). The degree to which groundwater infiltrates into the stormwater system in the drainage basin is unknown. Several seeps have been observed along the shoreline in the vicinity of the iAOPC, but no seep water quality data are available.

11.3.2.3.5 Riverbank Erosion

The shoreline at iAOPC 2 is identified as natural on Figure 4.6-1; its susceptibility to erosion is unknown. No riverbank sampling has been identified for this area.

11.3.2.3.6 Sediment Transport

The degree to which PCB-contaminated sediment has been transported into iAOPC2 from elsewhere in the river is unknown. PCB concentrations in nearshore surface samples collected immediately upstream were an order of magnitude lower than those in the single surface sample in iAOPC2, suggesting minimal contribution from upstream sediment sources. PCB concentrations in surface sediments within 1,000 ft. downstream of the iAOPC were lower than those in iAOPC2, but are higher than samples collected upstream of the iAOPC.

11.3.2.4 Relationship of Upland Sources to the Distribution of iCOCs

Based on the foregoing evaluation of historical chemical sources and pathways and the in-water distribution of the iCOC (PCBs) for iAOPC 2, there is evidence of a link between the stormwater Outfall 53A and concentrations in sediment. PCBs were detected in onsite catch basins and in-line sediments draining the OSM facility and in the surface sediment sample from the iAOPC. However, the surface sediment sample within the iAOPC had a dominant signature of Aroclor 1242 (although nearby surrounding sediments did not), which suggests that other sources may also have contributed to the PCBs in the iAOPC sediments.

A preliminary evaluation of the relationship between sources, pathways, and iCOCs in iAOPC 11 is summarized in Figure 11.3.2-1. Preliminary assessments of the current and historical relative contributions of each source for iAOPC 11 are summarized in Table 11.3.2-2.

11.3.3 CSM for iAOPCs 3, 4, 5

This section provides a preliminary CSM for iAOPCs 3, 4, and 5, which occupy 24.3-acres along the eastern shore of the river between RM 3.6 and RM 4.2. iAOPC 3 is entirely within the International Terminal Slip. iAOPC 4 includes the mouth of International Terminal Slip and nearshore areas upstream of the slip. iAOPC 5 is nearly adjacent to iAOPC 4 and extends farther upstream but short of Terminal 4, Slip 1 (Map 11.3.3-1). This CSM examines the physical setting of the iAOPC and adjacent upland properties, the chemical distribution of iCOCs in in-water media, and potential sources of the iCOCs.

The following iCOCs have been identified for these three iAOPCs:

- **iAOPC 3:** Total PCBs
- **iAOPC 4:** Total PCBs
- **iAOPC 5:** Total PCBs.

The potential ecological iCOCs for iAOPC 3 include:

- **iAOPC 3:** Total PCBs, zinc, DBP, diesel-range hydrocarbons (DRH), residual-range hydrocarbons (RRH), and endrin ketone.

The potential iCOCs are identified through less certain and/or less rigorous evaluations based on fewer lines of evidence, FPM results, or other high uncertainty lines of evidence (see Sections 8 and 9).

Map 10.5-3a–j shows the areas where this preliminary analysis identified the potential for risk for individual exposure scenarios that were considered in iAOPC development, and Table 10.5-1 identifies the iCOCs associated with the exposure scenarios. PCBs are iCOCs for all areas within the iAOPCs. The remaining iCOCs were found only at the head of the slip in iAOPC 3.

The relative proportion of Aroclors in sediment samples appears to be unique at all three iAOPCs, which may suggest local sources. These may be legacy sources from historical operations, but the distributions of sediment concentrations in the slip are strongly associated with outfalls at the head of the slip at iAOPC 3. The distributions of PCB concentrations in sediment at iAOPCs 4 and 5 do not correlate well with outfalls or other features. Groundwater is not expected to be significant source of iCOCs for the iAOPCs due to the general lack of iCOCs in groundwater and the distance between plumes and the river. Riverbank erosion is not a significant current source due to presence of armoring, but may have been a historical source. Overwater activities occur at the iAOPCs, and may be an important current and historical source of iCOCs.

11.3.3.1 Physical Setting, Infrastructure, and Operational History

In-river and upland physical characteristics, infrastructure, and operational history relevant to these iAOPCs are briefly described in this subsection. Information on adjacent upland sites was obtained from the LWG site summaries (Integral and GSI 2004; 2005a,b,c) and updates (Integral 2007) unless otherwise noted.

11.3.3.1.1 In-River

The channel area in the portion of the river adjacent to the International Terminal Slip iAOPCs is characterized in the Portland Harbor Work Plan as transitional/depositional. The Sediment Trend Analysis® (STA®) results suggest that the nearshore area along this site, both along the river frontage and into the slip, alternates episodically between net accretion and net erosion (Map 11.3.3-1). The STA® results suggest that the channel offshore of the site is in dynamic equilibrium. Time-series bathymetric change data

over the 25-month period from January 2002 through February 2004 show small-scale (mostly less than 1 ft) sediment accretion along the Schnitzer Steel Industries (SSI) side of the International Terminal Slip. Along the river frontage, no bathymetric change data were obtained above the -10 ft NAVD88 contour due to the presence of in-water structures and moored vessels. From the -10 to the -30 ft NAVD88 contours, areas of net sediment erosion (up to 1 ft in extent) predominate. From the -30 ft NAVD88 contour out into the main channel, areas of no measurable change are dominant. Finally, in the channel offshore of the upstream end of the site, a borrow area previously dredged to -60 ft NAVD88 shows sediment accumulations up to about 1 ft in extent.

The most recent large dredging project occurred in 2004 in the slip adjacent to the SSI facility docks. The maintenance dredging was conducted because silt accumulation had reduced the bottom clearance to an unnavigable level for certain river vessels. A new 40,455-square-ft dock was constructed along the south shore of the slip in 2006.

Sediment grain-size distribution within the iAOPCs is shown on Maps 11.3.3-2a–c. The majority of the surface sediment deposits consist of silt or sandy silt. Limited areas characterized by silty sand or sand occur at the downstream end of the International Terminal Slip adjacent to the Premier Edible Oils (PEO) shoreline. Silt and sandy silt also dominate the subsurface sediment cores upstream of the International Terminal Slip.

Riverbank/shoreline conditions for the area are shown on Map 5.1-2. The river shoreline on the upstream portion of the iAOPCs is currently covered with concrete riprap and is lightly vegetated in the upper portions. Old timber pilings left over from the Oregon Shipbuilding Corporation are located in the main channel offshore of the SSI shoreline. The southern shoreline of the International Terminal Slip is covered with dock structures, with unclassified fill at the head of the slip and natural bank along its northern side. New rock material has been placed along the top of the bank in the northeast portion of the PEO site along the slip.

Significant in-water facilities and structures within the iAOPCs include the following:

1. Three main vessel moorage loading docks along the SSI river shoreline
2. One continuous large vessel loading dock on the south side of the International Terminal Slip
3. An area of piling remnants close to the shore adjacent to the SSI site to the south of the entrance to the International Terminal Slip
4. An area of piling remnants close to the shore midway along the northern side of the International Terminal Slip
5. Thirty private stormwater outfalls (WR-21, WR-82 through WR-85, WR-108 through W-R125, WR-184, WR-382 through WR-387).

Primary site uses for the in-river structures are described in the following upland site summary section.

11.3.3.1.2 Upland

Upland properties adjacent to the iAOPCs include SSI, PEO, and Jefferson Smurfit. These properties are zoned for industrial use. Historical and current operations and predevelopment features (when available) for the upland properties were obtained from site summaries prepared by LWG and are provided below.

Schnitzer Steel Industries (SSI)

The Schnitzer Investment Corporation's (SIC's) 200-acre Burgard Industrial Park property is located on the east side of the Willamette River at approximately RM 4. SSI incorporates the 11-acre International Terminal Slip and a number of other contiguous properties owned by SIC (ECSI #2355). SSI receives materials such as automobiles, appliances, discarded steel members, and other ferrous products via ship, truck, or occasionally rail. They process the scrap metal using a shearer or portable acetylene torches.

Site features include offices, warehouses, and other buildings; paved or graveled work surfaces, roadways, and parking lots; railroad tracks; utilities (water, sewage, stormwater, electrical); small aboveground storage facilities for fuels and oils, and some undeveloped areas. The majority of the land in the southwest portion of the Park is paved.

Prior to 1941, the property was largely undeveloped except for bulk petroleum storage in six aboveground storage tanks (ASTs) near the river. During WWII, the site was the location of a large shipyard owned by the Oregon Shipbuilding Corporation. The deep-draft International Terminal Slip was created during this period, and portions of the marshy, low-lying areas on the site were filled. Over 450 ships were built on this property from 1941 to late 1945. Ship breaking activities were reported in 1946 (*The Oregonian* 1946). The year in which shipyard was dismantled has not been presented in documents reviewed, but the shipways were filled between the early 1960's and 1972. Post shipyard industrial uses were included metal fabrication, log rafting, and upland log storage. The property was converted for use in 1972 as a metals scrap yard. Automobile shredding operations began in 1980.

Since 1980, white goods such as home appliances and autos are shredded for recovery of metals in the southwestern corner of the site. SSI operates a maintenance facility in the northern end of Building B to repair onsite equipment such as loaders, cranes, trucks, and the shredder and shearer. They also receive and store bulk commodities at the site, which are unloaded by three rail-mounted cranes along the International Terminal Slip and stored in the northern portion of the site (either on pavement or in a building).

The SSI site has 18 private outfalls, 12 of which are currently active. Only WR-116 and WR-121 are currently used for GEN12Z-permitted stormwater discharge directly to the International Terminal Slip.

Premier Edible Oils

The 18.5-acre PEO property (ECSI #2013) is situated on the north side of the International Terminal Slip (at the mouth of the slip) and is surrounded by the Willamette River to the west, the slip to the south, and bulk petroleum facilities owned by Time Oil to the north and east. Six of these acres are under water, 2 acres include riverbank and shoreline, and the remaining acreage was the original operating area and some undeveloped land.

The PEO site was a marsh prior to 1941. The bottomlands were filled soon thereafter. During the war years, the site was used to store products and raw materials. Between 1946 and 1972 activities on the site were limited and consisted of the manufacture of chemicals and metals; transport of petroleum products via a surface pipeline and then an underground pipeline; petroleum product storage; and miscellaneous storage buildings housing paint, cable, firebrick, and coke.

SIC purchased the site in 1972 and leased the site to PEO by 1973. The site was graded and most of the structures were removed, including the railroad track. PEO constructed an office/processing building, an AST farm for edible oil storage and blending, bulk chemical storage, and a 10,000-gallon aboveground diesel storage tank for energy backup (all on concrete pads). PEO constructed a dock on the Willamette to transfer edible oil between ships and the facility. By 1991 the dock in the slip was no longer present. The site is currently unoccupied except for office space used by tenants.

Jefferson Smurfit Corporation

The 9.53-acre Jefferson Smurfit property (ECSI #2371) is located about 800 ft east of the Willamette River, on the north side of the International Terminal Slip. The site is currently occupied by a 200,000-square-ft sheet-metal warehouse on a concrete slab. Asphalt and/or gravel cover the areas surrounding the warehouse. Two railroad spurs cross the northern part of the property. A 60,000-gallon fire-suppression water tower is located on the eastern property line. Diesel fuel is stored in a 6,000-gallon double-walled AST for use as backup fuel for the boiler.

The Jefferson Smurfit property has been used for the manufacture of corrugated boxes since the 1950s. Equipment within the facility includes one corrugator, three printer/folder/gluers, two rotary die cutters, a "window machine" (which glues polyfilm to corrugated boxes), a bailer/hogger (for waste paper shredding and bailing), a slitter (which cuts paper to size), and various conveyors to produce paper products. Raw materials include paper, cornstarch and starch additives, glue, and inks. Land use in this area is zoned for heavy industry.

Aerial photographs show that the Jefferson Smurfit property and surrounding area were undeveloped and included a wetland in 1940. Sometime between 1940 and 1943,

dredge material from the Willamette was used as fill to bring the area up to its current grade. The existing structure was built in 1943 and used as a warehouse for the shipbuilding industry from 1943 to 1945.

The major operations of ECSI sites not adjacent to the river, but within the outfall basins of outfalls draining to the river, include Calbag Metals, RoMar Transportation Systems Portland Container Repair, Joseph Ryerson & Sons, Northwest Pipe, Boydstun Metal Works, Morgan CFS, SSI, and SIC. The properties range in size from 2 to 26 acres and are located near and east of the head of the slip. Site operations are generally related to steel and steel pipe manufacture and storage and temporary storage related to loading and unloading of various materials.

Portions of these sites were part of the Oregon Shipbuilding Corporation during WWII years and activities on the site included warehousing, woodworking, and shipbuilding.

11.3.3.1.3 Upland Hydrogeology

The hydrogeology for the northern side of the International Terminal Slip has not been extensively studied at sites adjacent to the slip. Based on nearby work (Time Oil) there appear to be upper and lower groundwater zones, separated by a silt unit. The silt unit is not always contiguous and tapers out toward the Willamette River based on work conducted at Time Oil, to the north of the iAOPCs. Groundwater flows generally toward the river. Seeps have been observed along the north side of the slip (GSI 2003b). Specific information related to groundwater gradient is not available.

The hydrogeology for the area south of the International Terminal Slip consists of localized zones of perched groundwater that may be present in the dredge fill. Such perched zones have been encountered at a depth of about 15 to 20 ft on nearby properties. The presence and extent of the perched zones are expected to be variable and related to the presence of higher silt content in the dredge fill. The groundwater flow gradients in the perched zones are anticipated to be variable and relatively low; discharge from the perched groundwater zones either discharges toward the river or infiltrates downward into the underlying dredge fill and alluvial deposits. The groundwater flow direction in the alluvial groundwater zone is generally to the west, toward the Willamette River, with local variations in groundwater flow expected. No seeps have been observed between the International Terminal Slip and Terminal 4 (GSI 2003b). Specific information related to groundwater gradient is not available.

11.3.3.2 Chemical Distribution of iCOCs

This section describes the distribution of iCOCs and potential iCOCs to iAOPCs 3, 4, and 5. Map 11.3.3-1 shows the sediment sampling locations, and all iCOC data for the iAOPCs can be found in Appendix I.

11.3.3.2.1 Sediments

iAOPC 3

iCOCs for iAOPC 3 include total PCBs; potential ecological iCOCs include total PCBs, zinc, DBP, DRH, RRH, and endrin ketone. For the purposes of evaluating sources to iAOPC 3, the following discussion of chemical distribution of iCOCs is limited to PCBs, DBP, DRH, and endrin ketone. Table 11.3.3-1a provides a statistical summary of all iCOCs for sediment in iAOPCs 3, 4, and 5.

PCBs

Surface and subsurface samples were collected following the 2004 dredging in this area, and surface samples represent pre-dredging subsurface conditions. PCBs were detected in 21 of 22 surface sediment samples. Two types of analyses were conducted for these samples: PCB Aroclors (Map 11.3.3-3) and PCB congeners (Map 11.3.3-4). Concentrations of total PCB Aroclors ranged from 18 to 3,370 µg/kg, with a mean value of 925 µg/kg. Total PCB congener concentrations ranged from 307 to 4,340 µg/kg, with a mean of 730 µg/kg. The highest surface sediment concentrations of PCBs (>1,000 µg/mg) are located in a 400-ft-long area along the south shore. The area extends downstream from near the head of the slip, near WR-123, and does not include the head of the slip near WR-124. The lowest concentrations are present north of the centerline of the slip.

The relative proportion of individual Aroclors in surface sediment is somewhat distinct in iAOPC 3 compared to samples collected several hundred feet downstream of the slip and upstream of the slip, including Terminal 4 (Map 6.1-48i). The upstream and downstream Aroclors are dominated by Aroclor 1260. Samples within the iAOPC typically include more than 50 percent Aroclor 1254. Samples with more than 50 percent Aroclor 1254 are seen primarily on the south side of the slip, from the head to the area upstream of the mouth of the slip. Similar Aroclor proportions are seen in subsurface sediments Map 6.1-49g).

PCBs were detected in 24 of 36 subsurface samples analyzed. Detected total Aroclor concentrations ranged from 2.2 to 26,000 µg/kg (Map 11.3.3-5a), with a mean of 2,270 µg/kg. The highest concentration was detected downstream of WR-123. The distribution of the highest concentrations of subsurface total Aroclors generally correlates to high surface concentrations. In the head of the slip, surface concentrations are lower than subsurface concentrations. Surface concentrations are similar to subsurface concentrations in the area dredged along the south bank of the slip. Surface and subsurface samples were collected following the 2004 dredging in this area and surface samples represent pre-dredging subsurface conditions. Aroclors were generally not detected in the deepest interval analyzed in individual cores. One subsurface congener sample was collected and had a concentration of 730 µg/kg (Map 11.3.3-6a).

DBP
DBP was detected in 10 of 18 surface sediment samples. Surface concentrations of DBP ranged from 4.6 to 1,800 µg/kg, with a mean value of 280 µg/kg. The concentration distribution was similar to that of PCBs (Map 11.3.3-7).
DBP was detected in 2 of 35 subsurface samples analyzed. Detected DBP concentrations ranged from 7.8 to 28 µg/kg, with a mean of 17.9 µg/kg. The vertical concentration trend is difficult to evaluate due to the number of samples with no detected DBP; however, surface concentrations are higher at locations near WR-121 and WR-122 (Map 11.3.3-8).

DRH
DRH was detected in all 13 surface sediment samples analyzed, at concentrations ranging from 8 to 1,300 µg/kg, with a mean value of 372 µg/kg. The concentration distribution was similar to that of PCBs (Map 11.3.3-9).

DRH was detected in 21 of 30 subsurface samples analyzed. Subsurface DRH concentrations ranged from 7.1 to 3,500 µg/kg, with a mean of 660 µg/kg. Surface concentrations were generally lower than subsurface concentrations, and the concentration in the deepest core was generally below detection limits or 10 mg/kg (Map 11.3.3-10).

Endrin Ketone
Endrin ketone was detected in 12 of 19 surface sediment samples (Map 11.3.3-11). Concentrations ranged from 0.099 to 12 µg/kg, with a mean value of 3.3 µg/kg. The surface concentration distribution was similar to that of PCBs.

Endrin ketone was detected in 2 of 31 subsurface samples analyzed, at concentrations of 1.5 and 16 µg/kg, with a mean of 8.75 µg/kg. The vertical concentration trend is difficult to evaluate due to the number of non-detects (Map 11.3.3-12).

iAOPC 4
iCOCs for iAOPC 4 are limited to total PCBs.

PCBs
PCBs were detected in each of the six surface sediment samples. Concentrations of total Aroclors ranged from 104 to 302 µg/kg, with a mean of 213 µg/kg (Map 11.3.3-3). Total PCB congener concentrations ranged from 66.1 to 258 µg/kg, with a mean of 162 µg/kg (Map 11.3.3-4). The highest surface sediment concentrations are located near the confluence of the slip and the main channel of the river; however, the small range in concentrations within the iAOPC does not indicate a specific source.

The relative proportion of individual Aroclors in iAOPC 4 surface sediment is similar to that of iAOPC 3 and somewhat distinct compared to areas several hundred feet upstream and downstream of the slip (Map 6.1-48i).

PCBs were detected in 10 of the 16 subsurface samples analyzed. Detected PCB concentrations (Aroclors and congeners) ranged from 7.8 to 630 µg/kg, with a mean of 158 µg/kg. There is no distinct vertical trend in the samples collected (Map 11.3.3-5b).

iAOPC 5
iCOCs for iAOPC 5 are limited to total PCBs.

PCBs
PCBs were detected in each of the 18 surface sediment samples. Concentrations of total Aroclors ranged from 17.9 to 1,530 µg/kg, with a mean value of 273 µg/kg (Map 11.3.3-3). Total PCB congener concentrations ranged from 55.3 to 699 µg/kg, with a mean of 312 µg/kg. The highest surface sediment concentration was located near a dock structure near the center of the iAOPC; all other concentrations were less than 350 µg/kg (Map 11.3.3-4).

Samples containing relatively high proportions of Aroclor 1242 are present in this iAOPC (Map 6.1-48i). This is the only area in the Study Area with a cluster of samples with high proportions of Aroclor 1242. High proportions of Aroclor 1242 are also present in some, but not all, subsurface samples.

PCBs were detected in 14 of 17 subsurface samples analyzed. Detected PCB concentrations (Aroclors and congeners) ranged from 16 to 407 µg/kg. There is no distinct vertical trend in the samples collected (Map 11.3.3-6b).

11.3.3.2.2 Surface Water
There were no Round 2 surface water samples collected in iAOPCs 3, 4, and 5.

11.3.3.2.3 Transition Zone Water
No porewater was sampled for iCOCs. TZW sampling has not been conducted within the iAOPCs.

11.3.3.2.4 Biota
Single samples of crayfish (whole body) and sculpin (whole body) were collected from the head of the slip in iAOPC 3. As summarized in Table 11.3.3-1b, PCBs and zinc were detected in both samples. Endrin ketone and DBP were not detected. PCBs were detected in the samples at concentrations of 280 µg/kg and 360 µg/kg (Aroclors) and 207 and 758 µg/kg (congeners).

A single clam sample (body without shell) was collected near the mouth of the slip iAOPC 4. As summarized in Table 11.3.3-1b, PCBs were detected in the sample at a concentration of 234 µg/kg (Aroclors) and 306 µg/kg (congeners).

A single sample of crayfish (whole body) and two sculpin (whole body) samples were collected in iAOPC 5 near WR-108. As summarized in Table 11.3.3-1b, PCB Aroclors were not detected in the crayfish, and congeners were detected at 31.5 µg/kg. PCB

Aroclor concentrations were 305 and 324 µg/kg in the two sculpin samples; congeners were detected in a single sample at 818 µg/kg.

11.3.3.3 Potential Sources of iCOCs

This section presents a summary of the current understanding of potential sources of Round 2 iCOCs to iAOPCs 3, 4, and 5. These iAOPCs include contiguous properties within the Burgard Industrial Park that abut the International Terminal Slip and the main stem of the Willamette, in addition to noncontiguous upland properties that are part of the Park's stormwater basins.

Information presented is this section was obtained from site summaries unless otherwise noted. In addition to iCOCs, COIs associated with nearby upland areas are also discussed in this section. The COIs are presented to provide a comprehensive understanding of the upland issues and to support the identification of potential sources to the iAOPCs. The relevance of the pathway to iCOCs is summarized at the end of each pathway discussion. Potential sources, COIs, and pathways for ECSI sites associated with these iAOPCs are summarized in Table 11.3.3-2.

11.3.3.3.1 Upland Releases

During World War II, a large portion of the Burgard Industrial Park was occupied by a 330-acre shipyard owned by the Oregon Shipbuilding Company, the City of Portland, and the federal government. Between 1941 and 1945, 455 ships were built at the shipyard, employing approximately 27,000 workers (U.S. Maritime Commission 1947). As shown in a 1945 oblique aerial photograph, in the area where Schnitzer Steel and Calbag operations are currently located, there were 11 building ways, five outfitting berths, and one wharf. A mold loft and plate shop occupied the property now used by Northwest Pipe. A large assembly building was located on land now used by Boydstun Metal Works, and the Jefferson Smurfit property was formerly a warehouse. The barracks area during the war years was located in the vicinity of the RoMar property. At the head of the slip was a large parking area.

Industrial processes that took place at the shipyard included sandblasting, metal plating and surface finishing, painting, fiberglass construction, and machining and metal working. The operations conducted on the site involved building ships with Maritime Commission-owned equipment, machinery, and raw materials. Based on studies of WWII-era shipyards conducted by EPA (1997c), discharges of hazardous substances to the surface waters and sediments were likely to include, but not necessarily be limited to, lead, zinc, copper, chromium, mercury and other heavy metals, grease and oils, abrasives, solvents, cutting fluids, organic compounds, organotins, resins, fiberglass, cyanide, and used paints. Typical waste streams associated with these processes included air emissions, wastewater, residual wastes, sanitary sewer wastes, and stormwater runoff.

The Oregon Shipbuilding yard continued to be used for ship construction after the war, but episodes of fire and flooding limited its use (U.S. Maritime Commission 1947; *The Oregonian* 1945). After the shipyard property was sold in 1950, it was used by various

entities for industrial activities. The building ways were filled over a 10-year period in the 1960s and 1970s.

iAOPC 3

This iAOPC includes the head of the slip, SSI, Jefferson Smurfit, and Northwest Pipe properties located along the shoreline, and facilities within the stormwater drainage basins that discharge into this iAOPC. These facilities include Boydstun Metal Works, Western Machine Works, Portland Blast Media, Portland Container Repair, Joseph Ryerson & Sons, RoMar Transportation Systems, and SIC remnant parcels.

Schnitzer Steel Industries

SSI processes scrap metal such as automobiles, appliances, discarded steel members, and other ferrous products that are delivered to the facility via ship, truck, or occasionally rail. They process the scrap metal using a shearer or portable acetylene torches. Metals are separated from non-metal material after shredding. Non-metal material is disposed of at local landfills. The automobile shredder residue process is fully enclosed in the former shipyard Plate Shop building and uses an enhanced metals recovery and waste minimization system.

Releases of oil from the former aboveground tanks near the southwest shoreline of the slip have been documented prior to 1941. Current sources with potentially complete pathways to the river at the SSI properties include auto shredder residue, contaminated groundwater (VOCs in shallow and deep groundwater), contaminated soils (PCBs, TPH, PAHs, and lead in deep soils), stormwater runoff, and overwater activities. Historically, auto shredder residue has contained low levels of cadmium, lead, and PCBs. Potential COIs associated with these sources include VOCs, SVOCs, TPH, PAHs, PCBs, and metals.

Jefferson Smurfit

Jefferson Smurfit operates a corrugated container manufacturing facility on this property. Equipment within the facility includes one corrugator, three printer/folder/gluers, two rotary die cutters, a "window machine" (which glues polyfilm to corrugated box), a bailer/hogger (for waste paper shredding and bailing), a slitter (which cuts paper to size), and various conveyors to produce paper products. Raw materials include paper, cornstarch and starch additives, glue, and inks. The Jefferson Smurfit facility is a conditionally exempt generator of hazardous waste. Jefferson Smurfit discharges its wastewater to the City's sanitary sewer system under a wastewater discharge permit.

Site investigations have been limited to soil sampling that occurred after the removal of petroleum-contaminated soil during a 1996 cleanup of a fuel release from underground piping associated with a 14,200 gallon AST, and during the decommissioning of the AST and related underground piping in 1997. After the piping and a total of 750 tons of contaminated soil were removed from the site in 1996 and 1997, confirmation soil sampling indicated that a small pocket of about 1 cubic yard of soil with up to 2,500

mg/kg of heavy oil was left in place beneath the railroad tracks, with concurrence from DEQ.

Northwest Pipe
As a RCRA small-quantity generator, Northwest Pipe uses aerosol degreasers, aerosol cleaners, and soluble oil in the manufacture of steel pipes. Used epoxy thinner, used epoxy thinner absorbent, used oil, and hydraulic fluids are also generated onsite. Depending on the RCRA category, wastes are disposed of at an offsite waste management facility (e.g., paint sludge still bottoms, jelled residual paints, cresol-contaminated materials), landfill (e.g., sand/cement grit, polyethylene tapes, baghouse dust, punctured aerosol cans, welding flux, mill sludge), or offsite waste oil recycler.

Historical and current sources with potentially complete pathways to the river at the Northwest Pipe property include waste oil AST and drum storage areas, transformer storage area, contaminated soils (PAH, TPH, and VOCs), industrial well, catch basin sludge, shallow VOC groundwater plumes, and stormwater discharge. Potential COIs associated with these sources include VOCs, SVOCs, TPH, PAHs, PCBs, metals, and phthalates. Both groundwater plumes appear to flow offsite in a southerly direction; VOC concentrations in groundwater were detected above JSCS screening levels in 2004 and 2005. PCBs were detected in surface soil in the vicinity of the maintenance shop and near transformers. PCBs were also detected in catch basin solids (4.5 mg/kg).

Areas of the site containing a gasoline underground storage tank (UST), solvent storage, asphalt dipper tank, dust suppressant use and storage, and an alleged petroleum dumping location were also identified as areas of concern, but were determined to need no further action based on the results of soil sampling.

Boydstun Metal Works, Western Machine Works, Portland Blast Media
Boydstun manufactured automotive trailers for commercial haulers in the southeast area of the Park until operations were moved to the north end of the slip in 2000. Operations at Western Machine Works include repairing, machining, and constructing industrial parts for the paper and pulp industry. Sandblasting and painting of solid waste and recycling drop box containers takes place at the Portland Blast Media site. Blasting is conducted in a temporary shelter on the northwest corner of the property. Magnesium, iron, and aluminum oxide silica are used as blast materials. These materials were tested for leachable metals, and the concentrations were determined to be within acceptable waste limits.

Sources with potentially complete pathways to the river identified at the site include the oil storage area on the Boydstun parcel, contaminated surface soils (heavy oils, PAHs, and metals have been detected) at the Portland Blast Media wash pad and at the Western Machine Works compressor areas, and groundwater contaminated with chlorinated solvents in this area. Test pit excavations in the southeast area of the property detected PAHs, PCBs, and lead in soil above DEQ soil cleanup levels at two

locations. Potential COIs associated with these sources include VOCs, PAHs, TPH, PCBs, and metals.

Portland Container Repair
Activities at the Portland Container Repair facility include storage, maintenance, and cleaning of intermodal containers. Repair activities include riveting, welding, seam caulking, and limited painting. Diesel refrigeration units found in some containers are also sometimes repaired on the property. All activities occur in the facility's main building except for washing, which occurs outside on a concrete pad. A fuel tanker truck is parked on unpaved ground with no containment provided. Any spills from the truck could contaminate surface and subsurface soils. The wash pad is also lacking curbed containment. Based on staining adjacent to the pad, wash water has affected surface soils in this area. Following a 20-mg/kg detection of PCBs (Aroclor 1254 and 1260) in soil in the northwestern portion of the site, approximately 50 tons of PCB-contaminated soils with concentrations greater than 1 mg/kg were removed and disposed of offsite in 1994. Potential COIs associated with activities on this property include VOCs, PAHs, TPH, and PCBs.

RoMar Transportation Systems
The RoMar site is occupied by a commercial warehouse and is used for storage of clothing, parts, and lumber. The facility does not generate, treat, or store any hazardous wastes. Scrap metal parts containing PCB oils were stored on the site prior to 1994 and resulted in soil contamination. Soil and groundwater samples were collected in 2005, and PCB concentrations greater than human health-based preliminary remediation goals (PRGs) were found in a borehole sample in the northwest portion of the property. Consequently, RoMar excavated shallow soils from a 30- by 50-ft area surrounding the borehole in January 2006.

iAOPC 4
This iAOPC is located at the mouth of the slip and includes the PEO facility on the north shore and the SSI parcel on the south shore and along the main stem of the river.

Premier Edible Oils
The PEO site is currently unoccupied except for office space used by tenants. During WWII, seven ASTs (owned by NW Oil Company, a predecessor to Time Oil) were located here, and product was transferred from ships to tanks via a dock in the slip. In 1943, the tanks were moved to the current location of Time Oil. During the war years, the Oregon Shipbuilding Company used the site to store products and raw materials. Between 1946 and 1972, little activity occurred on the property. American Metallic Chemicals manufactured chemicals and metals on the site and stored them in multiple ASTs from the early 1950s until 1956. SIC purchased the site in 1972 and leased the site to PEO by 1973. The site was graded and most of the structures were removed, including the railroad track. PEO constructed an office/processing building, an AST farm for edible oil storage and blending, bulk chemical storage, and a 10,000-gallon aboveground diesel storage tank for energy backup (all on concrete pads). PEO

constructed a dock on the Willamette to transfer edible oil between ships and the facility. Building demolition and AST removal activities have occurred on this site since 1999.

Schnitzer Steel Industries
Operations, sources, and COIs associated with the SSI facility were discussed in iAOPC 3 above.

iAOPC 5
This iAOPC extends along the river and encompasses the southern end of the SSI facility, Calbag Metals, and leased Port of Portland property. Operations, sources, and COIs associated with the SSI facility were discussed in iAOPC 3 above. Calbag Metals receives, briefly stores, and transports non-ferrous metals offsite for recycling. Aluminum, copper, and stainless steel are the primary materials handled at the facility. Generally, no cutting or processing of scrap metal is performed. Potential sources on the Calbag Metals include contaminated surface soils and stormwater discharge. COIs associated with these sources include TPH and metals.

Information about the Port of Portland leased property was not available in DEQ files.

11.3.3.3.2 Stormwater/Overland Transport
The Oregon Shipbuilding facility had separate stormwater drainage and sanitary sewer systems consisting of multiple outfalls that discharged directly to the outfitting basin and to the Willamette. The upland site drainage patterns were also conducive to the migration of contaminants to the river through stormwater sheet runoff. Potential contaminants found in stormwater, sanitary sewer, and overland sheet runoff were likely associated with sandblasting, metal plating and surface finishing, painting, fiberglass construction, and machining and metal working activities at the shipyard. These could have included VOCs, SVOCs, PCBs, PAHs, TPH, metals, cyanide, and butyltins. The outfalls and drainage basins for the shipbuilding era have not been evaluated.

Approximately 18 active outfalls drain to the slip or the main stem of the Willamette. Twelve other outfalls are inactive and are remnants of the former shipyard. Other basins that are controlled by other entities outside of the Burgard Industrial Park also drain to the slip.

Based on the distribution of sediment concentrations and the apparently unique proportions of Aroclors (e.g., high proportion of Aroclor 1254), outfalls near the head of the slip (WR-121, WR-122, WR-123, and WR-124) appear to be a significant source of iCOCs to iAOPC 3. PCBs have been detected in shallow soils at Portland Container Repair, Boydstun Metal Works, Northwest Pipe, and RoMar Transportation Systems, and in deep soil at SSI. Information on Aroclor composition is only available for Portland Container Repair, where the detected Aroclors in a single sample were Aroclor 1254 and 1260. Stormwater from these sites is routed to the Burgard Industrial Park stormwater system and discharges primarily at private outfalls WR-123 or WR-124.

Seven outfalls currently or historically drain to iAOPC 4. The highest concentrations of PCBs are not clearly associated with the nearby outfalls. A similar lack of association is true for the five outfalls at iAOPC 5.

11.3.3.3.3 Overwater Discharge

Shipbuilding operations and associated infrastructure consumed a major portion of the current Burgard Industrial Park from 1941 to 1950. As noted earlier, ships were moored along the southern edge of the slip within iAOPCs 3 and 4 after they were assembled in the shipways. Overwater activities included interior mechanical and electrical installation and deck painting. Incidental spills of paint residue and fuels into the slip were possible during this time. In 1945, a fire destroyed the dock and shops along the south side of the dock. Several ships were damaged, and cranes fell into the slip as the dock collapsed. In-water contamination resulting from the fire and collapse of the cranes has not been quantified, but could likely include PAHs, TPH and metals.

At the former PEO facility within iAOPC 3, a wooden dock and pilings were located in the slip from the 1950s until the early 1990s. PEO received edible oils for refining by ship, but it has not been confirmed that the slip dock was used for this purpose. Nevertheless, inadvertent spills during transfer activities or leakage of diesel, motor oils, or other contaminants may have been sources of sediment contamination in the slip.

The magnitude of overwater releases has decreased dramatically over time as the former shipyard was converted to other uses and best management practices (BMPs) were implemented for activities on the docks. Current overwater activities in the slip and along the river are associated with SSI's bulk metal off-loading operations within iAOPC 3, which may result in inadvertent releases of diesel, motor oils, or other contaminants to the river. Diesel and oil/water ballast were released to the slip in 2000 and 2001, respectively, but the quantities were not determined. Ten gallons of diesel were released to the river in 2003. DEQ's ERIS database contains numerous incidents of oily sheens observed on the river surface in the slip. Barge activities associated with SSI's operations are the suspected sources of these spills, but the sheens could also have originated from stormwater outfalls.

Overwater activities may have contributed to the distribution of iCOCs within the iAOPCs, but no clear relationships are apparent. One possible exception is the presence of the highest surface PCB concentrations immediately downstream of the pier leading to the dock at iAOPC 5.

11.3.3.3.4 Groundwater Discharge

As shown on Map 5.1-1a–h, four separate VOC plumes and a TPH plume have been identified in the International Terminal Slip area. Groundwater is not expected to be a significant source of iCOCs to the iAOPCs. PCBs, DBH, zinc, and endrin ketone have not been groundwater investigation targets at nearby sites and are not expected to be significant groundwater constituents. TPH (as DRH and RRH) is an iCOCs for iAOPC

3. Due to the low concentrations and/or distance of nearby VOC plumes, TPH in groundwater is not expected to be a significant source.

11.3.3.3.5 Riverbank Erosion

As shown on Map 4.6-1-, the shoreline of the International Terminal Slip is covered with dock structures on its southern side (iAOPCs 3 and 4), unclassified fill at its head (iAOPC 4), and natural bank along its northern side (iAOPCs 3 and 4). The Willamette River shoreline is currently covered with concrete riprap and is lightly vegetated in the upper portions (iAOPCs 3 and 5). Old timber pilings left over from the Oregon Shipbuilding Corporation are located offshore in this area. No seeps or evidence of erosion have been observed along the river shoreline.

SSI collected soil and groundwater samples in the northwest corner of the property to determine whether there were current pathways for site contaminants to reach the river. Analytical results for PAHs, PCBs, TPH, and metals in subsurface soils were all lower than DEQ's soil matrix and applicable draft generic risk-based concentrations. No riverbank sampling appears to have been conducted for the majority of the south bank of slip, where the highest concentrations of iCOCs are present.

11.3.3.4 Relationship of Upland Sources to the Distribution of iCOCs

The International Terminal Slip area has a long history of heavy industrial use. WWII shipbuilding operations are likely sources of iCOCs in the river, but specific sources or pathways for in-water impacts are obscured due to significant changes in land configuration and land use since the shipbuilding era.

The relative proportion of Aroclors at all three iAOPCs suggests local sources for all three of the iAOPCs. These may be legacy sources from historical operations, but the distributions of sediment concentrations in the slip are strongly associated with outfalls at the head of the slip. These outfalls drain large areas with sites that have documented evidence of PCBs and other iCOCs in surface and near-surface soils.

The distributions of PCB concentrations in sediment at iAOPCs 4 and 5 do not correlate well with outfalls or other features, but, again, the proportions of Aroclors at these iAOPCs suggest nearby sources.

Groundwater is not expected to be significant source of iCOCs for the iAOPCs. With the exception of TPH (as DRH and RRH), iCOCs are not groundwater investigation targets. The low concentrations and distance between VOC plumes and the river indicate that TPH in groundwater is not a significant source.

Riverbank materials have not been investigated to a large extent. Currently, the riverbank is generally armored; however, neither the potential for historical bank erosion nor the potential effects of previous land reconfiguration near the river have been investigated.

Overwater activities occur at the iAOPCs. It is expected that overwater activities were an important pathway during shipbuilding years, but that impact and the expected considerably lower impact of recent operations is not quantifiable.

A preliminary evaluation of the relationship between sources, pathways, and iCOCs in iAOPCs 3, 4, and 5 is summarized in Figure 11.3.3-1. Preliminary assessments of the current and historical relative contributions of each source for iAOPCs 3, 4, and 5 are summarized in Table 11.3.13-3.

11.3.4 CSM for iAOPC T4

This section provides the preliminary Round 2 CSM for iAOPC T4 (Terminal 4). This 28.85-acre area is located along the eastern shore of the river between RM 4.3 and 4.7. It includes Slip 1 at the northern end of Terminal 4 (RM 4.3), Slip 3 at the southern end of Terminal 4 (RM 4.6), and Wheeler Bay between the two slips (Map 11.3.4-1).

The Port of Portland is currently conducting an early action cleanup at Terminal 4. The cleanup plan selected by EPA for Terminal 4 will dredge approximately 115,000 cubic yards of contaminated sediments, cap 8.7 acres and monitor 10.9 acres for natural recovery. The dredged material will be placed in an onsite confined disposal facility (BBL/Ash Creek/Newfields 2006). This CSM examines the physical setting of the iAOPC and adjacent upland properties, the chemical distribution of iCOCs in in-water media, and potential sources of the iCOCs.

iCOCs for this iAOPC include the following:

- Total PCBs
- Dioxin TEQ
- Benzo(a)pyrene (BAP).

Potential iCOCs for this iAOPC include:

- Cadmium
- Lead
- Silver
- Zinc
- DRH.

Potential iCOCs are identified through less certain and/or less rigorous evaluations based on fewer lines of evidence, FPM results, or other high uncertainty lines of evidence (see Sections 8 and 9).

Map 10.5-3a–j shows the areas where this preliminary analysis identified the potential for risk for individual exposure scenarios that were considered in iAOPC development, and Table 10.5-1 identifies the iCOCs associated with the exposure scenarios. PCBs

are identified as iCOCs all areas within the iAOPC; remaining iCOCs are restricted to the head of Slip 3.

The CSM evaluation is summarized as follows: Overwater activities (including transfer of pencil pitch, a coal tar distillate) at this shipping terminal may represent the most significant historical source of iCOCs to the iAOPC. Groundwater appears to represent a source of iCOCs (DRH and PAHs). Groundwater migration was determined to be a complete and primarily historical pathway of petroleum hydrocarbons to the river. Riverbank erosion represents a potential source of iCOCs to the iAOPC. Pencil pitch has been observed in riverbank soils at Slip 3. In addition, several iCOCs have been detected in Wheeler Bay riverbank soils that are not currently stabilized against erosion. However, the majority of potentially erodable banks are currently armored with riprap or bulkheads in other areas adjacent to the iAOPC.

11.3.4.1 Physical Setting, Infrastructure, and Operational History

In-river and upland physical characteristics, infrastructure, and operational history relevant to this iAOPC are briefly described in this subsection. Information on adjacent upland sites was obtained from the LWG site summaries (Integral and GSI 2004; 2005a,b,c) and updates (Integral 2007) unless otherwise noted.

11.3.4.1.1 In-River

The channel area in the portion of the river adjacent to the Terminal 4 iAOPC is characterized in the Portland Harbor Work Plan as transitional between the narrow transport zone upstream of RM 5 and depositional zone below RM 3. The Sediment Trend Analysis® results suggest that this reach as well as Slips 1 and 3 are in dynamic equilibrium. Time-series bathymetric change data over the 25-month period from January 2002 through February 2004 show small-scale sediment accretion (up to 1 ft) along the inner, upstream portion of Slip 3 and essentially no change throughout most of Slip 1. Sediment loss (1-2 ft) was evident in small areas between the shoreline and -25 ft NAVD88 and the upstream side of Slip 1, potentially from vessel propwash. Sediment accumulation up to 2 ft was shown from the area immediately offshore of Slip 1 to -50 or -60 ft NAVD88; however, the center of the main channel showed no net elevation change.

Sediment loss of 2 ft and greater was shown in the area along the dock face representing the downstream border of Slip 3 out to the mid-Slip 3 area (approximately the -40 ft NAVD88 contour). A dredging operation conducted in this area during the bathymetric measurement activities may help explain the change. Another area characterized by a sediment loss of 2 ft or more, possibly due to propwash, is the part of Slip 3 that faces the river near the upstream portion of the iAOPC out to -25 ft NAVD88. Sediment accumulation (up to 1 ft) occurred in a depression from -40 to -50 ft NAVD88 immediately offshore of Slip 3.

The area near Berths 410 and 411 in Slip 3 was dredged in 1994-1995 as an interim action to remove pencil pitch, which had historically been transferred from ships' holds directly to truck trailers and rail cars.

Sediment grain-size distribution within the iAOPC is shown on Maps 11.3.4-2 (surface) and -3a,b (subsurface). Most surface sediment samples consisted of over 75 percent fines. The two subsurface cores in this iAOPC (both from Slip 3) were also dominated by fines (70 and 75 percent).

Riverbank and shoreline conditions for the area are shown in Map 5.1-2. The river shoreline on the upstream portion of the iAOPC at Slip 1 (RM 4.3) is mostly covered with riprap or bulkheads, especially where there is the potential for erosion. The riverbank soils along Wheeler Bay, which are not currently stabilized to prevent erosion, contain elevated concentrations of iCOCs. Source control measures are being planned with the sediment Early Action. The south bank along Slip 3 (Berth 412) is armored with riprap. The head of Slip 3 has been stabilized with a bulkhead (short wood pile) and riprap at the toe of the riverbank. The lower portion of the riverbank along the Willamette River (Berth 413) is armored with riprap and the upper portion is vegetated. Pencil pitch has been detected in riverbank soils near Berth 413 and investigations are being planned to evaluate the extent of contamination of this material, as well as other potential constituents (Integral 2007).

Significant in-water facilities and structures within the iAOPC include the following; their primary in-water uses are described in the next subsection:

1. Pier 1 is located along Berth 405 on the northeastern shoreline of Slip 1.
2. Pier 2 is located along Berth 408 on the southeastern shoreline of Slip 1 directly across the slip from Pier 1.
3. Pier 4 is located along Berths 410 and 411 along the entire shoreline of Slip 3 and extending into the river between the slip and Wheeler Bay to the northwest.
4. Ten private stormwater outfalls (WR-20, WR-154, WR-171 through WR-178) discharge into the iAOPC.

City Outfall 52C is located at the head of Slip 1, just outside the boundary of the iAOPC. This outfall drains a 22-acre basin located 1,000 ft from the shoreline of Slip1.

11.3.4.1.2 Upland

Upland properties adjacent to the iAOPC are used by Cereal Food Processors, Kinder Morgan Bulk Terminals (KMBT), and International Raw Materials, under leases from the Port of Portland. All are zoned for industrial use. A fourth entity—Rogers Terminal and Shipping—is active in the adjacent uplands to maintain equipment associated with terminal operations. Historical and current operations and predevelopment features (when available) for the upland properties were obtained from site summaries by LWG.

Four companies are active in the uplands associated with this iAOPC:

- **Cereal Food Processors.** This company currently leases 1.6 acres north of Slip 1 for milling grain into flour. Grain milling activities began in 1919 by the

Eagle Flour Mills Company, which operated until 1923. Terminal Flour operated the facility from1923 to 1992, when Cereal Food Processors began their lease.

- **Kinder Morgan Bulk Terminals.** KMBT currently leases 6.56 acres of upland adjacent to the north side of Slip 3. The facility has operated since 1998, importing soda ash by railcar and loading it onto ships at Pier 4 along Berths 410 and 411. The site is currently occupied by rails, associated buildings, a storage dome, and utilities. The gearlocker building is used by the Port of Portland to store maintenance equipment.
- **International Raw Materials.** Since 1919, liquid fertilizer, molasses, tallow, urea, caustic soda, fats, and other liquids have been handled on this property. The liquids have been stored in tanks at the head of Slip 1, the number of which in simultaneous use has ranged between 1 and 14. Pacific Molasses was the first occupant after initial development of the terminal, followed by PM-Ag and International Raw Materials.
- **Rogers Terminal and Shipping.** This company is currently contracted to support the loading and unloading ships at Terminal 4. Their service activities include maintenance of vehicle and metal gangways and storage of tarps, boxed equipment, lumber, and metal.

Industrial activities in the adjacent uplands began in the first decade of the 1900s. In 1906, the Union Pacific Railroad (UPRR) unloaded petroleum products at Pier 5 in Slip 3. Diesel, No. 6 fuel, and Bunker C oil were transferred from the railcars via pipeline to bulk fuel storage tanks located offsite to the east at the St. Johns Tank Farm (ECSI #2017). Petroleum operations ceased in 1983. In 1997 and 1998, various portions of the remaining pipelines were drained, cleaned, and removed.

Development began in 1917, when City of Portland Commission of Public Docks (City CPD) purchased a portion of the land. Vegetation was removed from most of the floodplain, and dredged fill material was deposited in low-lying ground and along the riverbank, which was extended out into the channel. In addition, most of lower Gatton Slough was filled at that time. Additional parcels were purchased from UPRR in 1920 and again in 1948.

From 1953 to 1985, Quaker State conducted an oil canning operations east of Slip 3. The facility included an underground transfer pipeline, eight ASTs, and a packaging building. Bulk oil was delivered via rail or ship at Berth 412. Oil was transferred first to the ASTs and then via pipeline to the packaging plant, where it was blended and bottled into 1-quart containers of motor oil. When Quaker State operations ceased in 1985, the ASTs and pipeline were removed, and the packaging building was converted to the current gearlocker building and an electrical shop for Oregon Terminal Company. Gasoline and diesel USTs were installed south of the building at that time; they were removed in 1991. An older waste oil UST was removed in 1996.

At present, the Terminal 4 facility includes 11 berths (on the river, within Slip 1, and on the north side of Slip 3), eight warehouses, one flour mill, and bulk storage facilities. A third slip between Slips 1 and 3 had been planned (Slip 2) and excavated; however, it was subsequently filled and is now known as Wheeler Bay. The Port of Portland has owned the property since 1971, when it merged with the City CPD. Most of the upland Terminal 4 facility is paved with asphalt or concrete. Areas formerly occupied by structures and rail lines have been covered with gravel. The upland site is generally flat with an average elevation of approximately 30 ft above MSL. Rail lines cross its northern and eastern portions. Two buildings remain: the KMBT building and the gearlocker building.

11.3.4.1.3 Upland Hydrogeology

Upper and lower groundwater zones separated by a silt unit are found in the uplands adjacent to the iAOPC. The upper water-bearing zone is characterized as the fill unit, and the deeper zone is an alluvial unit. The silt at the top of the alluvium divides the two groundwater zones, causing the groundwater in the sandy upper unit to be "perched." Additional detail appears in cross sections prepared for the Terminal 4 facility (see Supplemental Figures 8-10).

Groundwater elevations measured monthly from September 2004 through September 2005 in the upland portion of Slip 1 ranged from 8.3 to 30 ft bgs in the fill unit and the upper portion of the alluvial unit. Seasonal water fluctuations upgradient of Slip 1 were approximately 2 ft, with more pronounced fluctuation along Slip 1 and the river (approximately 4 ft). Groundwater elevations in the central portion of the Slip 3 upland generally ranged from 12 to 23 ft bgs during the past 10 years.

For the most part, groundwater flows toward the river, Slip 1, or Slip 3, with highly variable groundwater gradients in the eastern portion of the upland property. No groundwater gradients were discerned in the western portion of the uplands south of Slip 3 (Century West 1994; Hart Crowser 2000a,b). Seeps have been observed along the east side of Slip 1 (Integral 2007).

11.3.4.2 Chemical Distribution of iCOCs

This section describes the distribution of iCOCs and potential iCOCs for iAOPC T4. Sediment sampling locations are shown in Map 11.3.4-1, and all iCOC data for the iAOPC can be found in Appendix I.

11.3.4.2.1 Sediments

For the purposes of evaluating sources to iAOPC T4, the following discussion of chemical distribution of iCOCs is limited to PCBs, DRH, BAP, and zinc. Table 11.3.4-1a provides a statistical summary of all iCOCs for sediment in iAOPC T4.

PCBs

PCBs were detected in 31 of 35 surface sediment samples. Two types of analyses were conducted for these samples: Aroclors (Map 11.3.4-4) and congeners (Map 11.3.4-5). Concentrations of total Aroclors ranged from 5.3 to 820 µg/kg, with a mean value of

66.5 µg/kg. Total PCB congeners ranged from 0.54 to 69.2 µg/kg. The highest surface sediment concentrations of PCB Aroclors (820 µg/kg) were found adjacent to the southwestern shoreline of Slip 1, near the head of Slip 1 (66-96 µg/kg), and offshore of Wheeler Bay towards the river channel (86 µg/kg).

PCBs were detected in 58 of 133 subsurface samples analyzed. Detected total Aroclor concentrations ranged from 3.3 to 1,000 µg/kg (Map 11.3.4-6a,b), with the highest concentration at the head of Slip 3 near outfall WR-174. There was no analysis of congeners in subsurface sediment. The spatial distribution of the highest subsurface concentrations generally correlates to that of high surface concentrations. However, the cores collected outside the slips adjacent to the river tended to exhibit higher concentrations in the deeper horizons, suggesting an older source of these chemicals. In the head of the slips, concentrations were generally higher in the surface and shallow subsurface than in the deeper sediments. Except in Wheeler Bay and farther offshore toward the river channel, Aroclors were generally not detected in the deepest interval analyzed in individual cores.

Zinc

Zinc was detected in all 63 surface sediment samples analyzed (Maps 11.3.4-8). Concentrations of zinc ranged from 38.6 to 1,300 mg/kg, with a mean value of 281 mg/kg. The highest surface sediment concentrations were generally located at the heads of each slip, especially in Slip 3.

Zinc was detected in all 145 subsurface samples analyzed (Maps 11.3.4-9a,b). Detected zinc concentrations ranged from 30.4 to 656 mg/kg. Locations of the highest subsurface concentrations generally correlated with those of elevated surface concentrations. However, the subsurface concentrations tended to be higher than surface concentrations in Wheeler Bay and near the mouth of Slip 3 adjacent to the river.

DRH

DRH was detected in 40 of 71 surface sediment samples. Concentrations ranged from 9.1 to 2,100 mg/kg, with a mean value of 259 mg/kg. The concentration distribution was generally similar to that of PCBs (Maps 11.3.4-4 and -10).

DRH was detected in 57 of 133 subsurface samples analyzed. Detected DRH concentrations ranged from 15 to 620 mg/kg, with a mean value of 185 mg/kg. Subsurface concentrations were generally higher than surface concentrations, with the exception of two cores collected adjacent to outfalls WR-154 and WR-178 in the head of Slip 1 and in the northeastern corner of the head of Slip 3. Concentrations in the deepest horizons of the cores were below detection limits (approximately 25 mg/kg), except, as for PCBs, in samples from Wheeler Bay and adjacent to the river outside of the slips (Maps 11.3.4-10, -11a, -11b).

BAP

BAP was detected in 69 of 70 surface sediment samples (Maps 11.3.4-12). Concentrations of BAP ranged from 3 to 94,000 µg/kg, with a mean value of 10,700

µg/kg. The highest concentrations were generally located inside the slips, especially at the head of Slip 3 adjacent to outfall WR-176 in the northeastern corner. Elevated concentrations were also detected in samples collected immediately upstream of Slip 3.

BAP was detected in 106 of 149 subsurface samples analyzed. Detected BAP concentrations ranged from 0.2 to 23,000 µg/kg with a mean of 1,530 µg/kg. The locations of the highest subsurface concentrations generally correlated with those of high surface concentrations, although the latter tended to be higher (Map 11.3.4-12, -13a,b).

11.3.4.2.2 Surface Water

Table 11.3.4-1b provides a statistical summary of selected iCOCs for surface water in iAOPC T4. Only one surface water sample was collected (Station LW2-W008 in Slip 3).

11.3.4.2.3 Transition Zone Water

No porewater samples were collected for analysis of iCOCs. TZW sampling has not been conducted within this iAOPC.

11.3.4.2.4 Biota

Single samples of crayfish (whole body) and sculpin (whole body) were collected from the head of Slips 1 and 3. As summarized in Table 11.3.4-1c, total PCB Aroclors were detected in whole-body sculpin samples only, at concentrations of 156 to 196 µg/kg. Analyses were not conducted for total PCB congeners or DRH. BAP was not detected. Zinc was detected in all four samples at similar concentrations (16.4 – 18 mg/kg).

Single clam samples (body without shell) were collected from the head of Slip 1 and the head of Wheeler Bay. As summarized in Table 11.3.4-1c, PCBs were detected in the sample collected from Slip 1 at concentrations of 68.4 µg/kg (Aroclor) and 99.5 µg/kg (congener); PCBs were not analyzed in the sample collected from Wheeler Bay. BAP was detected at concentrations of 9.8 µg/kg (Slip 1) and 7.7 µg/kg (Wheeler Bay). DRH analyses were not conducted. Zinc was detected at concentrations of 29 mg/kg (Slip 3) and 33.5 mg/kg (Wheeler Bay).

Sediments for the clam (body without shell) and mudworm (whole body) laboratory bioaccumulation tests were collected from roughly the same locations in Slip 1 and Wheeler Bay. For organisms exposed to sediment from Slip 1, PCBs as Aroclors were detected at 38.7 µg/kg in clams and 101 µg/kg in mudworms; comparable values for PCB congeners are 45.5 µg/kg in clams and 147 µg/kg in mudworms. For organisms exposed to sediment from Wheeler Bay, PCBs as Aroclors were detected at 17.1 µg/kg in clams and 89.2 µg/kg in mudworms; comparable values for congeners are 21.2 µg/kg in clams and 131 µg/kg in mudworms. BAP concentrations in clams exposed to sediments from Slip 1 and Wheeler Bay were 1.4 and 1.5 µg/kg, respectively. BAP concentrations in mudworms exposed to sediments from Wheeler Bay and Slip 1 were 24 and 79 µg/kg, respectively. Zinc concentrations were generally similar in both tissue types (11.6 – 24 mg/kg).

11.3.4.3 Potential Sources of iCOCs

This section presents a summary of the current understanding of potential sources of Round 2 iCOCs to iAOPC T4. Information presented in this section was obtained from site summaries unless otherwise noted. In addition to iCOCs, COIs associated with nearby upland areas are also discussed. The COIs are presented to provide a comprehensive understanding of the upland issues and to support the identification of potential sources to the iAOPC. Potential sources, COIs, and pathways associated with this iAOPC are summarized in Table 11.3.4-2.

11.3.4.3.1 Upland Releases

The Port of Portland conducted a remedial investigation of the uplands at Slip 1 in 2004 and at Slip 3 in 2001(Hart Crowser 2000a,b). At Slip 1, iCOCs were detected intermittently at low concentrations in upland soils, with the exception of a few localized areas and along riverbanks. Neither widespread contamination nor significant sources were apparent in the Slip 1 area. BAP and metals (cadmium, lead, silver, and zinc) were detected at elevated concentrations in potentially erodible riverbank soils in Wheeler Bay, the stabilization of which is being planned in coordination with the sediment Early Action.

At Slip 3, upland sources of iCOCs include historical releases of petroleum hydrocarbons (diesel and heavier fuel oil range hydrocarbons) from the UPRR underground pipelines and rail loading facilities (east of the Terminal 4 uplands). In 1970, four documented pipeline leak points were identified after a petroleum seep was discovered in the southeast corner of Slip 3. The pipeline was decommissioned in 1998, and small leak points were identified along its entire length.

Three USTs located south of the gearlocker building in the KMBT area were decommissioned without indication of significant impact to the subsurface, except for 10 cubic yards removed during the excavation and 17 cubic yards of inaccessible soil beneath the gearlocker building. TPH was detected in the inaccessible soil originally associated with the waste oil UST removed in 1996; however, given its location above the water table and beneath the building, the inaccessible soil was not determined to be an ongoing source. A *No Further Action* determination for the waste oil UST was granted by DEQ on February 15, 1995.

Pencil pitch, a coal tar distillate, was unloaded at Berths 410 and 411 by Jones Oregon Stevedoring (1979-1987) and Hall-Buck Marine (1987-1998). Pencil-pitch-contaminated soil was discovered in November 2003 on the riverbank of Berth 413 in Slip 3. Approximately 50 yd^3 of contaminated soil was immediately removed for offsite disposal. Pencil pitch has also been found approximately 20-25 ft north and 100 ft south of the excavation, as well as near the northeast corner of Slip 3, in a location referred to as the Slip Bank Area. PAHs are associated with pencil pitch.

Upland subsurface soils containing DRH, oil, and PAHs are mostly restricted to an area east of Slip 3. Petroleum hydrocarbons are characterized as having a low solubility, and LNAPL is continuously monitored and removed from the subsurface. A bank

excavation and backfill project and LNAPL recovery system were implemented to intercept and recover dissolved-phase COIs in groundwater. PAHs associated with pencil pitch are present on the riverbanks near Berth 413 (adjacent to Slip 3) and in the Slip Bank Area. Efforts to further stabilize these potentially erodible areas are being planned.

11.3.4.3.2 Stormwater/Overland Transport

Ten outfalls are located within the iAOPC boundary (WR-20, WR-154, WR-171 through WR-178). Three of these outfalls—WR-20 along the shoreline of Wheeler Bay, WR-176 and -177 at the head of Slip 1—discharge actively; the other outfalls have not been evaluated.

In 2005, stormwater was sampled as part of the Terminal 4 Early Action. No significant sources of contamination were identified, and it appears unlikely that current stormwater discharges contribute substantial amounts of iCOCs to the river. A stormwater evaluation and recontamination analysis that began in 2004 is still underway to determine whether discharges are of concern.

Outfall 52C is located just outside the boundary of the iAOPC at the head of Slip 1. This 36-inch-diameter outfall drains approximately 22 acres of primarily industrial land located 1,000 ft from the slip. Stormwater discharge permits have not been issued to any of the facilities within the basin of Outfall 52C. Two ECSI sites are partially located in the basin: Borden Packaging and Industrial Products (ECSI #1277) and Klix Corp. (ECSI #1075). Drainage entering the City's conveyance system from these facilities is primarily from roofs and parking lots. The City found considerably elevated concentrations of chromium, and slightly elevated concentrations of HPAH, LPAH, and phthalates in sediment collected near this outfall (CH2M Hill 2004b).

Upland properties are relatively flat and most areas are paved, graveled, or covered with buildings. There are no known overland transport pathways that could deliver contaminants to the river from the uplands associated with this iAOPC.

11.3.4.3.3 Overwater Discharge

A wide variety of materials and products has been handled at the terminal over the years, including grains, ores, fuels, and chemicals. Between 1920 and 2003, the grain facility at Pier 1 was operated by several entities: the City CPD from 1920 to 1942, the U.S. Army from1942 to 1947, City CPD again from 1947 to 1954, and Kerr-Gifford (which was bought by Cargill through stock acquisition) from 1947 to 2003. Grain was transported via railcar between Berth 401 on the river and the track shed. A conveyor system was used to transport materials to and from Berth 405 located at the northeastern corner of Slip 1. Tri-calcium phosphate was also handled at Pier 1.

Metal ore and other raw products were handled at Pier 2 in Slip 1 from 1921 to 1996. Materials including alumina/bauxite and chromite (1955-1956), ferro-phosphorous iron ore, and manganese (1958) were handled and transported via gantry and container cranes along the pier.

At Pier 4 (Berths 410 and 411) in Slip 3, pencil pitch was handled from 1978 to 1998. A clamshell-equipped Dravo unloading tower was used to move this material from the holds of ships directly into truck trailers or rail cars adjacent to the pier. Other materials handled at Pier 4 (and dates, where known) include ammonium sulfate (1970), sodium sulfate, soybean meal, sulfur (1961-1967), lead and zinc concentrates (1961-1971), soda ash (beginning in 1988), and alumina/bauxite and chromite (1963). Currently, KMBT exports soda ash at Slip 3, Berths 410 and 411. Ships are loaded and bulk cargo is unloaded from rail car at the berths.

Bulk materials including ores and coal were unloaded from ships at Berths 412 (south side of Slip 3) and 413 (adjacent to Slip 3). Petroleum products were unloaded at Berth 413 by UPRR between 1906 and 1983. There are no documented historical releases from these berths, although incidental releases could have occurred.

11.3.4.3.4 Groundwater Discharge

Groundwater in the vicinity of Slip 3 has been identified as a complete pathway by which contaminants can enter the Willamette River (Hart Crowser 2000a). Cleanup work involving bank excavation and backfilling was conducted in 2004 to mitigate discharge of dissolved phase hydrocarbons from Slip 3, observed as a petroleum sheen at the east end of the slip. Manual LNAPL removal from existing facility wells has been ongoing since 2004. The TPH and PAHs present in groundwater east of Slip 3 are likely associated with releases of diesel and heavier fuel oil to the shallow groundwater table (Integral 2007). Dissolved-phase contaminants, such as LNAPL within the sandy fill, appear to migrate west towards Slip 3. Although the LNAPL interim remedial actions have significantly reduced the volume of this material east of Slip 3, its ongoing presence in groundwater represents a potentially significant source to the iAOPC. There do not appear to be any contaminant plumes in the Slip 1 area.

Three groundwater seeps (North, Middle, and South Seeps) have been identified at the head of Slip 1. Low concentrations of DRH (180 µg/L) and oil-range hydrocarbons (1,200 µg/L) were detected from the South Seep; however, the laboratory analysis may have been compromised by the exclusion of the proper silica gel cleanup procedure (Integral 2007). PAHs were detected from the South and Middle Seeps (benzo[a]anthracene and BAP), at concentrations greater than DEQ screening level values for freshwater aquatic receptors. Petroleum seeps have also been observed in the Slip 3 vicinity. The cleanup conducted in this area mitigated the most recently observed seep from the upland facility.

11.3.4.3.5 Riverbank Erosion

Riverbank erosion along the Wheeler Bay and Slip 3 shorelines represents a potential transport pathway for iCOCs, particularly PAHs. As shown on Map 4.6-1, the river shoreline on the upstream portion of the iAOPC at Slip 1 (RM 4.3) is mostly covered with riprap, especially where there is the potential for erosion. Riverbank soils along Wheeler Bay contain elevated concentrations of iCOCs but are not currently stabilized to prevent erosion.

The PAH contamination is associated with pencil pitch found in riverbank soil near Berth 413 in Slip 3. Source control measures are being considered as part of the sediment Early Action (Integral 2007). The south bank of Slip 3 (Berth 412) has been stabilized with riprap. The head of Slip 3 has been stabilized with a bulkhead (short woodpile) and riprap at the toe of the riverbank. The lower portion of the riverbank along the Willamette River (Berth 413) is armored with riprap and the upper portion is vegetated.

11.3.4.4 Relationship of Upland Sources to the Distribution of iCOCs

The in-water distribution of several iCOCs and the evaluation of chemical sources/pathways presented above were used to assess potential links between chemical sources/pathways and the distribution of those chemicals in in-water media.

The highest concentrations of PCB Aroclors were found in the deeper cores samples, especially near the head of Slip 3. The concentration distribution for DRH was similar to that of PCBs; surface concentrations were lower than subsurface concentrations, except at the head of Slip 1 in the vicinity of the outfalls. Zinc concentrations followed a similar pattern, with subsurface levels higher in Wheeler Bay and near the mouth of the slips. BAP was detected at the highest concentrations in subsurface sediment at the head of Slip 3.

Historical overwater water releases and riverbank erosion appear to be the most significant pathways by which iCOCs entered in-water media at iAOPC T4. Unloading of pencil pitch appears to have resulted in overwater releases of DRH and BAP. Groundwater migration is also a significant historical contributor of petroleum hydrocarbons near the head of Slip 4. Specific sources of PCBs and zinc have not been identified, but the concentration distributions in sediment suggests that overwater and possibly historical stormwater releases are significant contributors Pencil pitch has been observed in unarmored riverbank soils at Slip 3, and several iCOCs have been detected above DEQ screening levels in riverbank soils along Wheeler Bay. Erosion of these soils, both historically and at present, represents a potential pathway. Source control measures for riverbank soils are currently underway.

Results of recent stormwater sampling within the Terminal 4 Early Action Area indicate that stormwater discharge is not a significant current source of iCOCs. The ongoing stormwater evaluation and recontamination analysis may provide further insight.

A preliminary evaluation of the relationship between sources, pathways, and iCOCs in the iAOPC is summarized in Figure 11.3.4-2. A preliminary assessment of the current and historical relative contributions of each source is summarized in Table 11.3.4-3.

11.3.5 CSM for iAOPC 6

This section provides the preliminary Round 2 CSM for iAOPC 6, which consists of a 0.4-acre area along the western shore at approximate RM 4.8 (Map 11.3.6-1). The only adjacent upland property is ARCO/BP Terminal 22T. This CSM examines the physical

setting of the iAOPC and the adjacent upland property, the chemical distribution of iCOCs and potential iCOCs based on TZW in in-water media, and potential sources of the iCOCs.

iAOPC 6 was delineated solely on the basis of measured (sediment toxicity bioassay) and predicted (FPM) toxicity to benthic invertebrates. The following potential iCOCs are associated with benthic toxicity in iAOPC 6:

- Mercury
- Silver
- DRH.

These chemicals are identified through less certain and/or less rigorous evaluations based on fewer lines of evidence, FPM results, or other high uncertainty lines of evidence (see Sections 8 and 9).

Map 10.5-3a–j shows the areas where this preliminary analysis identified the potential for risk for individual exposure scenarios that were considered in iAOPC development, and Table 10.5-1 identifies the iCOCs associated with the exposure scenarios.

The risk evaluations presented in Sections 8 and 9 of this report also identified potential iCOCs based on TZW for human health drinking water and shellfish consumption scenarios, and for ecological risk to the benthic community (Table 11.1-1). In the vicinity of iAOPC6, benzo(a)pyrene was detected at concentrations that contributed to its identification as a potential iCOC based on TZW for risk to the benthic community.[78] For the reasons discussed in Section 10, however, iPRGs have not been established for potential iCOCs based on TZW at this stage in the RI/FS process, and potential areas of risk associated with TZW did not influence the delineation of iAOPCs. TZW sampling locations within and/or near iAOPC 6 where chemicals in TZW were detected at concentrations that led to their identification as potential iCOCs based on TZW are discussed further below. Potential uncertainties in iAOPC delineation associated with potential iCOCs based on TZW are discussed in Section 10.

Historical subsurface seepage of LNAPL (and associated dissolved-phase groundwater constituents) from the central portion of the ARCO site to the river appears to be an important source of DRH at iAOPC 6. While it is possible that iCOCs in upland groundwater and LNAPL may continue to migrate to iAOPC 6 at very low rates, ongoing source control activities have substantially reduced the importance of these sources. Additional contributions are likely the result of historical and recent

[78]Trichloroethene (TCE), a potential human health iCOC based on TZW for drinking water scenarios, was detected at a low concentration (0.46 µg/L) in a single TZW sample in this area. Estimated TCE loading to the water column (Appendix D) from this location is minimal. Therefore, TCE was not identified as a potential iCOC based on TZW in the vicinity of iAOPC 6.

stormwater releases, overwater spills, and sediment transport from proximal upriver areas. Riverbank erosion is not a significant current source, because the banks are currently armored, but may have been a historical source. Specific upland and/or in-water sources of silver and mercury in iAOPC 6 have not been identified.

11.3.5.1 Physical Setting, Infrastructure, and Operational History

In-river and upland physical characteristics, infrastructure, and operational history relevant to iAOPC 6 are briefly described in this subsection. Information on the adjacent upland site was obtained from the LWG site summaries (Integral and GSI 2004; 2005a,b,c) and updates (Integral 2007) unless otherwise noted.

11.3.5.1.1 In-River

iAOPC 6 is located on the west bank of the river at the upstream end of a river reach characterized as transitional between an upstream transport zone (RM 5-7) and a downstream depositional zone (RM 1-3) (Map 11.3.6-1). The riverbed drops sharply from the shoreline to full channel depth just offshore of the ARCO dock structures. This river reach, based on Sediment Trend Analysis®, periodically experiences both net accretion and net erosion on the west side of the channel and is in dynamic equilibrium in the center and east side of the channel. The time-series bathymetric change data over the 25-month period from January 2002 through February 2004 show a large region of sediment accretion (with some deposits greater than 2 ft in extent) around and immediately offshore of the ARCO dock extending down to about the -30 ft NAVD88 contour. Conversely, there is a roughly circular area of net erosion centered on the -30 ft NAVD88 contour just downstream of the dock and iAOPC 6 near the downstream edge of the ARCO property (Map 11.3.6-1). Farther downstream of this scoured area (e.g., off of Linnton Plywood), the channel toe and slope area is again depositional. The origin of this isolated scour area is unknown, but it is possibly related to ship traffic.

Upland geologic cross-sections and in-river subsurface sediment core data (Supplemental Figure 2) indicate that material within and adjacent to the nearshore portions of the iAOPC is generally recent fill (sand, sandy gravel and cobbles, and/or gravelly sand and some debris) overlying a fine-grained and sandy alluvium.

A concrete seawall and apron span the 800-ft river frontage. Boulder and concrete riprap underlie the toe of the seawall. Former private outfall WR-355 is located within the iAOPC; this outfall is inactive and has been abandoned (plugged/grouted). Outfalls WR-356 and WR-357 are located just upstream of the iAOPC and have also been abandoned. Just downstream of the iAOPC is outfall WR-25, an active outfall with a GEN15A permit to discharge treated stormwater.

The sediment grain-size distribution in most surface samples in the vicinity of iAOPC 6 exhibits a general pattern of less than 50 percent fines in nearshore samples, transitioning to dominantly fine-grained sediment in samples collected on the channel slope and the base of the navigation channel (Map 11.3.6-2a). Subsurface core samples upstream of the iAOPC boundary exhibit a similar spatial pattern in the shallower B and C intervals, but become dominantly fine-grained in both nearshore and offshore samples

in the deeper intervals. Within and downstream of the iAOPC boundary, subsurface sediments are dominantly fine-grained in all depth intervals in both nearshore and offshore areas.

Significant in-water facilities/structures adjacent to the iAOPC and their associated uses are as follows (Map 11.3.6-1):

- Dock – at which petroleum products are delivered to the site via marine vessels
- Private stormwater outfalls WR-25, WR-355 (abandoned), WR-356 (abandoned), and WR-357 (abandoned).

11.3.5.1.2 Upland

ARCO/BP Terminal 22T is the only upland site immediately adjacent to iAOPC 6. Upland conditions at this site are described in the site summaries prepared by LWG and are summarized in this subsection. The ARCO facility and surrounding areas are zoned for heavy industrial uses. Historical and current operations and predevelopment features (when available) for the ARCO property are described below.

The upland site is generally flat (approximate elevation of +32 ft NAVD88) with a slight upward slope to the west, toward St. Helens Road, and a slight downward slope toward the river. An 800-ft concrete seawall is located along the river. Concrete riprap and rubble underlie the toe of the seawall, and portions of the shoreline mudflats are exposed at low tide.

Currently, the ARCO terminal receives, stores, blends, and transfers petroleum products. Petroleum products are delivered to the site via marine vessels, railroad tank cars, and pipelines. Products are distributed by marine vessels, tank cars and trucks, and pipelines. There is no manufacturing or refining at this facility. Most of the site operations occur on Parcels A and B, which comprise the property adjacent to the river and iAOPC 6.

Since before 1937, the facility has been used for petroleum storage and distribution. Activities conducted in Parcels A and B on the west side of the railroad tracks have included a foamite plant and a toy manufacturing facility. The concrete seawall adjacent to the Willamette River was constructed between 1942 and 1945. A stormwater collection system and oil water separators were added in 1968. By 1971, additional storm drainage systems and four interceptor wells were installed. Two more interceptor wells were installed in 1994.

11.3.5.1.3 Upland Hydrogeology

The general stratigraphy of the upland site consists of the following: recent fill, Pleistocene-Recent alluvium, and Columbia River Basalts. Groundwater flow at the ARCO site occurs primarily in the surface fill layer that underlies the site and consists of sand and sandy gravel. The fill layer is underlain by an alluvial deposit that transitions with depth from finer-grained silty materials to sandier materials, and

generally forms two layers: an overlying fine-grained alluvium, and an underlying sandy alluvium. The alluvium is underlain by basalt bedrock. A west-east-trending, buried erosional channel is present beneath the middle of the ARCO site. This feature cuts into the fine-grained alluvium layer and is filled with coarser channel-fill material (sand and gravel). Fill materials outside the channel are less permeable. The more permeable materials of the buried erosional channel represent a preferential pathway for groundwater flow.

Groundwater at the site fluctuates seasonally by as much as 8 ft, as documented in monitoring wells. Water levels at the site appear to be influenced by the presence of the seawall. Tidal and river stage fluctuations are clearly evident in water level measurements taken from monitoring wells within coarser channel deposits landward of the seawall.

The overall long-term groundwater flow direction is east, toward the Willamette River. Aquifer tests completed at the ARCO site determined the transmissivity of the hydrostratigraphic units of the shallow aquifer: the coarser-grained channel fill material (k=33 to 100 ft/day, T=1,800 to 3,200 ft^2/day), the finer-grained alluvium (k=~0.5 to 2 ft/day), and the sandy alluvium deposit (k=~1 to 2 ft/day).

The Round 2 Groundwater Pathway Evaluation identified two areas of nearshore groundwater discharge offshore of the ARCO site (see Supplemental Figure 5-7 in Integral 2006g). The first is located in the nearshore area immediately north of the ARCO facility. The second is immediately offshore of the buried paleochannel and in the general vicinity of iAOPC 6. Other areas offshore of the site were identified as low- to no-flow discharge zones.

Groundwater seeps (through cracks in the seawall) were identified at the site by the iron staining and wet appearance above the high-water mark.

11.3.5.2 Chemical Distribution of iCOCs and Potential iCOCs based on Transition Zone Water

This section describes the distribution of iCOCs and potential iCOCs in environmental media at iAOPC 6. Map 11.3.6-1 presents sampling locations. Tables 11.3.6-1a and 11.3.6-1b provide statistical summaries of iCOCs for sediment in iAOPC 6 and for potential iCOCs in TZW in the vicinity of iAOPC 6. All iCOC data for the iAOPC can be found in Appendix I.

11.3.5.2.1 Sediments

Sediment sampling locations within iAOPC 6 include 2 surface samples and 1 subsurface core (2 subsurface samples). This section describes the distribution of iCOCs in surface and subsurface sediments within the iAOPC.

Mercury

Mercury was detected in both of the surface sediment samples within the iAOPC that were analyzed for mercury (Map 11.3.6-3). Concentrations of mercury in surface

sediment were 0.022 and 0.74 µg/kg, with a mean of 0.381 µg/kg. The highest mercury concentration in surface sediment within the iAOPC is located offshore, north of the docks.

Mercury was detected in both subsurface samples from the core within the iAOPC that was analyzed for mercury. Mercury concentrations were 0.152 and 0.194 µg/kg (Map 11.3.6-4). The subsurface core is located near the shore between the seawall and the docks. Maximum subsurface concentrations were lower than the maximum surface concentration.

Silver
Silver was detected in both of the surface sediment samples within the iAOPC that were analyzed for silver (Map 11.3.6-5). Concentrations of silver in surface sediment were 0.09 and 0.174 µg/kg. The highest silver concentrations in surface sediment within the iAOPC were lower than nearby surface sediment concentrations outside the iAOPC boundary.

Silver was detected in both subsurface samples from the core, located behind the docks, that was analyzed for silver. Silver concentrations were 0.276 and 0.357 µg/kg (Map 11.3.6-6). The highest subsurface concentration of silver was detected in the deeper interval within this core. The maximum subsurface concentration was higher than both of the surface concentrations measured with the iAOPC.

DRH
DRH was detected in the surface sediment sample within the iAOPC that was analyzed for DRH (Map 11.3.6-7). The concentration of DRH in the surface sediment was 400 mg/kg. The surface sediment sample was collected from a location within the iAOPC between the shoreline and the dock structure. The DRH concentrations in adjacent upstream surface sediments were generally higher than in the surface sediment sampled within the iAOPC.

DRH was detected in both subsurface samples from the core station located between the shoreline and dock structure at concentrations of 470 and 800 mg/kg (Map 11.3.6-8). Maximum subsurface concentrations were higher than the surface concentration, and were generally similar to adjacent subsurface concentrations upstream and downstream of the iAOPC.

11.3.5.2.2 Surface Water
No surface water samples were collected from this iAOPC during Round 2.

11.3.5.2.3 Transition Zone Water
No TZW samples were collected within the boundaries of iAOPC 6. Shallow TZW samples (<38 cm bml) were collected from 10 locations offshore of the ARCO facility in the vicinity of iAOPC 6 during Round 2 Groundwater Pathway Assessment

sampling.[79] TZW sampling locations are shown on Map 11.3.6-1, and summary statistics of the results are listed in Table 11.3.6-1b.[80] Only benzo(a)pyrene was identified as a potential iCOC in TZW near iAOPC 6.

Benzo(a)pyrene was detected in 7 of 28 shallow (0- to 38-cm bml) TZW samples analyzed for PAHs. Detected concentrations ranged from 0.0064 to 0.21 µg/L. The maximum concentration was detected at location R2AR01 in an unfiltered Trident sample.

11.3.5.2.4 Biota

No tissue samples were collected from this iAOPC during Round 2.

11.3.5.3 Potential Sources of iCOCs

This section summarizes the current understanding of potential sources of iCOCs to the iAOPC. Information presented is this section was obtained from site summaries unless otherwise noted. In addition to iCOCs, COIs associated with nearby upland areas are also discussed in this section. COIs are presented to provide a comprehensive understanding of the upland issues and to support the identification of potential sources to the iAOPC. The relevance of the pathway to iCOCs is summarized at the end of each pathway discussion. Potential sources are summarized in Table 11.3.6-2.

11.3.5.3.1 Stormwater/Overland Transport

Overland transport of sheet runoff from the uplands to the river is minimal at this site, as all stormwater is either directed to the stormwater system or directly infiltrates the ground (in the tank farm areas). However, contributions of contaminants to river water and sediment from stormwater runoff would be expected to be greater in the past, prior to installation of the treatment system.

Stormwater is currently routed to a carbon treatment system and oil/water separator before being discharged through two NPDES-permitted outfalls on the Willamette. Treated stormwater is discharged from Outfalls WR-26 and WR-25 and monitored under ARCO's NPDES 13J and 15A permits, respectively. These outfalls are located downstream of the iAOPC boundary and are therefore unlikely to influence the sediment composition in iAOPC 6. Data related to these outfalls are available in the ARCO site summary and addendum.

One private stormwater outfall (WR-355) historically drained to the iAOPC and two other outfalls (WR-356 and WR-357) drained just upstream of the iAOPC. The drainage area of these outfalls is unknown. All three have been abandoned, although

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[79]Deeper TZW samples, from a target depth of at least 90 cm (up to 150 cm) were collected from nine locations. See Section 6.2 and Integral (2006g) for discussion of deeper TZW sampling results.

[80]Sample counts shown in Table 11.3.6-1b are higher because filtered and unfiltered samples were collected from some locations.

some seepage has been observed. These outfalls may constitute a historical source of iCOCs to sediment in iAOPC 6. Seepage may constitute a current source of iCOCs.

11.3.5.3.2 Overwater Discharge

Spills and leaking pipelines from fuel transfer activities at the dock may be a source of surface water and sediment contamination. The updated DEQ ERIS database contained records of overwater spills, which are summarized below. The database also included numerous incidents of oily sheens observed on the river surface, which have not been included in the following table. When the spill surface is indicated as "unknown," the release may have occurred on land or over water.

Date	Material(s) Released	Volume Spilled (gallons)	Spill Surface (gravel, asphalt, sewer)	Action Taken (yes/no)
5/4/95	Gasoline	20 released, unknown amount in river	River	Yes
6/30/95	Diesel	Unknown	Unknown	Unknown
8/10/95	Gasoline	2	River	Yes
12/18/95	Diesel	Unknown	Boom area	Unknown
12/16/96	Heavy fuel oil	Unknown	Unknown	Unknown
12/12/03	Oil	Unknown	Boom area	Yes
1/13/03	Diesel	5	River	Yes
April 2003	Oil	April release followed by observations of very small quantities "blurbs of oil" rising inside of permanent boomed area	River	Yes
10/31/05	Diesel	1,000	River	?

No sampling has been conducted specifically related to overwater discharges. However, decades of overwater fuel and oil transfers were conducted at the ARCO site. Upland COIs identified for overwater discharges at ARCO are summarized in Table 5.1-5 and include PAHs, TPH, and metals.

11.3.5.3.3 Groundwater Discharge

Periodic releases from underground pipelines, tanks, and during product transfer contaminated surface and subsurface soil and groundwater. These activities occurred in the truck-loading rack area, remanufacturing warehouse, and storage and transfer operations areas.

ARCO began conducting groundwater investigations at the site in the early 1970s. The focus of past environmental work at the site has been on the investigation, containment, and recovery of LNAPL. LNAPL product consists of relatively weathered and unweathered diesel product with a maximum thickness of 17 ft measured in March

1996 (SECOR 2002). Two primary LNAPL source areas have been identified at the ARCO site. The first is located in the sand and gravel deposits of a buried erosional channel near the center of the site. The second is located in an area north of the site beyond the northern extent of the seawall, which extends to the property boundary. Total LNAPL in the subsurface beneath the ARCO site recently was estimated at 250,000 gallons, with 133,000 to 185,700 gallons estimated as recoverable NAPL (URS 2004).

The natural buried erosional channel, oriented west to east and containing coarse gravel material, is considered a preferential pathway for groundwater flow at the site and tends to concentrate the LNAPL and the dissolved plume at the site. This unit is much more permeable than the surrounding finer-grained alluvial deposits. The effect of the seawall at the erosional channel/river interface is unclear at this time. Contour maps of the DNAPL and plume are provided in Supplemental Figure 35 from SECOR (2002) and Supplemental Figure 3. The western boundary of iAOPC 6 is adjacent to the area where the LNAPL and associated petroleum plume meet the seawall.

A dissolved gasoline and diesel petroleum hydrocarbon plume present in the shallow aquifer beneath the site has been investigated since the mid-1990s. The plume extends from the truck-loading rack on the western portion of the site to the river to the east (see Supplemental Figure 3). Primary COIs in upland groundwater are PAHs, petroleum hydrocarbons, BTEX, and several metals (e.g., arsenic, chromium, copper, and lead). Mercury was not detected in groundwater at ARCO Terminal 22T and silver was detected at a very low concentration in only one (unfiltered) sample. Concentrations of dissolved-phase COIs in groundwater are highest in the immediate vicinity of, and downgradient from, the two primary LNAPL source areas at the ARCO site.

ARCO installed a groundwater interceptor well system in 1971 to reduce migration of petroleum product to the river. This system was expanded to include additional LNAPL recovery wells in 1994 and in 1997. LNAPL was reported seeping to the river when the recovery system went down (URS 2004). The system was upgraded and overhauled in 2004 and 2005 to more completely prevent liquid and dissolved-phase petroleum from migrating to the river (URS 2004). The installation of total fluid pumps (which extract more fluid and require much less maintenance than skimmer pumps) was planned for spring of 2006 in most of the pumping wells along the seawall to improve product recovery.

The Source Control Implementation Report (URS 2006) demonstrates that the reverse hydraulic gradient is being maintained by the source control system under normal and low water conditions (with no comment on whether the reverse hydraulic gradient is being maintained by the source control measures during high water conditions) and that the potential for liquid petroleum hydrocarbon (LPH) plume migration from the central portion of the site toward the riverfront has been reduced; however, it is believed that historical LPH trapped beneath the revetment portion of the seawall may continue to be a source during high water conditions.

The groundwater/product extraction system captures a majority of this shallow free product and a portion of dissolved-phase groundwater plume before it discharges to the river. LNAPL and dissolved-phase COI migration to the river cannot be completely controlled with the existing source control measures, however, and there are still possible paths for groundwater to reach the river. The seawall is not keyed into the fine-grained alluvium, so there is some possibility that dissolved groundwater COIs may migrate toward the river beneath the wall. In addition, a residual "detached" plume may be present east of the seawall. Portions of the plume associated with the northern LNAPL source area are located beyond the northern extent of the seawall and extraction well system and may migrate to the river. Finally, groundwater and/or LNAPL seepage through cracks in the seawall at times of high groundwater levels may represent a complete transport pathway to the river system. Additional measures are planned, including the installation of a sheet pile wall to completely prevent LPH from seeping through the cracks in the existing seawall and to block the section of stream deposits containing saturated and unsaturated LPH from entering the river.

11.3.5.3.4 Riverbank Erosion

A concrete seawall and apron span the 800-ft river frontage. Boulder and concrete riprap underlie the toe of the seawall. Due to the presence of the seawall, riverbank erosion is expected to be minimal.

11.3.5.4 Relationship of Upland Sources to Distribution of iCOCs

The in-water distribution of DRH and the foregoing evaluation of chemical sources and pathways constitute evidence of a link between this iCOC in known sources and its distribution in sediment of iAOPC 6. A comparable link for mercury and silver cannot be established, because specific upland or in-water sources of these metals have not been identified.

Historical subsurface seepage of LNAPL (and associated dissolved-phase groundwater constituents) from the central portion of the ARCO site to the river appears to be an important source of DRH at iAOPC 6. Mercury was not detected in groundwater at ARCO Terminal 22T and silver was detected at a very low concentration in only one (unfiltered) sample. Based on these limited data, groundwater is not expected to be a significant source of these iCOCs. Source control measures have substantially reduced the potential for ongoing LNAPL seepage, but groundwater seeps observed at a crack in the seawall and LPH trapped beneath the revetment portion of the seawall may continue to be sources of DRH during high water conditions. Additional seeps have been reported from storm drains leading to WR-355 within the iAOPC and WR-356 and WR-357 just south (upstream) of the iAOPC. All of these sources are intermittent and cannot be quantified.

The Round 2 Groundwater Pathway Assessment found that concentrations of petroleum-related chemicals in TZW and sediment are similar in the offshore groundwater discharge zones and the low- to no-flow zones (Integral 2006g). While it is possible that DRH in upland groundwater and LNAPL may continue to migrate to

iAOPC 6 at very low rates, ongoing source control activities have substantially reduced the importance of these sources.

Although overwater spills of DRH have been documented, estimates of loading of iCOCs to sediments from historical overwater activities are not possible due to lack of complete records and the incidental nature of overwater releases. Spilled DRH would be expected to float and be dispersed by the movement of wind and water. Contact with sediment would occur at the water's edge during low river stage. No records are available regarding overwater releases of substances containing mercury or silver.

Overland runoff is not currently a pathway to the river, although it may be a historical pathway. Stormwater is likely a current and historical pathway to the river, but not to iAOPC 6, as the active stormwater outfalls from the ARCO facility are located downstream of iAOPC 6. Three outfalls that have been closed off may historically have discharged stormwater to iAOPC 6.

Due to the presence of the seawall, riverbank erosion is not expected to be a source of iCOCs to the sediment. Riverbank erosion may have been a source of iCOCs prior to construction of the seawall in 1942.

DRH, mercury, and silver concentrations in the single sediment core collected from this iAOPC are all lower in concentration in the surface interval than in the underlying intervals. This suggests that sources to the sampled area of the iAOPC have been less active recently than in the past. DRH and silver concentrations in surface sediment are higher upstream of iAOPC 6 (i.e., near the main dock of the terminal and offshore of the crack in the seawall, than at the sampled location within the iAOPC). In this area of alternating sediment erosion and deposition, sediment transport from the main dock area may contribute to the DRH and silver present in iAOPC 6 surface sediment. The mercury concentration in surface sediment from the eastern (offshore) section of iAOPC 6 was higher than in surrounding areas. This may represent a spurious laboratory result, or reflect an unknown source such as an overwater release.

A preliminary evaluation of the relationship between sources, pathways, and iCOCs in the iAOPC is summarized in Figure 11.3.6-1. A preliminary assessment of the current and historical relative contributions of each source is summarized in Table 11.3.6-3.

11.3.6 CSM for iAOPC 7

This section provides the preliminary Round 2 CSM for iAOPC 7. The 12.36-acre iAOPC is located along on the eastern shore of the river between RM 5.5 and 5.8, adjacent to the Mar Com and Cathedral Park properties (Map 11.3.7-1). The CSM examines the physical setting of the iAOPC and adjacent upland properties, the chemical distribution of iCOCs in in-water media, and potential sources of the iCOCs.

The following iCOCs have been identified for this iAOPC:

- Total PCBs.

Potential iCOCs for this iAOPC include:

- Silver
- DRH.

These potential iCOCs are identified through less certain and/or less rigorous evaluations based on fewer lines of evidence, FPM results, or other high uncertainty lines of evidence (see Sections 8 and 9).

Map 10.5-3a–j shows the areas where this preliminary analysis identified the potential for risk for individual exposure scenarios that were considered in iAOPC development, and Table 10.5-1 identifies the iCOCs associated with the exposure scenarios. PCBs are an iCOC for the entire iAOPC. Silver and DRH are potential iCOCs in an upstream, primarily offshore area of the iAOPC.

The following CSM evaluation is summarized as follows: The distinct PCB Aroclor distribution in surface sediment samples between the Mar Com site boundaries suggests a proximal source of these PCBs. The major pathways of iCOCs in sediment appear to be private stormwater outfalls and overland runoff from the Mar Com site. Stormwater outfalls also may represent a source of silver to the iAOPC based on the distribution of elevated surface sediment concentrations of this iCOC. Riverbank erosion and overwater operations from past activities at the Mar Com site may have contributed iCOCs, but a clear relationship cannot be established on the basis of lateral gradients in sediment concentrations. Groundwater is not expected to be a significant source of iCOCs. Vertical gradients in sediment concentrations (higher in subsurface than surface) suggest that inputs for PCBs and DRH were significantly greater in the past than more recently. The sources of iCOCs in the portion of the iAOPC upstream of Mar Com, and offshore of Cathedral Park, are uncertain.

11.3.6.1 Physical Setting, Infrastructure, and Operational History

In-river and upland physical characteristics, infrastructure, and operational history relevant to iAOPC 7 are briefly described in this subsection. Information on adjacent upland sites was obtained from the LWG site summaries (Integral and GSI 2004; 2005a,b,c) and updates (Integral 2007) unless otherwise noted.

11.3.6.1.1 In-River

iAOPC 7 is located near the center of the middle ISA hydrodynamic regime described in Section 4.5 (RM 5-6.9), a relatively narrow and dynamic stretch of the river. The STA survey results suggest that sediment movement offshore of the Mar Com site is in a state of dynamic equilibrium (i.e., surface sediments are scoured from and deposited in this area without net erosion or accretion). The 2002-2004 time-series bathymetric change data showed that from the top of the channel slope to the channel boundary offshore of

the structures, areas of net erosion alternate with less extensive pockets of net deposition, with areas of small-scale net erosion (up to 1 ft) in the main channel offshore of the iAOPC. Inshore of a former dry dock at the site , bathymetric changes could not be measured, however, when bottom shear stresses in the sheltered area immediately downstream of the dry dock (and a large pier) were modeled, they were markedly lower than those in exposed areas immediately offshore (see Map 4.5-1).

Upstream of the Mar Com boat way and Cathedral Park boat launches, shallow topographic benches extend from shore 100-150 ft towards the main channel. In other areas of the iAOPC, the river bottom slopes consistently from the shore to the base of the shipping channel at an angle of 20 to 30 degrees, with a trough approximately 100 ft wide downslope of the Mar Com boat way (Map 11.3.7-1). The edge of the navigation channel is 150-350 ft from and approximately 50 ft below the shoreline.

Surface sediment samples collected in the iAOPC are predominantly fine-grained, with most having greater than 50 percent fines (Map 11.3.7-2a,b). In general, finer surface sediments are found in the center of the iAOPC, in the trough off the former boat launch, than at the upstream and downstream ends. Subsurface sediment samples typically become coarser with depth, with most less than 50 percent fines below a depth of approximately 150 cm bml.

The following in-water facilities and structures are/were located within or near the iAOPC (Map 11.3.7-1):

- Former Mar Com former floating dry dock
- Mar Com marine ways (2) (current activity level undetermined)
- Former Langley boat way with barge crane and catwalk over river and steel mooring dolphins
- Cathedral Park boat launch
- Two public stormwater outfalls (Outfall 52 and Outfall 52A)
- Four private stormwater outfalls (WR-219, WR-86, WR-376, and WR-286).

All shipbuilding and repair activities at these in-water structures appear to have discontinued by 2004, except the marine ways. The Cathedral Park boat ramp continues to be used by the general public for recreational purposes. The stormwater outfalls are discussed elsewhere in this section.

11.3.6.1.2 Upland

Upland sites adjacent to the iAOPC include Mar Com, with a zoning classification of Industrial, and Cathedral Park, with a zoning classification of Parks & Open Space. Land within the Outfall 52 drainage basin is zoned Industrial and Employment, Rural and Open Space, and Residential (Map 4.1-2). Roads and railways constitute almost one-third of the basin. Historical aerial photographs (Maps 4.1-5a–e) indicate activities

at the current Cathedral Park related to operations at the Mar Com facility in the 1940-1960s.

Mar Com
The Mar Com site (ECSI #2350) was used for shipbuilding and vessel repair from 1905 to 2004, under Mar Com's name since 1995 or 1996. Since activities ceased in 2004, DEQ has managed the site as two parcels, the North Parcel and the South Parcel, as summarized below:

- **North Parcel** - In old aerial photographs, the northern section of the North Parcel appears to have been used for surface storage of lumber and timber materials. Fill activities in the North parcel extend from 1917 to 1983-1984. From the 1940s until approximately 1990, a portion of the parcel near North Bradford Street was occupied by a sawmill. While Mar Com occupied the site (since 1969), most of the North Parcel remained vacant, with areas for storage for abandoned ship repair equipment and excess parts (bone yard).
- **South Parcel** - Although buildings, docks, and marine ways had been built, reconfigured, and demolished over the years, use of the South Parcel varied little between 1905 and 2004. Most of the activities involved shipbuilding and repair: steel and piping repairs, welding, machinery overhauls, high-pressure water blasting, sandblasting, painting and electrical repairs. Historical industrial activity also included, operation of a steel foundry, storage of support equipment, as well as storage and distribution of manufactured lumber products.

11.3.6.1.3 Upland Hydrogeology
Hydrogeologic information is available only for the Mar Com facility. Dredged fill material placed at the site ranges from 7 to 18 feet deep, underlain by fine-grained alluvium consisting of a sandy to clayey silt, as shown in the generalized geologic cross-section of Figure 11.3.7-1.

A shallow aquifer has been identified in the fill material. In November 2001, water level elevations measured in 5 of the 13 monitoring wells installed in the fill above the alluvium ranged from approximately 3 to 13 ft above sea level (NAVD88). Although site-specific groundwater flow directions cannot be ascertained from the available data, the shallow groundwater beneath the site likely discharges to the Willamette River.

No groundwater seeps that discharge to the iAOPC have been identified.

11.3.6.2 Chemical Distribution of iCOCs
This section describes the distribution of iCOCs and potential iCOCs for iAOPC 7. Sampling locations are shown in Map 11.3.7-1, summary statistics are provided in Tables 11.3.7-1a–c, and the full iCOC data set for is provided in Appendix I.

11.3.6.2.1 Sediments
PCB Aroclor analyses were conducted on 21 surface samples and 23 subsurface sample intervals collected from 9 cores in iAOPC 7. PCB congener analyses were conducted

on 11 surface samples and 2 subsurface. DRH analyses were conducted on 24 surface samples and 23 subsurface sample intervals collected from 9 cores. Silver analyses were conducted on 33 surface samples and 24 subsurface samples collected from 10 cores.

PCBs

PCB Aroclors were detected in all 21 surface sediment samples analyzed (23-270 µg/kg, mean of 115.5 µg/kg; Table 11.3.7-1a). Total PCB congeners (sum of all congeners measured) were also detected in all 11 surface samples analyzed (3.24-250 µg/kg, mean of 61 µg/kg). The highest concentrations were found offshore of outfalls WR-86 and WR-219 near the Mar Com/Cathedral Park boundary, offshore the Mar Com former floating dry dock, and offshore of Cathedral Park approximately 250 feet upstream of the Cathedral Park boat launch (Maps 11.3.7-3 and -4).

The relative proportion of individual Aroclors in surface sediment collected within the Mar Com site boundaries can be distinguished from those in to samples collected several hundred feet upstream and downstream (Map 6.1-48a–i). The latter are dominated by Aroclor 1260, where the former include relatively high proportions of Aroclors 1254, 1268, and 1248.

PCBs Aroclors in the subsurface were detected in proportionately fewer samples (13 of 26, or 56 percent) but at higher concentrations (36.4 to1,110 µg/kg; Table 11.3.7-1a).Total PCB congeners were detected in both samples examined, again at higher concentrations than for surface sediment (486 and 2,830 µg/kg). Maximum concentrations were found 30-150 cm bml, although PCBs were generally not detected in the deepest interval analyzed in individual cores (Maps 11.3.7-5 and -6). The highest concentrations of subsurface PCBs (Aroclors) were detected offshore of the Mar Com boat way and in the vicinity of WR-86 and WR-219 near the Mar Com/Cathedral Park boundary.

In the nearshore areas of the iAOPC under typical hydrologic conditions in the LWR, surface sediments appear to be physical stable. By comparison, they were likely disturbed and locally redistributed by the ship repair, and launching of the past. Considered with the observed concentration gradient (higher in the subsurface), these factors suggest that historical PCBs inputs were significantly greater than more recent inputs.

Silver

Silver was detected in 32 of 34 surface sediment samples analyzed (0.05-5.65 mg/kg, mean of 0.813 mg/kg; Table 11.3.7-1a). The highest concentrations were found upstream of the Cathedral Park boat launch (approximately 400 ft downstream of the St. Johns Bridge) and along the riverbank adjacent to WR-286 (Map 11.3.7-7).

Silver in the subsurface was detected in all 24 samples analyzed (0.021 to 1.2 mg/kg, mean of 0.337 mg/kg; Table 11.3.7-1a). The highest concentration was detected just offshore of the Mar Com former floating dry dock. Silver was not detected at depth

offshore of the Cathedral Park boat launch, where this analyte was detected at a high concentration in the surface sediment. Concentrations generally increased slightly below the surface to approximately 200 cm, subsequently decreasing with depth (Map 11.3.7-8).

DRH

DRH were detected in all 24 surface sediment samples analyzed (19.9-360 mg/kg, mean of 143 mg/kg; Table 11.3.7-1a). The highest concentrations were found offshore of the Cathedral Park boat launch, offshore the Mar Com former floating dry dock, and immediately upstream of the Mar Com former floating dry dock (Map 11.3.7-9).

DRH in the subsurface were detected in 19 of 23 samples analyzed (28 to 3,500 mg/kg, mean of 1,270 mg/kg; Table 11.3.7-1a). The highest concentrations were detected in similar locations to elevated surface concentrations, with the exception of upstream of the Cathedral Park boat launch, where DRH were undetected at depth. Concentrations at depth generally increased below the surface and subsequently decreased at depths greater than approximately 200 cm below the sediment-water interface (Map 11.3.7-10).

11.3.6.2.2 Surface Water

Surface water samples were collected at one location within the iAOPC during three sampling events (see Section 6.3 and Integral 2006l). This station (W010) is located off the boat ramp at Cathedral Park in a nearshore area. The samples represent a vertical integration of the water column from near-surface to near-bottom. PCB Aroclors were not detected at this station in any sample during Round 2A (detection levels ranged from 0.0025 to 0.00267 µg/L; Table 11.3.7-1b). In addition, total and dissolved silver were not detected at this station in any sample during Round 2A (detection limits ranged from 0.000005 to 0.000009 mg/L; Table 11.3.7-1b).

11.3.6.2.3 Transition Zone Water

Transition zone water sampling for this iAOPC is limited to porewater samples collected at four surface sediment sample locations. PCBs and potential iCOC DRH were not measured in these porewater samples. Potential iCOC silver was not detected in porewater samples (detection limit of 0.002 mg/L; Table 11.3.7-1c).

11.3.6.2.4 Biota

Three invertebrate samples collected within the iAOPC (Map 11.3.7-1) were analyzed for PCBs and potential iCOC silver—a crayfish composite, field and sediment-exposed clams, and sediment-exposed worms (the sediment-exposed samples were for laboratory bioaccumulation tests). PCBs (total Aroclors) were detected in each, at concentrations ranging from 27 (crayfish) to 186.66 µg/kg (lab-exposed worm) (Table 11.3.7-1c). Only Aroclor 1260 was detected in crayfish. Aroclors 1260, 1262, 1242 were detected in the other tissue samples (Map 6.3-3). Measured as total congeners in the clam and worm samples, PCBs were detected at 27.1 (lab clam) to 282 µg/kg (lab-exposed worm). Silver was detected in the three samples at concentrations ranging from 0.0068 (lab-exposed worm) to 0.0623 mg/kg (clam).

11.3.6.3 Potential Sources of iCOCs

This section presents a summary of the current understanding of potential sources of iCOCs to the iAOPC. Information presented is this section was obtained from site summaries unless otherwise noted. In addition to iCOCs, COIs associated with nearby upland areas are also discussed in this section. COIs are presented to provide a comprehensive understanding of the upland issues and to support the identification of potential sources to the iAOPC. The relevance of the pathway to iCOCs is summarized at the end of each pathway discussion. Potential sources and pathways are summarized in Table 11.3.7-2.

The Mar Com facility (ECSI #2350) is being managed by DEQ as two parcels, the North Parcel and the South Parcel. Current and historical potential contaminant sources for Mar Com are summarized below:

- Operations at Mar Com have been limited to the South Parcel since 2004. The extent of these activities has not been addressed in documents reviewed.
- The Mar Com facility is situated on land that had been used for ship building and vessel repair since approximately 1905.
- While Mar Com occupied the site (since 1995-96), the majority of the North Parcel was vacant with the remaining areas used to store abandoned ship repair equipment and excess parts (bone yard). A sawmill (stud mill), occupied a portion of the site along North Bradford Street between the late 1940s and approximately 1990. Reportedly, wood treating was not conducted at the sawmill. In specific areas near the bone yard, large surfaces had been permeated by oil or fuel. The presence of considerable amounts of sandblast grit has been reported near the North and South parcel boundary.
- Use of the South Parcel varied little between 1905 and 2004 and primarily involved ship building and repair. Historical industrial activities conducted on the South Parcel were associated with ship building and repair, the machine shop and truck maintenance, the steel foundry, storage of support equipment as well as storage and distribution of manufactured lumber products.
- General ship building and repair operations performed on the South Parcel included steel and piping repairs, welding, machinery overhauls, high-pressure water blasting, sandblasting, painting and electrical repairs. Chemical products stored and used onsite included diesel fuel, unleaded gasoline, lubricating oils, cleaning solvents, paints and thinner products, and sandblast grit.

11.3.6.3.1 Stormwater/Overland Transport

Private and public stormwater systems drain to the iAOPC. The basin areas and characteristics are summarized in Map 5.2-1a–d and Table 5.1-3. Four private stormwater outfalls—WR-286, WR-86, WR-219, and WR-376—have been identified at Mar Com. WR-286 appears to be an abandoned 4-inch PVC pipe. WR-86 is an 8-inch steel pipe with an unknown drainage area, and WR-376 appears to be channelized flow from the Mar Com boat way area. WR-219 is an18-inch steel pipe; this outfall is not

included in the Mar Com stormwater control plan (Mar Com 1999). The relationship between the three drainage areas identified in the plan and outfalls at the site is not clear. The drainage basins appear to drain predominantly the present South Parcel. Facility features that could or did contribute COIs to the Mar Com private outfalls and overland transport are listed in Table 5.1-3. The channelized flow and private outfall WR-86 were monitored under a NPDES 1200-Z permit between 1998 and 2004. iCOCs were not included in the monitored parameters.

Two public outfalls (Outfall 52 and Outfall 52A) discharge to the iAOPC (CH2M Hill 2004b). Outfall 52 is a 30-inch-diameter pipe upstream of the Cathedral Park boat launch. Constructed in 1920 as a CSO-only outfall and mostly separated in 1995, Outfall 52 discharges directly into the LWR approximately 150 ft beyond the river's edge. It now drains stormwater from a 23-acre area, including the basins for former outfalls Outfall 51 and Outfall 52 and areas upland of Cathedral Park. Nearly half (46 percent) of the basin is zoned Industrial and one-third is roads and railway. Prior to park construction between 1972 and 1976, there were no major structures on the land occupied by Cathedral Park; it may have been used for parking and storage, one building is shown on aerial photographs in the 1960s. There are no ECSI sites within the drainage area and no facilities with permitted discharges.

Outfall 52A is a 36-inch-diameter stormwater outfall constructed in 1972 near the boundary of the Mar Com North and South Parcels. Discharging to a ditch approximately 200 ft from the river, Outfall 52A drains 24 acres of primarily industrial lands and rights-of-way. Approximately half of the drainage area is zoned Industrial. Outfall 52A empties into a sheltered portion of the river protected by the Mar Com pier and former dry dock, where reduced flows may produce local shoaling. There are no ECSI sites within the drainage area and one facility with an NPDES 1200-Z permit. No non-stormwater discharges are associated with the basin.

Based on what is known of Mar Com site operations and surface soil chemistry, potential stormwater COIs include diesel and heavier TPH, VOCs, SVOCs, PAHs, phthalates, metals, PCBs, and butyltins. In the only known stormwater sampling activity conducted outside permit requirements (a VOC sample from an outfall on the Mar Com property), no VOCs were detected.

In general, the highest concentrations of PCBs in surface and subsurface sediment are offshore of the Mar Com boat way (near private outfalls WR-376), the Mar Com-Cathedral Park boundary (near private outfall WR-86 and 219), and upstream of the Cathedral Park boat launch (near Outfall 52). PCB and DRH concentration distributions are similar both upstream and downstream of Outfall 52, suggesting that the outfall itself may not be the source of PCBs in this area. Aroclor signatures in surface sediment from within the Mar Com site boundaries, differ from that in samples collected several hundred feet upstream and downstream (Map 6.1-48a–i). However, the highest concentrations of silver were detected in surface sediment samples collected

in the vicinity of Outfall 52, which suggests the outfall as a potential source of this iCOC to iAOPC 7.

Outfall 52A is probably not a major contributor to the PCBs found in the river sediments. In the three surface sediment samples collected from the open drainage ditch between Outfall 52A and the river, total PCB congener concentrations (sum of 15 congeners) were low (8-30 µg/kg). Silver was detected at a high concentration in surface sediment adjacent to Outfall 52A, but the private outfall, WR-285, is more likely a source of this metal to the iAOPC.

11.3.6.3.2 Overwater Discharge

Until it was removed in 2004, a floating dry dock was positioned off of the Mar Com's shoreline for ship repairs, hull overhauls, and maintenance services (e.g., mechanical/electrical retrofits). Support platforms for the overwater operations were provided by barges. PCB-containing materials (e.g., hydraulic fluids, wire insulation) could have been used during the servicing activities. Small-volume overwater spills are reported in the DEQ spill database for this facility (Table 5.1-5). The volume of fuel oil released from a tipped barge in the 1970s, however, was not recorded. Overwater activities no longer take place at the Mar Com site.

A crane dock is located upstream of the Mar Com boat way. No information on this feature was available in the files reviewed.

Sampling has not been conducted specific to overwater discharges. However, ship building and repair operations were performed for decades over or very near the water at Mar Com. Upland COIs identified for overwater discharges at Mar Com are summarized in Table 11.3.7-2 and include diesel and heavier TPH, VOCs, SVOCs, PAHs, phthalates, metals, and butyltins.

PCBs, DRH, and silver were detected at relatively high concentrations in surface sediments offshore of the upstream and downstream ends of the former dry dock near the base of the slope toward the shipping channel. However, the relationship of these samples to former overwater activities cannot be separated from other potential sources, including stormwater, overland transport and sediment transport.

11.3.6.3.3 Groundwater Discharge

Groundwater investigations have been limited to the Mar Com upland site. Investigations on the South Parcel include installation of five monitoring wells in 1990 and 2001. The wells on the South Parcel were sampled only once, immediately after installation. In addition to the single round of well samples, 17 groundwater samples were collected from probe borings located on the South Parcel in 2000.

The limited groundwater data from the South Parcel suggest that low levels of chlorinated VOCs and PAHs are present in the shallow groundwater. Two plumes appear to be present, trending north-northeast and south-southwest, with low-level chlorinated VOCs (chloroform, tetrachloroethene, and 1,1,1-trichloroethane) ranging up

to 11.8 µg/L. A few low-level PAHs were also detected in well MW-5. The approximate locations of the plumes are shown on Map 5.1-1a–h.

Groundwater investigations at the North Parcel were conducted in 2004. Sampling included existing wells and grab samples from direct-push borings. PAHs and VOCs were detected at levels below DEQ Level 2 SLVs, barium was detected above the SLV.

With the exception of the limited porewater sampling described in the previous section, transition zone water has not been sampled and no groundwater seeps have been identified discharging to this iAOPC.

PCBs have not been analyzed in groundwater. But given their low mobility in water, groundwater is not expected to be a significant source of PCBs to this iAOPC. DRH is not a reported groundwater analyte, but PAHs were detected at low concentrations in groundwater (less than 2 µg/L). Silver is not a reported groundwater analyte.

11.3.6.3.4 Riverbank Erosion

The sloped riverbank at Mar Com facility's consists alternately of vegetated and exposed soils. Extensive filling has occurred at the riverfront (GRI 1986), with fill material originating from various sources. For example, more than 10,000 cy excavated from the Veterans Hospital site is documented to have been place at Mar Com.

Natural erosion of the riverbank was exacerbated by the positioning of vessels for transportation on and off the slipways located on the shoreline. A small area of soil contamination, primarily petroleum hydrocarbons (including DRH), had been detected close to the riverbank. According to DEQ (2003), this area may have some erosion potential and the ROD for the North Parcel selected an excavation and disposal remedy to address soil in this area.

The potential for riverbank erosion exists within the drainage ditch of Outfall 52A, which approximately 200 ft from the river to the outfall. Riverbank soil may be eroded during high stormwater flow events. PCBs, DRH, and silver were detected in ditch sediments between the outfall and the river.

11.3.6.4 Relationship of Upland Sources to the Distribution of iCOCs

Available nature and extent information indicates a likely relationship between the iCOCs for iAOPC 7 and both upland sources and local receptors. PCBs and silver were detected in all invertebrate biota tissues collected directly from iAOPC 7 or exposed in the laboratory to surface sediments from the area.

Stormwater and overland runoff are current and historical pathways to the river and appear to be significant contributors to in-water media. The highest concentrations of PCBs and DRH in surface sediment are near the Mar Com boatway downstream of outfalls WR-86 and WR-219. The source of PCBs offshore of Cathedral Park and near Outfall 52 is more uncertain since concentrations were similar both upstream and downstream of the outfall; PCB concentrations at the Cathedral Park beach were low

(<20 µg/kg). The distinct distribution of Aroclors found in surface sediment samples within the Mar Com site boundaries, relative to those upstream and downstream, suggests a proximal source of these PCBs, most likely stormwater and overland runoff; other sources (e.g., bank erosion, overwater discharges) are also possible. Silver concentrations in surface sediment were highest near Outfall 52 and Outfall 52A.

Subsurface PCBs and DRH were found mainly in the Mar Com boat way area, and at concentrations greater than those of overlying surface sediment. The depth below mudline of subsurface maxima is consistent across core samples in this area, suggesting more significant releases in the past than recently. This pattern is consistent with Mar Com's operational history. Subsurface PCBs and DRH were not detected upstream of Mar Com, which suggests that the surface PCBs found off Cathedral Park are not a result of historical releases from the Cathedral Park site. Subsurface silver concentrations were generally low upstream of Mar Com in iAOPC 10.

Historical overwater activity is also a likely former source, although lack of records and the incidental nature of overwater releases preclude an assessment of impacts, hydraulic fluids, wire insulation, and other PCB-containing products could have been released. Based on the concentrations and horizontal and the vertical distribution of PCBs, the former floating dock and perhaps the boat way operations appear to have been a source of PCBs.

Surface water, groundwater, and riverbank erosion do not appear to be sources of PCBs and silver to in-river media. PCBs were not detected in surface water, possibly due to the relatively high detection limits and their hydrophobic nature. Groundwater was not analyzed for iCOCs, but PAHs (a potential surrogate for DRH) were detected at low concentrations. DRH was detected in soil collected close to the riverbank, therefore riverbank erosion may be a source of this iCOC to in-river media.

Based on site operations, history, and the limited data on riverbank samples, current and historical loading for iCOCs from riverbank sources is expected to be moderate relative to other sources in the iAOPC.

A preliminary evaluation of the relationship between sources, pathways, and iCOCs in the iAOPC is summarized in Figure 11.3.7-2. A preliminary assessment of the current and historical relative contributions of each source is summarized in Table 11.3.7-3.

11.3.7 CSM for iAOPCs 8 and 9

This section provides a preliminary Round 2 CSM for iAOPCs 8 and 9. These small areas (0.18 acres for iAOPC 8 and 0.97 acres for iAOPC 9) are separated by a few hundred feet along the western shore of the river at RM 5.7-5.8 (Map 11.3.7-1). iAOPC 9 lies upstream of iAOPC 8. Until December 2004, the adjacent uplands (9.7 acres) had been owned by Marine Finance Company (ECSI #2352); their current owner is Advanced American Construction Properties (AACP). The Hendren Tow Boats Company (ECSI #2389) operates a dock adjacent to iAOPC 9. This CSM examines the

relationships among the physical setting of the iAOPCs and adjacent upland properties, the chemical distribution of iCOCs in in-water media, and potential sources of the iCOCs.

The following iCOCs have been identified for these two iAOPCs:

- **iAOPC 8:** Total PCBs
- **iAOPC 9:** Total PCBs, sum DDT.

Map 10.5-3a–j shows the areas where this preliminary analysis identified the potential for risk for individual exposure scenarios that were considered in iAOPC development, and Table 10.5-1 identifies the iCOCs associated with the exposure scenarios. PCBs were identified as an iCOC for both iAOPCs 8 and 9, affecting all areas within the former and the downstream portion of latter. Total DDTs were identified as an iCOC for iAOPC 9, only affecting risk areas in its upstream portion.

A high degree of uncertainty is associated with the evaluation of the pathway by which iCOCs may have migrated to iAOPCs 8 and 9. Some lines of evidence suggest that sediment transport from upstream sources is the dominant pathway by which iCOCs have migrated to the iAOPCs. For example, the concentrations and homolog distributions of PCB congeners detected in surface samples within the iAOPCs were similar to those in samples from beyond the iAOPC boundaries up- and downstream. However, there appears to be little upland analytical data for the iCOCs from the adjacent properties at these iAOPCs. Although PCBs and DDTs were not identified by DEQ as COIs for the adjacent AACP properties, former scrap metal salvage operations on the properties involved the storage of scrap transformers (a potential source of PCBs) and drums labeled as formerly containing pesticides (a potential source of DDT) strongly suggest that upland sources for the iCOCs may have existed.

11.3.7.1 Physical Setting, Infrastructure, and Operational History

In-river and upland physical characteristics, infrastructure, and operational history relevant to iAOPCs 8 and 9 are described in this subsection. Unless otherwise noted, information on adjacent upland sites was obtained from the LWG site summaries (Integral and GSI 2004; 2005a,b,c) and updates (Integral 2007).

Advanced American Construction Properties, which acquired the adjacent upland property in December 2004 from Marine Finance, is redeveloping it for river-related use. Their site is bisected east-west by the elevated St. John's Bridge, to create a northern (downstream) parcel and a southern (upstream) parcel. Plans calling for demolition of existing structures and construction of a large warehouse and office are underway. The majority of the property is now paved or covered with buildings. The southern end of the land that fronts iAOPC 9 is occupied by Hendren Tow Boats.

11.3.7.1.1 In-River

The iAOPCs extend from the shoreline offshore toward the edge of the main channel along the northern and southern AACP properties (Map 11.3.7-1). The channel line and channel depths are close to shore in this reach. At iAOPC 8, the riverbed drops quickly from the shoreline, about +5, to -25 ft NAVD88 over a horizontal distance of about 100 ft. In contrast, over two-thirds of iAOPC 9 is a broad, shallow shelf that runs from the shoreline (approximately +5) to only -10 NAVD88 over 200 ft. From the mid-dock area to the outer edge of this iAOPC, the riverbed then drops quickly from -10 to -40 NAVD88 over about 80 ft. The offshore channel in this narrow river reach is a relatively high-energy, sediment transport zone characterized by sandy sediments and sand waves (see Section 4.5.1).

According to Sediment Trend Analysis® results, sediment movement along this side of the river alternates between net accretion and net deposition. Bathymetric change measurements could not be obtained in the shallow, inshore portion of iAOPC 9; the change data from the outer, steeply sloping portion of iAOPCs 8 and 9 show a mosaic of small-scale (< 1 ft) scour and no change, with areas of sediment accretion around nearby structures (e.g., St. Johns Bridge footing) (Map 11.3.7-1). Just offshore of the iAOPCs at the toe of the channel slope, there is a relatively large continuous area of sediment scour with some areas showing up to 2 ft of net erosion.

Even in this relatively high-energy portion of the river, the modeled bed shear (Map 4.5-7) under high-flow conditions indicates much reduced shear stresses immediately along the shoreline where these iAOPCs lie. From upstream to downstream, the series of nearshore structures (e.g., the Hendren Docks, St. Johns Bridge footing) from iAOPC 9 through iAOPC 8 reduce flows and may be loci of episodic sediment deposition.

Grain size (percent fines) in the vicinity of the iAOPCs is shown in Map 11.3.7-2a,b. Offshore samples in the channel are dominated by sands to depth. Although scattered pockets of surface and subsurface sand layers are evident in some cores on the channel slope, most of cores from the channel slope are dominated by approximately fines (50-70 percent). This pattern is consistent with the apparent offshore – onshore hydrodynamics.

The upland topography on the AACP parcels adjacent to the iAOPCs slopes gently to the northeast, with the steep embankment along the river margin armored with concrete rubble and riprap. Artificial fill material was placed at the site during the 1930s and 1960s, creating much of the current site uplands.

Current in-water features include three dock structures (Map 11.3.7-1). The Hendren fleet operations and office are located on the dock on the southern end of the AACP property. The dock is located within and immediately upstream of the iAOPC 9 boundary. On the northern property, Mark Even Construction constructs houseboats on the shoreline using the docks immediately downstream of iAOPC 8. A third dock between iAOPCs 8 and 9 was likely used for vessel fueling in the past.

11.3.7.1.2 Upland

The AACP property is located on the west side of the Willamette River just north of the St. Johns Bridge at approximately RM 5.8 (Map 11.3.7-1). Approximately two-thirds of the property is located north of the bridge, and one-third of the property is located south of the bridge. Hendren operates on the property and dock south of the bridge. AACP occupies the northern parcel. At the time of this publication, it was uncertain if other occupants share the northern parcel with AACP. This 9.7-acre site is used for office trailer storage, warehouses, and houseboat construction. Structures on the site consist of two large metal-clad Quonset huts on concrete slabs, a wood-frame modular office building, a small metal trailer house, a small wooden shed, a floating home builder's dock, and a gangway and floating facilities owned by Hendren.

The site is located in an area of mixed industrial, commercial, and residential uses. Twenty-two houses are within approximately 0.25 mile of the adjacent uplands. Lying at the base of the Portland Hills, the site is composed of various thicknesses of fill and slopes gently to the northeast, with a steep embankment dropping approximately 18 ft to the river. Until it was recently paved, most of the site was covered with 12-18 inches of tightly compacted road-base material. Vacant land lies to the north, Highway 30 to the west, and a USACE storage yard to the south. Burlington Northern railroad tracks and an Olympic Pipeline easement containing two high-pressure fuel lines bisect the site north to south. The St. Johns Bridge is elevated above the site as it crosses the Willamette River.

Over the years, the properties adjacent to the iAOPCs have been used for a wide range of purposes:

- Northern property (iAOPC 8)
  - Ferry landing
  - Tavern
  - Import/export storage
  - Access road to water pumping station
  - Storage, sorting, and reshipping of logs
  - Ferrous and scrap metal salvage
  - Commercial diving
  - Marine construction
  - Art studio
  - Sailboat and houseboat construction
- Southern property (iAOPC 9)
  - Tug and barge transport
  - Pile driving, dock work and bridge building/equipment warehouse
  - Drum storage.

11.3.7.1.3 Hydrogeology

The general upland stratigraphy from the ground surface downward consists of fill, alluvial and Pleistocene glaciofluvial deposits, and Columbia River Basalts.

The fill material underlying the site is approximately 9 to 30 ft thick and consists of road-base material, poorly graded fine to medium sand and silty sand, and organic and construction debris. Underlying the fill is an unknown thickness of recent terrace and Quaternary alluvial deposits, and fine-grained Pleistocene glaciofluvial deposits consisting of dark gray to brown fine sand with lenses of silt and sandy silt. The Columbia River Basalts are thought to underlie the alluvial deposits at an unreported depth. No site-specific cross-sections have been constructed for the adjacent uplands during past investigations.

A single unconfined aquifer was identified beneath the site in the fill material and Quaternary alluvial deposits. Data from onsite monitoring wells indicate a depth to groundwater of 7 to 20 ft bgs and a flow direction of northeast toward the Willamette River at a gradient of 0.045 ft/ft.

11.3.7.2 Chemical Distribution of iCOCs

This section describes the distribution of iCOCs in environmental media at iAOPCs 8 and 9.

11.3.7.2.1 Sediments

Analytical data are available for surface sediment samples and subsurface samples. Summary statistics are provided in Tables 11.2.7-1a–c; all iCOC data may be found in Appendix I.

iAOPC 8

The only iCOC for iAOCP 8 is total PCBs. The single surface sample from the iAOPC (G230) was analyzed for both PCB Aroclors (Map 11.3.7-3) and PCB congeners (Map 11.3.7-4). The concentration of total PCBs reported as Aroclors was 220 µg/kg (entirely Aroclor 1254); the congener concentration was 31.7 µg/kg. In contrast, results from Aroclor and congener analyses in nearby LWG surface samples offshore and up- and downstream match one another much more closely, with Aroclor 1260 predominant. The disparity at Station G230 suggests interferences from other organic compounds present in the sample (e.g., PAHs, TPH), differences in the quantification procedures between the two analytical methods, or both. As a result of this evaluation, the congener result is a more accurate measure of the PCB concentration in this sample. While the Aroclor result from G230, located near the shoreline, is the highest concentration in the vicinity of iAOPC 8 (Map 6.1-5b), the PCB congener concentration and homolog pattern from the same sample are similar to those in samples up- and downstream of the iAOPC (Map 6.1-50a–i).

PCBs as Aroclors were not detected above the 350 µg/kg detection limit in the one subsurface sample located within iAOPC 8 (Map 11.3.7-5). No subsurface samples from iAOPC 8 were analyzed for PCB congeners.

iAOPC 9

Two iCOCs have been identified for iAOPC 9: total PCBs and total DDTs.

PCBs

Four surface sediment samples from iAOPC 9 were analyzed for PCB Aroclors (Map 11.3.7-3), and one of these four was analyzed for PCB congeners (Map 11.3.7-4). Concentrations of total Aroclors ranged from 19 to 98 µg/kg, with a mean value of 58 µg/kg. The highest surface sediment Aroclor concentration (Aroclors 1254 and 1248) was detected in sample G241, located near the shoreline and adjacent to the Hendren Tow Boat docks. Total PCBs as congeners (sum of 15 congeners) were detected in this sample at a concentration of 12.6 µg/kg. As for surface sediment at iAOPC 8, the differences in reported Aroclor and congener concentrations may be attributable to interferences with other organic compounds in the sample (e.g., PAHs, or TPH), differences in the quantification procedures between the two analytical methods, or both. The PCB congener homolog pattern from the sample within iAOPC 9 is similar to those up- and downstream of the iAOPC.

PCBs were analyzed as Aroclors in one subsurface sample located within the iAOPC, approximately 175 ft from the shoreline adjacent to the Hendren docks. Aroclors were detected at a total concentration of 76 µg/kg (Map 11.3.7-5). The detected concentration was reported as consisting of Aroclor 1260. PCB congener analyses were not conducted in subsurface sediment.

DDT

DDT was detected in each of the two surface sediment samples analyzed within iAOPC 9, at estimated concentrations of 13 µg/kg (G241) and 276 µg/kg (G242; Map 11.3.7-6). The sample with the higher DDT concentration was collected approximately 125 ft from the shoreline, adjacent to Hendren docks. This concentration is the highest detected in samples from the vicinity of the iAOPC (Map 11.3.7-6).

DDT analysis was not performed on subsurface samples within the iAOPC; however, the highest DDT concentration in the vicinity (estimated at 100 µg/kg) was detected in subsurface samples taken from a core located approximately 600 ft upstream of the iAOPC (Map 11.3.7-7).

11.3.7.2.2 Surface Water

No surface water samples were collected within iAOPCs 8 or 9 during Round 2 sampling events of November 2004, March 2005, and July 2005. However, surface water samples were collected at one location (Station W009) approximately 120 ft downstream of iAOPC 8 in what EPA has determined is a potential amphibian habitat area (Integral 2006l). Near-bottom peristaltic pump samples were collected at water depths ranging from 1.0 to 4.2 ft.

Neither PCB Aroclors nor DDT was detected, at detection limit values ranging from 0.00125 to 0.0025 µg/L for individual PCB Aroclors and 0.000485 to 0.000532 µg/L

for DDT. A more detailed discussion of surface water sampling is provided in Section 6.3.

11.3.7.2.3 Transition Zone Water

No transition zone water samples were collected in iAOPCs 8 and 9.

11.3.7.2.4 Biota

One whole-body sculpin tissue sample is available to represent exposure of biota to COIs at iAOPC 8 (Map 11.3.7-1). Total PCB Aroclors were detected in the sculpin tissue sample at a concentration of 132 µg/kg (Table 11.3.7-1c).

No tissue samples were analyzed from iAOPC 9.

11.3.7.3 Potential Sources of iCOCs

This section presents a summary of the current understanding of potential sources of iCOCs to the iAOPCs. Information presented in this section was obtained from site summaries unless otherwise noted. In addition to iCOCs, COIs associated with nearby upland areas are also discussed in this section. The COIs are presented to provide a comprehensive understanding of the upland issues and to support the identification of potential sources to the iAOPCs. The relevance of the pathway to iCOCs is summarized at the end of each pathway discussion. Potential sources, COIs, and pathways for ECSI sites associated with these iAOPCs are summarized in Table 11.3.7-2.

11.3.7.3.1 Upland Releases

Contaminant releases have been documented for the upland areas adjacent to both iAOPCs, as listed in Table 11.3.7-2 and summarized below.

Upland releases include onsite historical surface and subsurface releases and spills in the vicinity of drum storage areas and/or former underground storage tanks. Although DEQ noted that PCB analysis was performed on some samples during an expanded preliminary assessment in 2000, PCBs were not subsequently identified as being of significant concern at the property. Former scrap metal salvage operations involved the storage of scrap transformers (a potential source of PCBs) and drums labeled as formerly containing pesticides (a potential source of DDT). According to the operators, only previously cleaned transformers and drums were received onsite. No analytical results for either of the iCOCs in upland media were reported in the documents reviewed. The impacts of potential upland releases of iCOCs remain unclear and may be a data gap.

In 2005, AACP performed source control activities in keeping with its prospective purchaser agreement with DEQ. Shallow soils containing benzo(a)pyrene, copper, and lead at concentrations greater than source control screening levels were removed, or covered by asphalt or buildings. The majority of the site was paved, and a deed restriction was put in place requiring future property owners to notify DEQ before disturbing buried soil at the site.

iAOPC 8
The northern AACP property abutting iAOPC 8 has been developed since the 1800s. Over its history, this portion of the property supported a ferry landing, a tavern, marine construction operations, scrap metal salvage operations, storage for import/export operations, sail- and houseboat construction, houseboat moorage, and an art studio. Locations historically used for scrap metal storage, USTs and associated fuel lines, and stormwater piping have been flagged as potential source areas, as have current and historical dock operations (the latter likely included vessel fueling). On the basis of upland soil sampling, the COIs related to these sources are petroleum hydrocarbons, SVOCs, PAHs, metals, and butyltins.

iAOPC 9
The southern AACP property abutting iAOPC 9 has been in use since the 1920s, if not earlier, by construction, tug and barge transport, and, likely, scrap metal salvage companies. Potential source areas identified include a former construction equipment warehouse, former drum storage areas, and current and historical dock operations.

In May 2001, after the expanded preliminary assessment the year before, DEQ conducted a removal action involving abandoned containers, drums, and batteries (LECG 2006). The specific location of the removal action is not clear but probably included drum storage areas on the southern property.

COIs identified in the upland source areas from soil analyses include petroleum hydrocarbons, PAHs, metals, and butyltins.

11.3.7.3.2 Stormwater/Overland Transport
This section includes discussions of stormwater outfalls, seeps, and adjacent upland overland transport to the iAOPC.

Stormwater has historically drained to iAOPCs 8 and 9 through overland flow, and stormwater runoff is a potential transport mechanism by which contaminants in uplands surface soils can reach the Willamette River. Stormwater has not been analyzed for PCBs or DDTs, and its contributions to the iAOPCs are unknown.

Until recently, no catch basin or stormwater collection system was apparent at the AACP property; stormwater runoff infiltrated the gravel surface or traveled overland across the site and directly into the river. No obvious preferential pathways of stormwater flow toward the river (e.g., surface scouring) were observed.

A pipe at the northern property boundary, downstream of iAOPC 8, apparently collects precipitation infiltrating into the northern part of the site and the adjacent property to the north. The City of Portland has identified this Oregon Department of Transportation 24-inch steel pipe as Outfall WR-208. However, there is no report indicating that stormwater from the AACP property was routed to this outfall. A surface water sample was collected from the pipe in 2000; VOCs and SVOCs were not detected, and concentrations of metals (except barium) were less than DEQ aquatic biota screening

level values. An area of pooled water has historically existed on the beach approximately 60 ft below this drain; DEQ associated this pooled water with a groundwater seep. TPH, SVOCs, lead, and zinc were detected in a sediment sample collected from the area of pooled water. No stormwater samples were analyzed for the iAOPC 8 and 9 iCOCs.

A second 24-inch steel pipe ODOT outfall, WR-207, exists at the upstream boundary of the AACP property, upstream of iAOPC 9. No information has been provided regarding its drainage basin. There is no report indicating that stormwater from the AACP property site was routed to either WR-207 or WR-208.

The majority of the site is currently paved or covered by buildings, and a new stormwater collection system was to have been installed in 2006. The site's current general permit for stormwater discharge during construction does not require chemical monitoring.

11.3.7.3.3 Overwater Discharge

Overwater activities have occurred at the property since the mid-1800s when a ferry landing was established at the downstream property line. Current overwater structures at the property include a floating home builder's dock, and a gangway and floating facilities owned by Hendren Tow Boat Company. Hendren performs maintenance activities at the dock, but fueling operations occur elsewhere. Specific operations conducted by Hendren are reported to include, or are likely to include, the use of lubricants, hydraulic oils, anti-freeze, paints and antifoulant biocide paints, solvents, and other maintenance materials (LECG 2006). Although the current activities at the third dock structure, located upstream of iAOPC 8, is unclear, records suggest that historical uses included vessel fueling.

Historical and current activities at the docks may have caused inadvertent release of diesel, motor oils, or other contaminants to the river. Poor housekeeping practices were noted by the U.S. Coast Guard in a January 1998 spill report; drums of oily rags, antifreeze, and other waste materials were also noted. On May 7, 2003, approximately 1 gallon of oily bilge water was released from a tug to the river. The exact location of the spill is not specified, but is likely to have been the Hendren dock (iAOPC 9).

COIs identified in the site summary associated with overwater discharges include diesel- and oil-range petroleum hydrocarbons, SVOCs, PAHs, and metals. It is possible that historical lubricant and other vessel-related oils may have contained PCBs.

The highest concentration of DDT in the vicinity of iAOPCs 8 and 9 was found in a surface sample collected from next to the Hendren dock at iAOPC 9, suggesting a possible overwater release from an unidentified source. No subsurface DDT data are available from within iAOPC 9 to assess the vertical distribution and potential historical releases.

11.3.7.3.4 Groundwater Discharge

Two PAH groundwater plumes have been identified in the upland properties bordering this iAOPC. One of the plumes is located in the northwest portion of the site downgradient of the former location of three USTs, and the other in the southeast portion of the site downgradient of a former drum storage area. Both plumes are likely related to residual contamination from the storage activities.

The current groundwater data set consists of groundwater levels and analytical data from temporary well points and permanent monitoring wells. VOCs, PAHs, and dissolved metals (arsenic, chromium, copper, lead, mercury, nickel, silver, and zinc) have been detected in the shallow groundwater at the property during site investigations.

The individual detected dissolved metals were not detected consistently across the site and do not appear to indicate a well-defined groundwater plume. The source of the dissolved metals in groundwater has not been identified. DEQ (2007) concluded that "based on the general low frequency of detection, and the very limited detections above screening level criteria, discharge of shallow groundwater does not appear to present a significant threat to the Willamette River for any of these metals."

No groundwater analyses for PCBs or DDT have been performed, but the hydrophobic nature of PCBs suggests potential groundwater contributions to the iAOPCs are likely low or insignificant.

Water from the seep identified near the northern property boundary below the former stormwater pipe was sampled and analyzed for VOCs, SVOCs, and metals. Like the surface water sample collected from the outfall, VOCs and SVOCs were not detected in the seep sample, and concentrations of metals (except barium) were less than DEQ aquatic biota screening level values.

11.3.7.3.5 Riverbank Erosion

The land surface was built up with fill material in the late 1930s and again in the 1960s. The early fill likely originated from private dredging operations; the source of the later fill is not identified. In the absence of bank samples from the AACP properties, iCOC concentrations in riverbank soil are not known. The steep riverbank is armored with concrete rubble and riprap, minimizing the likelihood of riverbank erosion.

11.3.7.4 Relationship of Upland Sources to the Distribution of iCOCs

Based on current information, the in-water distribution of the iCOCs (PCBs at iAOPC 8, and PCBs and DDT at iAOPC 9) cannot be directly linked to source areas at the AACP property because they were not identified as COIs for these sources and were largely excluded as analytes in upland media investigations.

In-water media samples are limited to sediment and sculpin tissue at iAOPC 8, and sediment at iAOPC 9. PCBs were detected in both media types from iAOPC 8.

Although there is a high degree of uncertainty in the pathway assessment, sediment transport appears to be a likely significant pathway for iCOC migration to both iAOPCs based on the observed distribution of iCOCs in the surface and subsurface nearshore sediment. Localized occurrences of the highest reported Aroclor concentrations in both iAOPCs occur in surface sediment near the shoreline; however, the results of the PCB congener analyses, which report lower concentrations in each case, show concentrations and homolog distribution patterns that are very similar to those in samples from the wider up- and downstream area. This evidence suggests that the observed PCB concentrations in surface sediment are the result of migration to the iAOPCs via the sediment transport pathway, and that the observed higher concentrations reported by the Aroclor results may be due to interferences with other organic compounds in the sample (e.g., PAHs or TPH, which are COIs at the upland property) and/or differences in the quantification procedures between the two analytical methods. The importance of the sediment transport pathway is also suggested by subsurface sample results, which show the highest nearby subsurface concentrations of both PCBs and DDT occurring in a core located upstream of the AACP property.

The occurrence of the highest concentration of DDT in surface sediment in the area of the iAOPCs in a sample adjacent to the Hendren dock suggests a locally significant and recent overwater release. Since DDT was not identified as a COI at the Hendren dock or at the upland facilities, an as-yet unidentified potential source at the AACP property is indicated.

Although groundwater migration and stormwater runoff/overland flow were identified as important pathways from the upland sources, the iCOCs are not very mobile in the subsurface and they have not been identified in the upland areas from which runoff and overland flow originate. Thus, contributions of iCOCs from these pathways may be less significant.

No riverbank samples have been collected adjacent to these iAOPCs. Currently, the banks are armored with concrete rubble and riprap, suggesting that the likelihood of ongoing riverbank erosion is low. The potential of historical erosion is unknown.

A preliminary evaluation of the relationship between sources, pathways, and risk drivers in the iAOPC is summarized in Figure 11.3.7-1. A preliminary assessment of the relative current and historical contributions of each source and pathway is summarized in Table 11.3.7-3.

11.3.8 CSM for iAOPC 10

This section provides the preliminary Round 2 CSM for iAOPC 10, which includes a 9.8-acre area extending from approximately RM 5.8 to 6.3 along the eastern shore of the river, adjacent to the City of Portland Bureau of Environmental Services (BES) Water Pollution Control Laboratory (WPCL) and Steel Hammer (SHP; former Crawford Street Corp.) properties (Map 11.3.8-1). This CSM examines the physical

setting of the iAOPC and adjacent upland properties, the chemical distribution of iCOCs in in-water media, and potential sources of the iCOCs.

iCOCs for this iAOPC include:

- Total PCBs
- Arsenic.

Map 10.5-3a–j shows the areas where this preliminary analysis identified the potential for risk for individual exposure scenarios that were considered in iAOPC development, and Table 10.5-1 identifies the iCOCs associated with the exposure scenarios. PCBs affect all exposure scenarios for this iAOPC except in the SHP property beach area, for which the only iCOC is arsenic based on human health beach exposure risk.

The relative concentrations of iCOCs displayed by sediment samples suggest local sources. The observed PCB concentrations in surface and subsurface sediment most likely stem from historical stormwater runoff and overland transport of fill material containing oily sands located on the upland riverbank of the SHP property that eroded onto the nearby beach, or are possibly a legacy from historical outfall discharges or overwater operations. Concentrations of arsenic in surface sediment are highest in samples collected in 2002 near Outfall 50; however, these concentrations are downstream of the beach area where arsenic is an iCOC. The SHP fill material is also the most likely potential source of arsenic to the beach area. Historical sources or placement/erosion of the fill material have likely contributed to the minor, localized increases observed in subsurface sediment arsenic concentrations in the upstream portion of the iAOPC. Groundwater data from the upland properties are somewhat limited and potential groundwater contributions are unclear, but contributions of iCOCs from this pathway are likely less significant than the stormwater runoff and erosion of the fill material from the SHP uplands.

11.3.8.1 Physical Setting, Infrastructure, and Operational History

In-river and upland physical characteristics, infrastructure, and operational history relevant to this iAOPC are briefly described in this subsection. Unless otherwise noted, information on adjacent upland sites presented in this section was obtained from the LWG site summaries (Integral and GSI 2004; 2005a,b,c) and updates (Integral 2007).

11.3.8.1.1 In-River

iAOPC 10 is located in the center of a relatively narrow river reach (RM 5-7), where the nearshore bottom slopes fairly steeply to channel depth.

The area is characterized as a transport/non-depositional zone. The Sediment Trend Analysis® results suggest that dynamic equilibrium transport paths dominate in this portion of the river. A swath between -0 and -20 ft NAVD88 is dominated by sediment scour (up to 2 ft) at the upstream half of the site and transitions to sediment accretion (to 1 ft) at the downstream end of the site. Below -20 ft NAVD88 and out across the

channel, the riverbed is a mosaic of small-scale erosion and no change areas. Overall, minimal sediment accretion is evident in this segment of the river.

The sediment grain-size distributions within the iAOPC generally consist of silty sands in the surface interval, but range from silts to sandy silts to sands in the subsurface (Map 11.3.8-2a,b).

The riverbank along the northwestern boundary of the iAOPC (adjacent to the BES property) between RM 5.9 and 6.0 has been stabilized with riprap and vegetation. Along the southwestern boundary (adjacent to the Crawford Street Corporation property) vegetation (blackberry bushes), concrete debris, and logs exist along the entire bank line. Riverbank erosion has occurred along this portion of the iAOPC. The extent of erosion is unclear; however, black sand fill material historically placed along the top of the riverbank had eroded to the beach and into the Willamette River. This fill material is discussed further in Section 11.3.10.3 below.

Significant shoreline and in-water features and structures are currently limited to Outfall 50 located on the northwest side of the BES property and abandoned outfall pipes along the southeastern shore of the Crawford property, including WR-187 (a 12-inch corrugated metal pipe) and WR-188 (a 10-inch corrugated steel pipe). Other abandoned outfalls, which do not appear to correspond to the location and/or description of WR-187 or WR-188 are identified as two 8-inch steel pipes, a 10-inch corrugated steel pipe, and a 10-inch concrete pipe. Large docks and overwater buildings historically existed along the iAOPC shoreline.

11.3.8.1.2 Upland

The iAOPC is bounded by the City of Portland's BES WPCL, and the SHP site along the eastern bank of the Willamette River. This area is zoned EG2, which allows both commercial and industrial site uses. The predominant land use zoning surrounding the properties upgradient of these sites are primarily light industrial, commercial and residential zoning. LWG has prepared site summaries for the BES WPCL and the Crawford Street (now known as Steel Hammer) properties. Upland conditions at these sites are described in the site summaries and are briefly summarized in the subsections below.

City of Portland's BES WPCL

The BES WPCL (ECSI #2452) comprises 8.9 acres along the eastern bank of the Willamette River between RM 5.9 and RM 6.0. The site is currently used by the City of Portland's BES as an analytical laboratory and offices for BES Source Control staff.

Land features and the operational history of the WPCL property include:

- The Coast Veneer Box Company was located on the northwest portion of the site, adjacent to N. Pittsburg Avenue. This facility manufactured fruit boxes from the mid-1930s until the late 1970s. In the early 1970s, fill material was placed in the foundation of the Coast Veneer Box Company and along the bank

of the river. Sometime prior to 1979, "black sand" fill was placed in the Coast Veneer area and in isolated piles along the southern portion of the site.

- Between 1963 and the early 1970s, a lumber mill operated on the southern parcel of the property, while the northern parcel was used for log storage. Sometime prior to 1970, fill material was brought in to bring the Portland Lumber Mill site to the grade of the pavement adjacent to the Union Pacific Railroad (UPRR). The lumber mill was demolished sometime prior to 1974.
- From 1988 to 1989, construction and other debris were disposed of in the southern and northwestern portions of the site.
- In 1979, the City of Portland (Portland Development Commission) bought the site from the Brand S Corporation. The site was vacant until 1988, when Lampros Steel rented the property from the City for the storage of new steel until approximately 1993.
- Prior to construction of the WPCL in 1996, contaminated soils were investigated and removed. Residual contamination was placed under pavement or vegetated areas. The WPCL was designed to be a showcase for stormwater treatment technologies and all drainage (e.g., roofs, parking lots and offsite drainage) is treated.

Steel Hammer Properties, LLC (Former Crawford Street Corp.)
The Steel Hammer Properties site (ECSI #2363) comprises approximately 15 acres along the eastern bank of the Willamette River between RM 6.0 and RM 6.1. Two companies currently operate on the site: Columbia Forge and Machine Works (CFMW) and Lampros Steel, Inc. (Lampros). CFMW has operated at the site since 1971, and produces metal forging and stamping products. Lampros has operated a structural steel distribution center at the site since 1989.

Land features and the operational history of the SHP property include:

- At least as far back as 1905, the site had been used for the following:
  - Northern Portion – various small machine shops, foundries, forges, lumber/log storage, plywood/lumber mill wood waste storage, small auto repair shop, a box factory, a mercantile warehouse, a "pattern shop" and coal bin.
  - Southern Portion – various small machine shops, lumber and plywood mills, a planning mill, lumber storage, a "Woolen Mill" warehouse, a foundry and machine shop, and docks associated with sand and gravel staging.
- Current facility structures were constructed between 1957 and 1963.
- From 1977 to 1978, up to approximately 6 ft of black sand fill material was placed along the northern bank of the SHP property by previous property owners

during the demolition of the former lumber mill building. The source of the sand was obtained from a local sandblasting company, and had previously been used to clean land-and ship-based oil tanks.

- CFMW occupied the former "pattern shop" in 1971. The CFMW facility includes forges, lathes, machining equipment, steel cutting equipment, an air compressor, two parts washers, upsetter forges, induction heaters, a drop forge, and welding equipment.
- Property ownership transferred to the Crawford Street Corporation in the late 1980s.
- In 1989 Lampros Steel started their operations in a building located on the northeastern quarter of the site. The Lampros facility operations include offloading trucks and railcars, bending and cutting steel (using saws), and loading trucks.

11.3.8.1.3 Upland Hydrogeology

The general site stratigraphy at the BES WPCL site from the ground surface downward consists of fill materials, unconsolidated alluvium deposited by the Willamette River, and lava flows of the Columbia River Basalt Group (CRBG). The fill material is between 10 and 20 ft thick and consists primarily of silt with wood chips, and rubble. Alluvium consisting of silt and sand are expected to be approximately 90 to 100 ft thick. The CRBG is estimated to be approximately 120 ft bgs in the vicinity of the site.

The general site stratigraphy at the SHP site from the ground surface downward consists of recent fill and Quaternary alluvial deposits. The fill consists of predominantly sand with silts, clays, and gravels and extends to approximately 20 ft bgs. The Quaternary alluvial deposits consist of sand and silt. The base of the Quaternary alluvial deposits was not encountered during site investigations.

Depth to groundwater at the BES WPCL site ranges from approximately 23 to 28 ft bgs. Information regarding the direction of groundwater flow was not available, however, it is likely towards the river. There are no monitoring wells currently on site.

The depth to groundwater at the SHP site was reported at approximately 29 ft bgs. Additional information regarding the groundwater gradient and flow direction for this site was not available; but again, groundwater flow is likely to be towards the river.

11.3.8.2 Chemical Distribution of iCOCs

This section describes the distribution of iCOCs in environmental media at iAOPC 10. iCOCs within the iAOPC include total PCBs and arsenic. All iCOC data for the iAOPC can be found in Appendix I.

11.3.8.2.1 Sediments

Sediment sampling locations within iAOPC 10 include 14 surface samples (including beach samples) and 3 subsurface cores (7 subsurface samples). Map 11.3.8-1 shows the

sediment sampling locations, and Table 11.3.8-1 provides a statistical summary of iCOCs in the iAOPC. This section describes the distribution of the iCOCs in sediment within the iAOPC.

PCBs
PCBs were detected in all surface 14 sediment samples (Map 11.3.8-3 and -4). Two types of PCB analyses were conducted for these samples: Aroclors on seven samples, and PCB congeners on seven samples. Detected concentrations of total Aroclors in surface sediment ranged from 16 to 220 µg/kg, with a mean value of 132 µg/kg, while total PCBs congeners for the seven surface samples analyzed ranged from 2.35 to 111 µg/kg. PCB concentration distributions occur in two groups, concentrations ranging from 147 to 220 µg/kg along the length of the iAOPC and a cluster of concentrations less than 12 µg/kg at the downstream end, in the vicinity of Outfall 50.

Subsurface samples from three cores were analyzed for Aroclors. Subsurface samples were not analyzed for PCB congeners. PCB Aroclors were detected in 2 of the 7 samples analyzed (Map 11.3.8-5). Detected total Aroclor concentrations ranged from 133 to 219 µg/kg and both were detected in one core (C244), located in the upstream portion of the iAOPC offshore of the SHP site.

Arsenic
Arsenic was detected in all of the 14 surface sediment samples analyzed (Map 11.3.8-6). Concentrations in surface sediment ranged from 2.96 to 22 mg/kg, with a mean of 10.5 mg/kg. The highest arsenic concentrations in surface sediment within the iAOPC are located in nearshore areas, offshore of Outfall 50. Concentrations upstream of this area were less than 11 mg/kg.

Arsenic was detected in all 7 of the subsurface samples from 3 cores at concentrations ranging from 1.49 to 9.18 mg/kg (Map 11.3.8-7). The highest concentrations in the subsurface were detected offshore of the SHP site where maximum subsurface concentrations were higher than surface concentrations. Subsurface concentrations in the single sediment core adjacent to the BES site ranged from 1.5 to 1.7 mg/kg.

11.3.8.2.2 Surface Water
No surface water samples were collected within or near to iAOPC 10 during Round 2.

11.3.8.2.3 Transition Zone Water
No porewater samples were analyzed for the iAOPC-specific iCOCs. TZW sampling has not been conducted within iAOPC 10.

11.3.8.2.4 Biota
No tissue samples were collected within iAOPC 10.

11.3.8.3 Potential Sources of iCOCs
This section presents a summary of the current understanding of potential sources of iCOCs to iAOPC 10. Information presented is this section was obtained from site

summaries unless otherwise noted. In addition to iCOCs, COIs associated with nearby upland areas are also discussed in this section. COIs are presented to provide a comprehensive understanding of the upland issues and to support the identification of potential sources to the iAOPC. The relevance of the pathway to iCOCs is summarized at the end of each pathway discussion. Potential sources, COIs, and pathways are summarized in Table 11.3.8-2.

11.3.8.3.1 Upland Releases

Documented upland releases are available for both the SHP and BES properties. These releases are listed in Table 11.3.8-2 and summarized below. Releases included fill activities, on-site releases and spills of fuels (gasoline and heavy oil) from underground storage tanks, leaks or spills of motor, lubricating, hydraulic and transformer oils, and waste/stormwater discharges.

Steel Hammer Properties, LLC (Former Crawford Street Corp., ECSI #2363)

Two companies currently operate at the Steel Hammer Properties (SHP) property: CFMW and Lampros. CFMW has operated at the property since 1971, producing metal forging and stamping products. Lampros has operated a structural steel distribution center at the property since 1989. Site operations, including steel products manufacturing and equipment maintenance operations that use lubrication and cutting oils, solvents, and diesel fuel, have been identified as one of several onsite sources with potentially complete pathways to the river. Minor spills of motor, hydraulic, lubricating oils, and transformer oil were reported, all of which were contained and reportedly did not impact soil. Soil in the railroad right-of-way (ROW), which receives runoff from the operations yard in the northern parcel, has been identified as a current upland contaminant source. COIs identified as associated with the railroad right-of-way include TPH, and PCBs. COIs detected in soil samples from the CFMW operations yard and along the railroad ROW include oil-range TPH, PAHs, and total and leachable metals. Samples were not analyzed for PCBs or phthalates.

The two parcels of the SHP property were developed at least as far back as 1905, and have been used historically for a wide variety of operations, including lumber, chain, and steel manufacturing; various mills (planing, plywood, lumber); a woolen mill; various machine shops; auto repair; metal forging, cleaning, machining, shaping, cutting, and painting; shipbuilding; and unidentified electrical utility operations. Possible substances associated with these operations are uncertain but may include lubricating and cutting oils, solvents, and wood preservatives. Contaminants potentially associated with historical operations include oil-range petroleum hydrocarbons, phenols, PCBs, pesticides/herbicides, and butyltins, but no sampling to assess historical operations as contaminant sources has been conducted.

Four USTs (formerly storing Bunker C, diesel, and gasoline) were previously located on the SHP parcels. The site summary lists TPH, VOCs, and metals as COIs associated with the former USTs. Limited subsurface soil sampling was performed during the removal of these tanks in the 1980s; gasoline-range hydrocarbons, total lead, and oil and grease were detected.

Fill material consisting of sandblast grit ("black sand") was placed on the uplands and riverbank as fill in approximately 1977-1978, and over time eroded onto the beach fronting the property and into the river. The material had previously been used to clean oil tanks and appeared oily when first placed on site (SE/E 1988). Runoff from the black sand fill was observed to create a slick where it drained to the river (SE/E 1988). The location of the black sand fill material on the beach corresponds to the beach portion of the iAOPC boundary (Map 11.3.8-1). COIs detected in samples of the black sand fill include diesel- and heavy oil-range hydrocarbons, oil and grease, total PCBs, halogenated organics, PAHs, xylene, several total metals (arsenic, chromium, copper, lead, mercury, nickel, selenium, and zinc), and leachable metals (barium, chromium, lead, zinc). The composition of Aroclors or congeners comprising the total PCB concentration was not provided in the site summary.

In October 2001 approximately 381 tons of black sand was removed from the beach and bank edge. The extent of the removal action, which was determined in the field based on visual indicators of the presence of the fill material, removed "the most clearly identifiable black sand from the beach"; some of the material remains on the beach beneath obstructions (e.g., logs, concrete debris; Bridgewater 2002), and in the uplands. The removal area along the top of the bank was backfilled with clean, compacted fill material and an erosion control blanket following the removal action (Bridgewater 2002). Black sand material remaining on the upland portion of the site is covered with a gravel cap (Bridgewater 2002).

Samples from black sand areas along the beach were analyzed for PCBs in two samples and concentrations were 224 and 1,111 µg/kg. Arsenic was not analyzed prior to removal. Backfill was not placed in the beach removal area. An area of degraded metal wire debris measuring approximately 300 ft^2 is also present along the southwestern shoreline. The confirmation samples collected after the 2001 removal action indicate levels of TPH, PAH, and metals were lowered but not completely remediated. PCBs in confirmation samples were not detected above the 0.05 mg/kg detection limit used.

BES Property (ECSI #2452)

No contaminant sources have been identified with current WPCL operations, which include research and laboratory analysis of samples related to the City's storm and sanitary sewer systems, and staff offices. The City has owned the property since 1979, and constructed the WPCL in 1996.

Lampros rented a portion of the property for steel storage beginning in 1988 until sometime in the 1990s. No potential sources have been identified with that historical use. Prior to City ownership, lumber mill and fruit box construction operations were present beginning in the 1930s. Based on investigation of historical sources, petroleum-contaminated fill materials (including black sand fill) placed on the property during its history, and releases of a petroleum-based liquid with PCBs from a subsurface electrical conduit were identified. No evidence of wood treatment facilities or activities associated with the mill operations was found in property records.

Investigations in the 1990s included upland soils and fill material. Fill material was identified in areas primarily in the south-central and northwestern portions of the property, not extending to the riverbank edge. TPH and PCBs were detected in upland soils. Based on the characterization and delineation of the fill material, a remedial excavation removed 2,113 yd^3 of black sand fill and debris from the property, and the fill is not considered a current source. Remediation occurred in 1993-1994 prior to construction of the WPCL.

The only documented release at the property occurred in 1993 during the removal of the electrical conduit and resulted in PCB contamination of subsurface soil. During the remedial excavation of the release that year, another historical release of PCBs to subsurface soil was discovered and removed. Soil containing remnant concentrations of PCBs and TPH is capped under the new structures and paved surfaces and is not a likely current or ongoing contaminant source to the river. The identification of Aroclors or congeners comprising the detected PCB concentrations was not provided in the Site Summary.

11.3.8.3.2 Stormwater/Overland Transport

Stormwater currently drains to the iAOPC through one public outfall (Outfall 50), and direct overland flow from the southern portion of the SHP property.

Outfall 50 is a 30-inch diameter pipe located on the northwestern riverbank of the BES/WPCL property. The outfall receives stormwater from approximately 45 acres of residential and commercial properties, roads, and railways (CH2M Hill 2004b). Outfall 50 was built as a combined sewer overflow (CSO) outfall in 1906. The potential sanitary overflow component was separated in 1995 as part of the St. Johns Basin Separation Project, and Outfall 50 has been a stormwater-only outfall since that time. Prior to the mid 1990s stormwater discharging from Outfall 50 included runoff from the northern portion of the SHP property; at least a portion of runoff from that property still enters the Outfall 50 system through sheet flow onto the BES property.

Currently, the majority of stormwater from the Outfall 50 basin is treated in the WPCL stormwater treatment pond before it is discharged to the outfall. The treatment pond was installed in approximately 1996 when the WPCL was developed. Some non-stormwater discharges through Outfall 50, including groundwater seepage that enters stormwater treatment pond. No stormwater data is available for Outfall 50; a DEQ stormwater permit is not required for the property, but discharges from Outfall 50 fall under the City of Portland's Municipal NPDES stormwater permit (#108015).

Most of the stormwater from the northern portion of the SHP property drains to municipal storm drain lines that currently drain to Outfall 52, downstream of the iAOPC. As mentioned above, Outfall 50 received runoff from this area prior to the mid-1990s, when the Outfall 50 and Outfall 52 conveyance systems were reconfigured. Historically, drainage from the CFMW operations yard on the northern parcel, including wash water from a former paint room, discharged directly to the ground surface near the railroad ROW, and stormwater from upgradient properties (to the

north) flowed onto the CSC property during heavy rainfall events. During extended rainfall periods, water ponded along the northern edge of the UPRR tracks. Based on information regarding site operations, TPH, VOCs, PAHs, and metals have been identified as potential COIs associated with site runoff. COIs detected in soil samples from the CFMW operations yard and along the railroad ROW include oil-range TPH, PAHs, total metals (antimony, arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc) and leachable metals (cadium, copper, nickel, and zinc). Runoff from this area historically entered the City catch basin on North Burlington Street, which currently discharges to the Willamette River through Outfall 52 but discharged to Outfall 50 prior to1995. Since 2000, operations yard runoff drains to a sand filter/retention box located south of a central operations yard near the Union Pacific Railroad (UPRR) railroad right-of-way, and then to the ground surface.

CFMW was issued a General NPDES permit No. 1200-L on October 7, 1992, but it was terminated soon thereafter when it was determined that the facility did not discharge directly to a waterway and that a permit was not required. Limited stormwater sampling has been conducted onsite to determine the extent of possible site contributions to runoff in the northern portion of the property. A sample was collected in 1997 from the western drain pipe outlet CFMW facility yard area by the Portland BES and was analyzed for metals. Copper (0.01 mg/L), selenium (0.047 mg/L), and zinc (0.065 mg/L) were detected at concentrations exceeding Portland Harbor Joint Source Control Strategy screening levels. The 2006 Milestone Report (DEQ 2006c) indicates that additional monitoring is needed for stormwater at the SHP property.

Stormwater on the southern portion of the SHP property infiltrates the unpaved ground surface or drains to the shoreline through localized erosional gullies in the riverbank, which historically was composed, in part, of black sand fill. An erosion control blanket was placed on the clean, compacted backfill material placed on the bank edge following the 2001 black sand removal action (Bridgewater 2002).

Several abandoned pipes were located along the SHP property shoreline. These pipes were not observed carrying flow or discharge and are likely related to historical usage. As mentioned previously, two of the pipes on the SHP riverbank are identified as WR-187 and WR-188. No discharge data exist from any of the outfalls, though bank material beneath four of the existing pipes was sampled in 2001 as discussed in the Riverbank Erosion section below.

Stormwater from the BES property is collected and conveyed to onsite stormwater treatment systems consisting of engineered bioswales and the Outfall 50 stormwater treatment pond. There is currently no overland transport of stormwater from the BES property directly to the river. Limited information is available regarding historic discharges of stormwater at the site but based on historic aerial photographs, it appears that most of the stormwater at the site likely infiltrated into the ground since most of the site was unpaved or uncovered.

11.3.8.3.3 Overwater Discharge

There are no current overwater activities at either the SHP or BES properties. Riverbank structures extending over the upland shoreline associated with historical operations were formerly present at both properties, including a large structure that covered the upstream portion of the BES property shoreline. This structure was associated with Portland Lumber Company operations and included an electric traveling crane (Bridgewater 2000). A saw mill (1905) and woolen mill warehouse (1924) structures extended from the SHP shoreline at the upstream boundary of the iAOPC, and sawmill and machine shop facilities extended over the downstream portion of the shoreline in the 1960s. Details of overwater activities at both upland properties are unknown. Possible contaminants associated with historical dock/overwater facility operations include those associated with potential releases from lumber mill operations when the dock was present. The PA (Bridgewater 2000) identified petroleum-based lubricants as potential contaminants of concern associated with mill operations, as well as possible wood preservatives used on dock pilings.

11.3.8.3.4 Groundwater Discharge

No groundwater plumes have been identified in the upland properties bordering this iAOPC.

A limited number of groundwater samples have been collected at the SHP property. Detections of halogenated organics (TOX) in two samples collected from borings in 1988 are considered suspect due to possible interference issues stemming from the analytical method. Samples collected from three monitoring wells located near the riverbank in April, 2001 were analyzed for petroleum hydrocarbons, SVOCs, PAHs, and VOCs. Metals were analyzed only at the well near the upstream property line, outside of the black sand fill area. PAHs, total metals (arsenic, chromium, copper, lead, mercury, nickel, selenium, and zinc) and dissolved metals (arsenic, mercury, nickel, and zinc) were detected in this well. Due to turbidity in the groundwater sample, the well was resampled for PAHs in June 2001, and none were detected in the second sample. It was concluded that the original groundwater sample was not representative of groundwater. Based on the limited data, which lack information regarding metals concentrations in groundwater from the area of the black sand fill, groundwater does not appear to be a migration pathway for contaminants from the SHP property to the Willamette River.

The two groundwater investigations at the BES property (1989 and 1993) did not identify the presence of groundwater plumes. A "slightly elevated level" of 2,4-dimethylphenol was detected in one of the samples from the 1989 investigation during which groundwater samples were collected from soil borings. Based upon the fact that the water sample was collected from a boring, rather than a developed monitoring well, it was concluded this result is likely not reliable. Groundwater samples collected from five monitoring wells during a 1993 groundwater monitoring event were analyzed for PCBs and chlorinated phenols. No PCBs were detected. PCP was detected in one well. This detection was considered attributable to either 1) matrix interference by sediment

in the sample or 2) the presence of treated timber pilings (from the former dock structure) in the area of the groundwater sample. No data regarding metals concentrations in groundwater at the BES site were reported.

No samples have been collected from the groundwater seep that discharges to the Outfall 50 stormwater treatment pond mentioned above.

11.3.8.3.5 Riverbank Erosion

Fill materials 16-20 ft thick was apparently placed along the riverbank of the SHP property southern parcel and at least four areas of erosion were identified along the bank. The black sand fill material historically placed along the top of the downgradient portion of the riverbank apparently eroded onto the adjacent beach into the Willamette River. Surface and subsurface soil samples collected along the riverbank of the SHP property, both within and beyond the black sand fill area, contained detected concentrations of gasoline-, diesel-, and heavy oil-range hydrocarbons, PCBs, PAHs, total metals (arsenic, beryllium, chromium, copper, lead, mercury, nickel, selenium, and zinc) and leachable metals (chromium, lead, and zinc). Most sample locations were within the current iAOPC boundary, but five were located just upstream along the SHP property bank and shoreline. The maximum concentrations of PCBs (1.11 mg/kg in black sand fill material) and arsenic (12.7 mg/kg beneath an abandoned outfall) occurred in bank samples within the iAOPC boundaries. Arsenic concentrations in samples from the bank outside the black sand fill area (upstream of the iAOPC boundary) were up to 5.17 mg/kg in surface soil to 8.08 mg/kg in subsurface soil.

A removal action for the black sand fill on the beach and bank edge was performed in 2001. Diesel- and oil-range hydrocarbons, PAHs, total metals (chromium, copper, lead, mercury, nickel, and zinc), and leachable lead were detected in confirmation samples from the bottom and perimeter of the excavation. The removal action was limited to the most obvious area of the black sand fill, on the downstream portion of the SHP property shoreline. Bank fill material outside this area remains in place. The beach sediment sample containing the arsenic concentration that identified the SHP beach as a potential human health exposure risk area was collected in 2002 during Round 1 sampling, after the removal action was completed.

An area of degraded metal wire debris measuring approximately 300 ft^2 was present on the beach shoreline fronting the SHP property. Based on available information this debris pile was located immediately upstream of the iAOPC boundary. Arsenic, chromium, copper, nickel, and total and leachable zinc concentrations were detected in a soil sample from beneath the metal debris. The arsenic concentration (12.6 mg/kg) is higher than the sediment sample collected from the beach and similar to the bank samples discussed above.

No riverbank samples have been collected at the BES property. The bank has been stabilized with riprap and vegetation.

11.3.8.4 Relationship of Upland Sources to the Distribution of iCOCs

Based on the in-water distribution of the iCOCs (PCBs and arsenic) and the evaluation of chemical sources/pathways presented above, there is evidence of a link between chemicals in upland sources and those in the sediment within the iAOPC.

Overall, stormwater runoff/overland transport and riverbank erosion appear to be the dominant pathways of iCOCs to the iAOPC. Contaminated black sand fill material placed on the SHP property in the 1970s appears to have been the significant source contributing PCBs to the iAOPC. Stormwater runoff and physical erosion of material was observed, and the highest concentrations of PCBs occur in the central portion of the iAOPC in samples close to the shoreline, adjacent to and downstream of the black sand area. The relatively elevated concentrations in the surface and subsurface sediment indicate that the source was current or relatively recent at the time of sampling (a large portion of the black sand area was remediated in 2001), and that a historical source was present for some time in the past. Possible releases from the historical stormwater pipes or overwater operations in this area are other potential PCB sources to the subsurface sediment; however, no data exist from these historical sources so they cannot be confirmed. Further, no subsurface data exist near the former dock structure on the BES property shoreline, so subsurface trends in this area cannot be assessed.

The highest concentrations of arsenic were found in surface samples near Outfall 50, suggesting a source at or near the outfall. However, these concentrations are downgradient of the SHP beach area, which is the only area of the iAOPC where arsenic was identified as an iCOC based on human health exposure risk. The black sand fill material appears to be the most likely source of arsenic concentrations in that area of the iAOPC. The fill was transported to the beach from the uplands via historical stormwater/overland flow and bank erosion. Some fill material remains on the beach and in the uplands, indicating the stormwater runoff and overland flow pathways remain important, but the potential for continued erosion from the top-of-bank was significantly reduced or eliminated by the 2001 removal action.

The subsurface sediment samples in the upstream portion of the iAOPC offshore of the black sand area display slightly increased arsenic concentrations relative to nearby cores. Historical runoff from or erosion of the black sand fill or other bank material, or releases from the historical stormwater pipes or overwater operations that formerly existed in this same area may have contributed to the observed arsenic concentrations; however, arsenic is not an iCOC for the in-water portion of iAOPC 10.

Potential groundwater contributions to the iAOPC remain unclear due to limited groundwater analyses in the area. PCBs were not analyzed in groundwater at the SHP property; however groundwater transport of PCBs, which are strongly hydrophobic, is not expected to be a significant pathway. Existing groundwater arsenic data are limited to a single detection in a monitoring well near the upstream boundary of the SHP property; metals in groundwater in the black sand fill area have not been characterized.

However, groundwater contributions of arsenic, even if the pathway is complete, are likely comparatively low relative to the pathways identified above.

Contributions from the sediment transport pathway also appear to be relatively insignificant based on the distribution of higher iCOC concentrations in sediment within the iAOPC boundaries relative to those immediately upstream.

A preliminary evaluation of the relationship between sources, pathways, and iCOCs in the iAOPC is summarized in Figure 11.3.8-1. A preliminary assessment of the relative contributions of each current and historical source is summarized in Table 11.3.8-3.

11.3.9 CSM for iAOPC 11

This section provides the preliminary CSM for iAOPC 11, which consists of a 17.6-acre area on the west shore between RM 6.1 and 6.6 (Map 11.3.9-1). Upland properties adjacent to this iAOPC include the U.S. Army Corps of Engineers (USACE) Moorings facility, Gasco/NW Natural, and Siltronic. This CSM examines the physical setting of the iAOPC and adjacent upland properties, the chemical distribution of iCOCs in in-water media, and potential sources of the iCOCs.

iCOCs for iAOPC 11 include the following:

- Total PCBs
- Sum DDT
- Benzo(a)anthracene (BAA)
- Benzo(a)pyrene (BAP)
- Benzo(b)fluoranthene
- Dibenz(a,h)anthracene
- Indeno(1,2,3-cd)pyrene.

Potential iCOCs for iAOPC 11 include:

- Ammonia
- Sulfide
- beta-Hexachlorocyclohexane (beta-HCH)
- delta-HCH
- Endrin ketone
- Sum DDD
- DRH
- RRH.

The potential iCOCs are identified through less certain and/or less rigorous evaluations based on fewer lines of evidence, FPM results, or other high uncertainty lines of evidence (see Sections 8 and 9).

Map 10.5-3a–j shows the areas where this preliminary analysis identified the potential for risk for individual exposure scenarios that were considered in iAOPC development, and Table 10.5-1 identifies the iCOCs associated with the exposure scenarios. No single exposure scenario and therefore no single group of iCOC (i.e., PAHs, pesticides, PCBs) dominates the definition of risk areas. Pesticides affect the largest area, followed by PAHs, and then PCBs.

The risk evaluations presented in Sections 8 and 9 of this report also identified potential iCOCs based on TZW for human health drinking water and shellfish consumption scenarios, and for ecological risk to the benthic community (Table 11-1-1). In or near iAOPC 11, TCE was identified as a potential iCOC based on TZW for human health drinking water scenarios. Cyanide and several individual PAHs were identified as potential iCOCs based on TZW for risk to the benthic community. For the reasons discussed in Section 10, iPRGs have not been established for potential iCOCs based on TZW at this stage in the RI/FS process, and potential areas of risk associated with TZW did not influence the delineation of iAOPCs. Potential iCOCs based on TZW identified in the vicinity of iAOPC 11 are discussed further below. Potential uncertainties in iAOPC delineation associated with potential iCOCs based on TZW are discussed in Section 10.

The CSM evaluation for iAOPC 11 is summarized as follows: Historical direct discharge of manufactured gas wastes to upland areas and subsequent overflow from waste storage ponds appears to be the major contributor of PAHs and petroleum hydrocarbons. Manufactured gas effluent may have also contributed arsenic to sediment. Historical placement of contaminated fill and historical riverbank erosion also contribute to iCOC distribution. Riverbank stabilization measures implemented by Siltronic and Gasco have substantially reduced riverbank erosion potential, and Gasco is planning additional bank stabilization measures. Although the potential contribution of upland groundwater to iCOCs and potential TZW iCOCs is currently under assessment, findings of the Round 2 Groundwater Pathway Assessment (Integral 2006e) suggest that the observed concentrations of potential TZW iCOCs may be attributed to a combination of existing in-water sources and/or transport from upland sources via the groundwater pathway depending on the particular location along the shoreline.

Sediment transport from upstream sources is likely the most important migration pathway for pesticides, and possibly PCBs. No sources of these chemicals from the Gasco or Siltronic site historical or current operations have been identified. The sources for pesticides are likely former upstream pesticide manufacturing. As described in the CSM for iAOPC 14, the available information suggests that the primary sources of PCBs along this reach of the river are historical discharges from outfalls. PCBs have been reported to be a COI associated with former Doane Lake, an area drained by

stormwater outfalls upstream of the iAOPC. Sediment transport is also expected to be a factor in the observed distribution of manufactured gas waste products within the iAOPC.

11.3.9.1 Physical Setting, Infrastructure, and Operational History

This subsection briefly describes in-river and upland physical characteristics, infrastructures, and operational history relevant to iAOPC 11. Information on adjacent upland sites was obtained from the LWG site summaries (Integral and GSI 2004; 2005a,b,c) and updates (Integral 2007) unless otherwise noted.

11.3.9.1.1 In-River

iAOPC 11 is located along the west side of the upstream portion of the middle Study Area hydrodynamic reach. The river narrows here compared to upstream and is relatively high-energy; sediments are coarse-grained in this portion of the navigation channel , but are dominantly fine-grained in nearshore areas (Map 4.4-5b). The navigation channel boundary is approximately 150 ft offshore along the length of the iAOPC and the riverbed slopes steeply from the shoreline to the bottom of the channel. The Sediment Trend Analysis results suggest that episodic net erosion and net accretion occur in the downstream portion of this iAOPC, while dynamic equilibrium is dominant in the upstream portion.

Bathymetric data collected from 2002-2004 show that the deeper, in-channel portion of the riverbed (i.e., beyond about -30 ft NAVD88) is a mosaic of small-scale erosional and no-change areas. No-change and small-scale (up to 1 ft) net erosion is evident in much of the inshore portion of the iAOPC, with only isolated and small areas of sediment accretion in some areas above -20 ft NAVD88, particularly around structures. Periodic monitoring of beach sediment stakes placed along the Gasco shoreline from July 2002 through January 2004 indicated sediment accretion of about 10 cm on the lower beach (+7 ft NAVD88). Mid beach (+10 ft NAVD88) sediment stake measurements indicated brief periods of sediment accretion of up to 10 cm, followed by longer periods (up to a year) of net scour (up to 29 cm in extent). Predicted bed shear stresses during high flows are moderate to high (see Map 4.5-1) throughout most of this iAOPC, from the outer boundary to the river's edge. Sampling associated with the tar body removal post-construction cap (discussed more below) indicated deposition of up to 8 inches of new silt in this area during the winter flows of 2005/2006.

The sediment grain size distribution in most surface and subsurface core samples indicates over 50 percent fines (Map 11.3.9-2a–c). Exceptions include the surface sediment in cores collected in the upstream area and approximately half of the middle and bottom intervals in selected cores located near the middle of the iAOPC and just outside the iAOPC boundary.

The sediment tar body offshore of the Gasco facility (adjacent to the loading docks) was removed in accordance with EPA requirements in 2005. Map 11.3.9-1 shows the location of the removal. Approximately 15,000 yd^3 were dredged from the tar body area and the area was subsequently capped with a layer of sand.

The riverbank along the iAOPC has a relatively steep slope. The majority of the area is armored with riprap to minimize bank erosion. Geotextile fabric was used along the Siltronic property embankment as an additional erosion control measure. Vegetated areas exist along Gasco's embankment, and a shoreline stabilization plan is currently being considered for areas with minimal vegetation.

Significant shoreline and in-water features and structures include the dock structures on the USACE Moorings and Gasco properties (see Map 11.3.9-1), and three private stormwater outfalls. In-water uses for this iAOPC are the docking and maintenance of USACE boats, and the loading/unloading of heated liquid coal tar pitch and transfer of fuel products from the Gasco dock.

11.3.9.1.2 Upland

The iAOPC is bounded by two industrial facilities and one mooring facility along the western bank of the Willamette River in a section of northwest Portland zoned as Heavy Industrial. LWG has prepared site summaries for Gasco, Siltronic Corporation, and the USACE Moorings facility. Upland conditions at these sites are described in the site summaries and are briefly summarized in the subsections below.

Gasco

Gasco (ECSI #84) occupies 45 acres along the western bank of the Willamette River between RM 6.1 and RM 6.4. The site is currently used by NW Natural as a liquefied natural gas (LNG) storage and distribution facility, while the southern portion of the site is leased by Koppers Industries, Inc. (KI) for use as a coal tar pitch distribution facility. Fuel and Marine Marketing, Inc. (FAMM) leases the northern portion of the site for use as a bulk fuel storage and distribution terminal.

Land features and the operational history of the Gasco property include:

- Portland Gas & Coke (PG&C) constructed an oil manufactured gas plant (MGP), known as Gasco, on the property in 1913. The MGP was expanded during the 1930s and 40s. Once natural gas became available in the 1950s, much of the MGP was shut down, with the last full year of operation occurring in 1955.
- PG&C changed its name to Northwest Natural Gas Company, and more recently to NW Natural, and constructed an LNG storage/distribution plant in 1969. At this time, most of the MGP was demolished and associated underground utilities were removed.
- From 1966 to 1973, Koppers Co. (now Beazer East, Inc.) operated a coal tar distillation facility at the southwestern portion of the property where selected oil products, creosote, and pitch from coal tar distillates were produced. From 1974 through 1977, Koppers Co. manufactured electrode-grade pitch, a product derived from both coal tar and petroleum residuals. KI now occupies this portion of the property.

Siltronic

Siltronic Corporation (ECSI #183) occupies 85 acres along the western bank of the Willamette River between RM 6.4 and RM 6.8. iAOPC 11 is adjacent to the downstream half of the Siltronic property, and begins approximately 400 ft upstream of the current property boundary (RM 6.4). The upstream boundary generally corresponds to the location of a former ditch that drained the PG&C facility, including the waste disposal lagoon. The site is currently used by Siltronic to manufacture silicon wafers from silicon crystal ingots.

Land features and the operational history of the Siltronic property include:

- Prior to 1900, the property was essentially undisturbed lowlands. A portion of the property contained part of a small, shallow lake known as Doane Lake, and a creek ran through the property. In 1908, the Astoria and Columbia River Railroad constructed a double-track railroad bridge across Doane Lake and the Willamette River.

- PG&C excavated and maintained multiple MGP waste disposal areas in the northwestern quadrant of the property from approximately 1940 through 1956, when operations at the MGP ceased. Disposal areas included a waste effluent pond on the Siltronic/Gasco property boundary, an 11-acre effluent overflow area, a small apparent waste disposal area, and a spent oxide/lampblack disposal pile. PG&C sold the property in 1960. MGP waste also discharged directly to the Willamette River from a ditch located approximately 400 ft upstream of the current property boundary (corresponding generally to the upstream boundary of the iAOPC). Sediment and core samples collected by MFA in 2004 and 2005 offshore of WR-66 (i.e., Siltronic's combined NPDES/stormwater outfall) confirmed the historical direct discharge to the Willamette River that occurred from multiple locations (see the Siltronic site summary for details regarding historical discharges). Free product (i.e., MGP-related NAPL) and sheens were observed in the cores; these observations were confirmed by LWG sampling at station 299.

- Following cessation of MGP operations, the lagoon was filled, and MGP waste was spread across most of the property later purchased by Siltronic.

- Between 1968 and 1977, the site was covered with fill up to 30 ft thick in places during filling that occurred from the late 1950s through the mid-1970s. The fill consisted of former MGP process wastes, dredged material from Willamette River dredging operations, quarry rock, and possibly materials and wastes from other onsite and offsite sources.

- The southern portion of the site was mostly undeveloped until it too was filled to about 30 ft above MSL (current grade) between 1971 and 1977. The fill

included quarry rock, Willamette River dredge spoils, and MGP waste from the PG&C facility.

- After the filling activities described above, the site was vacant and unused until 1978, when Wacker Siltronic purchased the site for the purpose of constructing the wafer fabrication plant.

U.S. Moorings

USACE's Moorings facility (ECSI #1641) occupies 13 acres along the western bank of the Willamette River between RM 5.9 and RM 6.1. A portion of the upstream end of the property is adjacent to iAOPC 11. The overwater structure containing Docks A and B, located along the southeast property boundary, is the only portion of the property within iAOPC 11. The site is currently used by USACE to provide docking facilities, maintenance, and overhaul services to support the dredge fleet and the hydrographic survey vessels. The USACE acquired the site in 1903 and has occupied it since 1904.

11.3.9.1.3 Upland Hydrogeology

The general site stratigraphy at the Gasco site from the ground surface downward consists of a surface fill unit (unconfined water bearing zone [WBZ]), a laterally discontinuous silt unit, an alluvial water-bearing zone (semi-confined WBZ), and the Columbia River Basalt Group (CRBG) (Figure 11.3.9-1a; Integral 2006e). The general site stratigraphy at the Siltronic site largely parallels that of the Gasco site and consists, from the ground surface downward, of a surface fill unit (unconfined WBZ), a laterally discontinuous silt unit, an alluvial water-bearing zone ranging in size from silts and sands to gravel and cobbles at the base of the unit (semi-confined WBZ), and the CRBG (Figure 11.3.9-1b; Integral 2006e).

Groundwater in the surface fill generally flows toward the river, with the majority of the flow likely occurring in the more permeable sands/silty-sands. A silt layer underlies a majority of the fill, becoming thin to absent toward the shoreline and variably thicker at the shoreline and offshore (Figure 11.3.9-1a,b; Integral 2006e). It is probable that the fine-grained silt, where present, impedes nearshore direct lateral discharge of groundwater to the river; however, shallow unconfined groundwater ultimately discharges to the river. In upland areas, a downward vertical groundwater gradient is typically observed between the fill and the underlying alluvium, especially in areas where the underlying silt unit is absent. Consequently, groundwater in the fill can be expected to migrate to the alluvium and ultimately discharge to the river. The findings of Siltronic's 2004 and 2005 in-water investigation (using direct-push techniques; MFA 2005a,b) suggest that discharge of COIs to the river associated with deeper groundwater flow (i.e., potentially related to upland sources) may occur farther offshore beyond the silt layer (e.g., MGP-related iCOCs at location GP74). NW Natural is currently conducting a similar in-water investigation to explore the potential for deep groundwater COI discharge at the Gasco site.

11.3.9.2 Chemical Distribution of iCOCs and Potential iCOCs based on Transition Zone Water

This section describes the distribution of iCOCs and potential iCOCs in environmental media at iAOPC 11. For the purposes of evaluating sources to iAOPC 11, the discussion of chemical distribution of iCOCs is limited to PCBs, DDD, DRH, and BAA. Potential iCOCs based on TZW relevant to iAOPC 11 are cyanide, TCE, BAP, and naphthalene. Map 11.3.9-1 presents sampling locations. Tables 11.3.9-1a–d provide statistical summaries of iCOCs for sampled media in the iAOPC. All iCOC and potential iCOC data for the iAOPC can be found in Appendix I.

11.3.9.2.1 Sediments

This section describes the distribution of the iCOCs in surface and subsurface sediment within the iAOPC. The sediment data for iAOPC 11 are from 34 surface sampling locations and 41 subsurface cores (95 subsurface samples). As noted above, the tar body offshore the Gasco facility was removed and the area was capped in 2005. The location of the tar body removal area and samples affected by the removal are shown on Map 11.3.9-1. Samples collected in the area prior to the removal are included in the following discussions.

PCBs

Two types of PCB analyses were conducted for these samples: Aroclors on all of the samples, and PCB congeners on a subset of the samples (Table 11.3.9-1a). PCB Aroclors were detected in 15 of 30 surface sediment samples, and PCB congeners were detected in all 3 surface sediment samples (Maps 11.3.9-3 and 11.3.9-4). Detected concentrations of total PCB Aroclors in surface sediment ranged from 9.29 to 170 µg/kg, with a mean value of 68.4 µg/kg. Total PCB congeners for the three surface samples ranged from 29.9 to 188 µg/kg. The highest total PCB concentrations in surface sediment within the iAOPC are located in nearshore areas: near private outfall WR-66, near the upstream end of the iAOPC boundary, at the upstream end of the former tar body, and adjacent to the northern end of the Gasco dock structure. Higher concentrations (303 µg/kg) of PCB Aroclors are found upstream and mid-channel within iAOPC 12, and within portions of Willamette Cove (iAOPC 13) across the river from iAOPC 11, where the highest concentration was 3,130 µg/kg.

PCB Aroclors were detected in 21 of the 56 subsurface samples analyzed and PCB congeners were detected in all 3 subsurface samples analyzed. Detected total PCB Aroclor concentrations ranged from 20 to 542 µg/kg (Maps 11.3.9-5a and 11.3.9.5b), and maximum subsurface concentrations were generally higher than surface concentrations. Total PCB congener concentrations in subsurface samples ranged from 13.6 to 223 µg/kg (Maps 11.3.9-6a and 11.3.9-6b). The highest concentrations of subsurface total PCB Aroclors were detected in the same areas as the Aroclor maxima for surface sediment. Total PCB Aroclor concentrations in the upper intervals of sediment cores were generally higher than in the deeper intervals, and were well within the range of PCBs detected site-wide. PCB Aroclors were generally not detected in the deepest interval analyzed in individual cores or replicate core pairs.

DDD

DDD was detected in 28 of the 29 surface sediment samples within the iAOPC that were analyzed for DDD (Map 11.3.9-7). Concentrations of DDD in surface sediment ranged from 6.85 to 2,220 µg/kg, with a mean of 245 µg/kg. The two surface sediment samples with the highest DDD concentrations (i.e., greater than 1,000 µg/kg) are located in nearshore areas, within the upstream edge of the former tar body area, and at the upstream end of the iAOPC offshore of the Siltronic facility. DDD surface sediment concentrations are higher upstream of the tar body, with an average of 363 µg/kg, compared to an average of 100 µg/mg downstream. There is no distinct lateral trend in either area; high-concentration samples are adjacent to much lower-concentration samples.

DDD was detected in 51 of the 58 subsurface samples analyzed at concentrations ranging from 0.128 to 1,110 µg/kg (Maps 11.3.9-8a b). The highest DDD concentrations in subsurface sediment are located in nearshore areas, within and upstream of the former tar body area. The highest subsurface concentrations, as shown in the map views, are upstream of the iAOPC. No distinct vertical trend in DDD concentrations was observed; concentrations increased with depth for some cores, and decreased with depth for other cores upstream and downstream of the tar body.

The area shaded as capped or dredged on Map 11.3.9-8b was compared to the delineation of the former tar body in Supplemental Figure 11 (Hahn and Associates 2004). No cores collected beneath the tar body depicted in the figure were analyzed for DDD.

DRH

DRH was detected in all 36 of the surface sediment samples within the iAOPC that were analyzed for DRH (Map 11.3.9-9). Concentrations of DRH in surface sediment ranged from 100 to 39,000 mg/kg, with a mean of 4,110 mg/kg. Six surface samples had concentrations of DRH greater than 10,000 mg/kg and all were located within the immediate vicinity of the former tar body. Other features in this area include the Gasco dock structure, former outfall WR-347, and current outfall WR-107. DRH concentrations were generally higher downstream of the former tar body compared to those upstream. A concentration of 9,000 mg/kg is present near outfall WR-66, which also coincides with the area impacted by historical direct discharge of MGP waste.

DRH was detected in 66 of the 71 subsurface samples analyzed at concentrations ranging from 17 to 190,000 mg/kg (Maps 11.3.9-10a,b). Maximum subsurface concentrations were generally higher than surface concentrations. With the exception of a core located within the area impacted by historical direct discharge of MGP waste, subsurface concentrations greater than 10,000 mg/kg were found within the former tar body area.

BAA

Benzo(a)anthracene was detected in all 55 of the surface sediment samples within the iAOPC that were analyzed for PAHs (Table 11.3.9-1a). Concentrations of BAA in

surface sediment ranged from 350 to 460,000 µg/kg with a mean of 35,900 µg/kg. The distribution of BAA concentrations in surface sediment was similar to that of DRH. BAA concentrations throughout the iAOPC are elevated in comparison to samples collected upstream and downstream of the iAOPC (Map 11.3.9-11).

BAA was detected in all 92 subsurface samples analyzed at concentrations ranging from 1.8 to 760,000 µg/kg (Maps 11.3.9-12a,b). Maximum subsurface concentrations were higher than surface concentrations. The highest concentrations of subsurface BAA were found within the immediate vicinity of the former tar body area. Concentrations greater than or equal to 10,000 µg/kg were present off the U.S. Moorings dock, downstream of the Gasco dock, and in five cores upstream of the former tar body.

11.3.9.2.2 Surface Water

Surface water samples were collected at one sampling location within the iAOPC during three sampling events, as described in the Round 2A Surface Water Site Characterization Summary Report (Integral 2006l). Station W012, located in the center of the iAOPC within the former tar body area, is within the Gasco beach area (see Map 11.3.9-1). A water sample was collected using a peristaltic pump at a depth of between 0.3 and 1.2 ft below the water surface. Analytical results for samples from Station W012 are summarized in Table 11.3.9-1b and provided in full in Appendix I.

PCB Aroclors were not detected in Round 2A at this station at detection limit of 0.0025 µg/L. BAA was detected in the November 2004 and July 2005 sampling events at concentrations of 0.019 and 0.11 µg/L, respectively. DDD was detected in the July 2005 sampling event at a concentration of 0.000839 µg/L.

11.3.9.2.3 Transition Zone Water

Shallow TZW samples (< 38 cm bml) were collected from 17 locations in or near iAOPC 11 during Round 2 Groundwater Pathway Assessment sampling (6 offshore of Gasco and 11 offshore of Siltronic). Siltronic has also collected numerous shallow TZW samples as part of its in-water investigations (MFA 2005a,b).[81] TZW sampling locations are shown on Map 11.3.1-1, and summary statistics of the results are listed in Table 11.3.9-1d[82]. TCE was identified as a potential iCOC based on TZW for human health drinking water scenarios. Cyanide and several individual PAHs were identified as potential iCOCs based on TZW for risk to the benthic community. For the purposes of evaluating sources to iAOPC 11, the discussion of chemical distribution of potential iCOCs based on TZW is limited to cyanide, TCE, BAP, and naphthalene.

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[81]Deeper TZW samples, from a target depth of at least 90 cm (up to 150 cm) were collected from nine locations in the Round 2 Groundwater Pathway Evaluation (see Section 6.2 of Integral 2006g). Siltronic also collected numerous deeper TZW samples (MFA 2005a,b).

[82]Sample counts shown in Table 11.3.9-d are higher because filtered and unfiltered samples were collected from some locations.

Cyanide
Total amenable cyanide[83] was detected in 32 of 34 shallow (0 to 38 cm bml) TZW samples analyzed. Detected concentrations ranged from 0.006 to 23.1 mg/L, with a median value of 0.0826 mg/L. The maximum concentration was measured at TZW sampling location GS02A near the downstream end of the iAOPC.

TCE
TCE was detected in 11 of 62 shallow (0 to 38 cm bml) TZW samples analyzed. Detected concentrations ranged from 0.31 to 88,500 µg/L, with a median value of 4.31 µg/L. The maximum concentration was measured at Siltronic Geoprobe sampling location GP67 (1 ft bml), which is located on the boundary of the iAOPC and within the area impacted by historical direct discharge of MGP waste.

BAP
Benzo(a)pyrene was detected in 29 of 44 shallow (0 to 38 cm bml) TZW samples analyzed. Detected concentrations ranged from 0.0063 to 37.8 µg/L, with a median value of 0.11 µg/L. The maximum concentration was measured at Siltronic Geoprobe sampling location GP73 (1 ft bml), which is located within the iAOPC boundary in the area impacted by historical direct discharge of MGP waste.

Naphthalene
Naphthalene was detected in 54 of 72 shallow (0 to 38 cm bml) TZW samples analyzed. Detected concentrations ranged from 0.0677 to 13,700 µg/L, with a median value of 22.9 µg/L. The maximum concentration was measured at Siltronic Geoprobe™ sampling location GP73 (1 ft bml), which is located within the iAOPC boundary in the area impacted by historical direct discharge of MGP waste.

11.3.9.2.4 Biota
Limited tissue data for field-collected clams are available to represent exposure of biota to iAOPC 11 sources. Clams represent one composite collected over a nearshore area within the iAOPC (see Map 11.3.9-1), located on the downstream end of Siltronic property boundary. iCOCs detected in clam tissue included PCBs, DDD, BAA, BAP, benzo(b)fluoranthene, dibenz(a,h)anthracene, indeno(1,2,3-cd)pyrene, and beta-HCH. Potential iCOC detected in clam tissue included delta-HCH and endrin ketone (Table 11.3.9-1c). Beta-HCH and delta-HCH were not detected above concentrations shown in Table 11.3.9-1c. PAHs generally had the highest concentrations, followed by PCBs, then pesticides.

11.3.9.3 Potential Sources of iCOCs
This section summarizes the current understanding of potential sources of iCOCs to iAOPC 11. Information presented in this section was obtained from site summaries

[83] Total amenable cyanide does not necessarily equate to free cyanide (the form generally considered toxic), and the use of amenable cyanide data for interpretation of toxicity should be done with caution recognizing that such comparisons will likely over-predict toxicity.

unless otherwise noted. In addition to iCOCs, COIs associated with nearby upland areas are also discussed in this section. The COIs are presented to provide a comprehensive understanding of the upland issues and to support the identification of potential sources to the iAOPC. The relevance of the pathway to iCOCs is summarized at the end of each pathway discussion. Potential sources, COIs, and pathways are summarized in Table 11.3.9-2.

11.3.9.3.1 Upland Releases

Upland releases have been documented on both Gasco and Siltronic sites and are shown on Table 11.3.9-2. Because the downstream boundary of this iAOPC only includes a portion of the USACE Moorings dock, the upland releases and pathways discussion will focus on Siltronic and Gasco sites. Releases from overwater activities at the USACE Moorings site are discussed in the *Overwater Releases* section below. Potential sources of contamination from current and past operations within iAOPC 11 can be roughly categorized as historical site operations, historical spills, contaminated fill material, contaminated surface soils and groundwater, releases from former underground storage tanks (USTs), overwater activities, and stormwater drainage from private storm basins. Current potential sources specific to each of the facilities are summarized below.

Siltronic

Known sources of contamination identified on Siltronic's property include MGP wastes from former operators, MGP-contaminated fill material, contaminated groundwater impacted by a release or releases from leaking former leaking trichloroethylene (TCE) UST systems, offsite sources affecting groundwater, overwater refueling, leaks from petroleum pipelines, ditch infiltration, and a former leaking stormwater pipeline. The locations of these sources are shown on Supplemental Figures 1 through 4 in the Siltronic site summary (Integral 2007). COIs detected in various media on the Siltronic property include MGP-related chemicals (BTEX, PAHs, SVOCs, TPH, metals cyanide, and VOCs), methyl-*tert*-butyl ether (MTBE), chlorinated VOCs, and organochlorine pesticides (Table 11.3.9-2). A release of TCE to soil and groundwater has been a primary focus of environmental investigations conducted by Siltronic.

During construction of a fabrication building in 1995, Siltronic encountered soil contaminated by MGP waste (i.e., containing petroleum hydrocarbons, tar residue, and high-carbon solids). Approximately 5,490 tons of contaminated soil were segregated and thermally treated onsite. Similarly contaminated soil is presumed to be present in some portions of the site.

Gasco/NW Natural

Potential sources of contamination at the Gasco site are divided into two general areas: 1) process or operational areas, and 2) by-product and residue placement areas. The historical and/or current process areas of potential concern at the site are the former retort area, tar processing area, light oil plant (currently the Koppers tank farm), Koppers Industries (KI) property (currently KI pencil pitch storage area), naphthalene plant, coke oven area, pitch plant/tar loading area, and current and historical overwater activities. The by-product and residue placement areas of potential concern at the site

are the former lampblack storage/central fill area, spent oxide storage area, tar settling ponds/southern fill area (partly or entirely located on the property later purchased by Siltronic), KI land disposal area, and contaminated fill material.

PAHs and BTEX (particularly benzene) are the primary COIs at MGP sites because of their association with the raw materials, by-products, and residues of the oil gasification process and also with products such as heavy oils, oil tars, lampblack, pencil pitch, creosote, and coke. Cyanide and metals (particularly arsenic, chromium, copper, lead, nickel, and zinc) are typically related to spent oxide/purifier box wastes at MGP sites, and these metals have therefore also been identified as COIs.

11.3.9.3.2 Stormwater/Overland Transport

Listed below are the active outfalls (from upriver to downriver) that drain into the iAOPC:

- **WR-66** (Siltronic)
- **WR-107** (NW Natural Gas, Koppers Industries, Fuel and Marine Marketing)
- **WR-94** (USACE).

Three additional outfalls owned by FAMM (WR-347, -284, and -285) have been identified adjacent to the iAOPC, but these outfalls were not located during recent site reconnaissance activities conducted by Gasco and are presumed to no longer exist. The current or historical discharge or drainage areas and the current status are unknown for outfall WR-94, located on the southern boundary of the USACE property. Table 5.1-4 summarizes the outfalls and associated drainage basins for this iAOPC.

Siltronic

Stormwater at the Siltronic facility is routed to a series of catch basins and stormwater pipes before discharging to the Willamette River at NPDES-permitted outfalls WR-66, WR-67, and WR-287, or City Outfall 22C (discussed as part of iAOPC 14). Only WR-66 discharges into the iAOPC (which is a combined NPDES and stormwater outfall), and it discharges offshore near the Siltronic and Gasco site boundaries. Siltronic's process-related wastewater is treated onsite and discharged to the City of Portland sanitary sewer or to the Willamette River via WR-66.

TSS and zinc have occasionally exceeded NPDES permit benchmarks at the Siltronic facility (Jurries 2006, pers. comm.). Based on analytical data collected during site characterization efforts, and knowledge that TCE has not been used on the site since 1989, the stormwater system does not provide a pathway for TCE-contaminated groundwater to reach the Willamette River. However, recent investigations by MFA and LWG suggest that TCE may have been released to the Willamette River via the combined effluent outfall (NPDES outfall WR-66) during the early 1980s.

Siltronic and DEQ are evaluating the backfill for the combined stormwater/NPDES outfall (WR-66) as a possible preferential pathway for TCE and its degradation

products. During construction of the outfall, a concrete cutoff collar was installed around the outfall at the riverbank to minimize groundwater migration along the backfill. An initial evaluation of the upland and in-river groundwater and TZW data indicates that this backfill is not acting as a preferential pathway. Additional evaluation is ongoing.

Substantial investigation by Siltronic indicates that overland transport is not presently a significant pathway for either MGP-related waste or TCE impacts. Historically, overland transport may have been a complete pathway to the river for COIs related to MGP waste and/or filling activities.

Gasco/NW Natural

NW Natural has one combined stormwater/wastewater outfall (WR-107) that discharges to the embankment above the Willamette River upstream of the dock. Stormwater runoff from a large portion of the Gasco site, with the exception of the KI lease area, drains to outfall WR-107. A large portion of this stormwater and all wastewater is actively treated prior to discharge at this outfall. FAMM has a separate NPDES permit for discharge from their sumps, and this water is not currently actively treated prior to discharge. That discharge is also being directed through this outfall until the company constructs its own outfall. In 2005, a hard pipe was installed in the drainage ditch feeding WR-107 for surface water flow, and the drainage ditch was filled with clean sand. There is no longer contact between soil in the ditch and stormwater or wastewater in the pipe. This outfall has not been sampled since the ditch was hard-piped and backfilled with clean sand. Also, a large portion of the site consists of pervious surfaces with no stormwater collection or discharge system. Water within these areas appears to mostly infiltrate the ground.

Stormwater within the KI pitch handling areas feeds into the KI tank farm area where it is collected by a concrete collection sump. The runoff is then pumped to storage tanks, where the water is sampled prior to batch discharge in accordance with KI's permit requirements. The batch discharge, as well as surface water runoff from two catch basins located in non-process areas of the KI area, is discharged through KI's NPDES-permitted outfall, which drains to an open ditch located at the southern corner of the property. This ditch (Doane Creek) ultimately leads to City Outfall 22C, located on the Willamette River at the railroad bridge.

PG&C disposed of liquid MGP waste (including oil and tar) to low-lying areas of the site with drainage features leading from the production area to the Willamette River from 1913 until approximately 1941. Discharge was primarily in the former tar body area, as shown on Supplemental Figure 11 (Hahn and Associates 2004). In 1941, settling ponds were constructed near the eastern corner of the current Gasco facility property. Between 1941 and the cessation of MGP operations in approximately 1956, overflow from settling ponds was discharged near the Gasco and Siltronic property boundary, and also via a ditch constructed along the upstream boundary of the large tar pond that discharged near the upstream boundary of the iAOPC. Gasco characterizes

pond overflows (ponds not specifically identified) as periodic and having occurred between 1941 and 1956. All ponds and ditches were filled by 1981.

Currently, there is minimal potential for overland transport of chemicals in site soils to the river at the Gasco site. There is also little potential for chemicals in site soils to be transported in stormwater to the stormwater/wastewater point-source discharge to the Willamette River, since the vast majority of unpaved soils provide infiltration of stormwater and the open ditch that previously carried stormwater to outfall WR-107 was hard-piped in 2005 and backfilled with clean sand.

11.3.9.3.3 Overwater Discharge

Overwater activities on the Siltronic property included the former Western Transportation facility, which refueled tugboats. The time frame of the tugboat refueling operations is unclear, but aerial photography suggests that operations were suspended between 1940 and 1955. These overwater activities predate spill records for the LWR.

FAMM currently conducts overwater transfer of bulk petroleum from barges to its bulk storage facility. Koppers also transfers heated liquid coal tar pitch from barges to its bulk storage facility. Several overwater spills have been documented within the past 10 years at the Gasco/NW Natural site, with material spilled including coal tar pitch dust, several gallons of fuel oil, several gallons of oily water, and several gallons of coal tar pitch.

Current operations at the USACE Moorings facility include docking facilities, maintenance, and overhaul services to support the dredge fleet and the hydrographic survey vessels. Occasional minor oil spills from overwater activities have been recorded as recently as 2000.

11.3.9.3.4 Groundwater Discharge

This discussion focuses on the Siltronic and Gasco sites, as groundwater sampling has not been performed on the U.S. Mooring property.

Siltronic

Primary COIs in upland groundwater at the Siltronic site are halogenated VOCs (primarily TCE and degradation products) and chemicals associated with historical manufactured gas production (BTEX and other aromatics, PAHs, and metals and cyanide). Near the river, TCE and degradation products are present in groundwater in the intermediate zone of the alluvial aquifer (80-140 ft bgs). The highest concentrations of TCE and its degradation products are found immediately upgradient and downgradient of the Fab 1 building. MGP waste and DNAPL have been observed in subsurface investigations in the former tar pond areas at the Siltronic site. BTEX and PAHs in groundwater at the Siltronic site are known to be associated with the surface fill WBZ and silt unit, and extend also into the alluvial aquifer in the northern portion of the site in an area that corresponds to the former tar pond footprint. The highest groundwater concentrations of MGP-related constituents are found in this area.

Northwest Natural is developing an RI work plan to evaluate the lateral and vertical extent of MGP-related impacts throughout the Siltronic property.

A deeper zone, characterized by COIs (dichlorobenzene and Silvex) that appear to be associated with upgradient offsite sources, is present in the lower alluvial aquifer (166-207 ft bgs). Vertical profiling of groundwater COI concentrations with depth through the alluvial zone suggests that much of the COI mass is migrating at depth, below the elevation of the navigation channel. Siltronic has submitted a *Draft Source Control Alternative Evaluation Work Plan* to DEQ, EPA, and its partners. Pilot testing of enhanced bioremediation along the riverbank is underway, and has resulted in significant reductions of TCE concentrations (i.e., below JSCS SLVs).

The Round 2 Groundwater Pathway Assessment (Integral 2006e) identified nearshore and offshore groundwater discharge zones, separated by an intermediate zone of low-to-no groundwater discharge, adjacent to the Siltronic site (see Supplemental Figure 8-7; Integral 2006e). The nearshore discharge zone was designated based on positive average seepage meter flux measurement of 10.5 cm/d at location SLSEEP-4A. Additionally, BTEX, PAH, and TPH were detected at relatively elevated concentrations in nearshore TZW. The stratigraphic understanding of the site also supports this designation of a nearshore discharge zone.

Immediately offshore of the nearshore zone, the stratigraphy (projection of silt layer), TZW results (relatively low concentrations of COIs), and seepage meter results (three seepage meter measurements with average flux measurements of 0.2, 0.3, and -1.7 cm/d) support designation of a low-to-no groundwater discharge zone.

Farther offshore, a second groundwater discharge zone was identified where the coarser-grained alluvial zone is expected to project into the river. In this area, positive 24-hr average seepage meter measurements of 5 cm/d and 3.5 cm/d were recorded. Additionally, the TZW COI concentrations in this zone were substantially higher than in the adjacent designated low-to-no flow zone.

Gasco/NW Natural

Primary COIs in upland groundwater at the Gasco site include BTEX and other VOCs, naphthalene and other PAHs, and cyanide. COIs have been identified in groundwater in both the surface fill and the alluvial deposits. COI concentrations in groundwater, including NAPL, are highest for most chemicals within the alluvial deposits beneath the former tar pond area in the southeastern portion of the site, while the highest concentrations in the fill occur in the southwestern portion of the site (i.e., away from the shoreline) (see Map 5.1-2). Vertical profiling of nearshore upland groundwater COI concentrations indicates that COIs are vertically distributed over a range of depths, with the highest concentrations generally encountered deeper within the alluvial zone, below the intervening silt and often at depths well below the river bottom.

The Round 2 Groundwater Pathway Assessment (Integral 2006e) identified approximate zones of relative groundwater discharge offshore of the Gasco site (see

Supplemental Figure 7-7; Integral 2006e). Portions of the nearshore area adjacent to the Gasco site were designated a "variable nearshore discharge zone" based on the confirmed indications of variable groundwater discharge conditions from seepage meters and the corresponding variability in the presence and thickness of silt in the shallow nearshore alluvium. Variable groundwater discharge to the river in this nearshore area is likely due to varying presence and thickness of silt in the upper sands and gravels across the site.

The nearshore area around GS01B and GS02A, where elevated BTEX and/or PAH concentrations were detected in TZW relative to sediment, but where other lines of evidence do not show clear indications of groundwater discharge, are designated as indeterminant on Supplemental Figure 7-1. Insufficient information is available for the remaining nearshore areas where the originally planned sampling program could not be completed due to access limitations during the 2005 tar body removal. This area is indicated as "no designation" on Supplemental Figure 7-7.

The area between the variable nearshore groundwater discharge zone and the toe of the slope that defines the transition to the navigation channel is designated as the intermediate indeterminant groundwater discharge zone. The adjacent zone at the Siltronic site is designated as a low-to-no groundwater discharge zone based on multiple seepage meter measurements and TZW results. Because the seepage meter measurements in this zone at Gasco were limited to 2 meters very close together, the presence or absence of groundwater discharge could not be verified across the entire offshore area at this elevation. Seepage meters in this zone showed no average positive seepage; it is acknowledged, however, based on stratigraphic information, that the thickness and presence of the silt layer projecting into the river at this depth horizon is variable and that where absent, groundwater discharge is likely occurring. The in-water sediment chemical sources known to exist throughout this zone complicate the evaluation of the TZW results. Due to these inconclusive results, this zone was designated "indeterminant."

Farther offshore, the available information is not sufficient to provide strong evidence for the presence or absence of groundwater discharge. However, based on the stratigraphic understanding of both the Gasco site and the adjacent Siltronic site and the fact that the intervening silt subsurface layers appear less frequently at depths equivalent to the river channel, a possible offshore groundwater discharge zone is designated. The term "possible" was applied to acknowledge the uncertainty associated with this designation based solely on stratigraphy. This offshore area was not the focus of the Round 2 discharge mapping and sampling work because this area is slated for evaluation during NW Natural's ongoing in-water investigation.

11.3.9.3.5 Riverbank Erosion

Fill material contaminated with MGP wastes extends along the Gasco/NW Natural and Siltronic riverbanks. COIs include MGP-related wastes. Map 4.6-1 shows that the shoreline of iAOPC 11 is composed of riprap (installed in the 1970s) along the Siltronic

bank, and natural bank and fill material on Gasco/NW Natural property. Gasco indicates that the majority of their shoreline is vegetated or covered with riprap. Bank stabilization plans are in progress for the Gasco facility.

In 1998, Siltronic repaired the entire length (2,300 ft) of the bank that had been damaged during the 1996 flood and added geotextile fabric and additional riprap. An oily sheen was observed when silt adjacent to the bank was disturbed. Subsequent analysis of the sediments in the area of the sheen confirmed the presence of MGP-related constituents, including tar, oil, PAHs, and aromatic VOCs. Prior to site improvements in the 1970s, riverbank erosion was a complete historical pathway for MGP wastes to in-water media.

11.3.9.4 Relationship of Upland Sources to the Distribution of iCOCs

The in-water distribution of several iCOCs and the evaluation of chemical sources/pathways presented above were used to assess potential links between chemical sources/pathways and the distribution of those chemicals in in-water media. The pathways responsible for the distribution of iCOCs for iAOPC 11 can be broadly broken into two groups: those that are associated with operations at adjacent facilities (primarily MGP wastes) and those that are not.

MGP Waste-Related Pathways

Historical direct discharge of manufactured gas wastes and subsequent overflow from waste storage ponds appears to be the major contributor of PAHs and petroleum hydrocarbons (DRH and RRH). Historical placement of contaminated fill and historical riverbank erosion also contribute to iCOC distribution. Discharge of MGP wastes to low-lying areas of the site with drainage features leading from the production area to the Willamette River prior to 1941 resulted in the former tar body. Subsequent overflow discharges from ponds both near the Gasco and Siltronic site boundary and at the upstream boundary of the iAOPC, appear to have contributed to the distribution of MGP wastes (including NAPL) in sediments offshore of outfall WR-66. Fill materials contaminated with the MGP wastes were used to fill at least portions of the adjacent upland areas, and fill placement and historical riverbank erosion appear to have contributed to MGP waste concentrations along the nearshore of the iAOPC. Improvements in stormwater controls suggest that stormwater is not a current significant source; however, the stormwater has not yet been sampled to verify this conclusion. Similarly, overland transport, bank erosion, and direct discharge do not currently appear to be major ongoing sources. Riverbank stabilization measures implemented by Siltronic and Gasco have substantially reduced riverbank erosion potential, and Gasco is planning additional bank stabilization measures.

Sediment transport appears to be an active process in nearshore sediments. Downstream sediment transport has not been directly evaluated for MGP iCOCs, but is expected to influence their lateral and vertical distribution.

Groundwater is impacted with MGP wastes beneath the Gasco and Siltronic sites. Although there is strong evidence of complete groundwater transport pathway for MGP

wastes to reach in-water media, the contribution of the groundwater transport pathway relative to other pathways is not certain. MGP waste (including NAPL) is present in sediments as a result of historical discharges and the effect of groundwater migration has not been separated from effects of wastes directly deposited in the river.

PAHs and cyanide, both of which were identified as potential TZW iCOCs in iAOPC 11, are present in upland groundwater beneath the Gasco and Siltronic sites. There are also extensive historical in-water sources of chemicals in sediment that extend over all of the nearshore zone, contributing the same chemicals to TZW. It is difficult to conclude based on available information whether concentrations of cyanide and PAHs in TZW are the result of sediment chemical sources (i.e., representative of direct discharge), transport of upland groundwater COIs, or a combination of the two. Patterns of elevated potential iCOC concentrations in TZW do not always correspond to in-water sediment concentrations; therefore, it cannot be ruled out that some of the observed concentrations of cyanide and PAHs in TZW are attributable to transport from upland groundwater.

Non-MGP Waste-Related Pathways

PCBs and pesticides are not associated with historical or current operations at either the Siltronic or Gasco sites, although PCBs are commonly associated with electrical equipment at major industrial facilities such as these. Migration of PCBs and pesticides via sediment transport from upstream locations is the probable source of these iCOCs. As described in the CSM for iAOPC 14, the available information suggests that the primary sources of PCBs along this reach of the river are historical discharges from outfalls. Pesticide manufacture was a major industry at sites upstream of the iAOPC. DDD was widespread in surface and subsurface sediment samples in the nearshore areas of iAOPC 11, and concentrations generally decrease in the downstream direction. This distribution is likely primarily due to sediment transport from upstream sources.

TCE has not been used at the Siltronic facility since 1989. There are no current pathways other than groundwater for TCE and its degradation products. TCE concentrations in TZW within and near iAOPC 11 are substantially higher in the offshore groundwater discharge zone (Supplemental Figure 8-7) than in the nearshore and intermediate zones. As suggested by MFA (2005a,b), it is possible that the source of some of the chlorinated VOCs detected in TZW (particularly at the northwest end of the Siltronic shoreline) immediately offshore of outfall WR-66 may be an historical release via the outfall, rather than migration of VOCs from upland groundwater to the river.

The offshore area upstream and to the southeast, however, is interpreted to be a probable expression of upland groundwater based on stratigraphic considerations, projection of the upland groundwater plume along the groundwater flow path, and the chemical signature of VOCs observed in samples of TZW and offshore groundwater. TCE and its degradation products were typically undetected in the nearshore zone adjacent to the Siltronic site.

A preliminary evaluation of the relationship between sources, pathways, and iCOCs in iAOPC 11 is summarized in Figure 11.3.9-2. A preliminary assessment of the current and historical relative contributions of each source for iAOPC 11 is summarized in Table 11.3.9-3.

11.3.10 CSM for iAOPCs 12 and 13

This section provides the Round 2 CSM for two contiguous iAOPCs: iAOPC 12 and iAOPC 13. The iAOPCs collectively include 30.12 acres and extend from RM 6.5 to about 6.9 (Map 11.3.10-1). iAOPC 12 is in the center of the river, largely in the federal navigation channel. iAOPC 13 is contiguous with the upstream portion of iAOPC 12 and extends eastward into Willamette Cove and includes most of the cove. Willamette Cove is immediately downstream of the McCormick & Baxter (M&B) Superfund Site. This CSM examines the relationships among the physical setting of the iAOPCs and adjacent upland properties, the chemical distribution of iCOCs in in-water media, and potential sources of the iCOCs.

iCOCs identified for these two iAOPCs include:

- **iAOPC 12:** Total PCBs
- **iAOPC 13:** Total PCBs, PCB TEQ, Sum DDT, Dioxin TEQ.

Potential iCOCs include:

- **iAOPC 13:** Mercury, DRH, RRH.

The potential iCOCs are identified through less certain and/or less rigorous evaluations based on fewer lines of evidence, FPM results, or other high uncertainty lines of evidence (see Sections 8 and 9).

Map 10.5-3a–j shows the areas where this preliminary analysis identified the potential for risk for individual exposure scenarios that were considered in iAOPC development, and Table 10.5-1 identifies the iCOCs associated with the exposure scenarios. PCBs define the risk areas in both iAOPCs. The other iCOCs and potential iCOCs identified in iAOPC 13 are found in the upstream and nearshore portions of the iAOPC.

The CSM evaluation indicates that sediment quality in Willamette Cove has been affected by historical wood-treating, timber products manufacturing, and shipyard activities in areas in and adjacent to iAOPC 13. Groundwater and NAPL migration from M&B has been documented to contain petroleum hydrocarbons, and dioxin may also have migrated into the iAOPC via this pathway. Upland soils and riverbank soils from both Willamette Cove and M&B contain PCBs, petroleum hydrocarbons, and mercury. It should be noted that Round 2A sampling was conducted prior to installation of the M&B in-water cap and subsurface sheet pile/slurry wall and likely does not reflect current conditions in some areas.

Historical riverbank erosion and overland runoff may also have been potential sources of these chemicals. There is no current stormwater collection system for the Willamette Cove property. Historical stormwater and overland runoff may have contributed some or all iCOCs to sediments, and historical overwater releases may have contributed PCBs, petroleum hydrocarbons, and mercury to surface water and sediments of the iAOPC. The relative contribution of historical stormwater and overwater releases is not known. Sediment transport from upstream sources is also a likely source of iCOCs to the iAOPC.

11.3.10.1 Physical Setting, Infrastructure, and Operational History

This subsection briefly describes in-river and upland physical characteristics, infrastructure, and operational history relevant to iAOPCs 12 and 13. Information on adjacent upland sites was obtained from the LWG site summaries (Integral and GSI 2004, 2005a,b,c) and updates (Integral 2007) unless otherwise noted.

11.3.10.1.1 In-River

iAOPCs 12 and 13 include the upstream and inner portion of Willamette Cove, an off-channel embayment located on the east side of the LWR centered at about RM 6.8. These iAOPCs extend out into the navigation channel and then downstream to approximately RM 6.5 (Map 11.3.10-1). This relatively narrow and dynamic stretch of the river is at the upstream end of the middle Study Area hydrodynamic regime described in Section 4.5 (RM 5–6.9). The Sediment Trend Analysis® results suggested that this entire portion of the river was in dynamic equilibrium (i.e., transport without net accretion or erosion). Time-series bathymetric data indicates areas of small-scale net erosion and accretion at the head of the cove, but most of the cove exhibited no measurable changes in riverbed elevation from January 2002 through February 2004.

Most of the offshore portion of iAOPC 12, particularly in the navigation channel, shows net erosion of up to 1 ft. Limited boat access precludes collection of bathymetric change data for a significant nearshore swath of the cove along its upstream edge; however, much of this area was capped as part of the M&B remedial action in the summer of 2004. Periodic beach sediment stake monitoring in Willamette Cove indicates that the lower beach (+7 ft NAVD88) experienced small-scale (<5 cm) erosion from July 2002 to July 2003 (Anchor 2004). No beach elevation changes were evident at the mid- and high-beach stakes (+9 and +15 ft NAVD88). Map 4.5-1 shows modeled bottom shear stresses during a high-flow event (160,000 cfs). The mainstem of the river in this reach exhibits bottom shears that are markedly higher than those immediately up- or downstream and are comparable to those seen at RM 11 and above. As expected, the sheltered Willamette Cove exhibits much lower bottom shear stress than the mainstem.

Grain size associated with surface sediments is highly variable in the relatively dynamic channel setting of iAOPC 12, ranging from 3.4 to 75.4 percent fines; subsurface sediment samples encompass a similarly wide range (Map 11.3.10-2a). This portion of the river is transitional between an upstream region dominated by fines and a sandy downstream reach (see Map 4.4-3). The surface sediment in Willamette Cove

(iAOPC 13) is generally fine-grained with greater than 75 percent fines in most cases, although there are some surface and subsurface sands at the head of the cove (Map 11.3.10-2b). The fine-grained sediments in the cove typically extend to depths of approximately 6 ft bml or greater, with the exception of one core from the inner cove above 0 ft NAVD88 where a 1-ft layer of fines overlies sandy sediments.

No in-water facilities or structures are present in these iAOPCs. Past in-water structures in Willamette Cove included:

- Willamette Cove Central Parcel:
  - Dry docks, piers, and docks
  - Historical outfall (WR-191, inactive)
- Willamette Cove East Parcel:
  - Pilings for log storage.

11.3.10.1.2 Upland

iAOPC 13 is located offshore and to the west of upland parcels associated with Willamette Cove (Central and Eastern Parcels, ECSI #2066, in part) and north of the M&B (ECSI #74) site. iAOPC 12 lies mid-river within the federal navigation channel, downstream and adjacent to iAOPC 13 and iAOPC 11. Nearby upstream iAOPCs include iAOPCs 14 and 15. Upland conditions are described in the site summaries and are briefly summarized in this subsection. The Willamette Cove parcels have been inactive since 1980 and are currently zoned as EG2 (General Employment 2) with greenway and river water quality overlay zones. The current owner, METRO, plans to preserve the property as an undeveloped greenspace or develop it as a park. Access to the M&B site is restricted, as it is currently undergoing extensive remediation. A site reuse study conducted by the City of Portland concluded that recreational use was the best future designation for the M&B site (EPA 2004b).

Historical operations at each of the parcels adjacent to iAOPC 13 included the following:

- Central Parcel:
  - Shipbuilding, repair, and maintenance on dry docks, with supporting activities in the adjacent uplands and surrounding piers
  - Plywood manufacturing plant and sawmill.
- East Parcel:
  - Manufacturing of wood products including wooden vats, kegs, barrels, shingles, and other timber products
  - Plywood mill.
- McCormick & Baxter Parcel:

- Sawmill
- Wood treating with creosote, pentachlorophenol, and inorganic (arsenic, copper, chromium, and zinc) preservatives.

11.3.10.1.3 Upland Hydrogeology

Results from the environmental site investigations and literature sources indicate that the general stratigraphy from the ground surface downward adjacent to iAOPC 13 consists of the following:

- Sandy Fill
- Alluvium
- Troutdale Formation.

The sandy fill consists primarily of sand and silty sand. The alluvium consists of clayey silt, silt, and sand. Before and during facility development (by 1930), fill was placed on a lowland strip adjacent to the bluff and outward into the Willamette River. Fill can be distinguished from alluvium based on historical topographic maps and the presence of anthropogenic debris (consisting mostly of bricks, metal, and wood). In the Central Parcel, debris was present between 12 and 27 ft below the ground surface (bgs) in the western half of the parcel, and surface debris was on the eastern half. In the East Parcel, debris was present only along the southeast perimeter, at depths of up to 15 ft. Debris, particularly wood chips from the former saw mill, was encountered at the M&B site during the construction of the sheet pile and slurry wall, which extended up to 80 ft bgs. Coarser sand or gravel has been encountered in several borings at depths greater than 19 ft. Together, the fill and alluvium are estimated to be approximately 80 to 100 ft thick and overlie the Troutdale Formation, a poorly to moderately consolidated conglomerate with thin interbeds of claystone, siltstone, and sandstone.

Shallow groundwater in monitoring wells ranges from 25 to 30 ft bgs (i.e., groundwater is present within fill and/or alluvium). Based on environmental studies completed at the adjacent M&B site (to the southeast), the groundwater flow direction is anticipated to be toward the Willamette River (the nearest surface water body). These studies have also indicated that shallow groundwater is generally unconfined.

11.3.10.2 Chemical Distribution of iCOCs

This section describes the distribution of iCOCs for iAOPCs 12 and 13. Map 11.3.10-1 shows the sediment sampling locations, and all iCOC data for the iAOPC can be found in Appendix I. For the purposes of evaluating sources to iAOPCs 12 and 13, the discussion of chemical distribution of iCOCs is limited to PCBs, DRH, DDT, dioxin, and mercury.

11.3.10.2.1 Sediments

Sediment sampling locations within iAOPC 13 included 38 surface samples and 11 subsurface cores (33 subsurface samples). Eight samples were collected from three

surface and three subsurface sampling locations in iAOPC 12. Sampling locations are shown on Map 11.3.10-1, and Table 11.3.10-1a provides summary statistics of iCOCs for sediment in iAOPCs 12 and 13. This section describes the distribution of the iCOCs in surface and subsurface sediments within the iAOPCs.

PCBs

iAOPC 12 - Three surface sediment samples were collected within iAOPC 12. Aroclor concentrations in these samples ranged from 237 to 303 µg/kg, and a single sample analyzed for PCB congeners had a concentration of 191 µg/kg (Maps 11.3.10-3 and 11.3.10-4). Subsurface Aroclor concentrations ranged from 1.9 to 204 µg/kg; subsurface sediment samples were not analyzed for PCB congeners. Distribution trends are not apparent due to the low sample density and similar surface concentrations within this iAOPC. Concentrations decreased with depth at the two core locations (Map 11.3.10-5a).

iAOPC 13 - Sixteen surface sediment samples (i.e., grab samples and upper core intervals to 30 cm) and 10 sediment cores (17 subsurface samples) were analyzed for PCBs (as Aroclors) in iAOPC 13 (Maps 11.3.10-3 and -5b). Seven surface sediment samples were also analyzed for PCB congeners (Maps 11.3.10-4).

PCB Aroclors were detected in 11 of 16 surface sediment samples at concentrations ranging from 2.5 to 3,130 µg/kg, with a mean value of 467 µg/kg. Total PCBs congener concentrations ranged from 41.6 to 8,100 µg/kg, with a mean value of 1,420 µg/kg. The highest PCB concentrations were measured in surface sediments in the nearshore area of Willamette Cove adjacent to the East Parcel.

PCB Aroclors were detected in 5 of the 17 subsurface samples analyzed at concentrations ranging from 3.7 to 163 µg/kg (Map 11.3.10-5b). The distribution of the subsurface total Aroclors concentrations were generally much lower than the five surface locations where comparisons could be made. Aroclors were generally not detected in the deepest interval analyzed in individual cores.

The relative proportions of individual Aroclors detected in surface sediment within iAOPC 13 are similar to those in samples collected across the river (Map 6.1-48a–i). Samples from both locations tend to be dominated by Aroclors 1260 and 1254. In general, the PCB homolog distributions in the surface and subsurface sediment samples analyzed for PCB congeners (Map 6.1-50a–i) support the Aroclor 1254 and 1260 identifications, with relatively high proportions of hexachlorobiphenyl, heptachlorobiphenyl, and decachlorobiphenyl homologs.

DRH

Six surface samples (i.e., grab samples and upper core intervals to 30 cm) and five cores (10 subsurface samples) were analyzed for potential iCOC total DRH in iAOPC 13 (Maps 11.3.10-6 and -7). DRH was detected in all surface sediment samples at concentrations ranging from 66 to 2,400 µg/kg, with a mean value of 859 µg/kg. The

highest surface sediment concentrations within the iAOPC were located in the nearshore area at the head of the cove off the East Parcel.

DRH was detected in nine of 10 subsurface samples analyzed at concentrations ranging from 5.85 to 800 µg/kg, with a mean value of 235 µg/kg. The highest subsurface DRH concentration within the iAOPC is located in the head of the cove adjacent to the M&B cap.

DDT

Sediment samples analyzed for DDT within iAOPC 13 include 15 surface samples (i.e., grab samples and upper core intervals to 30 cm) and 9 cores (17 subsurface samples) (Maps 11.3.10-8 and -9). DDT was detected in 7 of 17 surface sediment samples at concentrations ranging from 0.422 to 320 µg/kg, with a mean value of 35.3 µg/kg. The highest surface sediment DDT concentration within the iAOPC is located in the middle portion of the inner cove.

DDT was detected in 7 of 17 subsurface samples analyzed at concentrations ranging from 0.085 to 169 µg/kg, with a mean value of 43.5 µg/kg. The highest concentration was located in the middle of the cove, in the deepest core interval sampled.

Mercury

Seventeen surface sediment samples (i.e., grab samples and upper core intervals to 35 cm) and 8 cores (19 subsurface samples) were analyzed for mercury in iAOPC 13 (Maps 11.3.10-10 and -11. Mercury was detected in 15 of 17 surface sediment samples at concentrations ranging from 0.077 to 0.94 µg/kg, with a mean value of 0.316 µg/kg. The highest surface sediment concentrations are located nearshore area of the cove off the Central Parcel.

Mercury was detected in 18 of 19 subsurface samples analyzed at concentrations ranging from 0.011 to 4.14 µg/kg, with a mean value of 0.721 µg/kg. The highest concentrations were located in the nearshore area and the middle of the cove. In the latter instance, the highest concentration within the individual core was located in the deepest interval. In most areas, subsurface mercury concentrations tended to be higher than surface concentrations.

Dioxin

Five surface (i.e., grab samples and upper core intervals to 35 cm) samples were analyzed for dioxins and furans (Maps 11.3.10-12) in iAOPC 13. TEQs were reported for all samples with concentrations ranging from 1.69 pg/kg to 102 pg/kg, with a mean value of 43.2 pg/kg. The highest concentration was reported in a sample from the nearshore area of the cove off the Central Parcel.

11.3.10.2.2 Surface Water

Surface water samples were collected at two locations (W013 and W014) within iAOPC 13 during the three Round 2A sampling events (see Section 6.3). Station W013, located near the head of the cove, is within a nearshore amphibian habitat area (Map 11.3.10-1). Single-point near-bottom water samples were collected using a peristaltic pump and XAD at depths of approximately 7.5 to 10.5 ft below the water surface. Station W0014, located near the head of the cove approximately 300 ft east of W0013, is within an area being evaluated in the HHRA for contact by recreational and transient users. Integrated water column samples were collected using a peristaltic pump, without XAD. Since the W014 samples were collected nearby W013 XAD samples, and the XAD method has much lower detection limits, the following discussion is generally limited to Station W013 results. In addition, the frequency of detection of iCOCs was lower in W014. Surface water sampling results are summarized below and presented in Table 11.3.10-1b.

PCBs

PCB Aroclors and PCB congeners were detected in the XAD columns and filters at Station W013 during every sampling event. Total PCB Aroclors were detected at concentrations ranging from 395 to 1,603 pg/L in XAD columns (dissolved phase) and 1,300 to 9,950 pg/L in XAD filters (particulate phase). Total PCB congeners were detected at concentrations ranging from 624 to 2,420 pg/L in columns and 1,380 to 9,550 pg/L in filters.

DDT

DDT (sum of 2,4'- and 4,4'-DDT) was detected in the XAD columns at Station W013 during every sampling event at concentrations ranging from 0.744 to 10.6 pg/L, with a mean value of 4.94 pg/L. These pesticides were detected in five of six XAD filter samples (station W013) at concentrations ranging from 0.598 to 12.6 pg/L, with a mean value of 7.2 pg/L, during the three Round 2A sampling events.

Mercury

Surface waters samples collected using the bottle collection method (i.e., peristaltic pump) were analyzed for total and dissolved mercury. Nine samples were analyzed for total mercury and eight were analyzed for dissolved mercury. Total mercury was detected during one sampling event at a concentration of 0.000187 mg/L and dissolved mercury was not detected during any of the sampling events.

Dioxins

Dioxins were detected in all six XAD samples at station W013 during the three sampling events. Dioxin TEQ concentrations ranged from 0.000903 to 0.0378 pg/L in XAD column samples and 0.103 to 0.91 pg/L in XAD filter samples.

11.3.10.2.3 Transition Zone Water

No TZW was collected in iAOPC 12 or 13. One porewater sample was collected from Willamette Cove as part of the M&B RI. Mercury, the only iCOC analyzed for, was not detected in porewater (Table 11.3.10-1c).

11.3.10.2.4 Biota

Biota samples were not collected at iAOPC 12. Fish and invertebrate tissues were collected at iAOPC 13 for clams (*Corbicula fluminea*; field-collected and laboratory-exposed), worms (*Lumbriculus variegatus*; laboratory-exposed), crayfish, sculpin, and epibenthic organisms (sampled from multiplate samplers). Crayfish and epibenthic samples were sampled from one location each within the iAOPC.

All iCOCs were detected in fish and invertebrate tissue, with the exception of petroleum hydrocarbons, for which the samples were not analyzed. Results are summarized below and presented in Table 11.10-1d.

PCBs

All biological samples from this iAOPC were analyzed for PCB congeners. PCB Aroclors were also reported for all samples; however, Aroclors were quantified from the congener analyses for the clam, worm and epibenthic invertebrate samples. Total PCB Aroclors were detected at concentrations from 43 to 1,860 µg/kg in laboratory-exposed clam and worm tissue, respectively. The highest concentrations of total PCB congeners were measured in worm (3,910 µg/kg) and field-collected clam tissue samples (2,660 µg/kg). Crayfish whole-body tissue exhibited the lowest concentration of PCB congeners (50.7 µg/kg). PCBs concentrations in sculpin ranged from 382 to 2450 µg/kg for totals based on Aroclors and from 600 to 2,300 µg/kg total PCBs based on congener sums.

DDT

DDT (sum of 2,4'- and 4,4'-DDT) was detected in all fish and invertebrate tissues sampled from this iAOPC. Sample concentrations were relatively similar across species, ranging from 0.0927 to 11 µg/kg in laboratory-exposed clam and field-collected sculpin tissue, respectively.

Mercury

Mercury was detected in all fish and invertebrate tissues (except invertebrates collected with multiplate samplers, where mercury was not analyzed) sampled from this iAOPC. Sample concentrations were relatively similar across species, ranging from 0.0103 mg/kg to 0.047 mg/kg in laboratory-exposed clam and sculpin tissue, respectively.

Dioxins

Dioxins and furans were detected in all fish and invertebrate tissues analyzed from this iAOPC. Sample concentrations expressed as TEQs ranged from 0.18 to 4.59 pg/g in laboratory-exposed clam and worm tissue, respectively.

11.3.10.3 Potential Sources of iCOCs

This section presents a summary of the current understanding of potential sources of iCOCs to iAOPC 12 and 13. Information presented in this section was obtained from site summaries unless otherwise noted. In addition to iCOCs, COIs associated with nearby upland areas are also discussed in this section. The COIs are presented to

provide a comprehensive understanding of the upland issues and to support the identification of potential sources to the iAOPC. The relevance of the pathway to iCOCs is summarized at the end of each pathway discussion.

Remedial investigations have been conducted for the upland and riverbank portions of Willamette Cove and both the upland and aquatic portions of the M&B site. A remedy (groundwater/NAPL containment wall along the shoreline and an armored nearshore cap) for the M&B site was implemented in April through September 2003 (upland work) and June through October 2004 (in-water work); the aquatic cap extends into the southern portion of the cove and bisects the iAOPC.

The focus of this analysis is on potential sources to iAOPC 13, as iAOPC 12 lies offshore and downgradient of iAOPC 13, and it is therefore also subject to potential upstream sources (e.g., far-field sources may also affect iAOPC 12 due to its mid-river location), but these are not addressed here.

11.3.10.3.1 Upland Releases

The upland parcels adjacent to iAOPC 13 are currently unoccupied, with no known ongoing sources or releases. Historical activities on the Willamette Cove parcels, as well as documented historical releases from the adjacent M&B site, are listed in Table 11.3.10-2 and summarized below.

Historical releases are associated with wood preservation and waste disposal activities at the former M&B site south of Willamette Cove; ship repair and maintenance adjacent to the Willamette Cove central parcel; and plywood or other wood product (e.g., barrels, vats, shingles) manufacturing on the eastern parcel.

While there are no records of upland spills or releases associated with the Willamette Cove parcels, some upland soil samples exhibit detections of TPH, PAHs, PCBs and metals. No wastewater outfalls presently discharge to Willamette Cove and historical discharges cannot be characterized due to a lack of records. The Port of Portland and DEQ investigated five potential outfalls that had been identified by the City and concluded that three (WR-191, WR-192 and -193) were not outfalls and one (WR-189 and WR-190) may have historically discharged but was no longer active.

Preservative (creosote and pentachlorophenol) wastes/sludges and process waters were discharged into ponds or in-ground disposal areas on the M&B site. Treated logs and wood products were stored on site prior to shipping. Hazardous materials were handled throughout the site. The M&B facility discharged process water directly to the river immediately upstream of the iAOPC. The M&B RI and ROD do not report PCB sampling results, though the ROD (EPA and DEQ 1996) indicates that PCBs were sampled in soil. As a result, the potential for the M&B site to be a PCB source cannot be evaluated at this time.

Upland releases adjacent to iAOPC 13 from the M&B site may have contributed petroleum hydrocarbons (e.g., DRH) and dioxins, which tend to co-occur with

pentachlorophenol use. The potential for release of PCBs from East Parcel riverbank soils to iAOPC 13 is being investigated by DEQ and the Port as part of upland source control activities. Other potential sources include upland and riverbank sources adjacent to the East Parcel, overwater activities, and sediment transport from upriver sources.

11.3.10.3.2 Stormwater/Overland Transport

No stormwater systems (piping, outfalls, or catchbasins) are present in the upland areas adjacent to Willamette Cove. The City of Portland had previously noted five non-City outfalls located along the Willamette Cove shoreline; however, as noted above, the Port of Portland and DEQ research suggests that the three outfalls identified in the area of the iAOPC were not outfalls and that two outfalls downstream of the iAOPC were not active.

The M&B facility is immediately upstream of Willamette Cove. While the facility was in operation, cooling water and contact wastewater was discharged through a wastewater outfall (WR-194), and stormwater was discharged through three outfalls (WR-195, WR-196, and WR-197; see Map 11.3.10-1). Two of the outfalls (WR-194 and WR-195) were permitted under NPDES. Following plant shutdown, DEQ placed earthen berms around stormwater collection sumps at the site to minimize offsite discharge. In 1999, the stormwater outfalls were removed as part of the first phase of the soil remedial action. The soil cap currently in the upland areas of M&B consists of a subsurface drainage system above a high-density polyethylene liner to collect stormwater percolating through the upper soil, rock, and sand layers of the cap. Stormwater is conveyed by gravity flow through conveyance piping to an outfall structure on the Willamette River. A drainage swale that conveys stormwater to an onsite retention/infiltration pond was also constructed to minimize stormwater runoff from the site to adjacent properties and the river.

The riverbanks immediately along these iAOPCs tend to be at a higher elevation than the adjacent uplands. These uplands also tend to be unpaved, unoccupied by buildings or structures, and heavily vegetated. In addition, soils in these areas are fairly permeable, such that rain water infiltrates into the ground, even under extreme rainfall conditions. Because of these characteristics, overland flow of stormwater to the iAOPC does not appear to occur.

11.3.10.3.3 Overwater Discharge

Overwater activities do not take place in Willamette Cove at present; however, historical activities included log storage and operation of dry docks for ship repair and maintenance. Logs were transported into the cove for use by the upland plywood manufacturing and cooperage (barrel making) operations. From the early 1900s through 1953, St. Johns Dry Docks operated an in-water facility adjacent to the Central Parcel. This facility included three large finger piers and docks, which surrounded two large moored dry docks. There are no reported or documented overwater spills of hazardous substances associated with these historical activities. However, based on studies of WWII-era shipyards conducted by U.S. EPA (1997c), discharges of

hazardous substances to the surface waters and sediments were likely to have included, among others, lead, zinc, copper, chromium, mercury and other heavy metals, grease and oil, abrasives, solvents, cutting fluids, organic compounds, organotins (shipyard activities at Willamette Cove likely predate extensive use of organotins), resins, cyanide, and used paints.

Typical waste streams associated with these processes included air emissions, wastewater, residual wastes, sanitary sewer wastes, and stormwater runoff. Fueling or overwater transfer of hydraulic oils or lubricants was also common and may have resulted in occasional spills. PCBs have been documented in many ship components (e.g., Pape 2004), including paints, rubber products, electrical cable insulation, bulkhead insulation, ventilation gaskets, and lubricants.

Overwater activities at the M&B site, immediately upstream of the iAOPC, included transfer of creosote from barges to the facility via a pipeline. Although spills have been noted at the site, no information about volumes or specific locations was available. Historical overwater activities at M&B likely contributed petroleum hydrocarbons (e.g., DRH) and possibly mercury to iAOPC sediment contamination.

11.3.10.3.4 Groundwater Discharge

The southern portion of the iAOPC within Willamette Cove has been affected by a contaminated groundwater plume containing SVOCs, including PAHs and NAPLs, emanating from the M&B site. This plume is known to extend from a disposal site in the northern part of the M&B site, under the railroad bridge, and into the southern cove shoreline. Prior to construction of the upland subsurface slurry wall and in-water cap in 2003/2004, visible sheens were often observed at the low water line along the southern cove shoreline. The cap currently covers about 24 percent of the iAOPC surface and extends into the southern cove shoreline.

Sheen was also noted during an additional M&B remedial action that involved removal of pilings in Willamette Cove prior to cap placement in July 2004. Subsequently, mobile product found in sediment/soils landward of the water line was excavated as part of an additional response action.

Groundwater samples were obtained from subsurface explorations (i.e., borings and probes) during investigations completed in the upland parcels surrounding Willamette Cove. Low concentrations of dissolved metals, PAHs, DRH, and VOCs have been detected in groundwater sampled from four monitoring events, primarily in the wells from the western portion of the site (not adjacent to the iAOPC). There do not appear to be any groundwater plumes associated with the Willamette Cove parcels, based on the sporadic nature of the chemical detections; however, additional groundwater monitoring is planned. Groundwater contribution to the Willamette Cove iAOPC from the upland parcels is considered unlikely; however, DRH is present in groundwater and other upland and in-water media.

Groundwater transport from the M&B site was likely a significant source of petroleum hydrocarbons, dioxins, and possibly mercury to the iAOPC, and may continue to be a source given the residual contamination in groundwater downgradient of remedial actions at the M&B site.

11.3.10.3.5 Riverbank Erosion

The riverbank is generally steeply sloped down to the river, with the exception of the head of the cove where there is a sandy beach and more natural shoreline (Map 4.6-1). Fill material was placed on a strip of lowland adjacent to the bluff and outward into the Willamette River prior to and concurrent with facility development (completed by 1930). Riprap is present along most of the riverbank adjacent to the Central Parcel and the upstream end of the East Parcel. Trails transect the banks in a few localized areas that do not contain riprap; riverbank erosion transport is possible in these areas.

Bank and beach soils/sediments were analyzed at Willamette Cove for TPH, PAHs, PCBs, and metals during the remedial investigation and subsequent sampling events. TPH was detected in several samples, two of which were collected from a NAPL seep area associated with the M&B site, which was subsequently capped. PAHs (particularly high molecular weight PAHs) and PCBs (as Aroclor 1260) were detected in bank samples from the East Parcel. The evaluation of PCB distribution in a bank area with erosion potential is currently planned. Arsenic, chromium, copper, lead, nickel, and zinc were detected in all bank samples analyzed for metals, while other metals (including mercury) were detected less frequently in this matrix.

Riverbank erosion appears to be one of several pathways that may have contributed iCOCs to in-water contamination given that the highest concentrations of PCBs, dioxins, and petroleum hydrocarbons were detected in surface sediment samples adjacent to the beach at the head of the cove. However, the relative contribution of these potential upland erosion sources is likely to be low in comparison to potential upstream sources like the M&B site.

11.3.10.4 Relationship of Upland Sources to the Distribution of iCOCs

Based on the detection and in-water distribution of iCOCs and the evaluation of historical chemical sources/pathways presented above, there is evidence of links between upland sources and iCOCs in sediment, biota, and surface water in iAOPC 13.

Sediment quality in iAOPC 13 has likely been affected by historical wood-treating, timber products manufacturing, and shipyard activities in and adjacent to Willamette Cove. Releases associated with historical wood-treating, wood products manufacturing, and shipyard activities appear to be sources of petroleum hydrocarbons (e.g., DRH), dioxins, mercury, and possibly PCBs. Wood preservation and waste disposal activities occurred at the former M&B site, ship repair and maintenance occurred in and adjacent to Willamette Cove, and plywood and wood products manufacturing occurred on the uplands. Some plant soils adjacent to the iAOPC exhibit detections of TPH, PAHs and metals. DRH and RRH are major contaminants at the M&B site. The highest

concentrations of DRH and RRH were detected in surface sediments collected near the head of the Willamette Cove, just downriver from M&B.

When M&B was operational, creosote and pentachlorophenol wastes/sludges and process waters were discharged into ponds or in-ground disposal areas and NAPL migration in groundwater has been documented. Groundwater transport was likely a significant historical source of petroleum hydrocarbons, dioxins (associated with wood preservatives), and possibly mercury to the iAOPC, and may continue to be a source given the residual contamination in groundwater downgradient of remedial actions at the M&B site. Dioxins and furans (represented as TEQs) in surface sediment exhibit their highest concentrations near the head of the cove.

Riverbank erosion and historical overland runoff are additional potential pathways for the movement of iCOCs to the river. For example, elevated mercury and PCB concentrations were detected in bank soils/sediments.

The extensive overwater dry dock and pier structures that existed in Willamette Cove for the first half of the twentieth century were potential sources of metals (e.g., mercury) and organic compounds (e.g., hydrocarbons) to surface water and sediments. Although overwater spills of hazardous substances have not been documented, discharges of hazardous substances likely occurred. PCBs are also likely COIs related to historical ship building and repair and PCBs were present in subsurface sediment. However, there also appears to be an additional, potentially recent source of PCBs based on the higher concentrations in surface sediment than subsurface sediments in Willamette Cove, which is inconsistent with historical operations. In addition, PCBs were measured in field-collected clams and sculpin and laboratory-exposed worms at some of the highest observed in the river for fish and invertebrate tissue, which is consistent with elevated concentrations in surface, biologically active sediments. Conversely, mercury was present in higher concentrations in subsurface sediments, suggesting releases associated with historical activities.

No stormwater collection system currently discharges to iAOPC 13, but historical stormwater (and overland runoff) may have been a pathway for iCOCs. Stormwater outfalls at Willamette Cove, shown on Map 11.3.10-1 have been inactive for some time (or in some cases were misidentified as outfalls). However, given the proximity of elevated PCB concentrations along the East Parcel shoreline, historical discharges cannot be excluded as a potential source. While the M&B facility was in operation, cooling water and contact wastewater were discharged through several outfalls (WR-194, WR-195, WR-196, and WR-197) just upstream of the iAOPC; these were likely sources of the iCOCs associated with the wood-treating operations. The relative contribution of historical stormwater is not known.

The contribution of sediment transport from upstream and other far-field sources to contamination in surface sediment in iAOPC 13 is unknown but represents a potential pathway. In the absence of anthropogenic disturbance, sediments within the cove are

likely stable over time and contaminants may accumulate there. This is not likely the case for iAOPC 12, which is in the more dynamic channel setting.

A source for DDT in iAOPC 13 is not apparent based on the available information. The highest concentrations of DDT were measured in subsurface sediments suggesting the presence of historical sources. However, there is no information about upland use or releases and this iCOC was not detected in upland soils or groundwater. This suggests that sediment transport from historical far-field sources or possible overwater activities have been pathways for subsurface DDT contamination.

Finally, the low frequency of sampling at iAOPC 12 and distance from upland areas precludes a detailed evaluation of potential PCB sources to that iAOPC.

A preliminary evaluation of the relationship between sources, pathways, and iCOCs in iAOPC 13 is summarized in Figure 11.3.10-1. A preliminary assessment of the current and historical relative contributions of each source for iAOPC 13 is summarized in Table 11.3.10-3.

11.3.11 CSM for iAOPC 14

This section provides the preliminary CSM for iAOPC 14, a 40.78-acre area located along the western shore of the river from RM 6.7 to 7.5 (Map 11.3.11-1a,b). It extends from the upstream end of the Arkema property downstream under the railroad bridge at RM 6.9, and includes the area adjacent to the upper one-third of the Siltronic property. This CSM examines the physical setting of the iAOPC and adjacent upland properties, the distribution of iCOCs and potential iCOCs based on TZW in in-water media, and potential sources of the iCOCs and potential iCOCs based on TZW.

The following iCOCs have been identified for iAOPC 14:

- Total PCB Aroclors
- PCB TEQ
- Dioxin
- Sum DDD
- Sum DDT
- Aldrin.

Potential iCOCs for iAOPC 14 include:

- Sulfide
- Arsenic
- Mercury

- Silver
- beta-HCH
- delta-HCH
- Sum DDD
- Sum DDE
- Sum DDT
- DBP.

These potential iCOCs are identified through less certain and/or less rigorous evaluations based on fewer lines of evidence, FPM results, or other high uncertainty lines of evidence (see Sections 8 and 9).

Map 10.5-3a–j shows the areas where this preliminary analysis identified the potential for risk for individual exposure scenarios that were considered in iAOPC development, and Table 10.5-1 identifies the iCOCs associated with the exposure scenarios. PCBs, DDT, and to a lesser extent dioxins, primarily define the risk areas.

The risk evaluations presented in Sections 8 and 9 of this report also identified potential iCOCs based on TZW for human health drinking water and shellfish consumption scenarios, and for ecological risk to the benthic community (Table 11.1-1). DDx pesticides, chloroform, and TCE were detected at concentrations that contributed to their identification as potential iCOCs based on TZW in or near iAOPC 14. For the reasons discussed in Section 10, however, iPRGs have not been established for potential iCOCs based on TZW at this stage in the RI/FS process, and potential areas of risk associated with TZW did not influence the delineation of iAOPCs. TZW sampling locations within and/or near iAOPC 14 where chemicals in TZW were detected at concentrations that led to their identification as potential iCOCs based on TZW are discussed further below. Potential uncertainties in iAOPC delineation associated with potential iCOCs based on TZW are discussed in Section 10.

The CSM evaluation may be summarized as follows: Industrial and stormwater outfall discharges, which function as both historical and current pathways to the river, appear to be substantial contributors of iCOCs to in-water media at iAOPC 14. Current outfall discharges are likely to be substantially less than historical discharges. The distribution of iCOCs in sediments is also consistent with localized erosion of contaminated riverbank fill materials. Upland groundwater plumes also appear to be a source of some iCOCs and/or potential iCOCs based on TZW to sediments and surface water, although groundwater loading has likely decreased as a result of interim groundwater remedial actions at upland sites. Overwater activities are not anticipated to be a current source of iCOCs to the river; however, these activities may have been a source of iCOCs in the past. Sediment transport processes have likely spread iCOCs from their sources downstream to other locations within the iAOPC and beyond.

11.3.11.1 Physical Setting, Infrastructure, and Operational History

In-river and upland physical characteristics, infrastructure, and operational history relevant to iAOPC 14 are described in this subsection. Information on adjacent upland sites was obtained from the LWG site summaries (Integral and GSI 2004; 2005a,b,c) and updates (Integral 2007) unless otherwise noted.

11.3.11.1.1 In-River

iAOPC 14 is located in a river reach that narrows in the downstream direction. The iAOPC area upstream of the railroad bridge (RM 6.9) is located at the downstream end of Upper Study Area 1, described in Section 4.5.1 as depositional with low to moderate bottom shear stresses and fine-grained sediments; these characteristics appear to be a function of the relatively wide cross-sectional area in this reach. The river narrows as it approaches RM 7 and the channel transitions into a more dynamic regime. The time-series bathymetry measurements (January 2002 to February 2004) show that between the navigational channel boundary and the shoreline of the adjacent Arkema facility, net sediment accretion on the order of 1 ft occurs in the majority of the upstream portion of the iAOPC (around and downstream of the farthest upstream pier), with net erosion predominant downstream of this area. The offshore iAOPC area in the main channel generally showed no elevation change or slight erosion over the 2-year observation period.

Downstream of the railroad bridge off the Siltronic facility, portions of iAOPC 14 lie at the upstream end of the higher-energy Middle Study Area, which is described in Section 4.5.1 as having a sediment transport/dynamic equilibrium regime. The riverbed drops more sharply to channel depth in this area than farther upstream off Arkema, and the time-series bathymetric change data from January 2002 through February 2004 show areas of no change and of sediment scour (to about 1 ft in extent) between 0 and -30 ft NAVD88. Little or no riverbed elevation change is evident nearshore above 0 ft NAVD88. The downstream portion of the iAOPC in the main channel shows areas of net sediment erosion on the order of 0.5 to 1 ft in extent interspersed with areas of no change.

The majority of the surface sediment deposits in the upstream portion of the iAOPC, offshore of the Arkema site consist of silt or sandy silt (Map 11.3.11-2a). An area dominated by sand or by sand with silt occurs adjacent to the beach area under the BNSF railroad bridge. The dominant surface sediment at the downstream end of the iAOPC near the Siltronic shoreline is also sand. Silts dominate the subsurface sediment cores from the upstream portion of the iAOPC, although there appears to be a transition to silty sands and sands with depth (Maps 11.3.11-2b,c). Sands are generally dominant in the subsurface cores intervals from the iAOPC downstream of RM 7. Silt beds of variable thickness interspersed in these sands are evident in some cores, particularly those collected downstream of the railroad bridge.

During the LWG Round 2 groundwater discharge mapping Geoprobe™ investigation (Integral 2004c) and the Arkema Phase II in-river investigations (Integral 2003), the

contact between the alluvial deposits and the coarse basaltic gravel marking the erosional surface of the Columbia River Basalt basal unit was observed at approximately -20 ft MSL adjacent to the western shoreline from RM 6.6 to 7.4. A fault zone, which crosses the shoreline in the vicinity of the railroad bridge, offsets the alluvium/basalt contact downward in the northern portion of iAOPC 14. The alluvium/basalt contact is reported to be at least -200 ft MSL offshore from the Siltronic site at approximately RM 6.4 – 6.5.

The bank in the vicinity of Arkema is partial river beach and steep slopes covered with bank stabilization material that includes large chunks of concrete, asphalt, and other impervious material. During site improvements in the 1970s, the riverbank adjacent to the Siltronic site was armored with riprap, and erosion where these bank reinforcement measures are intact is expected to be minimal. In 1998, Siltronic repaired a portion of the bank that had been damaged during the 1996 flood and added geotextile fabric and additional riprap. The beach area that separates the Arkema and Siltronic sites at RM 6.8 – 6.9 is the pathway for intermittent historical drainage from the former area of Doane Lake (now filled, and described below) to the river.

Significant in-water facilities and structures within the iAOPC (Map 11.3.11-1a,b) include the following:

- Three loading docks along the upstream portion of the Arkema shoreline, from upstream to downstream referred to as the Salt Dock, Dock 1 and Dock 2
- Footings for the BNSF railroad bridge at RM 6.8 – 6.9
- Piling remnants close to shore adjacent to the northern Arkema lots at RM 6.9 – 7.1
- A major City of Portland sewer line crossing the river at RM 6.9
- Two City of Portland stormwater outfalls (Outfall 22B and Outfall 22C)
- Eleven private stormwater and/or wastewater outfalls (WR-6, WR-95 through WR-101, WR-287, WR-290, WR-362)
- Front Avenue culvert; ownership unknown (WR-213).

Primary in-water site uses for the in-river structures are described in the following upland site summary section.

11.3.11.1.2 Upland

Upland sites adjacent to the iAOPC include Arkema, Siltronic, and BNRR. Other sites not adjacent to the LWR that lie within the drainage basins of municipal and private outfalls that discharge into iAOPC 14 include Rhone Poulenc, Schnitzer-Doane Lake (Air Liquide), Gould Industries, Santa Fe Pacific Pipelines, Koppers Industries, Inc., and Metro Central Transfer Station. All of these properties are zoned industrial. Other

properties outside and upland of this industrial zone that lie within the stormwater pipesheds draining into iAOPC 14 are zoned as parks/open space.

The upland area west of the Arkema and Siltronic properties was once predominated by small shallow lakes, including Doane Lake, which was interconnected to other small lakes through sloughs. In 1908, the Astoria and Columbia River Railroad constructed a double-track railroad bridge across Doane Lake, splitting it into two remnant lakes: Doane Lake and North Doane Lake. North Doane Lake now occupies the large triangular area between the railroad tracks that leads to the railroad bridge. Doane Lake was partially filled as industrial development in the area occurred in the early and mid-1900s. As a result of this filling, Doane Lake was gradually reduced to two remnants: East Doane Lake on and adjacent to the Gould, Schnitzer Investment Corporation, and American Steel Industries properties; and West Doane Lake, adjacent to the BNSF Railroad, Rhone-Poulenc, Inc., Gould, and Esco, Inc. properties. East and West Doane lakes were filled from all shorelines (except the shoreline along the raised railroad berm to the north) from the mid-1950s until the mid-1970s. In 1998, East Doane Lake was completely filled in during remediation of the Gould NPL site. West Doane Lake assumed its present-day configuration in the mid-1970s.

AMEC (2004) indicates the former Doane Lake and current West Doane Lake periodically discharged surface water to the Willamette River through a historical drainage ditch during severe storm events. Potential discharge from Doane Lake to the river was eliminated by construction of a berm in 1980 at the north end of West Doane Lake. According to the City of Portland (GSI 2006), the drainage ditch may have discharged to outfall WR-213 prior to 1980. When the municipal storm system was built in 1980, drainage from the lake may have entered the system until the Gould site completed remediation.

Operational History and Infrastructure

Arkema (ECSI #398)

Arkema, a chemicals manufacturer, ceased operations in 2001. Nearly all of the infrastructure associated with the manufacturing processes have been decommissioned and removed. Demolition was carried out in three phases. During Phase I, steel structures and tanks were removed. During Phase II, buildings on Lot 3 and the northern portion of Lot 4 were demolished. During Phase III, completed in 2004, remaining structures were removed. While operational, the facility engaged in a range of activities:

- The plant began producing sodium chlorate and potassium chlorate in 1941 in the Sodium Chlorate Area. Chlorate was produced by the electrolysis of sodium chloride solution, with sodium bichromate added to inhibit corrosion and improve electrical efficiencies. Chlorate solutions were shipped from the facility by truck or barge (Dock 2). Potassium chlorate manufacturing, a process similar to that of sodium chlorate, ended in 1978.

- Chlor-alkali operations started at the plant in 1946 to produce chlorine, sodium hydroxide, and hydrogen gas. Asbestos, used as a diaphragm in electrolytic cells, was buried in trenches on Lot 1 during the 1970s and 1980s. The trenches were excavated and the buried asbestos removed with DEQ oversight in 1992.
- The pesticide dichlorodiphenyltrichloroethane (DDT) was manufactured at the facility from 1947 to 1954. Chemical base stocks used in the DDT manufacturing process included monochlorobenzene (MCB, or chlorobenzene), chloral, and sulfuric acid.
- From 1958 to 1962, after DDT manufacturing ceased, ammonium perchlorate operations were conducted in the former DDT process building. During this period, sodium perchlorate was produced inside the chlorate cell-room and then transferred to the Acid Plant Area, the name assigned to the general area where DDT had been manufactured when hydrochloric acid production began. At the Acid Plant Area, the sodium perchlorate was converted to ammonium perchlorate by using ammonium chloride to form a solid material sold to produce propellants for guided missiles. The production of sodium perchlorate and ammonium perchlorate ceased in 1962.
- Hydrochloric acid production began in 1966 at the Acid Plant. Chlorine and hydrogen were burned together in aboveground towers to form hydrogen chloride vapor, which was then absorbed in water to form hydrochloric acid. This production ceased in 2001.

The Bonneville Power Administration (BPA) owned and operated an electrical substation on Arkema property for several decades (Integral 2006q). The main substation and a substation annex to the north, both located adjacent to N.W. Front Avenue, occupied a total area of 1.28 acres. The substation was decommissioned and the associated equipment was removed from the property in 2002. Thirteen transformers and five oil-filled power circuit breakers were located in the main substation, and one transformer was located in the substation annex. At least some of these transformers and circuit breakers contained PCBs (Integral 2006q).

Siltronic (ECSI #183)

Siltronic manufactures silicon wafers from silicon crystal ingots. Currently, all ingots are shipped to the facility from other locations. Buildings at the property include two manufacturing fabrication buildings, facilities support for pure water, boilers and chillers, utility support for air compressors and emergency generators, a warehouse, wastewater treatment facilities, and administrative offices. Chemicals in use include inorganic acids and caustic solutions for polishing and cleaning, and gases for epitaxy including hydrogen chloride, hydrogen, and nitrogen. All chemical products are stored under cover in secondary containment systems with leak detection systems monitored 24 hours per day.

The property was used for different purposes historically:

- Prior to 1900, the property was essentially undisturbed lowlands, including part of Doane Lake and a creek.
- In the 1930s, Western Transportation built a tug refueling dock at the eastern corner of the property (just downstream of the railroad bridge); it ceased operating sometime between 1940 and 1955.
- Pacific Gas & Coke Company (PG&C) excavated and maintained multiple manufactured gas plant (MGP) waste disposal areas in the northwestern quadrant of the property from about 1940 through 1967, among them a waste effluent pond on the Siltronic/Gasco property boundary, an 11-acre waste disposal lagoon, a small waste disposal pit, and a spent oxide/lampblack disposal pile. Following cessation of MGP operations, the lagoon was filled and MGP waste was spread across most of the property later purchased by Siltronic.
- Between 1968 and 1977, the site was covered with fill up to 30 ft thick in places. The fill consisted of former MGP process wastes, dredged material from the Willamette River, quarry rock, and, potentially, materials and wastes from other onsite and offsite sources.
- The southern portion of the site had been mostly undeveloped until filled to about 30 ft above MSL (current grade) between 1971 and 1977. The fill included quarry rock, Willamette River dredge spoils and MGP waste from the PG&C facility.
- After the filling activities described above, the site was vacant and unused until 1978, when Siltronic purchased it for the purpose of constructing the wafer fabrication plant.

Six ECSI sites are not associated with land immediately adjacent to the river, but lie within the drainage basins of municipal and private outfalls that discharge into iAOPC 14. Historically, some of these ECSI sites also may have had direct surface water connections to the river and the iAOPC:

- **Rhone Poulenc (ECSI #155):** This former pesticide manufacturing facility is located approximately 2,000 ft from the river, between the Arkema site and NW St. Helens Road to the southeast. At present, treated groundwater and stormwater for the site discharges to the Willamette River under NPDES-IW-B15 permit via outfall WR-6.

  Although most of the manufacturing and plant buildings have been removed, six structures remain: the waste storage facility, the maintenance building, the office/warehouse building, the water treatment plant, the office trailer, and the electrical controls compound. In addition, a construction trailer and an intermodal transportation container used for storage remain onsite.

The former Rhone Poulenc facility manufactured herbicides and formulated insecticides during its operational years of 1943 to 1990. Products were stored in aboveground and underground tanks or other areas. The historical activities are listed below:

- Early production included railroad right-of-way treatments, fertilizers, inorganic pesticide formulations, and sodium arsenite liquids
- Early 1950s: added formulation of organochlorine insecticides and chlorophenoxy herbicides
- 1956: added manufacture of 2,4-dichlorophenoxyacetic (2,4-D) acid/esters
- 1960: added manufacture of 4-chloro-2-methylphenoxyacetic acid (MCPA) acid/esters and 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) esters from purchased 2,4,5-T
- 1964: added manufacture of 4-(2,4-dichlorophenoxy)butyric (2,4-DB) acid/esters
- 1969: discontinued formulation of all insecticides
- 1971: added manufacture of bromoxynil products
- 1976: discontinued production of MCPA
- 1980: discontinued production of chlorophenoxy herbicides
- 1990: discontinued production of all products.

- **Schnitzer - Doane Lake (Air Liquide) (ECSI #395):** This facility is located approximately 1,320 ft from the river, between the Arkema site and the Rhone Poulenc facility to the southeast. At present, the paved portion of the site discharges stormwater to the Willamette River under a 1200-Z permit via Outfall 22B.

  Air Liquide America Corporation leases the property from Schnitzer Investment Corporation to manufacture acetylene gas. Historical activities at the site are noted below:

  - Air Liquide has manufactured acetylene gas since the early 1940s.
  - Calcium hydroxide, a byproduct was discharged into East Doane Lake until 1981.
  - The site stormwater was discharged to East Doane Lake until 2000, when a portion of the site was rerouted to Outfall 22B.
  - Until 1969, Schnitzer Steel Industries used a portion of the property to dispose of auto bodies and nonmagnetic auto shredder waste (e.g., glass, plastic, rubber, oil and sludges, paints)

- **Gould Industries (ECSI #49):** The Gould Site is located approximately 1,500 ft from the river, between the Arkema site and the Rhone Poulenc facility to the southeast. Remediation of the Soils Operable Unit at the Gould NPL Site was completed in August 2000 and includes an onsite containment facility (or landfill). Historically, wastewater and stormwater from the Gould Site was discharged to Doane Lake, which discharged periodically during storm events to the Willamette River via a drainage where outfall WR-213 is now located. In the early 1970s when filling divided Doane Lake into East Doane Lake and West Doane Lake, Gould site discharges to East Doane Lake. Although the site has never obtained a permit to connect to the City's system, East Doane Lake overflowed into a city catch basin when the lake elevation was high after the system was built in 1980. A connection from the site's french drain was made to the city system when the landfill cap was constructed. Leachate from the landfill is collected and treated by Rhone Poulenc and discharged through outfall WR-6. The stormwater collection system for the Gould Site cap discharges to the storm sewer along Front Avenue. Operations on this site ceased in 1981. It is currently fenced, with treated and stabilized soils and sediments in an onsite containment facility within the fenced area.
  - In the 1940s, the area of the current Gould property was formed by gradual anthropogenic filling of Doane Lake, using a wide range of materials: hydraulic dredge fill from the Willamette River, quarry rock, construction debris, foundry sand, steel mill slag, construction debris, and industrial waste materials from Gould and adjacent site operations (e.g., battery casing fragments, blast furnace matte, shredded automobile interiors, and alkaline acetylene waste).
  - A secondary lead smelter built on the property operated from 1949 to 1972 under the ownership of Morris P. Kirk and Sons, a subsidiary of NL Industries, Inc. Activities included lead-acid battery recycling, lead smelting and refining, zinc alloying and casting, cable sweating (removal of lead sheathing from copper cable), and lead oxide production (after 1965).
  - Prior to 1976, the facility had disposed of waste battery acid in Doane Lake. In 1976, the facility began treating the waste acid and discharged it to the City of Portland sanitary sewer system.
  - After purchasing the property in January 1979, Gould stopped receiving lead-acid batteries in October, but continued to process the large existing battery stockpile. Lead refining operations were discontinued in January 1980, battery-breaking operations were discontinued on April 1, 1981, lead oxide production was halted in May 1981, and the facility closed entirely in August 1981. By the summer of 1982, most facilities, structures, and equipment had been removed from the property.
  - Stormwater from the majority of the site and parts of adjacent properties was also directed to East Doane Lake.

- **Santa Fe Pacific Pipelines (ECSI #2104):** The Santa Fe Pacific Pipelines (SFPP) Portland Station is a booster facility for SFPP's fuel product pipeline. The facility consists of various pumps, pipe manifolds, valving equipment and a relief tank located within a containment area, and an office. A drainage ditch located adjacent to this site drains into North Doane Lake and then into Outfall 22C. Santa Fe Pacific Pipeline Co. was issued a 1500-A NPDES permit to discharge water associated with a tank cleanup. According to the DEQ ECSI database, this site had gasoline and diesel spills in 1991 and 1994 that affected the onsite and offsite soil and groundwater.

- **Koppers Industries, Inc. (ECSI #2348):** The southern portion of the Gasco site is leased by Koppers Industries, Inc. for use as a coal tar pitch distribution facility. From 1965 to 1973, Koppers used their lease area for coal tar formulation, storage, and distribution, and from 1973 to 1977, for electrode grade pitch manufacture and distribution.

  Stormwater within the Koppers' pitch handling areas feeds into the Koppers' tank farm area where it is collected by a concrete collection sump. The runoff is then pumped to storage tanks, where the water is sampled prior to batch discharge in accordance with Koppers' permit requirements. The batch discharge, as well as surface water runoff from two catch basins located in non-process areas of the Koppers area, is discharged through Koppers' NPDES-permitted outfall, which drains to an open ditch located at the southern corner of the property. This ditch (Doane Creek) ultimately leads to Outfall 22C.

- **Metro Central Transfer Station (ECSI #1398):** A succession of steel companies has operated a warehouse on the site at N.W. 61st Avenue since at least 1924. In 1989, the warehouse was converted into a solid waste transfer station for Metro.

11.3.11.1.3 Upland Hydrogeology

A brief summary of upland hydrogeologic conditions at the Arkema, Rhone Poulenc, and Siltronic sites is provided in the following paragraphs. Further details are provided in the site summary reports for Arkema and Rhone Poulenc (Integral 2007).

Groundwater at the Arkema site occurs in fill materials and four distinct groundwater zones: shallow unconfined alluvial aquifer, intermediate confined alluvial aquifer, deep confined alluvial aquifer, and basalt bedrock aquifer. The silts separating the groundwater zones (aquitards) vary in thickness across the site from approximately several inches to 5 ft. The distinct groundwater zones have been observed across the entire site, with the exception of the southeastern portion of the site. In that area, downgradient of the Chlorate Plant Area, the silt aquitards tend to become discontinuous, and the shallow and intermediate groundwater zones tend to coalesce. In general, the depth to groundwater increases from west to east across the property (from Front Avenue toward the Willamette River). On the upland portion of the site, vertical hydraulic gradients between groundwater zones are primarily downward, with

occasional upward gradients observed for well pairs near the Willamette River. Recharge to shallow groundwater at the site likely occurs from precipitation that infiltrates to the west of the site. Offshore, a thin layer of sand extends from the riverbank to about 0 to -5 ft MSL. Around and beyond the docks, surface deposits consist of silts and sandy silts. Silt is also present in the surface of most LWG Round 2A sediment cores, although sand dominates from below 2.5 to 4.5 ft bgs and is likely analogous to and an extension of the upland sands and silty sands. The sands and silty sand layer beneath the silt appears to daylight in the river near the shoreline behind the docks, and at the elevation of the bottom of the shipping channel.

Groundwater at the Rhone Poulenc site occurs in three hydrogeologic zones: the fill/shallow alluvium zone, the alluvium zone, and the basalt zone. In the alluvium and basalt zones, groundwater flows from south to north (i.e., from the Tualatin Mountains toward the river). The fill/shallow alluvium zone is characterized by a complex flow regime with a groundwater divide that strikes approximately north-south through the Lake Area. West of the divide, groundwater flows toward West Doane Lake. East of the divide, groundwater flows toward the river. The gravel zone at the base of the alluvium may act as a preferential pathway, sloping north-northeast toward the river (and possibly below the bottom of the channel) and north-northwest toward the Siltronic site at depths below the bottom of the channel. Shallow groundwater potentially discharges to a city storm sewer via leaks in the sewer pipe and subsequent discharge to the river via Outfall 22B. Stormwater Outfalls 22B and 22C are located near the BNSF railroad bridge that crosses the Willamette River (Map 11.3.9-1). The Rhone Poulenc property does not have any direct connections to the storm sewer systems associated with Outfalls 22B or 22C; however, the storm sewer associated with Outfall 22B was subject to infiltration of groundwater impacted with Rhone Poulenc-related constituents, as well as constituents related to other nearby sites. In 2006, SLLI initiated an interim source control action to eliminate infiltration of groundwater along the storm sewer associated with Outfall 22B.

The hydrogeology of the Siltronic site includes the following four units: fill, upper-fine-grained (silt), lower alluvial water-bearing zone, and Columbia River Basalt. The fill and upper fine-grained unit correspond to the fill/shallow alluvium zone at Rhone Poulenc. As described above, the contact between the alluvial water-bearing zone and the Columbia River Basalt occurs at much greater depth at Siltronic—approximately 100 ft bgs upland from the river and dipping to about 205 ft bgs near the riverbank—than at Arkema because of significant downward offset along a fault zone in the vicinity of the railroad bridge.

11.3.11.2 Chemical Distribution of iCOCs and Potential iCOCs based on Transition Zone Water

This section describes the distribution of iCOCs and potential iCOCs in environmental media at iAOPC 14. For the purposes of evaluating sources to iAOPC 14, the discussion of iCOCs in the river is limited to total PCBs, arsenic, sum DDD, delta-HCH, DBP, and dioxin TEQ. Potential iCOCs based on TZW relevant to iAOPC 14 are

DDx pesticides, chloroform, and TCE. All iCOC data for the iAOPC can be found in Appendix I.

11.3.11.2.1 Sediments

Sediment data for iAOPC 14 are available for 94 surface samples (including beach samples) and 54 subsurface cores (122 subsurface core intervals analyzed). Sampling locations are shown in Map 11.3.11-1a,b, and summary statistics of the results are listed in Table 11.3.11-1a.

PCBs

PCBs were detected in 27 of 50 surface sediment samples analyzed for Aroclors (Map 11.3.11-3); PCB congeners were detected in all 21 samples analyzed for congeners (Map 11.3.11-4). Detected concentrations of total Aroclors in surface sediment ranged from 2.27 to 322 µg/kg, with a mean value of 80.8 µg/kg. Total PCB congeners in the 21 samples analyzed ranged from 2.41 to 972 µg/kg. The highest detected surface sediment PCB Aroclor concentrations (i.e., greater than 75µg/kg) were located adjacent to the Siltronic property downstream of the railroad bridge between the shoreline and the navigation channel, and inshore of and just offshore of the Arkema docks. The spatial coverage of congener surface data is not as widespread but the distribution is similar to the Aroclors. Relatively high total PCB congener concentrations (greater than 75 µg/kg) are evident around Arkema Docks 1 and 2, near outfall WR-6, near the outer iAOPC boundary just upstream of the railroad bridge, and inshore and downstream of the bridge off Siltronic. For several samples in which PCB Aroclors were reported as undetected, the detection limits were very high, suggesting potential analytical interferences from other organic compounds.

PCBs Aroclors were detected in 30 of the 67 subsurface samples analyzed, and congeners were detected in the entire subset of three samples also analyzed for congeners. Detected total Aroclor concentrations in subsurface samples ranged from 11.9 to 1,180 µg/kg (Map 11.3.11-5a,b). Total PCB congeners concentrations in subsurface sediment ranged from 35.1 to 695 µg/kg (Map 11.3.11-6a,b). Elevated subsurface total Aroclors generally occurred in the same areas as elevated surface levels: near the Arkema docks and downstream of the railroad bridge. Elevated subsurface total Aroclors were also detected at the upstream end of iAOPC 14 (446 T µg/kg in C371, just upstream of the Salt Dock). Overall, detected concentrations were higher in subsurface sediments than at the surface. The highest Aroclor concentrations extended to maximum depths of approximately 6 ft bml. PCBs were generally not detected in the deepest interval analyzed in individual cores, with one notable exception just downstream of the Salt Dock, where the subsurface maximum was measured in the deepest interval at approximately 14 ft bml. Several cores throughout the iAOPC, and in particular downstream of the railroad bridge, showed relatively low PCB concentrations at the surface overlying elevated levels. Similar to the surface sediment samples, PCB Aroclors were reported as undetected in many subsurface sediment samples but at highly elevated detection limits.

The Aroclor composition in surface sediments from iAOPC 14 differs from that in samples collected above RM 7.5 and those collected offshore in the navigation channel (Map 6.1-48a from Section 6). The subsurface samples also show distinct Aroclor patterns (Map 6.1-49a–i). There are insufficient subsurface congener data to discern spatial trends.

Arsenic

Arsenic was detected in 65 of the 79 surface sediment samples within the iAOPC that were analyzed for arsenic (Map 11.3.11-7). Concentrations in surface sediment ranged from 1.55 to 27.7 mg/kg, with a mean of 5.45 mg/kg. The highest arsenic concentrations in surface sediments were located in a cluster of samples at the base of the railroad bridge offshore of Outfalls 22C, 22B, and private outfall WR-213.

Arsenic was detected in 68 of the 73 subsurface samples within the iAOPC that were analyzed for arsenic, with concentrations ranging from 1.28 to 16.5 mg/kg (Map 11.3.11-8a,b). Except for two deep (greater than 6 ft bml) samples, one between the Salt Dock and Dock 1 (10.6 mg/kg) and the other offshore of Siltronic (16.5 mg/kg), all subsurface arsenic concentrations were less than 10 mg/kg; subsurface concentrations were generally lower than surface concentrations. Aside from the exceptions noted above, arsenic concentrations are generally low and spatially uniform throughout the iAOPC.

Delta-HCH

The pesticide delta-HCH was detected in 7 of the 87 surface sediment samples in the iAOPC that were analyzed for it (Map 11.3.11-9); concentrations ranged from 0.153 to 3.7 µg/kg, with a mean of 1.7 µg/kg. The only detected delta-HCH concentrations in surface sediment were located off of outfalls 22B and WR-213, in the area of Arkema docks 1 and 2, and just downstream of the railroad bridge. Detection limits were elevated (e.g., greater than 10 µg/kg and often higher) for samples from most locations scattered throughout the iAOPC upstream of the railroad bridge.

Delta-HCH was not detected in any of the 116 subsurface samples within the iAOPC, although the detection limits were elevated, especially for samples from around the Arkema docks (Map 11.3.11-10a,b).

DDD

Total DDD (2,4' and 4,4' isomers) was detected in 89 of the 91 surface sediment samples within the iAOPC that were analyzed for DDx compounds. Concentrations of DDD in surface sediment ranged from 4.24 to 11,000 µg/kg, with a mean of 460 µg/kg. The surface sediment maxima were located inshore of the Arkema dock faces, just upstream of Dock 1 and between Docks 1 and 2 (Map 11.3.11-11). Surface concentrations decreased sharply with distance offshore and more gradually with distance downstream within and beyond the iAOPC.

Total DDD was detected in 103 of the 116 subsurface samples analyzed. Detected concentrations ranged from 0.093 to 690,000 µg/kg, with a mean of 23,200 µg/kg. The

highest subsurface concentrations of DDD (greater than 10,000 µg/kg) were detected in the vicinity of the Arkema docks (Map 11.3.11-12a,b). Relatively high concentrations (e.g., those exceeding 1,000 µg/kg) were more widespread in subsurface sediments than in surface sediments. DDD concentrations in the subsurface intervals of sediment cores remained relatively similar throughout the core although the deepest intervals generally had the lowest concentrations.

DBP

Dibutyl phthalate was detected in 33 of 88 surface sediment samples that were analyzed for DBP (Map 11.3.11-13). Detected concentrations ranged from 3.7 to 1,000 µg/kg, with a mean value of 122 µg/kg. The highest surface DBP concentrations were upstream of Arkema Dock 1 and inside of the downstream portion of Dock 2. Throughout most of the iAOPC, concentrations were relatively low (or undetected).

DBP was detected in 25 of the 84 subsurface samples analyzed. Detected concentrations ranged from 3.7 to 1,500 µg/kg (Map 11.3.11-14a,b),with the maximum level in a shallow subsurface sample (10-30 cm). Below 30 cm depth, the highest subsurface concentrations were lower than the elevated surface concentrations. The elevated subsurface DBP concentrations are restricted to the area upstream of Dock 1; the remainder of the iAOPC exhibits low or undetected subsurface concentrations. The deepest core intervals either had undetected levels of DBP or had the lowest detected concentrations.

Dioxin TEQ

Dioxins/furans were detected in all 27 surface sediment samples analyzed. Dioxin TEQ levels are shown in Map 11.3.11-15. Detected concentrations of dioxin TEQ in surface sediment ranged from 1.15 to 16,600 pg/g, with a mean value of 671 pg/g. The maximum dioxin TEQ concentration of 16,600 pg/g was measured between Arkema Docks 1 and 2. Other values exceeding 100 pg/g were evident off of and downstream of Arkema Dock 2, and offshore and just upstream of the railroad bridge.

Dioxin TEQ concentrations were detected in 37 of the 39 subsurface samples analyzed, over a range of 0.0012 to 9,680 pg/g, with a mean of 299 pg/g (Map 11.3.11-16a,b). Most of the subsurface dioxin data come from cores collected near the railroad bridge, although the highest subsurface concentration of 9,680 pg/g was located between Docks 1 and 2. Just upstream of the bridge, concentrations were generally higher in the surface sediments than in subsurface intervals, while downstream of the bridge the reverse prevailed. In general, the dioxin TEQ concentrations decreased with depth, and the lowest intervals either had undetected levels of dioxin TEQ or had the lowest detected subsurface concentrations.

11.3.11.2.2 Surface Water

Surface water samples were collected at two locations (Stations W015 and W016) in iAOPC 14 during three Round 2 sampling events (i.e., November 2004, March 2005, and July 2005) (Integral 2006l). Station W015 is located just upstream of the railroad bridge, offshore Outfall 22B, and just downstream of outfall WR-6 (Map 11.3.11-1a,b).

Station W016 is located inshore of the upstream end of Arkema Dock 2. Near-bottom high-volume XAD and standard peristaltic pump samples were collected at these locations at water depths ranging from 0.9 to 2.1 ft for W015, and 7.8 to 9.5 ft for W016.

Peristaltic pump water samples were analyzed for arsenic. XAD filter samples were analyzed for total PCB Aroclors, PCB congeners, dioxins, sum DDD, delta-HCH, and DBP. Summary statistics are provided in Table 11.3.11-1b, with more detailed discussion in Section 6.3.

Arsenic
Arsenic was detected in all seven of the peristaltic samples. Dissolved arsenic concentrations ranged from 0.00033 to 0.00045 mg/L, and total arsenic concentrations ranged from 0.000373 to 0.00052 mg/L.

PCBs
Total PCB Aroclors were detected in all three Round 2 XAD collection events at concentrations ranging from 112 to 604 pg/L for XAD columns (i.e., dissolved fraction), and from 158 to 1,030 pg/L for XAD filters (i.e., particulate fraction > 0.5 µm). Total PCB congeners were also detected in all sampling events at these stations, at concentrations ranging from 137 to 639 pg/L for XAD columns, and 201 to 1,290 pg/L for XAD filters. For both Aroclors and congeners, the highest concentrations were found at Station W015.

Dioxin
Dioxins/furans were detected in all Round 2 XAD sampling events at Station W015; concentrations ranged from 0.373 to 0.528 pg/L in XAD filters and 0.0275 to 0.0404 pg/L in XAD columns. Dioxin/furan analyses were not conducted on samples from Station W016.

DDD
DDD was detected in all the XAD filter and column samples collected during Round 2 XAD sampling events at Stations W015 and W016. Concentrations of total DDDs ranged from 368 to 2,560 pg/L for XAD columns, and 350 to 2,610 pg/L for XAD filters. The highest concentrations were found at Station W015.

Delta-HCH
Delta-HCH was detected in four of six Round 2 XAD column samples, at concentrations ranging from 1.38 to 6.25 pg/L. It was detected in only one of the six XAD filter samples, at a concentration of 0.508 pg/L. The maximum XAD column concentration was measured at Station W015, and the only detection in filtered samples was at Station W016.

DBP
DBP was not detected in any of the seven peristaltic pump samples analyzed, at detection limits that ranged from 0.062 to 0.17 µg/L.

Nor was DBP detected in any of the Round 2 XAD filter samples. In the three of six XAD column samples where it was detected, DBP was measured at 1,690 pg/L to 5,980 pg/L, with the maximum at Station W015.

11.3.11.2.3 Transition Zone Water

Shallow TZW samples (< 38 cm bml) were collected from 29 locations in or near iAOPC 14 during Round 2 Groundwater Pathway Assessment sampling (8 offshore of Rhone Poulenc Site, 10 offshore of the Arkema Acid Plant, and 11 offshore of the Arkema Chlorate Plant).[84] TZW sampling locations are shown on Map 11.3.11-1a,b, and summary statistics of the results are listed in Table 11.3.11-d[85]. TZW samples collected from the Rhone Poulenc study area were analyzed for conventionals, dioxins/furans, herbicides, metals, PAHs, DDx pesticides, and VOCs. TZW samples collected from the Arkema study area were analyzed for conventionals, metals, PAHS, DDx pesticides, and VOCs. DDx pesticides, chloroform, and TCE were identified as potential iCOCs in TZW at iAOPC 14.

DDX Pesticides

Total DDT and total DDD were detected in 5 of 14 and 10 of 14, respectively, shallow (0 to 38 cm bml) TZW samples analyzed for DDx pesticides. Detected concentrations ranged from 0.0078 to 1.89 µg/L for total DDT, and from 0.029 to 2.4 µg/L for total DDD. The maximum respective concentrations of total DDT and total DDD were detected at TZW sampling locations AP03A and AP02D.

Dioxin

Dioxin/furan TEQ was detected at very low concentrations (maximum 2.5 pg/L) in TZW offshore and south of the railroad bridge.

Chloroform

Chloroform was detected in 14 of 37 shallow (0 to 38 cm bml) TZW samples analyzed. Detected concentrations ranged from 0.24 to 770,000 µg/L. The median detected concentration was 13 µg/L, The maximum chloroform concentration was measured at TZW sampling location AP03B.

TCE

TCE was detected in 14 of 37 shallow (0 to 38 cm bml) TZW samples analyzed. Detected concentrations ranged from 0.14 to 2300 µg/L. The median detected concentration was 0.25 µg/L. The maximum TCE concentration was measured at TZW sampling location AP03B.

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[84]Deeper TZW samples, from a target depth of at least 90 cm (up to 150 cm) were collected from nine locations. See Section 6.2 and Integral (2006q) for discussion of deeper TZW sampling results.

[85]Sample counts shown in Table 11.3.11-d are higher because filtered and unfiltered samples were collected from some locations.

11.3.11.2.4 Biota

Fourteen tissue samples have been collected from iAOPC 14 for chemical analysis to measure body burdens of organisms exposed to abiotic media in this area:

- Four samples of field-collected clams
- Two samples of laboratory-exposed clams and mudworms
- One sample of epibenthic organisms (multiplate sampler)
- Four samples of crayfish (whole body)
- Three samples of sculpin (whole body).

Two of the composited field-collected clam samples were collected during Round 1 sampling in 2002 and the other two were collected during Round 2 in 2005. The Round 1 samples were composited from the shallow inshore area at the upstream end of the iAOPC and from the nearshore area between Arkema Docks 1 and 2. The Round 2 samples were composited from transects just off of Dock 2 and just upstream of the railroad bridge; sediments for the clam and mudworm laboratory bioaccumulation tests were composited from roughly the same locations. The epibenthic organism composite was collected from a multiplate sampler deployed in the summer of 2005. Collocated crayfish and sculpin composites were collected from three locations: the upstream end of the Salt Dock, between Docks 1 and 2, and just downstream of the railroad bridge (Windward and Integral 2006).

With the exceptions noted below, most of the iCOCs were detected in most of the invertebrate tissue samples from this iAOPC (see Table 11.3.11-1c for summary statistics). DBP was not detected in any tissue sample; DBP analyses of crayfish, epibenthic, and sculpin samples were not conducted. Beta-HCH was not detected in field or lab clams, aldrin was not detected in crayfish or sculpin, and silver was also not detected in sculpin.

11.3.11.3 Potential Sources of iCOCs

This section summarizes the current understanding of potential sources of iCOCs to iAOPC 14. Unless otherwise noted, information presented in this section was obtained from the LWG site summaries and the Arkema Engineering Evaluation/Cost Analysis (EE/CA) Draft Work Plan (Integral 2006q). In addition to iCOCs, COIs associated with nearby upland areas are also discussed in this section. COIs are presented to provide a comprehensive understanding of the upland issues and to support the identification of potential sources to the iAOPC. The relevance of the pathway to iCOCs is summarized at the end of each pathway discussion. Potential sources, contaminants of interest, and pathways are summarized in Table 11.3.11-2. Upland investigations have been performed on all of the ECSI properties located adjacent to or discharging to this iAOPC.

iAOPC 14 extends from approximately RM 6.7 to RM 7.5. Adjacent upland properties include the entire Arkema facility and a portion of the Siltronic site. Other properties

located in the drainage basin of municipal Outfalls 22B and 22C, which discharge at the base of the railroad bridge, have historical surface water connections to the river, and/or have ongoing groundwater discharges to the river include ECSI sites: Rhone Poulenc, Schnitzer-Doane Lake, Gould, Santa Fe Pacific Pipeline, Koppers Industries, and Metro Central Transfer Station; as well as non-ECSI sites. A small portion of the Arkema site may potentially drain to the Outfall 22B stormwater system. Small portions of the Gasco and Siltronic sites discharge to Outfall 22C. The Siltronic site is discussed in detail in the CSM for iAOPC 11 (Section 11.3.9).

11.3.11.3.1 Upland Releases

Potential sources of contamination from current and historical operations within iAOPC 14 can be roughly categorized as contaminated fill material (e.g., Doane Lake), historical site operations, historical spills, contaminated surface soils and groundwater, overwater activities, and stormwater drainage. Potential sources specific to each of the facilities are summarized below.

Arkema

As discussed in the Arkema EE/CA Work Plan (Integral 2006q), primary potential sources of COIs include former stormwater outfalls, a former manufacturing process residue (MPR) pond and trench, a former DDT process building, a former DDT disposal trench in Lot 1, former sodium chlorate manufacturing, historical spills, and contaminated fill material. COIs at the Arkema site associated with MPR, include DDT, its metabolites DDD and DDE, chlorobenzene. Additional COIs include chloride, perchlorate, hexavalent chromium, PAHs, PCBs, pesticides, SVOCs, and VOCs. Pesticides other than DDT were not manufactured or handled on the Arkema property. BPA operated an electrical substation on Arkema property for several decades (Integral 2006q) and other PCB-containing transformers were used at the facility. Because the site has undergone extensive remediation and demolition to date, including interim remedial source control measures (IRMs), areas that may once have functioned as important upland sources may no longer be considered sources.

Rhone Poulenc

Rhone Poulenc is one of three sites that make up the Doane Lake Study Area (the others are Gould and Schnitzer-Doane Lake). As a result of artificial filling, Doane Lake was gradually reduced to a single remnant: West Doane Lake. Fill materials included soil, coal tar, battery and lead smelting wastes, calcium hydroxide and radioactive zirconium sands. Wastewaters from operations at Rhone-Poulenc, Gould and Air Liquide were discharged into the lake. Known or potential COIs in the Doane Lake Study Area include chlorophenol, coal tar, creosote, PAHs, PCBs, dioxins/furans, herbicides, insecticides, phthalates, radioactive casting sand, lead, calcium hydroxide sludge, VOCs, sulfuric acid, and asbestos, not all of which are related to historical operations at the former Rhone Poulenc facility, but rather to other sources that discharged materials to Doane Lake.

The distribution of chemical constituents detected at the Rhone Poulenc property has not been correlated to specific potential sources, but instead appears to be associated

with the general manufacturing activities that occurred in each area of the property. Potential historical release areas include tank farms, loading areas, plant storage facilities and associated sumps, and feedstock and product pipeline systems. Manufacturing wastes were discharged to Doane Lake, and Doane Lake intermittently discharged to the Willamette River in the vicinity of the railroad bridge prior to 1980. The Rhone Poulenc site summary reports that the former Doane Lake and current West Doane Lake periodically discharged to the Willamette River through a historical drainage ditch. The historical drainage ditch that extends from near West Doane Lake to the river (through WR-213) was cut off from the lake with an earthen berm at the northern end in approximately 1980.

Schnitzer – Doane Lake

The Schnitzer facility is currently operated by Air Liquide America Corporation for manufacturing acetylene. Potential historical and current upland sources on the Air Liquide property include fill material, the former remnant lake, a former UST, and a compressor oil spill. Fill material in the former East Doane Lake remnant consists of metal slag, scrap metal, demolition debris, silty hydraulic dredge spoils, rock quarry spoils, shredded automobile interiors, shredded battery casings, and carbide sludge. Schnitzer also disposed of non-magnetic auto shredder wastes on the site, although the exact location or duration of disposal was not noted. Known or potential COIs associated with operations on this site include VOCs, PCBs, petroleum hydrocarbons, and metals.

Gould

Located southeast of the railroad line in the Doane Lake Study Area, Gould engaged in battery breaking and lead smelting activities during its 32-year operating history. Lead was the primary COC at the Gould Superfund site. However, wastes containing zinc, copper, and magnesium also were disposed of at and adjacent to the site. Remediation of the Soils Operable Unit at the Gould NPL Site was completed in August 2000. Potential historical sources of contamination to in-river media from the Gould site include the historical smelter and other site operations, historical adjacent facilities, and historical landfilling activities. Materials placed in the containment facility include sediments, untreated stockpiled materials, casings, soil, and debris. Some of the waste was placed in the form of "stabilized blocks." Detected contaminants in these materials include metals, herbicides, dioxins/furans, VOCs, phenols, and organochlorine pesticides. The current onsite containment facility is monitored and is not a likely source of iCOCs to the river.

11.3.11.3.2 Stormwater/Wastewater/Overland Transport

The following stormwater outfalls discharge to iAOPC 14 (listed from upstream to downstream with owners indicated):

- WR-95 (Arkema)
- WR-96 (Arkema)
- WR-97(Arkema)

- WR-98 (Arkema)
- WR-213 (Front Avenue culvert; ownership unknown)
- Outfall 22B (City of Portland)
- WR-6 (Rhone Poulenc)
- Outfall 22C (City of Portland)
- WR-287 (Siltronic).

A former 96-inch outfall not shown on the maps also existed downstream of Outfall 22C; this outfall of unknown ownership drained Doane Creek and North Doane Lake prior to the City replacing it in 1980. It discharged approximately 100 ft downstream of the existing Outfall 22C location.

Arkema

Since 1976, NPDES-permitted stormwater from Arkema has discharged through outfalls WR-95 though -98. Prior to 2001, these outfalls also carried wastewater from Arkema, discharged pursuant to NPDES permits. Noncontact cooling water from the Acid Plant was discharged through outfall WR-96. Combustion chamber cooling water from the Acid Plant was pumped to a wastewater treatment system for pH neutralization before discharging through outfall WR-98. Cooling water from caustic evaporators was conveyed to outfall WR-96. Cooling water from the chlorine cell room was conveyed to outfalls WR-97 and WR-98, and from the chlorine finishing process to WR-95. Prior to 1976, stormwater and wastewater discharged from five outfalls that are now abandoned (WR-99, WR-100, WR-101, WR-290, WR-362).

Although these outfalls historically discharged cooling waters into the Willamette River, only stormwater runoff has been discharged since the Arkema plant shut down in 2001. Since the reissue of the stormwater NPDES permit in January 2004, all permit limits have been met. As stipulated in the permit, quarterly monitoring has been conducted for total suspended soils, oil and grease, pH, copper, lead, and zinc, and monthly monitoring has been conducted for oil and grease, sheen, and floating solids.

For the RI, stormwater was sampled during four sampling events from 1999 to 2001 (EPA 2005d). Stormwater samples were collected from a storm drain system in the Acid Plant Area before mixing with noncontact cooling water. Total DDT and its metabolites were detected. Significant reductions of these constituents in stormwater were observed after the Phase I soil removal IRM was completed (ERM 2005).

Comprehensive stormwater monitoring was conducted monthly in 2004–2005 as a requirement for the renewal of an NPDES permit for the facility (Integral 2006p). Stormwater samples were collected from March 2004 through March 2005 (except for months when there was no precipitation) and analyzed for selected legacy and Clean Water Act Section 303(d) constituents. Analytical parameters included total dissolved solids, iron, manganese, mercury hexavalent chromium, DDT, DDD, DDE, PAHs,

PCBs, chlorobenzene, PCP, perchlorate, and chloride. DDT and metabolites were detected in site stormwater.

In 1947, at the initiation of DDT manufacturing, MPR was discharged to floor drains connected to a stormwater system that drained into the Willamette River. This stormwater outfall is referred to as the former process discharge pipe and was also used to discharge cooling water from upland production processes. The outfall (i.e., WR-100?) that is suspected to have received the MPR is located between Docks 1 and 2, near boring location WB-9. The exact position of the pipe is unknown.

Groundwater elevations in the Chlorate Plant Area and the Acid Plant Area are consistently below the invert elevations of the stormwater system (ERM 2005). For this reason, a complete pathway from groundwater to stormwater does not appear to exist.

With the exception of some erosion of bank soils, little overland transport of chemicals is expected via stormwater runoff. The northern third of the Arkema property consists of open fields of brush and healthy vegetation. No stormwater system is shown in the site summary for the northern third of the property. A former BPA substation annex also was located in this area, adjacent to N.W. Front Avenue. A small portion of the Arkema site may potentially drain to the Outfall 22B stormwater system.

At the request of the City of Portland, Arkema plugged two catch basins in 2006 that apparently drained to the City catch basins connected to the Outfall 22B system. One catch basin that was plugged is located on City of Portland right-of-way, west of Lot 4 and was reportedly installed to provide drainage for the railroad tracks that cross Front Avenue. The owner of the catch basin is unknown. The second catch basin plugged is located on an asphalted parking lot on Arkema property that is located on the west sides of Lots 3 and 4 adjacent to Front Avenue. Presently, the southern two-thirds of the property, where chemical manufacturing activities took place, is almost entirely covered by pavement, gravel, or a temporary cover system (e.g., asphalt pavement). A small portion of the Arkema site may potentially drain to the Outfall 22B stormwater system.

Rhone Poulenc

Rhone Poulenc discharges to private outfall WR-6, which discharges approximately 200 ft offshore, just upstream of the railroad bridge. Historically, private outfall WR-213 may have drained Doane Lake; it discharged approximately 35 ft upstream of Outfall 22B. On-property stormwater and extracted groundwater are collected and treated in an onsite water treatment plant that includes biological treatment followed by activated carbon adsorption prior to direct discharge to the LWR via outfall WR-6 under an Oregon DEQ-approved NPDES IW-B-15 wastewater permit.

The history of wastewater and stormwater discharges from the former Rhone Poulenc property operations is summarized as follows:

- Between the years of 1943 and 1955, stormwater and untreated wastewater from the Rhone Poulenc Property were discharged to Doane Lake.

- Between the years 1956 and 1966, stormwater and treated wastewater were discharged to Doane Lake. A seep north through the railroad fill into what is now North Doane Lake was observed as reported in 1964.
- Between the years of 1966 and 1977, treated wastewater was directly discharged through a pipe from the plant site to the LWR.
- Between the years of 1977 and 1984, treated wastewater was discharged to the City of Portland Publicly Owned Treatment Works (POTW).
- From 1984 to 1990, treated stormwater, treated groundwater and treated wastewater were directly discharged to the LWR via outfall WR-6 (in accordance with the DEQ-approved NPDES permit).
- From 1990 to 2006, treated stormwater and treated groundwater have been directly discharged to LWR via outfall WR-6 in accordance with the DEQ-approved NPDES permit.

Outfall 22B Basin

City stormwater Outfall 22B is a 48-inch-diameter pipe located on the west side of the river at RM 6.8, just upstream of the railroad bridge. A shallow erosional channel extends from the outfall terminus to the water line. Land uses within the 37-acre outfall basin are primarily industrial. Most of the area currently drained by Outfall 22B was originally Doane Lake (see Section 11.3.11.1.2 above for Doane Lake history). The outfall was constructed in 1980, after the lake had been mostly filled.

Three ECSI sites are located in the Outfall 22B basin: Gould Inc/NL Industries, Schnitzer-Doane Lake, and Metro Central Transfer Station (ECSI #1398). A small portion of the Arkema property also is partially located within the basin. Gould has known contamination by arsenic, lead, cadmium, sulfuric acid, zinc, and antimony. Schnitzer-Doane Lake has known or potential contamination by calcium hydroxide, lead, arsenic, TPH, PCBs, and CVOCs. The transfer station has known or potential contamination, including pesticides, herbicides, benzene, and heavy metals. Outfall 22B was also subject to infiltration of groundwater impacted with Rhone Poulenc-related constituents, as well as constituents related to other nearby sites. In 2006 SLLI initiated an interim source control action to eliminate infiltration of groundwater along the storm sewer associated with Outfall 22B. Most of the iAOPC 14 iCOCs, including dioxin, arsenic, mercury, beta-HCH, delta-HCH, DDD, DDE, DDT, DBP, and aldrin, have been detected in groundwater in the Doane Lake area, in addition to several herbicides. Historically, contaminants at these sites had the potential to migrate to the river via overland flow through the historical drainage ditch. Limited migration may have occurred after this time through the stormwater conveyance systems connected to Outfall 22B: Metro connected to the City system in 1991; Schnitzer connected to the system in 2000, and East Doane Lake on the Gould property overflowed into the City system after 1980 prior to completion of the Gould site remediation.

Outfall 22C Basin

City stormwater Outfall 22C is an 84-inch-diameter pipe located on the west side at RM 6.7, just downstream of the railroad bridge. The outfall is located above the water line at typical high river stages. This outfall drains upland wetlands, North Doane Lake (see discussion above), Forest Park streams, and some industrial properties, and receives the NPDES discharge from the Koppers Industries site. ECSI sites located in the drainage basin of Outfall 22C include Koppers Industries (ECSI #2348), which is part of the Gasco site (ECSI# 84) and only partially located in the drainage basin, and the Santa Fe Pacific Pipeline (ECSI #2104). A coal tar gasification plant was located on Gasco property, which has known or potential contamination by PAHs, BTEX, phenol, 2,4-D, metals, phthalate, carbozole, DDT, and dibenzofuran. Known or potential contamination at the Santa Fe Pipeline property includes 2-methylnaphthalene, carbozole, PAHs, 2,4-D, and 2,4-DB.

Currently, stormwater from the Koppers Industries lease area is collected and discharged through Koppers' NPDES-permitted outfall that drains to Doane Creek, located at the southern corner of the property, which ultimately leads to Outfall 22C. BTEX, PAHs, cyanide, and some metals have been detected in this discharge. Additional testing of the Koppers outfall to Doane Creek was conducted as part of seasonal surface water sampling activities related to Outfall 22C conducted by NW Natural in 2005. These sampling activities identified concentrations of PAHs and total cyanide in standing water at in the Koppers outfall pipe adjacent to Doane Creek (actual flow is anticipated to occur only during a Koppers' batch discharge). The 2005 sampling activities further identified that the buried culvert leading to Outfall 22C is likely a preferential pathway for nearby shallow groundwater (fill unit) to migrate to the Willamette River. Historically, a drainage ditch from the southern corner of the Gasco site (which included Koppers' operations at the time) was constructed in approximately 1966 and connected to North Doane Lake (NDL). At approximately the same time, a ditch was constructed that connected NDL to the Willamette River. The NDL-Willamette River ditch drained NDL until about 1972, when a 96-inch outfall was installed to serve the same function. The City abandoned the 96-inch outfall and constructed Outfall 22C in 1980. The 1966-1972 drainage ditch, 96-inch outfall, and Outfall 22C are all potentially direct discharge pathways for stormwater and MGP-related COIs to the river. Outfall 22C is also a potential discharge pathway for Rhone Poulenc COIs to the river.

One additional private outfall (WR-287) is located downstream of Outfall 22C. This outfall drains Siltronic property, and elevated PAH concentrations have been detected in sediment in the vicinity of the outfall.

11.3.11.3.3 Overwater Discharge

In-water access to the Arkema facility was historically provided from three docks—from upstream to downstream—the Salt Dock, Dock 1, and Dock 2. During operational periods, sodium chloride (salt) was delivered by ship to either the Salt Dock or Dock 1. Sodium hydroxide, sodium chlorate solution, and chlorine were

loaded onto barges for shipment from Dock 2. Inadvertent spills that may have occurred during transfer activities are not likely to have caused sediment contamination, as these materials are highly water-soluble or volatilize immediately upon release to the atmosphere. Nevertheless, leakage of diesel, motor oils, or other chemicals may have been sources of in-river contamination. Arkema maintains leases from the Oregon DSL for the docks in the Willamette River, but the docks are not currently in use.

The BNSF railroad bridge crosses the iAOPC at RM 6.9.

Western Transportation operated a tug refueling dock at the extreme downstream end of the iAOPC from the 1930s to sometime between 1940 and 1955.

11.3.11.3.4 Groundwater Discharge

Arkema

In-water iCOCs and/or potential iCOCs based on TZW that are associated with upland groundwater plumes at the Arkema Site include DDx pesticides, chloroform, and TCE. The DDT/DDD/DDE and VOC (primarily MCB) plumes overlap in the Acid Plant area and are present in nearshore wells. The Round 2 Groundwater Pathway Assessment identified a nearshore groundwater discharge zone and an intermediate variable groundwater discharge zone at the Arkema site (Figure 10-7 from Integral 2006a). Farther offshore, a zone of low-to-no groundwater discharge was identified. These zones span both the Acid Plant area and Chlorate Plant area. The analysis of Round 2 TZW and sediment chemistry within these zones indicates a complete pathway for transport of upland groundwater COIs to the transition zone.

The greatest dissolved-phase impacts to upland groundwater at Arkema are in the shallow groundwater zone, with decreasing impacts in the intermediate zone and minimal impacts in the deep zone. The highest concentrations of MCB in shallow-zone groundwater occur immediately north and northeast of the former MPR. DNAPL is primarily situated in the shallow zone, and, due to its residual nature, DNAPL is not likely migrating offsite. DNAPL has not been observed in the deep or basalt zones, nor was DNAPL detected in any of the sediment borings immediately adjacent to the Acid Plant area.

Rhone Poulenc

VOCs, phenols, herbicides, insecticides, dioxins/furans, and metals (primarily arsenic) have been detected in the three groundwater zones at Rhone Poulenc. Of these, only dioxins/furans (dioxin TEQ) and arsenic are iCOCs in sediment at iAOPC 14. Of the potential iCOCs based on TZW identified in iAOPC 14, chloroform and TCE have been detected in upland groundwater at Rhone Poulenc. The Round 2 groundwater pathway assessment identified two groundwater discharge zones offshore of the Rhone Poulenc site within which sediment and TZW chemistry indicate the probable existence of a complete pathway for transport of upland groundwater COIs to the transition zone

(Figure 9-7 from Integral 2006g). Another complete pathway was shallow groundwater infiltration into the city storm system that drains to Outfall 22B.

The distribution of dioxins/furans, arsenic, and VOCs (chloroform and TCE) in upland groundwater is summarized below (additional details are provided in the 2006 Former Rhone-Poulenc site summary; Integral and GSI 2004a,b,c):

Dioxins/Furans
Dioxins/furans in groundwater, including dioxins/furans from sources other than Rhone Poulenc Property operations, are generally encountered along the groundwater flow direction, in the southern portion of the Herbicide Area and extending northward to distal monitoring wells near the LWR. Concentrations of dioxins/furans generally increase with depth across the Rhone Poulenc Property to the Lake Area, and generally decrease with depth toward the distal monitoring wells. In near-river wells, the highest detected individual dioxin/furan congener concentration is 252 pg/L (OCDD).

Arsenic
Arsenic concentrations in groundwater do not show any specific patterns or trends. Arsenic also was detected at background concentrations in wells upgradient of the Rhone Poulenc site. In general, it is not fully clear whether arsenic in groundwater at the Rhone Poulenc Property and neighboring properties is the result of historical anthropogenic releases of arsenic compounds, as opposed to locations where the arsenic concentrations in groundwater may be due to release of native arsenic from aquifer materials due to dissolution of iron oxides under reducing aquifer conditions. Metals are also detected at locations upgradient of the Rhone Poulenc property, and the concentrations in these upgradient locations appear to be representative of background concentrations at the Rhone Poulenc Property (AMEC 2003). In near-river wells, the highest detected arsenic concentration is 0.154 mg/L.

VOCs
In general, VOCs, including VOCs from sources other than Rhone Poulenc, in groundwater are encountered along the groundwater flow direction, originating from the northern portion of the Herbicide Area and the Lake Area Drainage Ditch at the Rhone Poulenc Property and extending northward to distal monitoring wells and in-river LWG transition zone sample locations. Concentrations of VOCs generally decrease with depth across the Rhone Poulenc Property to the Lake Area, and generally increase with depth toward the distal monitoring wells (AMEC 2003). In near-river wells, the highest detected concentrations of chloroform and TCE are 1.63 µg/L and 17.4 µg/L, respectively.

Siltronic
Environmental investigations conducted at Siltronic have been focused on MGP-related groundwater COIs associated with historical Gasco operations and a TCE release near the downstream end of the site. These constituents are not associated with the upstream portion of the Siltronic site adjacent to iAOPC 14 and are discussed separately in the CSM for iAOPC 11.

11.3.11.3.5 Riverbank Erosion

Arkema

After DDT manufacturing ceased in the 1950s, the bank adjacent to the Arkema Acid Plant Area between Docks 1 and 2 has been widened with fill approximately 200 ft. Fill thickness ranges from a few feet in the former DDT manufacturing area to approximately 25 ft along the riverbank. Anecdotal information suggests that in the early years, thinner residue periodically was blended with used sandblast material and then incorporated into riverbank fill between Docks 1 and 2. Some of the decommissioned chlorine cells containing lead may have also been used as fill along the riverbank between Docks 1 and 2. DDT residuals have been measured in some portions of the fill; in some cases, the DDT residuals have been addressed as part of the ongoing upland IRMs. The riverbank in the vicinity of Arkema is partially river beach and steep slopes covered with bank stabilization material that includes large chunks of concrete, asphalt, and other impervious material. There is no evidence of large-scale bank erosion, although there was minor sloughing of the bank between Docks 1 and 2 during the 1996 flood.

Monitoring of sediment stakes placed at low-, mid-, and high-bank elevations indicated relatively small-scale erosion and accretion between July 2002 and January 2004. Nevertheless, erosion of riverbank soils and sediments during high water flooding or heavy rainfall events represents a potential source of COIs to sediments and surface water. Riverbank sampling along the Arkema shoreline is planned as part of the EE/CA and will likely be conducted in 2007.

Siltronic

The riverbank adjacent to the Siltronic site is armored with riprap, and erosion where these bank reinforcement measures are intact is expected to be minimal.

11.3.11.4 Relationship of Upland Sources to the Distribution of iCOCs

The in-water distribution of several iCOCs and the foregoing evaluation of chemical sources and pathways constitute evidence of a link between several iCOCs in the upland and those in sediment, surface water, and biota from iAOPC 14.

Industrial and stormwater outfall discharges, which function as both historical and current pathways to the river, appear to be substantial contributors of several iCOCs to in-water media at iAOPC 14. As described below, the spatial distributions of PCBs, metals, and DDT and its metabolites in surface and subsurface sediments all suggest that their primary sources to the iAOPC are historical discharges from outfalls. Current outfall discharges are likely to be substantially less than historical discharges. The distribution of iCOCs in sediments is also consistent with localized erosion of contaminated riverbank fill materials. Upland groundwater plumes also appear to be a source of some iCOCs and/or potential iCOCs based on TZW to sediments and surface water, although groundwater loading has likely decreased as a result of interim groundwater remedial actions at upland sites. Overwater activities were not likely an important historical source of iCOCs to the river based on dock uses reported by

Arkema, however, as at all facilities, there is considerable uncertainty associated with historical overwater activities. Sediment transport processes have likely spread iCOCs from their sources downstream to other locations within the iAOPC and beyond, particularly in the past when industrial discharges were more significant.

Total PCBs in surface and subsurface river sediment were detected at elevated concentrations in scattered nearshore areas within the iAOPC. High detection limits for many samples with undetected PCBs off of Arkema complicate an interpretation of the spatial distribution of PCBs within the southern portion of the iAOPC. A BPA electrical substation was present on Arkema property for several years. Other PCB-containing transformers were used at this facility and most likely at several other industrial facilities in the areas draining to the iAOPC. PCBs have also been detected in samples collected throughout the upland historical Doane Lake area that historically discharged to the river in the vicinity of the railroad bridge. PCBs are listed as COIs at sites within the historical Doan Lake area, including the Rhone Poulenc and Schnitzer-Doane Lake sites.

DDT and its metabolites have been detected at Arkema in riverbank fill soils, upland surface soil, groundwater, and catch basin solids. DDT and its metabolites have also been detected historically in stormwater samples collected at Arkema, however, significant reductions in stormwater levels have been observed since upland IRMs were implemented. Based on the spatial distribution of DDx concentrations within sediments, the historical discharges from the former process discharge pipe between Docks 1 and 2 is likely the primary source for DDT and metabolites in river sediments. DDx was also detected at moderately elevated concentrations in surface sediments immediately offshore of outfalls 22B and WR-213. More highly elevated DDx concentrations were detected in subsurface sediment downstream of the railroad bridge, suggesting historical downstream transport of DDx impacted sediment. DDx pesticides observed in TZW are most likely derived primarily from sources other than the upland groundwater, as observed TZW concentrations are often higher than the upland groundwater concentrations. This is most likely due to the direct discharge of DDT manufacturing process residues through a historical outfall pipe (the use of which was discontinued many years ago) during the first year of the DDT plant operations at the Arkema site.

Riverbank erosion also may represent a historical and/or current pathway for DDx pesticides and other iCOCs to the river. The uplands adjacent to the iAOPC have been significantly altered by physical activities including the application of contaminated fill material (e.g., Arkema Acid Plant Area). The placement and potential erosion of contaminated riverbank soils off the Arkema Acid Plant could explain the distribution of several iCOCs in nearshore sediments in the area between Arkema Docks 1 and 2.

Dioxin/furan TEQ was detected at elevated concentrations in the vicinity of the Arkema docks and, to a lesser degree, around the railroad bridge. Dioxin TEQ concentrations in subsurface sediment in the vicinity of the railroad bridge are substantially higher than

those in surface sediments. There are relatively few subsurface sediment samples off of Arkema that have been analyzed for dioxins/furans. Based on the distribution of available dioxin data and observed patterns of dioxin TEQ in sediments, identification of likely sources to the river is difficult. Although dioxin has been detected in upland groundwater adjacent to the iAOPC and in TZW within the iAOPC, transport of dioxins/furans from upland groundwater is considered to be much less significant in comparison to other sources.

The highest concentrations of arsenic were detected in surface sediments collected in the vicinity of the railroad bridge. The Schnitzer-Doane Lake site is located within the Outfall 22B basin and currently stormwater from only the paved portion of the site is discharged through this outfall. This site has known or potential arsenic soil contamination and it is uncertain if this site is a source of arsenic to in-river sediments. Historically, the Gould site also may have been a source of arsenic to the iAOPC.

The highest elevated concentrations of DBP were detected in nearshore areas around Arkema upstream of Dock 1 and behind Dock 2. However, there is no obvious link between upland sources and the elevated concentrations of DBP in sediment due to the absence of information regarding the historical handling of DBP at Arkema.

Delta-HCH was detected in surface sediments adjacent to outfalls 22B and WR-213, and offshore of Arkema (between and around Docks 1 and 2), but elevated detection limits throughout most of the iAOPC do not allow any conclusions to be made about spatial patterns of this constituent.

Chloroform and TCE detected in TZW offshore of the Arkema Acid Plant (maximum concentrations of 770,000 and 7,100 µg/L, respectively) appear to have reached the transition zone environment primarily as a result of migration of the VOC plume in the Acid Plant area to the river. Groundwater plume discharge from the Arkema site is estimated to contribute >99 percent of the chloroform load and approximately 3 percent of the total estimated TCE load to the water column from upland groundwater plume discharge (see Appendix D). Maximum detected concentrations of chloroform and TCE (< 1 and 1.1 µg/L, respectively) in TZW south of the railroad bridge are substantially lower.

A preliminary evaluation of the relationship between sources, pathways, and iCOCs in the iAOPC is summarized in Figure 11.3.11-1. A preliminary assessment of the current and historical relative contributions of each source is summarized in Table 11.3.11-3.

11.3.12 CSM for iAOPCs 15 and 16

This section provides the preliminary Round 2 CSM for iAOPCs 15 and 16. These iAOPCs lie along the eastern shore of the river between RM 7.1 and 7.3 (Map 11.3.12-1). iAOPC 15 covers 2.7 acres along the upstream end of property formerly owned by McCormick and Baxter Creosoting Company (M&B). iAOPC 16 covers 1 acre upstream of iAOPC 15, but not contiguous with it, on the north end of the ship moorage

area at Triangle Park. This CSM examines the physical setting of the iAOPCs and adjacent uplands, the chemical distribution of iCOCs in in-water media, and potential sources of the iCOCs.

These areas of the river were designated iAOPCs based on the following iCOCs:

- **iAOPC 15:** Dioxin TEQ
- **iAOPC 16:** Total PCBs.

The potential iCOCs include the following:

- **iAOPC 15:** Arsenic.

The potential iCOCs are identified through less certain and/or less rigorous evaluations based on fewer lines of evidence, FPM results, or other high uncertainty lines of evidence (see Sections 8 and 9).

Map 10.5-3a–j shows the areas where this preliminary analysis identified the potential for risk for individual exposure scenarios that were considered in iAOPC development, and Table 10.5-1 identifies the iCOCs associated with the exposure scenarios. Arsenic is a potential iCOC in the east half of iAOPC 15, and dioxin TEQ is an iCOC in the west half. PCBs are the iCOC for all areas in iAOPC 16.

The following CSM evaluation is summarized as follows: The highest arsenic concentrations in sediment at iAOPC 15 are located at the upstream end the M&B site near Outfall 48. Soils in both adjacent upland properties contain arsenic at concentrations exceeding risk-based cleanup levels for the sites. Outfall 48, discharges to this area, however, a documented arsenic source has not been identified within the outfall basin, which drains residential streets on the bluff above the river. The area near the iAOPC is subject to back-eddies and transport of downstream contaminants offshore of M&B likely occurred. Treated log storage in this area may also be an important historical source of arsenic.

Dioxin sources affecting iAOPC 15 could not be evaluated because of insufficient upland sampling. Upland releases of dioxins from the adjacent McCormick & Baxter have been documented.

PCBs are present in soils and groundwater of the uplands adjacent to iAOPC 16. Stormwater discharges, overland runoff, and riverbank erosion appear to be the primary pathways for PCBs to migrate to in-water media at iAOPC 16.

11.3.12.1 Physical Setting, Infrastructure, and Operational History

In-river and upland physical characteristics, infrastructure, and operational history relevant to these iAOPCs are described in this subsection. Information on adjacent upland sites was obtained from the LWG site summaries (Integral and GSI 2004; 2005a, b,c) and updates (Integral 2007) unless otherwise noted.

11.3.12.1.1 In-River

iAOPCs 15 and 16 are located in an off-channel cove in the downstream portion of a large area in the lower Willamette characterized as depositional (Map 11.3.12-1). The Sediment Trend Analysis® results suggest that the nearshore area along the upstream end and extending into the Triangle Park cove is a region of dynamic equilibrium; downstream of this area, the transport path transitions to net accretion (Map 11.3.12-1). Time-series bathymetric change data over the 25-month period from January 2002 through February 2004 show that most of the Triangle Park cove has experienced no measurable riverbed elevation change. Exceptions to this include an oval-shaped area of sediment scour (up to 1 ft in extent) at the upstream, riverside corner of the cove, which may reflect the influence of in-water structures, vessel traffic, or both. Just downstream of this scoured area, there is an area of sediment accretion (up to 1 ft in extent) centered along the outer margin of the cove between -15 and -25 ft NAVD88. In the eastern portion of the main stem of the river offshore of the Triangle Park cove, areas of no change are interspersed with areas of net sediment accretion ranging from 0.5 to 1 ft in extent. Because water depth or obstructions prevented the survey vessel from accessing the inner portions of cove above -5 ft NAVD88, no information is available on erosion or depositional patterns in nearshore areas immediately off of the Triangle Park uplands.

Surface lithologic conditions at both iAOPCs are depicted on Map 11.2.12-2a. Subsurface conditions at these iAOPCs are known only from a single core in iAOPC 16 (Map 11.3.12-2b). Sandy silt (56 percent fines) was observed to a depth of 90 cm.

The shoreline at Triangle Park is mostly steeply sloped banks, with structures such as docks and dolphins extending into the river and temporary barge moorage along the shoreline (Map 11.3.12-1). The upland site is currently zoned for industrial use. Triangle Park LLC plans to redevelop the site for the expansion of the University of Portland campus. Historically, significant in-water features included structures ancillary to shipbuilding, dry dock operations and log storage. Most of these structures have been removed.

One active municipal outfall (Outfall 48) discharges into iAOPC 15. This 30-inch-diameter pipe is located in the upstream corner of the M&B cove approximately 500 ft from the main river channel. At high river stage, the outfall sits below the high tide water line. Before drainage basin modifications in 1997, this outfall was a combined sewer overflow serving residential areas. The outfall currently drains 6 acres, primarily residential road runoff and is treated before discharge (CH2M Hill 2004b).

11.3.12.1.2 Upland

Two upland sites abut iAOPCs 15 and 16: the McCormick and Baxter Superfund site (ECSI #74; abuts iAOPC 15) and Triangle Park (ECSI #277; abuts both iAOPCs). Site summaries have been prepared and upland investigations performed on both properties. Conditions are summarized here.

McCormick and Baxter Creosoting Company
The M&B site was added to EPA's National Priorities List in 1994. Located within the boundaries of the Portland Harbor Superfund site, M&B is managed as a separate site and has undergone significant cleanup since 1999. It is currently vacant. The site was created with dredged material fill in the early 1900s. The earliest user was the Peninsula Lumber Company, which stored lumber and created log rafts in the early 1900s. Between 1944 and 1991, M&B treated wood products with creosote, PCP, and inorganic preservative solutions containing arsenic, copper, chromium, and zinc. Creosote was delivered by barge and conveyed by pipeline to a 750,000-gallon tank surrounded by a dike. Also present at the site was a diked tank area containing several additional tanks for storage of wood treatment chemicals.

Triangle Park
Although currently unoccupied, the Triangle Park property has been in active use since before 1900. The northern third of the industrial zoned site contains a grassy field bordered with bushes and trees. Its southern two-thirds are covered by broken pavement, gravel, and bare dirt, with a few patches of weeds. Eight structures remain on the site, including warehouse buildings and a former powerhouse.

The Union Pacific Railroad line and right-of-way bisects the site from northwest to southeast. An abandoned fuel pipeline is located under the UPRR property (MFA 2001, 2002). A pump station for an underground jet fuel pipeline owned by Chevron is located near the southernmost corner of the property; the pipeline passes under the site's south and southeast boundaries.

Historical operations at the site involved various industrial activities:

- Lumber milling
- Marine services - shipbuilding, dry-dock operations
- Electrical-power generation - possibly fueled with wood wastes, coal, bunker fuel, and diesel fuel
- Manufacturing and storage
- Transformer cleaning and storage.
- Hazardous waste storage and transfer, as part of the former Riedel Environmental operations
- Decommissioned UST storage and cleaning as part of the former Riedel Environmental operations

11.3.12.1.3 Upland Hydrogeology
Subsurface environmental investigations have been completed at both the M&B and Triangle Park sites. Lithologic logs of materials collected during numerous studies provide a comprehensive picture of site stratigraphic features, which generally consist

of fill, alluvial deposits, and Pleistocene flood deposits. Generalized geologic cross-sections are provided in Supplemental Figure 2 for M&B and Supplemental Figures 4-2 and 4-4 for Triangle Park.

Investigations at M&B identified shallow, intermediate, and deep aquifers. The shallow unconfined sand fill aquifer at the M&B site is up to 30 ft thick, and the depth to groundwater ranges from 20 to 25 ft bgs. The shallow unconfined aquifer at the Triangle Cove site is composed of the fill and recent alluvial deposits, and extends to approximately 70 ft bgs; the depth to water ranges from 9 to 25 ft bgs. The base of the shallow aquifer at each site is defined by a silt aquitard that ranges in thickness from zero to greater than 100 ft (beneath M&B). Shallow groundwater flow at both sites is generally toward the Willamette River. A possible seasonal seep was identified at the base of the embankment at the Triangle site.

On the basis of observations at M&B, the silt aquitard is truncated at the Willamette River and a thick sequence of Quaternary sand extends to 80 ft bgs. In this area, the shallow, intermediate, and deep aquifers are hydraulically connected and form a single continuous unconfined aquifer near the river boundary. Local variations have been observed and groundwater levels are known to be influenced by river stage as well as tidal fluctuations. Groundwater elevations were observed between 7 and 13 ft MSL and the groundwater gradient ranged from 0.005 to 0.006 ft/ft.

The intermediate aquifer below the silt aquitard at M&B is composed of fine- to medium-grained alluvium and varies in thickness from zero to more than 50 ft. In some portions of the site, the silt aquitard separating the intermediate zone from the shallow zone is thin or discontinuous. In these areas, the intermediate and deep zones are in hydraulic connection.

The deep aquifer was identified beneath all portions of the M&B site. It consists primarily of sands; however, along the northeast portion of the site the deep aquifer consists of sand and gravel of the Troutdale Formation and the Pleistocene Flood deposits. The deep aquifer is directly connected with the intermediate and shallow aquifers near the Willamette River. The Sandy River Mudstone was encountered below the Pleistocene deposits at the Triangle site.

Engineering controls implemented at the M&B site have substantially influenced groundwater flow. In 2003, a subsurface impermeable barrier wall was installed around a 16-acre area of contaminated groundwater to eliminate ongoing seepage of creosote into the Willamette River. The maximum depth of the barrier wall is 80 ft bgs. In 2004, a 23-acre sediment cap was constructed over contaminated sediments (including part of iAOPC 15) and creosote seeps. A soil cap for the entire site was completed in 2005 to reduce infiltration and groundwater recharge at the site.

11.3.12.2 Chemical Distribution of iCOCs

This section describes the distribution of iCOCs for iAOPC 15 and 16. Sediment sampling locations are shown in Map 11.3.12-1, a statistical summary of iCOC data for

sediment and biota is provided in Table 11.3.12-1, and the full iCOC data set for the two iAOPCs can be found in Appendix I.

11.3.12.2.1 Sediments

iAOPC 15

The iCOC for iAOPC 15 is dioxin TEQ; the potential iCOC is arsenic. Dioxins were detected in both surface sediment samples analyzed (Map 11.3.12-3). Dioxin TEQ concentrations were 28 µg/kg (nearshore, downstream of Outfall 48) and 39 µg/kg (offshore, downstream end of iAOPC), with a mean value of 33.5 µg/kg. Arsenic was detected in 9 of 10 surface sediment samples (Map 11.3.12-4). Concentrations ranged from 4 to 83.5 mg/kg, with a mean value of 30 mg/kg. The highest concentrations were located near shore downstream of Outfall 48. No subsurface samples were analyzed for arsenic or dioxin TEQ.

iAOPC 16

The only iCOC for iAOPC 16 is total PCBs. PCBs were detected in one surface and one subsurface sample collected within this iAOPC (Maps 11.3.12-5 and 11.3.12-6). The total PCB Aroclor concentrations were 200 µg/kg in the surface sample (all Aroclor 1254) and 230 µg/kg in the subsurface sample (Aroclors 1260 and 1254). The samples were collected near shore on the downstream end of the iAOPC. PCB congener analyses were not conducted.

11.3.12.2.2 Surface Water

There were no Round 2 surface water samples collected in iAOPCs 15 and 16.

11.3.12.2.3 Transition Zone Water

No porewater was sampled for iCOCs. TZW sampling has not been conducted within either iAOPC.

11.3.12.2.4 Biota

One composite sample of crayfish (whole body) was collected from iAOPC 15 near shore, downstream of Outfall 48. As summarized in Table 11.3.12-1b, arsenic was detected in the crayfish composite sample at a concentration of 0.5 mg/kg.

11.3.12.3 Potential Sources of iCOCs

This section presents a summary of the current understanding of potential sources of iCOCs to noncontiguous iAOPCs 15 and 16. iAOPC 15 is located in the upstream corner of the M&B cove, in the general vicinity of Outfall 48 and at the upstream boundary of the M&B sediment cap. iAOPC 16 is located in the northern corner of the Triangle Park cove.

Information presented is this section was obtained from site summaries unless otherwise noted. In addition to iCOCs, COIs associated with nearby upland areas are also discussed in this section. The COIs are presented to provide a comprehensive understanding of the upland issues and to support the identification of potential sources to the iAOPCs. The relevance of the pathway to iCOCs is summarized at the end of

each pathway discussion. Potential sources, COIs, and pathways are summarized in Table 11.3.12-2.

11.3.12.3.1 Upland Releases

Documented releases have occurred at both the M&B and Triangle Park sites. These releases are listed in Table 11.3.12-2 and summarized below.

iAOPC 15

The M&B property includes approximately 41 acres on land and 23 acres in the river. From 1944 to 1991, M&B treated wood with mixtures of creosote and diesel oil; mixtures of PCP and diesel oil; and water- and ammonia-based solutions containing arsenic, chromium, copper, and zinc. Three main contaminant sources areas have been identified at the site: the former waste disposal area, the central process area, and the tank farm. Other potential source areas include the southeast disposal trench and miscellaneous small waste disposal areas.

The following upland releases occurred on this site during its operational history (ATSDR 1995a):

- Two major creosote spills - a 50,000-gallon release in the tank farm area in early 1950s, and a large spill of unspecified volume from a tank car near the tank farm in 1956.
- Discharge of wastewater and noncontact cooling water directly into the river from 1945 to 1969.
- Disposal of boiler water, stormwater, and oily wastes in an unlined trench in the southeast area adjacent to the river prior to 1971. Contaminated soil was removed from this area in the 1980s.
- Placement of waste oil containing creosote and PCP on soils to improve structural stability.
- Disposal of residues from the retorts, oil/water separator, and evaporators in the former waste disposal area in the western portion of site for at least 5 years beginning in 1968.
- Placement of treated wood products in the river at various times prior to shipment. An area containing oily sediments was reportedly dredged approximately every 3 years during the Vietnam War; the disposal location of those sediments is unknown. 1960 aerial photographs show large rafts of logs in the sheltered portion of the M&B cove.
- Documented releases of wood-treating chemical compounds to soils, groundwater, and sediments from historical operations.

Potential COIs associated with these operations include TPH, VOCs, SVOCs, PAHs, phthalates, phenols, metals (including arsenic), dioxins, butyltins, creosote, and PCP. The M&B RI and ROD do not report PCB sampling results, though the ROD (EPA and

DEQ 1996) indicates that PCBs were sampled in soil. As a result, the potential for the M&B site to be a PCB source cannot be evaluated at this time.

The majority of the releases and affected media are located in the central and downriver portion of the M&B upland site. The M&B remedial investigation report (PTI 1992) identifies the upriver area of the M&B site as SS3. The area was mostly used for storage of treated wood and identified on the basis of surface soil contamination. The degree of contamination was identified as low relative to other onsite areas of surface soil contamination. Chemicals of concern for SS3 consisted primarily of pentachlorophenol, arsenic, and chromium.

iAOPC 16

The Triangle Park site has been in active use since before 1900 and is currently unoccupied. Past activities at the site included lumber milling, shipbuilding, dry-dock operations, electrical-power generation (possibly fueled with wood wastes, coal, bunker fuel, and diesel fuel), manufacturing and storage, and transformer cleaning and storage. Potential sources associated with these past activities include paints, petroleum products, solvents, degreasers, coal tar, lime and other chemicals used in historical operations, sludge disposal pond, leaking UST and ASTs, sandblasting areas, shipbuilding and repair activities, overwater product transfer, and tug and barge operations. A 100-gallon diesel spill was reported in 2004. Potential COIs associated with past and current operations at the site include TPH, VOCs, PAHs, PCBs, metals, dioxins, and PCP.

Soil investigations on the Triangle Park property revealed contamination in surface and subsurface soil by PAHs, Aroclor 1260, dioxins, arsenic, and lead. The 1996 ROD (EPA and DEQ 1996) identifies 20 discrete areas onsite that do not meet EPA Region 9 preliminary remediation goals for industrial soils for one or more chemicals. The ROD calls for removal of contaminated soil followed by capping, which is anticipated to occur in 2007. Some of these areas are considered hotspots under DEQ regulations.

Petroleum-related constituents, including PAHs, were detected in groundwater samples collected over a broad area at the site. Phthalates, halogenated volatile organic compounds, PCBs, and metals also have been detected in groundwater. DEQ believes that impacted groundwater is discharging to the river in the vicinity of the former docks immediately upstream of iAOPC 16 (see Map 11.3.12-1). However, additional data are required to assess the magnitude and extent of affected groundwater.

11.3.12.3.2 Stormwater/Overland Transport

Stormwater outfalls and basin characteristics within or near iAOPCs 15 and 16 are summarized in Table 5.1-3. Outfall basins are shown on Map 4.1-4a–i. Stormwater and overland transport pathways specific to each iAOPC are described further below.

iAOPC 15

While the M&B facility was in operation, cooling water and contact wastewater was discharged through a wastewater outfall (WR-194), and stormwater was discharged

through three outfalls (WR-195, WR-196, and WR-197); none of these outfalls is within the immediate vicinity of iAOPC 15. Two of the outfalls (WR-194 and WR-195) were permitted under NPDES.

PTI (1992) reported that total annual stormwater discharge from outfall 002 (WR-194) between 1986 and 1991 ranged from 1.9 to 4.1 million gallons. Unfiltered stormwater samples collected in 1991 from Outfalls 002 and 003 (WR-195) contained metals, pentachlorophenol, PAHs, and dioxins/furans through suspension of contaminated soil particles (EPA and DEQ 1996). PTI (1992) reported the same contaminants in stormwater data collected at Outfall 002 in 1988 – 1990. Following shutdown of the facility in 1991, earthen berms were placed around stormwater collection sumps to minimize discharge through the outfalls to the river. Currently, most stormwater infiltrates into the subsurface. The drainage areas and potential sources for the two private outfalls are unknown (Map 4.1-4a–i). Surface soils are contaminated with PAHs, PCP, Aroclor 1260, dioxins, arsenic, and lead. Arsenic, PCP, and PAH concentrations exceed background levels by factors of more than 1,000 (EPA and DEQ 1996). Concentrations of PAHs and PCBs in soil samples collected near the river and in stormwater catch basins were higher than DEQ sediment screening level values.

Following plant shutdown, DEQ placed earthen berms around stormwater collection sumps at the site to minimize offsite discharge. Later in 1999, the stormwater outfalls were removed as part of the first phase of the soil remedial action. The soil cap in the upland areas of M&B consists of a subsurface drainage system above a high-density polyethylene liner to collect stormwater percolating through upper soil, rock, and sand layers of the cap. Stormwater moves by gravity flow through conveyance piping to an outfall structure on the Willamette River. A drainage swale that conveys stormwater to an onsite retention/infiltration pond was also constructed to minimize stormwater runoff from the site to adjacent properties and the river.

City Outfall 48 is located on the southern border of the M&B site. The basin was fully separated in 1997; stormwater is treated at the Fiske stormwater treatment facility before being discharged back to the City stormwater system upstream of Outfall 48. Currently, Outfall 48 drains stormwater from residential right-of-ways in a 6-acre basin on the bluff above the site, and does not convey runoff from the M&B property. No information has been reviewed on differences in historical drainage, if any. During the City of Portland's outfall investigation, large timbers, other river debris, and sand had accumulated in the vicinity of the outfall, indicating significant accretion during high river stages (CH2M Hill 2004b). The outfall discharge area is sheltered by the cove from flow in the main channel. No information on the potential for the storm pipe to intercept groundwater has been reviewed, but groundwater in the nearby portion of the M&B site was not identified as a medium of concern. A petroleum groundwater plume on the Triangle Park property is located near the Outfall 48 storm pipe, but the potential for the pipe to be a preferential pathway for groundwater contaminants to reach the river has not been verified.

iAOPC 16
Two private outfalls, WR-214 and WR-248, are located on the upland Triangle Park property; however neither outfall is located in the immediate vicinity of iAOPC 16. There are no records of any NDPES-permitted discharges at this site. These outfalls were determined to be inactive, not present, or otherwise disused through the LWG preliminary evaluation of site-specific information (Table 5.1-3). Historical information on these outfalls has not been reviewed.

11.3.12.3.3 Overwater Discharge

iAOPC 15
A 180-ft dock at M&B, which was removed during remedial activities, was historically used for unloading creosote. The creosote was transported by pipeline to a large tank. Unloading at the dock was gradually phased out during the 1980s, replaced by rail car transport. No overwater spills from the dock were documented during M&B's operational history. The primary overwater activities took place downriver of the iAOPC, near the center of the M&B property.

Treated wood products were placed in the river at various times prior to shipment. An area containing oily sediments was reportedly dredged approximately every 3 years during the Vietnam War years (ATSDR 1995a). The locations of the dredged area and the associated disposal site are unknown. Aerial photos from the 1960s show wood rafts located within the iAOPC. Leaching from these treated wood products could have contributed to the high concentrations of arsenic and dioxin in this area.

iAOPC 16
Historical overwater activities at the Triangle Park site include product transfer, shipbuilding, and ship repair. These operations predate spill reporting requirements, and there are no reports of direct overwater releases.

11.3.12.3.4 Groundwater Discharge

iAOPC 15
Remedial investigations at the M&B site identified three areas where non-aqueous phase liquid (NAPL), dissolved constituents, or both are discharging to the river and affecting surface water and sediments. Dense and light NAPL with associated dissolved plumes are present at multiple locations at the site.

The primary source areas of groundwater contamination include the tank farm and creosote tank; the former waste disposal area; the central process area; and, to a limited extent, a localized area in the southeast disposal trench and an unknown source area near monitoring well MW-1. DNAPL and LNAPL, consisting predominantly of creosote compounds, have been observed primarily in the former waste disposal and tank farm areas. Contaminants identified in groundwater include PAHs, pentachlorophenol, dioxins, and metals (arsenic, chromium, copper, and zinc). In groundwater samples collected in 2002 from monitoring well MW-3, located near Outfall 48 and iAOPC 15, arsenic was detected at 2.07 µg/L; no analysis was conducted

for other iCOCs (DEQ 2004). Three seeps have been identified at the site, two of which were observed to contain NAPL.

To address contaminated groundwater, an underground barrier wall was constructed during remediation activities in 2003. The wall, which surrounds much of the contamination remaining on the upland portion of the site, was designed to minimize contaminant migration to the river. The barrier wall does not extend to the area of iAOPC 15, and groundwater and subsurface soil were not identified as media of concern in the area adjacent to and upland of iAOPC 15. As part of the ongoing remediation efforts in 2004, a 23-acre sediment cap extending into a portion of the iAOPC (Map 11.3.12-1) was constructed over contaminated sediments and creosote seeps. The final phase of remediation at the site included a soil cap over the entire property; it was placed in 2005.

MW-3s is located nearest iAOPC 15 near Outfall 48. Groundwater sampling results for 2002 detected arsenic at 2.07 µg/L, no analysis was conducted for other iCOCs (DEQ 2004).

iAOPC 16

Petroleum-related constituents, including PAHs, have been detected in groundwater over a broad area of the Triangle Park site. Four distinct areas of affected groundwater have been identified within the shallow aquifer (see Map 5.1-1a–h). All four areas contain petroleum-related constituents; two contain halogenated VOCs. Petroleum-related constituents, phthalates, and PCBs have been identified in several other areas. The groundwater data also suggest that metals concentrations might be elevated, although that assessment cannot be made until background groundwater metals concentrations have been established. DEQ believes that the groundwater pathway from the uplands to the Willamette River is complete and that impacted groundwater is discharging to the river in the vicinity of the former docks, upstream of iAOPC 16. Groundwater in this area contains heavy oil-range hydrocarbons that potentially originated from the former waste oil AST.

Additional data are required to assess the magnitude and extent of affected groundwater. Limited information is available regarding the groundwater flow direction and gradient. No information is available regarding the depths of the utilities at the facility relative to the shallow groundwater table or whether the utility and associated backfill function as a preferential migration pathway.

11.3.12.3.5 Riverbank Erosion

Riverbank erosion is considered a complete historical pathway for contaminated riparian soils to have impacted in-water media at the M&B site. During site operations prior to 1971, boiler water, stormwater, and oily wastes were disposed of in an unlined trench in the southeast area of the M&B site adjacent to the river. Waste oil containing creosote and PCP was also placed on soils throughout the site to improve structural stability. As a result of the extensive soil contamination in the riverbank area, 6 acres of

the contaminated upland bank soil were capped during remedial activities at the M&B site.

The riverbank along the Triangle Park shoreline is covered with riprap, with some unclassified fill along the northern shoreline. Erosion and transport of contaminated upland and bank area soils is a potentially complete transport pathway to the river.

No information on riverbank soil sampling in the immediate boundaries of iAOPCs 15 and 16 areas has been obtained.

11.3.12.4 Relationship of Upland Sources to the Distribution of iCOCs

For iAOPC 15, historical and current stormwater discharge, riverbank erosion, historical overwater discharge, sediment transport, and groundwater pathways all appear to be potential contributors of iCOCs to in-water media. For iAOPC 16, pathways that appear to be contributors of iCOCs are stormwater discharge, overland sheet runoff, riverbank erosion, and groundwater discharge. Additional information on the relationship of sources to the distribution of iCOCs in these iAOPCs is provided below.

The highest arsenic concentrations in sediment at iAOPC 15 are located at the upstream end the M&B site near Outfall 48. Arsenic was used in wood-treatment activities on uplands adjacent to iAOPC 15 and has been detected in surface soil of the M&B site near the iAOPC. Arsenic has also been detected in soils at the Triangle Park property. The arsenic concentrations in soils at these adjacent upland properties exceed risk-based cleanup levels for the sites. Although Outfall 48 discharges to the iAOPC, a documented arsenic source has not been identified within the outfall basin, which currently drains residential roads in a 6-acre basin and is treated prior to discharge. The contribution due to riverbank erosion cannot be assessed because no riverbank sampling data are available. Historical overwater activities and sediment transport may also contribute arsenic to this corner of the M&B embayment. Low concentrations of arsenic were detected in the monitoring well on the M&B property nearest to iAOPC 15 in 2002, before remedial actions were undertaken to reduce offsite migration of contaminated groundwater (installation of a barrier wall in 2003 and the completion of a soil cap in 2005). However, groundwater was not identified as a medium of concern in the area adjacent to iAOPC 15. The relationship between potential dioxin sources and the observed distribution of dioxins in sediment within iAOPC 15 suggest that sediment transport from the M&B site may have been a source before the M&B site was remediated in 2005.

Concentrations of total PCB Aroclors in surface and subsurface sediment were higher in iAOPC 16 than elsewhere offshore of Triangle Park. Historical stormwater discharges, overland runoff, and riverbank erosion appear to be the primary pathways by which PCBs migrated to in-water media at iAOPC 16. PCBs have been detected in surface and subsurface soils and occasionally in groundwater at the Triangle Park property. Because they are hydrophobic and not especially mobile, PCBs are not likely to have

contributed substantially to the observed sediment concentrations in iAOPC 16 via the groundwater pathway. No sampling information from the nearest stormwater outfall, located 300 ft upstream has been reviewed, making it difficult to quantify PCB concentrations from the stormwater pathway. There is insufficient information to evaluate historical loading of iCOCs from overwater sources.

A preliminary evaluation of the relationship between sources, pathways, and iCOCs in iAOPCs 15 and 16 is summarized in Figures 11.3.12-1a,b. A preliminary assessment of the current and historical relative contributions of each source is summarized in Table 11.3.12-3.

11.3.13 CSM for iAOPC 17

This section provides a preliminary Round 2 CSM for iAOPC 17, which extends from RM 7.5 to RM 7.8 within Willbridge Cove along the western shore of the Willamette River (see Map 11.3.13-1). This iAOPC is adjacent to four upland parcels:

- GS Roofing (ECSI #117)
- Kinder-Morgan Liquid Terminal (KMLT; ECSI #160)
- Chevron USA (ECSI #25)
- ConocoPhillips (ECSI #177).

Collectively, the last three parcels are also known as the Willbridge Terminal (ECSI #1549). Arkema (ECSI #398) is immediately downstream of the iAPOC, and Saltzman Creek flows directly into the downstream portion of iAOPC. This CSM examines the relationships among the physical setting of the iAOPCs and adjacent upland properties, the chemical distribution of iCOCs in in-water media, and potential sources of the iCOCs. Information presented is this section was obtained from site summaries, including recent addenda, prepared for these parcels (Integral and GSI 2004; 2005a,b,c; Integral 2007) unless otherwise noted.

Four Round 2 iCOCs were identified for this iAOPC:

- Total PCBs
- Sum DDD
- Sum DDT
- Dioxin.

Map 10.5-3a–j shows the areas where this preliminary analysis identified the potential for risk for individual exposure scenarios that were considered in iAOPC development, and Table 10.5-1 identifies the iCOCs associated with the exposure scenarios. PCBs are an iCOC for all risk areas. The risk areas for DDD, DDT, and dioxins are limited to the upstream portion of the iAOPC, in the general area of the two upstream docks.

The CSM evaluation is summarized as follows:

- Based on the evaluation of chemical sources/pathways and the in-water distribution of iCOCs for iAOPC 17, there is little evidence of a current link between upland sources immediately adjacent to the iAOPC and concentrations in sediment, biota, and surface water samples from iAOPC 17. Upland soils and groundwater collected along the shoreline do not contain iCOCs associated with this iAOPC; however, stormwater sampling has not included analysis of PCBs, DDx, or dioxins. Historical contributions are also uncertain; although elevated subsurface PCB concentrations (relative to surface sediment concentrations) in the nearshore area of the cove (adjacent to and offshore of Outfall 22, between the ConocoPhillips and Chevron docks, and east of the mouth of Saltzman Creek) suggest possible historical releases or deposition.
- With the exception of DDx, iCOCs for iAOPC 17 do not appear to be present in materials associated with onsite spills and waste disposal practices,
- Stormwater and overland transport of soils do not appear to have contributed to the release of iCOCs to iAOPC 17.
- The iCOCs associated with iAOPC 17 have not been reported as a constituent of materials spilled during overwater activities.
- Three seeps have been observed along the shoreline of Willbridge Terminals and represent a historical pathway (containment walls have been constructed at two locations) or potentially an ongoing preferential pathway from the upland facility; however, iCOCs for the iAOPC have not been detected in groundwater from the Willbridge Terminal upland sites.
- At the GS Roofing facility, a plume associated with a former gasoline UST is present, but has been determined to be receding; iCOCs for iAOPC 17 have not been reported in groundwater from this facility.
- DDT has been detected in one riverbank surface soil/sediment sample.
- All iCOCs were detected in most sediment and biota samples from the iAOPC.
- Although the Round 2 Groundwater Pathway Assessment identified areas of groundwater discharge in iAOPC 17 (Integral 2006g), no potential TZW iCOCs were identified in this area in the draft human health and ecological risk evaluations (Sections 8 and 9). Migration of upland groundwater plumes appears to be an incomplete pathway for transport of iCOCs or potential iCOCs to the sediment transition zone at concentrations that may pose unacceptable risk.

11.3.13.1 Physical Setting, Infrastructure, and Operational History

iAOPC 17 is a 10.4-acre area within the northern two-thirds of Willbridge Cove. In-river and upland physical characteristics, infrastructures, and operational history relevant to this iAOPC are described in this subsection.

11.3.13.1.1 In-River

iAOPC 17 is located along the western shore of the Willamette River in Willbridge Cove immediately upstream of the Arkema property. This area is the downstream portion of a large depositional zone in the main river channel that extends from RM 7 to 10. Three large finger piers used primarily for the transfer of fuel products extend outward from the Willbridge Terminal facilities to the main river stem. From upstream to downstream, these docks are operated by Conoco Phillips, Chevron, and Kinder-Morgan. Along this stretch of river, the bank generally drops sharply from the uplands to a channel depth of about -30 ft NAVD88 at the edge of the shipping channel. However, at the downstream end of Willbridge Cove and this iAOPC, there is a broad, very shallow (less than +5 ft NAVD88) bench area (Map11.3.13-1).

The area within the iAOPC as well as the area extending into the shipping channel is characterized as a depositional zone based on the Sediment Trend Analysis®. Modeled bed shear is low throughout the Willbridge Cove even during high flows on the LWR (see Map 4.5-1). Sediment accretion up to 5 ft in extent over a 2-year period (2002 through 2004) was evident beneath and along the length of the central pier (Chevron Dock), particularly at the shoreward end. Outside this area of accretion, dredging of up to 5-10 ft of sediment is evident on both sides of the central pier during the 2002-2004 period. The relatively shallow (from -20 to + 5 ft NAVD88) sloped area at the downstream of the KMLT dock is a mosaic of areas showing sediment scour, accretion, and no change. The scour areas are likely due to propwash. Net sediment accretion on the order of 1 ft was observed at the downstream site boundary (adjacent to GS Roofing). Periodic maintenance dredging is required to keep the areas between the docks serviceable for ship traffic.

Periodic monitoring of beach sediment stakes placed along the downstream corner of the Willbridge Cove from July 2002 to January 2004 indicated longer periods of sediment erosion of approximately 12-13 cm separated by brief periods of sediment accretion of up to 15 cm along the +7 ft NAVD88 contour. Sediment stakes placed at the +9 ft NAVD88 contour showed erosion of up to 17 cm through March 2003, after which the sediment stake was lost. Sediment stakes placed along the +16 ft NAVD88 contour showed either no change or slight accretion (2-4 cm) throughout the observation period (Anchor 2004).

Surface and subsurface sediments in the iAOPC are dominated by fine-grained particles although there are some sandy layers at depth just up and downstream of the iAOPC (Map 11.2.13-2a,b). A sandy surface sample overlying fine-grained sediments was collected on the slope at the downstream end of the iAOPC.

With the exception of the downstream end, the riverbank within the Willbridge Cove has a relatively steep slope. The riverbank downstream of the Chevron dock is armored with riprap, a natural slope armored with rock exists between the Chevron and ConocoPhillips dock, and a natural bank is present upstream of the ConocoPhillips dock. Sand is generally present in all areas at low water.

In addition to the three large finger piers extending into the main river stem, significant shoreline and in-water features include City of Portland stormwater Outfall 22, Saltzman Creek, and private stormwater outfalls at Chevron and ConocoPhillips (Map11.3.13-1).

11.3.13.1.2 Upland

The Willbridge iAOPC is bounded by four industrial facilities along the western bank of the Willamette River in a section of northwest Portland zoned as "Heavy Industrial." The LWG has prepared site summaries for GS Roofing Products, Inc. and Willbridge Terminals (Kinder Morgan, Chevron, and ConocoPhillips). Information on adjacent upland sites was obtained from the LWG site summaries unless otherwise noted. Upland conditions at these sites are described in the site summaries and are summarized here.

Genstar Roofing Products, Inc.

GS Roofing (ECSI #117) occupies 8.5 acres along the western bank of the Willamette River at RM 7.5. The site is currently used by GS Roofing to manufacture asphalt roofing products. Prior occupants were involved in the same industry:

- From sometime in the early 1940s to the present, roofing products have been manufactured on the site by various companies such as Pacific Roofing Co., Certain Teed Roofing Products, Fibreboard Paper Products, and most recently Genstar Roofing.
- In the late 1950s and continuing into the 1980s, asphalt was piped directly into the facility by Shell Oil Company. Asphalt is no longer piped to the facility, but is delivered by truck.
- In 1981, Bird and Son was issued a USACE permit to fill more than 1 acre of wetland along the river to expand the facility. GS Roofing inherited the permit when they acquired the facility in 1985.
- In 1986, GS Roofing completed the fill project. There is no information in the USACE files regarding the characteristics of the fill material. However, the original application stated that approximately 40,000 yd^3 of material would be required and would likely consist of construction materials or dredged material from the river.

Willbridge Terminals

Willbridge Terminals (ECSI #1549) comprises 83 acres along the western bank of the Willamette River between RM 7.5 and 7.8. While ownership has changed, the three original petroleum product terminals (Shell Oil/Kinder Morgan Liquid Terminal, Standard Oil/Chevron Products Company, and Union Oil/ConocoPhillips) are still operational and have been so since the early 1900s:

- In 1908, petroleum-handling operations began at the ConocoPhillips terminal. The facility currently stores and transfers a variety of bulk petroleum products

including gasoline, diesel, fuel oils, and lubricants. The facility also blends and packages a variety of lubricants.

- Since 1911, the Chevron Willbridge Distribution Center has stored and distributed a variety of refined petroleum products, including gasoline, diesel fuel, and lubricating oil
- In 1914, the KMLT terminal began petroleum-storage operations. At present, it stores a range of petroleum products including diesel, gasoline, ethanol, and aviation fuel. Historically, KMLT also stored fuel oils, motor oil, and lubrication oils.

11.3.13.1.3 Upland Hydrogeology

The site is located in the former Doane Lake Area. Over time, the several small lakes, including Kittridge and Doane lakes, as well as sloughs in the area have been filled with dredged materials from the Willamette River. Much of the Willbridge site is located on historical Kittridge Lake.

The general site stratigraphy at the Willbridge site from the ground surface downward consists of a surficial fill unit consisting of gravel, silt, and sand (a water-bearing zone [WBZ]) covering the Holocene alluvial deposits of clay, silt, and sand (semi-confined WBZ), overlying Columbia River Basalt (confined WBZ) (see Supplemental Figure 5-2a). The general site stratigraphy for GS Roofing, information for which is limited, is assumed to parallel that of the Willbridge site.

The depth to groundwater ranges from approximately 8 to 22 ft bgs at the GS Roofing site, and 4 to 22 ft bgs at the Willbridge site. The general groundwater flow direction for both is east to northeast toward the river, with flow at the Willbridge site occurring predominantly in the higher conductivity sand fill. The contact between the sandy fill and underlying alluvium at the Willbridge site is near the elevation of the river. Because of a silt ridge in the native alluvium near the river and parallel to the shoreline, which may have been a natural levee for a former lake in the area or a feature of the former Holbrook Slough, the groundwater gradient is relatively flat near shore over the downstream half of the site and steeper in the upstream part of the site, where the silt ridge may be discontinuous or breached. Information regarding the magnitude of the groundwater gradient or aquifer characteristics at GS Roofing was not available.

Three seep areas are adjacent to the iAOPC: one near the KMLT dock, one along the beach adjacent to KMLT, and one on the property line between the Chevron and ConocoPhillips terminals.

The Round 2 Groundwater Pathway Assessment (Integral 2006g) identified a nearshore area of higher-rate groundwater discharge in the vicinity of the former Holbrook Slough, and a lower-rate groundwater discharge area along the steep sediment face across the remaining portion of the site shoreline (Supplemental Figure 11-7 from Integral 2006g). Elsewhere, the Round 2 Groundwater Pathway Assessment identified low-to-no groundwater discharge.

11.3.13.2 Chemical Distribution of iCOCs

This section describes the distribution of iCOCs in environmental media at iAOPC 17. For the purposes of evaluating sources to the iAOPC 17, the discussion of chemical distribution is limited to total PCBs, total DDT (sum of 2,4'- and 4,4'-DDT), and dioxins (as TEQs). All iCOC data for the iAOPC can be found in Appendix I.

11.3.13.2.1 Sediments

Sediment data for iAOPC 17 are available for 21 surface samples and 6 subsurface cores (17 subsurface samples); locations are shown in Map 11.3.13-1. A statistical summary of all iCOCs in the iAOPC is provided in Table 11.3.13-1a.

PCBs

PCBs were detected in five of seven surface sediment samples (Map 11.3.13-3 and Map 11.3.13-4). Two types of PCB analyses were conducted for these samples: Aroclors for all of the samples and PCB congeners for a single sample. Detected concentrations of total Aroclors in surface sediment ranged from 0.851 to 703 µg/kg, with a mean value of 165 µg/kg; total PCB congeners in the one sample analyzed was 19.4 µg/kg. The highest PCB concentration in surface sediment within the iAOPC was found in a sample from a nearshore area between the Chevron and ConocoPhillips upstream docks. Two of the PCB samples are in areas that were dredged following sampling. Surface PCB concentrations elsewhere in the iAOPC were less than or equal to 33 µg/kg.

PCBs were detected in 11 of the 16 subsurface samples analyzed. All samples were analyzed for Aroclors and one was also analyzed for the full set of congeners. Detected total Aroclor concentrations ranged from 12.4 to 324 µg/kg, with a mean value of 114 µg/kg (Map 11.3.13-5). Subsurface concentrations were generally higher than surface concentrations. The total PCB congener concentration was 64.3 µg/kg (Map 11.3.13-6). The highest concentrations of subsurface total Aroclors were detected in the same general areas as the Aroclor maxima for surface sediment. The highest Aroclor concentrations were found between about 5 and 10 ft bml. PCB Aroclors were not detected in the deepest interval analyzed in the majority of individual cores.

DDT

Total DDT was detected in 5 of 16 of the surface sediment samples within the iAOPC that were analyzed for DDT isomers (Map 11.3.13-7). Concentrations of DDT in surface sediment ranged from 0.501 to 125 µg/kg, with almost all values below 5.12 µg/kg. The highest DDT concentration in surface sediment within the iAOPC was measured in a sample from a nearshore location downstream of the docks within the berth. However, this location is not within the risk area identified for DDT. The highest concentration in the risk area is a single detection of 5.12 µg/kg.

Total DDT was detected in 4 of the 16 subsurface samples within the iAOPC that were analyzed for DDT isomers. DDT concentrations ranged from 2.9 to 27.7 µg/kg, with a mean of 15.8 µg/kg (Map 11.3.13-8). The highest concentrations of subsurface DDT were detected on the upstream end of the iAOPC near the ConocoPhillips dock and in the nearshore area downstream of the docks in the vicinity of the surface maximum.

Dioxins
Dioxins were detected in the two surface sediment samples within the iAOPC that were analyzed for dioxins and furans (Map 11.3.13-9) at concentrations (represented as dioxin/furan TEQs) of 0.711 and 3.48 pg/g. Both dioxin/furan surface samples were collected in the southern portion of the cove downstream of the KMLT dock; the higher concentration was at the same location at the PCB maxima. There were no dioxin samples collected in the area identified as the risk area for dioxins.

Dioxins and furans were detected in the four subsurface samples within the iAOPC that were analyzed for dioxins, all which came from a single core located near the toe of the slope at the downstream end of the Willbridge Cove (Map 11.3.13-10). Dioxin TEQ concentrations ranged from 0.41 to 15.2 µg/kg, with the two highest concentrations (13.7 and 15.2 pg/g) present in the two deepest core intervals (greater than 8.9 ft bml).

11.3.13.2.2 Surface Water
Surface water samples were collected at one location within the iAOPC during three sampling events, as described in the *Portland Harbor RI/FS Round 2A Surface Water Site Characterization Summary Report* (Integral 2006l). Station W017, located in the corner of the cove downstream of the KMLT dock, is in a nearshore amphibian habitat area, Saltzman Creek (Map 11.3.13-1). A near-bottom water sample was collected using a peristaltic pump. Analytical results for samples from Station W017 are provided in Table 11.3.13-1b. Aroclors were not detected in Round 2A at this station for any of the sample collection events at detection limits of 0.0025-0.00256 µg/L. Total DDT was detected during the July 2005 sampling event at concentration of 0.000693 µg/L.

11.3.13.2.3 Transition Zone Water
Areas offshore of the Willbridge Terminal were included in transition zone water sampling performed during the Round 2 groundwater pathway assessment (Integral 2006c). TZW sampling locations are shown on Map11.3.13-1. TZW sampling results are described in detail in Integral (2006g) and are summarized in Section 6.2. Detected concentrations of petroleum-related chemicals in TZW were substantially lower than upland groundwater concentrations. No potential TZW iCOCs were identified for iAOPC 17 based on the results of Round 2 TZW sampling and the draft human health and ecological risk evaluations (Sections 8 and 9).

No porewater samples were analyzed for the iAOPC-specific iCOCs at this iAOPC.

11.3.13.2.4 Biota
Invertebrate tissue analyses for the clam *Corbicula fluminea* (both field-collected and laboratory-exposed) and the worm *Lumbriculus variegatus* (laboratory-exposed) are available to potentially represent exposure of biota to iAOPC 17 sources. These samples were collected within the iAOPC (Map 11.3.13-1) and analyzed for PCBs (Aroclors and congeners), dioxin/furans, and total DDT.

All iCOCs analyzed were detected in each of the invertebrate tissue samples from this iAOPC at the concentrations shown in Table 11.3.13-1c. Total PCB congener concentrations was highest in the field-collected clam sample and lab-exposed worm (99 and 91.4 µg/kg – wet) and lowest in the lab-exposed clam (50.7 µg/kg – wet). Total DDD concentrations were highest in the lab-exposed worm (64.2 µg/kg – wet), intermediate in the field clam (28.5 µg/kg – wet) and lowest in the lab-exposed clam (6.26 µg/kg – wet). Dioxin/furan TEQ showed the same pattern with the highest levels in the lab-exposed worm (2.35 pg/g – wet), intermediate levels in the field clam (0.816 pg/g – wet) and the lowest levels in the lab-exposed clam (0.279 pg/g – wet).

11.3.13.3 Potential Sources of iCOCs

This section presents a summary of the current understanding of potential sources of iCOCs to iAOPC 17. The upland parcels adjacent to the iAOPCs have been the site of industrial activities since the early 1900s. Activities have primarily been related to bulk storage of petroleum products (gasoline, diesel fuel, motor and lubricating oils, blended oils, aviation fuels, fuel additives, and asphalt products). A remedial investigation is currently being planned for the GS Roofing parcel. A number of soil and groundwater investigations have been jointly conducted for the Willbridge Terminals.

Information presented is this section was obtained from site summaries unless otherwise noted. In addition to iCOCs, COIs associated with nearby upland areas are also discussed in this section. The COIs are presented to provide a comprehensive understanding of the upland issues and to support the identification of potential sources to the iAOPCs. The relevance of the pathway to iCOCs is summarized at the end of each pathway discussion. Potential sources, contaminants of interest, and pathways are summarized in Table 11.3.13-2.

11.3.13.3.1 Upland Releases

The upland site adjacent to the iAOPC has been the site of bulk petroleum product handling and storage for almost a century. Numerous spills have released materials to stormwater and surface soils, with subsequent migration to groundwater. Investigations measuring contaminants in soils throughout Willbridge Terminals have confirmed the presence of VOCs, PAHs, metals, and TPH in soils, as well as TPH, VOCs, PAHs, metals in groundwater.

Spills resulting in product loss (diesel, gasoline, kerosene, asphalt, lubricating oils, machine oils, transmission fluid, xylene, ethanol, etc.) have occurred at all parcels adjacent to the iAOPC. Spills records typically date back to the 1970s, with little information available before that time. Spill information is summarized by parcel below.

Originally, asphalt was piped to the GS Roofing facility for manufacture of roofing materials; it is now delivered via trucks and stored in aboveground tanks. There are no records documenting spills or leaks; however, in their on-line ECSI site summary, DEQ references a January 1986 spill of 1,200 to 1,500 gallons from a leaking pipeline. In addition, petroleum-contaminated soils required removal and disposal during the

decommissioning of two underground storage tanks, further evidence of spills or leaks on the site. KMLT has lost more than 200,000 gallons of fuels and fuel additives to releases over its history of operation, in volumes of 1 to 126,000 gallons per event. At the Chevron parcel, petroleum product spills of 1 to 32,000 gallons each have totaled approximately 76,000 gallons. Records for the ConocoPhillips parcel show releases totaling 45,000 gallons (from 1 to 11,700 gallons) of the same type of materials. Most releases were to yard soils; spills to the river appear to have been limited to small volumes, with the exception of a pipe failure in which 7,000 gallons of asphalt were released to the river (during transfer to Paramount Petroleum from the waterfront) (Note: most of this spill was recovered). Spills of crude oils and asphalt have also occurred within the Paramount Petroleum facility, east of Willbridge Terminals. Because of the distance from the facility to the shoreline, only a portion two spills reached the river: a 150-gallon spill of heat transfer oil in 1989 of which about 40 gallons entered the storm drain system and likely discharged to the river at municipal Outfall 22 (just upstream of iAOPC 17) and a 9,000-gallon gasoline spill from a 1998 tanker truck crash of which a small fraction (unquantified) also entered the City's stormwater system.

DDT was reported to have been stored at the Kinder Morgan terminal between 1953 and 1955 (KHM 2003) while operated by Shell Oil. A 1984 letter from Shell (Schulz 1984, pers. comm.) indicates that DDT was stored in one of the smaller tanks and that DDT "sludge had been buried in a trench." The tank was located near the warehouse in the southwest corner of the Kinder Morgan facility, and the trench was located immediately west of Front Avenue along the southern property line. Soil samples near the tank had DDD and DDT detections up to 0.084 mg/kg; DDE, DDD, and DDT were detected in the trench samples at concentrations up to 0.044 mg/kg. Monitoring wells 5, 6, 11, and 12 were also tested, and three of the wells had DDx detections up to 0.049 mg/L.

Historically, several tenants and owners disposed of waste materials onsite. At GS Roofing, waste asphalt, paper from the manufacture of roofing felt, debris, and possibly barrels of oil as well as oil-soaked diatomaceous earth were buried in the southwest corner of the site (Integral 2007). The extent of the onsite landfill at GS Roofing is currently being investigated. DEQ's online ECSI site summaries list onsite waste disposal (e.g., tank bottom/sludge) as historical practices at both the Chevron and KMLT sites.

Little information is available to describe historical wastewater discharges. Prior to the construction of municipal stormwater and wastewater collection systems, process water was likely discharged directly to the Willamette River. GS Roofing was permitted to discharge cooling water and process water from its felt paper mill to the river between 1967 and 1971, when the process water was diverted to the City of Portland's sanitary sewer. DEQ reported that these discharges contained metals (and possibly PAHs) and may have occurred since the 1940s. Noncontact cooling water continued to be discharged to the river until 1996, when a cooling tower and wastewater recirculation system was constructed. Currently, the recirculation system is cleaned twice yearly, when about 200 gallons of water are processed through an oil-water separator and then

discharged under an NPDES permit to the river via private outfall WR-29/Saltzman Creek. Since that time, GS Roofing has been in compliance with the permit conditions, with the exception of occasional exceedences of biochemical oxygen demand limits.

Within Willbridge Terminals, wastewater is processed (e.g., by oil-water separator and a hydrocleaner, in the case of ConocoPhilips) before discharge to the river (some process water for the KMLT facility is discharged to Saltzman Creek). In recent years, monitoring data from Willbridge Terminals facilities have demonstrated compliance with NPDES permit conditions.

Based on available information, iCOCs for iAOPC 17 other than DDT do not appear to be present in materials associated with onsite spills and waste disposal practices (including wastewater discharges); however, no information has been reviewed indicating that PCBs, DDx, and dioxins have been analyzed for in wastewater or stormwater samples.

11.3.13.3.2 Stormwater/Overland Transport

The topography of the parcels adjacent to iAOPC 17 is generally flat (with the exception of a steep 1-acre area leading to the river on the GS Roofing property). Currently, runoff from impervious surfaces and within process and transfer containment areas is collected in onsite stormwater catch basins or tanks and typically discharged via the municipal or private stormwater system. Most of the Willbridge facilities drain to Outfall 22, Saltzman Creek, sheet flow, or private outfalls. Outfall 22 is just south of the iAOPC boundary or Outfall 19, at the end of Kittridge Avenue. A portion of the runoff from the ConocoPhillips site also discharges to Outfall 19, which is over one-half mile upstream. Some stormwater from the KMLT facility may discharge to Saltzman Creek. Stormwater from petroleum storage and transfer areas is treated before discharge to the river. Runoff from roof drains, parking lots, and general open space is not treated and may be discharged via onsite stormwater drains. Remaining yard areas tend to be gravel and promote infiltration, rather than runoff.

At the GS Roofing property, most of the stormwater is discharged to Saltzman Creek (a small area drains to municipal Outfall 22). There is also a steeply sloped area of undeveloped land located east of the GS Roofing manufacturing facility, adjacent to the river's edge. Drainage from this area occurs as infiltration or sheet flow directly to the Willamette River; however, there is no current industrial activity in this area. Some of the stormwater from the ConocoPhillips parcel is routed to City Outfall 19, upriver from Willbridge Cove; historically, stormwater was discharged via Outfalls 20 and 21, now abandoned.

Monitoring data from recent years for the Willbridge Terminals facilities demonstrate compliance with NPDES permit conditions. On a few occasions over the last 15 years, stormwater discharge from GS Roofing has not been able to meet permit conditions for oil and grease, copper, lead, or zinc. There appears to have been a period in the mid-1970s when process water, which had been diverted to the sanitary sewer in 1971, was not well-contained and entered the stormwater system, causing noncompliance with

BOD and total suspended solids limits. This situation was corrected following an engineering evaluation by DEQ.

There is no specific record or information on industrial activities to indicate stormwater and overland transport of soils have contributed to the release of iCOCs to iAOPC 17. A possible exception is storage and handling of DDx at the Kinder Morgan property, as noted above. Surface soil sampling for the RI (KHM 2003) resulted in detections of DDx in two samples on the Kinder Morgan property (up to 2,090 µg/kg). No information has been reviewed indicating that stormwater has been analyzed for iCOCs.

Outfall 22 drains 88 acres, 59.2 percent of which is industrial. This outfall and a number of private outfalls are located immediately upstream of iAOPC 17. A relatively high number of sediment samples have been collected offshore of Outfall 22, primarily as a part of the City's Source Control program (CH2M Hill 2004b) as well as one LWG Round 2 core. Maximum surface and subsurface concentrations in these samples are compared to maximums within iAOPC 17 below:

	Outfall 22 Max (µg/kg)	**iAOPC 17 Max (µg/kg)**
Surface		
Total PCB Aroclors	36.3	703
Total PCB Congeners	29.4	19.4
Total 2,4 and 4,4-DDT	14	125
Subsurface		
Total PCB Aroclors	812	324
Total PCB Congeners	888	64.3
Total 2,4 and 4,4-DDT	3	27.7

Maximum surface PCB Aroclor concentrations are less than concentrations within iAOPC 17. Subsurface PCB concentrations from the single core farther offshore from the outfall show higher concentrations with depth, suggesting an elevated historical source. This subsurface location is also adjacent to the ConocoPhillips dock so historical sources could include overwater operations. Elevated PCB levels are evident in cores from within the iAOPC just downstream of this dock. Surface and subsurface DDT concentrations off the Outfall 22 area indicate that the outfalls are not a source of the DDT compounds within the iAOPC. Too few dioxin/furan samples were collected to compare results for samples collected near the outfall to those within the iAOPC.

11.3.13.3.3 Overwater Discharge

All three parcels within Willbridge Terminals have marine docks for loading and unloading petroleum product. Releases have occurred during product transfer, although documented spills have tended to be rare and of small volume (one exception was the loss of 7,000 gallons of asphalt being transferred to Paramount Petroleum [then Chevron Asphalt] in 1989—most of which was recovered). All three terminals currently adhere to required best management practices including deployment of multiple in-water booms during transfer and onsite emergency response equipment.

Paramount Petroleum is not located on the river, but their asphalt materials are offloaded at the Willbridge Terminals. GS Roofing has no overwater activities. None of the iCOCs associated with the iAOPC have been reported as a constituent of spilled materials since reporting began in the 1980's.

11.3.13.3.4 Groundwater Discharge

Extensive groundwater monitoring has been conducted at Willbridge Terminals, including quarterly sampling since the remedial investigation of the terminals began in 1997. Groundwater contains measurable light non-aqueous phase liquids (LNAPL) and dissolved constituents including PAHs, volatile organic compounds, metals. The groundwater plume extends from the southwestern edge of the terminals near the railroad right-of-way east to the river along the ConocoPhillips and Chevron terminals shoreline and encompasses all or portions of the three terminals and the southwest portion of the Genstar property (Map 5.1-1a–h). Downgradient wells along the shoreline were sampled in March 2004; methyl tertiary butyl ether (MTBE), PAHs, and metals were detected in a number of wells.

As noted above, DDT was detected in groundwater in 1984 at the Kinder Morgan property. Testing of pesticides (including DDxs) for the RI (KHM 2003) included samples from 28 monitoring wells at Kinder Morgan and 18 hydropunch samples over the Willbridge facility. Pesticides were not detected at detection limits of 0.1-0.5 μg/L.

Several seeps have been observed along the shoreline: one between the Chevron and ConocoPhillips dock near the mouth of the former Holbrook Slough and co-located former stormwater outfall, one near the KMLT dock, and one along the KMLT beach. In a 2003 sampling event, mercury was detected in the seep near the KMLT dock and zinc was detected in the KMLT beach seep. PAHs and total petroleum hydrocarbons (diesel and gasoline) were detected in the seep between the Chevron and ConocoPhilips docks. This latter area has been considered a preferential pathway for release of site-related contaminants. A containment wall was constructed between the two docks in 2006.

A preferential groundwater pathway is present in the backfill of the 60-inch-diameter stormwater piping for Outfall 22. The portion of the pipeline trench excavated through the riverbank appears to have breached a natural ridge in the alluvium that may have prevented or restricted groundwater migration to the river. This breach in the alluvium ridge along with the bedding and backfill material appear to have created a preferential pathway for NAPL migration to the river as minor sheens. Small amounts of separate-phase hydrocarbons were observed in the vicinity of the 60-inch outfall for a period following construction of the storm line in 1982 and again beginning in September 2000. This pathway has now been eliminated with the installation of a 170-ft-long sheet pile cutoff wall around the 60-inch outfall, with extraction wells behind the wall to remove and treat contaminated groundwater.

In 2005-2006, Chevron installed 12 nearshore wells in the area between the Conoco Phillips and KMLT docks. Groundwater sampling of these and other wells included

PCBs and pesticides. PCBs were not detected at concentrations above 0.09 to 0.38 µg/L. DDx was not detected at concentration above 0.02 to 0.20 µg/L.

At the GS Roofing facility, a plume associated with a former gasoline UST is present, but has been determined to be receding. DEQ (2001) does not consider the plume to be a likely source of Willamette River water or sediment contamination, nor have iCOCs for iAOPC 17 been reported in groundwater from this facility.

While facility-related releases to groundwater have been documented to reach the river, investigations have not focused on the iCOCs for iAOPC 17. No potential TZW iCOCs were identified for iAOPC 17, based on the results of Round 2 TZW sampling and the draft human health and ecological risk evaluations (Sections 8 and 9).

11.3.13.3.5 Riverbank Erosion

The riverbank adjacent to the terminal docks is armored adjacent to the downstream areas of the iAOPC and becomes more natural in the upstream areas. A beach has formed along the shoreline within the Willbridge Cove; aerial photos show an extensive exposed beach during low water. The susceptibility of the site to bank erosion has not been reported and is unknown.

Riverbank samples were collected as part of a 2003 remedial investigation, but the results were combined with those for upland soils, precluding separate assessments.

In November 2005, 10 test pits were excavated in the beach area between the Chevron and KMLT docks. The surface soils consisted of sand covered by rock armor. Eleven shallow soil samples from the depth interval from 0 -1 ft were collected from test pits (7) and from new monitoring well (4) locations. Collected soil samples were analyzed for VOCs, SVOCs (including PAHs), metals, PCBs, and pesticides. PCBs were not detected at concentrations above 3.6 to 8.6 µg/kg. 4,4-DDT was detected at concentrations up to 31.5 µg/kg; 4,4-DDD and 4,4-DDE were not detected at concentrations above 0.725 to 8.46 µg/kg. Deeper samples (greater than 1 ft) were also collected from this area and analyzed for VOCs, SVOCs, PCBs, metals, and pesticides. PCBs were not detected (detection limits ranged up to 43 mg/kg). With three exceptions, DDx was not detected (detection limits ranged up to 52.1 µg/kg). The maximum detection was 31.5 µg/kg (4,4-DDT).

11.3.13.4 Relationship of Upland Sources to the Distribution of iCOCs

Based on the evaluation of historical chemical sources and pathways presented above and the in-water distribution of iCOCs for iAOPC 17, there is little evidence of a current link between upland sources and the iCOCs measured in sediment, biota and surface water samples and historical contributions of iCOCs are uncertain.

The chemicals of interest for the Willbridge Terminals include PAHs, petroleum hydrocarbons, volatile organic compounds, and metals, none of which are iCOCs for the iAOPC 17. The DEQ online ECSI database has no record of PCB use or spills in association with these facilities; however, PCB usage associated with electrical

equipment at major industrial facilities such as these was historically commonplace. DDx was stored at the Kinder Morgan facility in the 1950s and sludges were placed in a trench. Additional information related to this storage and handling has not been reviewed.

Sediment samples collected off Outfall 22, located immediately upstream of the iAOPC, indicate that areas drained by the outfall may have historically contributed to PCBs in the iAOPC, but historical overwater releases are also a possible source. The spatial distribution of DDT in sediment near the outfall and within the iAOPC suggests that Outfall 22 is not a source of DDT in the iAOPC. A similar comparison for dioxin was not possible due to limited data. Recent nearshore sampling in the area near the Chevron dock indicted no PCB detections in soil or groundwater and limited DDx detections in surface and subsurface soil; however, detection limits were higher than actual detected concentrations in iAOPC sediments for both these analytes. Detections of DDx in surface soil on the Kinder Morgan property may represent a source to stormwater.

Suspended sediments from upstream may be transported into the Willbridge Cove during high flows in the LWR. In addition, two iCOCs for iAOPC 17 (PCBs and DDx compounds) are present at elevated concentrations in nearshore sediments in iAOPC 14 immediately downstream and adjoining iAOPC 17. Resuspension of this material by natural or anthropogenic forces could result in upstream transport and deposition in Willbridge Cove during certain flow conditions.

The spatial distribution of PCBs in surface sediment indicates that overwater sources associated with the Willbridge Terminal docks cannot be ruled out as a current or historical source to the iAOPC.

Although the Round 2 Groundwater Pathway Assessment identified areas of groundwater discharge in iAOPC 17 (Integral 2006g), no potential TZW iCOCs were identified in this area in the draft human health and ecological risk evaluations (Sections 8 and 9). Migration of upland groundwater plumes appears to be an incomplete pathway for transport of iCOCs or potential iCOCs to the sediment transition zone at concentrations that may pose unacceptable risk, Pesticides (including DDx) were not detected in facility-wide groundwater sampling conducted for the RI.

A preliminary evaluation of the relationship between sources, pathways, and iCOCs in iAOPC 17 is summarized in Figure 11.3.13-1. A preliminary assessment of the current and historical relative contributions of each source for iAOPC 17 is summarized in Table 11.3.13-3.

11.3.14 CSM for iAOPC 18

This section describes a preliminary Round 2 CSM for iAOPC 18, which is a 7.1-acre area extending from approximately RM 8.15 to 8.35 along the western shore of the river, adjacent to Shaver Transportation and Parcel 3 of the Front Avenue LP property

(Map 11.3.18.1). This CSM examines the physical setting of the iAOPC and adjacent upland properties, the chemical distribution of iCOCs in in-water media, and potential sources of the iCOCs.

The following iCOCs have been identified for iAOPC18:

- Total PCBs.

Potential iCOCs for iAOPC 18 include:

- Ammonia.

Potential iCOCs are identified through less certain and/or less rigorous evaluations based on fewer lines of evidence, FPM results, or other high uncertainty lines of evidence (see Sections 8 and 9).

Map 10.5-3a–j shows the areas where this preliminary analysis identified the potential for risk for individual exposure scenarios that were considered in iAOPC development, and Table 10.5-1 identifies the iCOCs associated with the exposure scenarios. PCBs are an iCOC for all risk areas, while the risk area for ammonia is limited to a small portion of the upstream area of the iAOPC.

The evaluation indicates that the only source that has been evaluated for PCBs is one stormwater discharge, City Outfall 19. Several ECSI sites within the Outfall 19 drainage basin have known or potential PCB contamination. The amount of sediment removed from the onsite and offsite stormwater conveyance system for the Calbag Metals site alone shows that contaminant loading to Outfall 19 has been significant. It is uncertain if groundwater is a significant source of iCOCs for iAOPC 18. No riverbank sampling has been performed so it is uncertain if riverbank erosion is a significant source. Overwater activities occurring in this area may have been a historical source of iCOCs, particularly from the Shaver Transportation facility. Sediment transport may contribute to iCOC distributions, but it is not the dominant source.

11.3.14.1 Physical Setting, Infrastructure, and Operational History

In-river and upland physical characteristics, infrastructure, and operational history relevant to this iAOPC are briefly described in this subsection. Information about adjacent sites was obtained from the LWG site summaries (Integral and GSI 2004; 2005a,b,c) and updates (Integral 2007) unless otherwise noted.

11.3.14.1.1 In-River

iAOPC 18 is located in a river area that is generally depositional based on the sediment-profile and time-series bathymetry surveys, as well as the results of the Sediment Trend Analysis®. The time-series bathymetric change data over the 25-month period from January 2002 through February 2004 indicate trends may be more complex. Within the small embayment in which iAOPC 18 is located, there exists a relatively large, circular

area of net sediment erosion (of up to 2 ft) that extends toward the river channel. Along the main river, sediment accretion is evident at the upstream end of the property, but net erosion is evident close inshore along the downstream portion. No sediment transport information is available for the bank in this area.

The majority of the surface sediment deposits within iAOPC 18 consist of silty sand (Map 11.3.14-2a). Silty sands to sandy silts dominate the subsurface sediment cores from the LWG Round 2A investigation, with a sand bed at a depth of approximately 5 to 6 ft, ranging in thickness from 1 ft to <3.5 ft (Map 11.3.14-2b).

The bank in the vicinity of the Front Avenue property has been armored using slag from the historical operations at the adjacent Tube Forgings property. The slag and construction debris are present primarily along the current shoreline and in the central portion of the site, which was the historical riverbank area.

Significant in-water facilities and structures within the iAOPC include the following:

- A main dock including a ramp and three finger piers at the Shaver facility
- A 200-ft Shaver shop barge including ramp and fuel dispensers (unknown type and capacity), and a 200 ft^2 floating shed
- Two City of Portland stormwater outfalls (Outfalls 19 and 19A)
- Two private stormwater outfalls (WR-378 and WR-379).

Primary site uses for the in-river structures are described in the following upland site summary section.

11.3.14.1.2 Upland

Upland sites adjacent to the iAOPC include Parcel 3 of Front Avenue LP Properties (ECSI #1239), which is owned by Construction Materials Inc. NW (CMI NW)/Hampton Lumber; and Shaver Transportation Co. (ECSI #141). Upland conditions at these sites are described in the site summaries and are briefly summarized in this subsection. These properties are zoned industrial.

Front Avenue Parcel 3

The CMI NW/Hampton Lumber facility has been used for storage and reloading of lumber and other building products onto railroad cars for shipment since 1994. The lumber and products are delivered to the site by truck. A storage building and an office trailer are located onsite. The entire site is paved. An unused dock is present at the parcel riverfront. A 6,000-gallon diesel aboveground storage tank (AST) is located near the northwestern corner of the parcel. A propane AST used for fueling forklifts is located near the diesel AST. Stormwater at the facility is gathered by catch basins that discharge to the Willamette River through two private outfalls (WR-378 and WR-379).

Large portions of the Front Avenue site were formed by filling the riverbed from 1887 through 1980. The eastern portion of Parcel 3 was created by filling in the 1940s. The

fill consisted primarily of dredged material from the Willamette River, with slag material armoring the riverbank. Fill is estimated to range from 15 to 45 ft thick on all but the northeastern third of the property. The parcel was undeveloped until 1988 when it was leased by Tricon Forest Products and used as a lumber reloading facility until 1993. The ground surface in the western portion of the parcel also appears to be covered in part with slag.

Shaver Transportation

The Shaver site consists of one tax lot encompassing 1.78 acres of uplands and 3.39 acres of lowlands. Shaver has maintained a business presence on the Willamette River since 1935. Shaver tugboats have been used for vessel-, log raft-, and barge-towing. Shaver's barge vessels have been used for transporting anthropogenic materials (e.g., sludge, slop [oily bilge water], steel scrapings, petroleum products, quarry rock/sands, etc.) from offshore to onshore settings, up and down the lower Willamette River.

In 1956, Shaver operations on the east bank of the Willamette were transferred to their current NW Front Avenue site, which is now considered the company's headquarters. The site is used to dock and periodically service Shaver's fleet of vessels (11 tugboats and 16 barges). Current site operations include loading diesel fuels into the AST, transferring used/new oil between containers that are located on the shop barge or the fueling trucks, and changing oil in vessels. Historically, Shaver served as a lighter (i.e., large flat-bottom barge), collecting waste oils from throughout the harbor and depositing them at the Ramsey Lakes waste oil sumps located at RM 2. Shaver's lighter operations were run from this facility from 1956 to 1960.

Several ECSI sites are located in the drainage basin of City Outfall 19. These sites and their major operations are summarized below:

- **Anderson Brothers Property (ECSI #970):** This facility is located 0.5 miles away from the Willamette River, to the south of Front Avenue. Anderson Brothers and later Specialty Truck Parts used the property for trucking and hauling operations for nearly 40 years. Although the firm primarily transported bulk oil and gas, agricultural products and dry and bulk freight were also handled. All truck repair and service was performed on the property. Permitted stormwater was discharged from this site via Outfall 19 until 1999; routing of current storm drainage is unclear.
- **Brazil & Co. (ECSI #1026):** The owner of this site is believed to have dismantled transformers onsite and routinely dumped their contents onto the ground (DEQ 2006b).
- **Calbag Metals (ECSI #2454):** The Calbag Metals property is located approximately 1,000 ft upland from the river. IDEA purchased the property from Calbag in 2005. Historically, Calbag Metals discharged its stormwater to Outfall 19 under a 1200-Z general stormwater permit. The NPDES permit was

terminated in 2003; non-permitted stormwater is currently routed to the conveyance system that discharges at Outfall 19.

- **Dura Industries (ECSI #111):** No information has been obtained on site operations at this site (DEQ 2006b).
- **Mt. Hood Chemical Corp. (ECSI #81):** No information has been obtained on this chemical manufacturing plant (DEQ 2006b).
- **Mt. Hood Chemical Property (ECSI #1328):** This facility was historically used for bulk chemical storage and distribution, as well as for transport and storage of some hazardous wastes (mostly chlorinated solvent wastes) (DEQ 2006b).
- **Schnitzer-Kittridge (ECSI #2442):** This 4.95-acre site is located in the Guilds Lake Industrial Area, approximately 0.1 mile south of the river. The site is owned by Schnitzer Investment Corporation (SIC) and is being used by seven independent industrial and commercial businesses for storage and distribution services. The site has been used for acetylene production and lime recovery (1942-1985), wallboard manufacturing (1970-1975), industrial gas filling and distribution (1985-1987), and scrap metal recycling and diesel truck refueling (1991-1996). In 1989, when Chem Lime ceased operations, most of the lime sludge was removed from the facility. Partial site cleanup and remediation occurred, including the demolition of the Chem Lime building and acetylene production plants.

11.3.14.1.3 Upland Hydrogeology

The historical Guilds Lake was located to the southwest of the site and was filled sometime in the early 1900s to provide industrial land. The former shoreline at the Front Avenue LP site generally corresponded with the northeastern edge of Parcel 2. Parcel 1 and the northeastern half of Parcel 3 were created from 1940 to 1980 as the shoreline was extended riverward with material dredged from the Willamette River, slag, and construction debris.

The near-surface geology at the site is dominated by the presence of Willamette River dredged material consisting of silt, silty sand, and sand with some significant areas containing slag material and construction debris. The slag and construction debris are present primarily along the current shoreline and in the central portion of the site, which was the historical riverbank area. Based on the deep geotechnical borings, the thickness of the dredged fill material ranges from 30 to 40 ft bgs. Underlying the fill material to a depth of 40 to 70 ft bgs are deposits of Quaternary alluvium consisting of silt, silty sand, and sand. The Quaternary alluvium is underlain either by gravels and cobbles representing coarse-grained Quaternary deposits and/or Pleistocene flood gravels or by the Columbia River Basalt Group (CRBG).

Available files do not indicate any permanent monitoring wells installed. All documented groundwater information was obtained from temporary well points

installed in soil borings at Front Avenue LP. The majority of groundwater information at the property pertains to the shallow subsurface: the dredge fill and underlying alluvium to a depth of approximately 40 ft bgs. The uppermost groundwater zone at the site most likely occurs in the fill and alluvium. Groundwater was first encountered at the site at depths ranging from 18 to 35 ft. Site-specific information related to groundwater flow direction and hydraulic gradient is not available. Based on groundwater levels from monitoring wells at an adjacent property (McCall Oil & Chemical Corporation, ECSI #134), the shallow groundwater flow direction is generally toward the Willamette River. The groundwater regime in the lower coarse-grained Quaternary deposits and the CRBG has not been evaluated.

A line of groundwater seeps was identified along the shoreline of Parcel 3 during the 2002 Seep Reconnaissance Survey conducted by Groundwater Solutions, Inc. The seep line was present below the high tide level where fine-grained sediment crops out at the base of the shoreline embankment.

11.3.14.2 Chemical Distribution of iCOCs

This section describes the distribution of iCOCs in sediment at iAOPC 18. As stated earlier, iCOCs for the iAOPC include only total PCBs and the potential iCOC ammonia. For the purposes of evaluating sources to the iAOPC 18, the discussion of chemical distribution of iCOCs is limited to PCBs. All iCOC data for the iAOPC can be found in Appendix I.

11.3.14.2.1 Sediments

Sediment sampling locations within iAOPC 18 include 14 surface samples (including beach samples) and three subsurface cores (8 subsurface samples). Map 11.3.14-2a,b shows the sediment sampling locations, and Table 11.3.14-2 provides a statistical summary of iCOCs in the iAOPC. This section describes the distribution of the iCOCs in sediment within the iAOPC.

PCBs

PCBs were detected in all surface sediment samples (Map 11.3.14-3 and Map 11.3.14-4). Two types of PCB analyses were conducted for these samples: Aroclors on six samples, and PCB congeners on nine samples. Total Aroclors were detected in surface sediments at concentrations ranging from 71 to 590 µg/kg, with a mean value of 119 µg/kg; total PCBs congeners for the surface samples ranged from 4.92 to 164 µg/kg. The highest PCB concentrations in surface sediment within the iAOPC are located in nearshore areas adjacent to the Shaver docks.

PCBs were detected in four of the seven subsurface samples analyzed from three cores. Six samples were analyzed for Aroclors and one was analyzed for the full set of congeners. Detected total Aroclor concentrations ranged from 2.01 to 1,430 µg/kg (Map 11.3.14-5 and Map 11.3.14-6) and maximum subsurface concentrations were generally lower than surface concentrations, except in the upper interval of the core offshore of WR-378, where the highest subsurface total Aroclor concentration (1,430 µg/kg) was detected. The highest concentration of total PCB congeners (1,120 µg/kg)

was detected in the same interval where Aroclor maxima were detected. The highest concentrations of subsurface total Aroclors were detected generally in the same areas as the Aroclor maxima for surface sediment. PCB Aroclor concentrations in the surface interval of sediment cores were higher than the underlying core sample intervals at all locations. Aroclors were either not detected or were detected at relatively low concentrations in the deepest interval analyzed in individual cores.

11.3.14.2.2 Surface Water

No surface water samples have been collected within or nearby the iAOPC.

11.3.14.2.3 Transition Zone Water

No porewater or TZW samples were analyzed for the iAOPC-specific iCOCs at this iAOPC.

11.3.14.2.4 Biota

No tissue samples have been collected within or nearby the iAOPC.

11.3.14.3 Potential Sources of iCOCs

This section presents a summary of the current understanding of potential sources of iCOCs to iAOPC 18. This iAOPC includes the contiguous shoreline properties (Shaver and Parcel 3 of Front Avenue) in addition to noncontiguous upland properties that are part of the City Outfall 19 stormwater basin.

Information presented in this section was obtained from site summaries unless otherwise noted. In addition to iCOCs, COIs associated with nearby upland areas are also discussed in this section. The COIs are presented to provide a comprehensive understanding of the upland issues and to support the identification of potential sources to the iAOPC. The relevance of the pathway to iCOCs is summarized at the end of each pathway discussion. Upland source areas and releases for ECSI sites associated with this iAOPC are summarized in Table 11.3.14-2.

11.3.14.3.1 Upland Releases

Shaver

Documented upland releases on the Shaver site are limited to releases associated with two 10,000-gallon diesel underground storage tanks (USTs) that were removed in 1992. Approximately 48 yd^3 of diesel-contaminated soil were removed, and subsequent sampling confirmed that soil concentrations were within acceptable DEQ cleanup levels. No groundwater was encountered. DEQ issued a *No Further Action* for the USTs in November 2000 (LUST File 26-92-0034).

New and used oil is loaded and transferred between the shop barge (located overwater) and the uplands by Harbor Oil distribution trucks. No records of spills during transfer operations have been reported. A diesel fuel AST is located onsite. A single dry well is buried adjacent to an onsite shop and storage shed, which is used to contain stormwater from the shed's roof. Potential COIs associated with the decommissioned USTs, diesel AST, and combined shop and storage shed include TPH, VOCs, and SVOCs.

Front Avenue Parcel 3
Potential source areas identified on Parcel 3 of Front Avenue include slag fill material, vehicle maintenance, oil and antifreeze drum storage (without secondary containment), a diesel AST, and the railroad spur. Potential COIs associated with these sources include TPH, VOCs, SVOCs, PAHs, metals, and PCBs.

11.3.14.3.2 Stormwater/Overland Transport

Listed below are the active outfalls (from up- to downriver) within iAOPC 18:

- **Outfall 19A** (City of Portland or ODOT)
- **WR-379** (CMI NW/Hampton Lumber)
- **Outfall 19** (City of Portland)
- **WR-378** (CMI NW/Hampton Lumber).

A single dry well is buried on the Shaver property adjacent to a storage shed. The dry well is used to contain stormwater from the shed's roof. Outfalls WR-379 and WR-378 discharge stormwater from Parcel 3 of the Front Avenue property. Three additional private outfalls at the Front Avenue site (WR-7, WR-256, and WR-257) discharge downstream of iAOPC 18.

City Outfall 19A is a 60-inch-diameter outfall located approximately 150 ft upstream from Outfall 19 (see Map 11.3.14-1). This outfall was originally built by the Oregon Department of Transportation (ODOT) and may not be currently owned by the City (CH2M Hill 2004b). The outfall is below the high tide water line at high river stage, and river water may back up into the outfall. Riprap is located along the sides and in front of the outfall. The area in the immediate vicinity is significantly affected by propwash from vessel activities at Shaver. The outfall drains approximately 1.5 acres of Front Avenue Street, with some industrial frontage drainage. No facilities with permitted discharges are found in the drainage basin, which lies more than 400 ft from the shoreline (GSI 2006).

City Outfall 19 is a 42-inch-diameter outfall located on CMI NW/Hampton Lumber property in the area used by Shaver to dock tugboats and barges (see Map 11.3.14-1). The outfall extends into the river and discharges underwater, and is not visible at low river stage. The offshore area in the vicinity of the outfall is heavily affected by propwash. Approximately 490 acres of land are included in the outfall drainage basin. The majority of the basin is zoned for rural and open space, and approximately 27 percent is zoned for industrial use. Seven facilities in the basin have 1200-Z NPDES permits, one facility has an individual NPDES permit, one facility has a 1300-J NPDES permit, and one facility has a 100-J NPDES permit. Eight ECSI sites are located in the basin; known or potential contamination associated with these sites is listed below (GSI 2006):

- **Anderson Brothers (ECSI #970):** Oil, motor oil, Stoddard solvent, paint waste, solvent wastes
- **Brazil & Co (ECSI #1026):** PCBs
- **Calbag Metals (ECSI #2454):** Metals, PCBs, PAHs, phthalates
- **Dura Industries (ECSI #111):** Cadmium, chromium, lead, nickel, zinc
- **Mt. Hood Chemical Corp. (ECSI #81):** Corrosive liquids, methylene chloride
- **Mt. Hood Chemical Property (ECSI #1328):** Chlorinated solvents
- **Schnitzer Investment-Kittridge (ECSI #2442):** PCBs, petroleum compounds, arsenic, chromium, lead, nickel, zinc.
- **PGE-Forest Park (ECSI #2406):** PCBs.

Two facilities are partially located in the basin:

- **Front Avenue LP Properties (ECSI #1281):** Petroleum hydrocarbons, PCBs, PAHs, phthalates, metals
- **Chevron USA Asphalt Refinery (ECSI #1281):** Petroleum hydrocarbons, VOCs, PAHs, phenols.

In a separate investigation, the City noted an accumulation of sediment in stormwater pipes adjacent to the Calbag Metals facility that appeared to be site-related based on the presence of elevated metals concentrations (DEQ 2005b). Creekside, the contractor hired by Calbag, sampled sediments and stormwater in the stormwater pipe that discharges at Outfall 19 and confirmed the presence of metals, PCBs, and phthalates in the sediment and stormwater (Creekside 2005). Calbag subsequently removed 0.8 tons of sediment from City pipes adjacent to the facility and 3.2 tons of sediment from onsite catch basins and stormwater lines (DEQ 2005b). Although exact estimates of contaminant loading to the Willamette are not available, the amount of sediment removed from onsite and offsite stormwater conveyance system shows that contaminant loading through the stormwater pathway has been significant at the Calbag Metals site (DEQ 2005b).

Because the majority of the Shaver site is paved (date of paving unknown) or covered by buildings, limited overland transport of contaminants is expected. Grass and landscaping features that that cover the remaining areas of the site stabilize the soils and reduce the possibility of soil erosion.

Steel mill slag was used as fill material over a large portion of the Front Avenue site including the riverbank. The results of the EP Toxicity metals analysis of a single slag sample indicated low concentrations of barium and total chromium. The slag fill near the surface on Parcel 3 may be subject to erosion and overland flow.

11.3.14.3.3 Overwater Discharge

Shaver

Overwater activities at the Shaver site are primarily related to tugboat maintenance, offloading and loading of new and used petroleum products, and barge vacuuming operations using the shop barge as a servicing platform. The shop barge receives and/or transfers used oil from tugs, and distributes new oil to the vessel being serviced. Oil trucks pull completely onto the shop barge prior to the off- and on-loading of any oil so that no oil is transferred over the water. While there is the potential for spills during transfer of petroleum products between containers off- and/or onshore of the facility, no overwater spills or releases associated with dock or shop barges have been reported.

As described above, from 1956 to 1960 Shaver served as a lighter, collecting waste oils from throughout the harbor and depositing them at the Ramsey Lake sumps located at RM 2.

Front Avenue Parcel 3

A currently inactive loading dock is located within Parcel 3 and may have been associated with past operators on the CMI NW/Hampton Lumber property. Information about activities using this loading dock or records of overwater spills was not found.

11.3.14.3.4 Groundwater Discharge

Shaver

Groundwater has not been sampled at the site. DEQ issued a *No Further Action* determination for the Shaver site in June 2003 and stated that groundwater sampling was not warranted due to the lack of apparent upland contamination sources. Therefore, DEQ does not currently consider groundwater a pathway of concern at this site.

Front Avenue Parcel 3

Isolated detections of VOCs, SVOCs, and TPH have been recorded in two temporary well points on the Front Avenue property, but not within Parcel 3. Based on this limited information, groundwater is not currently considered a pathway of concern for Parcel 3 of the Front Avenue property.

11.3.14.3.5 Riverbank Erosion

Shaver

No riverbank samples have been collected on the Shaver property. Fill has been added to level the near-bank area where the lower parking lot was built. The source of the fill material is unknown. A line of vegetation present at the edge of this filled area (where the bank steeply slopes to the river) likely stabilizes and somewhat reduces erosion of fill-soil into the river. The potential for riverbank erosion at this site has not been addressed in the reviewed documents.

Front Avenue Parcel 3

No riverbank samples have been collected on Parcel 3 of the Front Avenue site. Riverbank erosion is expected to be limited in this area due to armoring of the bank

with slag. However, the riverbank consisting of slag and construction debris itself may serve as a source of metals contamination to river sediment.

11.3.14.4 Relationship of Upland Sources to the Distribution of iCOCs

The distribution of sediment PCB concentrations within iAOPC 18 may be associated with Outfall 19. Although Outfall 19 drains upland sites that have documented evidence of PCBs in catch basin/stormwater pipe sediment, the limited number of sediment samples analyzed for PCBs within the iAOPC confounds an obvious connection of the PCBs in sediment to specific sources and migration pathways.

Few riverbank samples have been collected in this iAOPC. The soil and slag and construction debris material armoring portions of the bank has not been analyzed for PCBs. Therefore, this pathway cannot be evaluated.

Overwater activities occur within iAOPC 18, but the importance of this pathway as a historical or current contributor of iCOCs to iAOPC 18 has not been quantified. Due to the high density of docks in the area, and Shaver's historical lighter operations at the site (i.e., use of large flat-bottom barge to collecting waste oils from throughout the harbor and deposit them at the Ramsey Lake sumps located at RM 2), the relative historical and current importance of the overwater pathway is considered medium.

Groundwater samples have not been collected on adjacent properties; however, groundwater has not been identified as a significant source of iCOCs to iAOPC 18 due to the lack of currently confirmed nearshore upland contamination sources and the very limited mobility of PCBs in groundwater.

Sediment transport may contribute to the distribution and concentrations of PCBs Within the iAOPC, however, the concentrations of PCBs within the iAOPC suggest that sediment transport may not be the dominant source of iCOCs.

A preliminary evaluation of the relationship between sources, pathways, and iCOCs in iAOPC 18 is summarized in Figure 11.3.14-1. Preliminary assessments of the current and historical relative contributions of each source for iAOPC 18 are summarized in Table 11.3.14-3.

11.3.15 CSM for iAOPC 19

This section describes the preliminary Round 2 CSM for iAOPC 19. This 40.6-acre area extends from approximately RM 8.7 to 9.3 along the western shore of the river, adjacent to the Gunderson, Equilon dock, and southernmost portion of the Fort James/GP Northwest Service Center properties (Map 11.3.15-1). This CSM examines the physical setting of the iAOPC and adjacent upland properties, the chemical distribution of iCOCs in in-water media, and potential sources of these constituents.

iCOCs for this iAOPC include the following:

- Total PCBs

- PCB TEQ
- Aldrin
- Sum DDT.

Potential iCOCs for iAOPC 19 include:

- Ammonia
- Cadmium
- Mercury
- Silver
- Total PCB Aroclors
- Alpha-HCH
- Dieldrin
- Endrin ketone
- DBP
- Sum DDD
- Sum DDE
- DRH
- RRH.

These potential iCOCs are identified through less certain and/or less rigorous evaluations based on fewer lines of evidence, FPM results, or other high uncertainty lines of evidence (see Sections 8 and 9).

Map 10.5-3a–j shows the areas where this preliminary analysis identified the potential for risk for individual exposure scenarios that were considered in iAOPC development, and Table 10.5-1 identifies the iCOCs associated with the exposure scenarios. PCBs are identified as iCOCs at most areas within the iAOPC. DDT and/or aldrin are iCOCs at nearshore areas. All other iCOCs are restricted to relatively small areas at RM 9 and between the Equilon and Gunderson docks.

The CSM evaluation for iAOPC 19 is summarized as follows: Each of the docks, and numerous outfalls characterizing the area, has a documented association with some or all of the iCOCs. As a result, in-water concentrations cannot be traced to specific sources. The area bounded by the Equilon and downstream end of the Gunderson docks has the highest concentrations of iCOCs. The high subsurface PCB concentrations downstream of this area suggest a long-term source. Other areas of high iCOC concentrations in surface sediment near the shoreline suggest recent local sources or recent sediment transport into the area. Stormwater discharge/overland transport and direct discharges appear to be the dominant pathways for upland contaminant migration to the iAOPC. Based on the results of a bank survey, current riverbank erosion is

anticipated to be limited, but may have contributed to the distribution of iCOCs in localized areas (this is uncertain due to limited riverbank soil sampling information).

Although the Round 2 Groundwater Pathway Assessment identified an area of groundwater discharge near the downstream boundary of iAOPC 19 (Integral 2006g), no potential TZW iCOCs were identified in this area in the draft human health and ecological risk evaluations (Sections 8 and 9). Migration of upland groundwater plumes appears to be an incomplete pathway for transport of iCOCs to the sediment transition zone at concentrations that may pose unacceptable risk.

11.3.15.1 Physical Setting, Infrastructure, and Operational History

In-river and upland physical characteristics, infrastructure, and operational history relevant to this iAOPC are described in this subsection. Information on adjacent upland sites was obtained from the LWG site summaries (Integral and GSI 2004; 2005a,b,c) and updates (Integral 2007) unless otherwise noted. For descriptive purposes, the Gunderson site within the iAOPC is divided into three parts, referred to as Areas 1, 2, and 3 (listed from downstream to upstream).

11.3.15.1.1 In-River

iAOPC 19 is located along the western side of the hydrodynamic regime referred to as the upper ISA. This reach is characterized by a relatively large cross-sectional area, and relatively low flows and bottom shear stresses, particularly along the slightly protected western edge from the toe of the channel slope up to the shoreline. A broad area of relatively low bottom shear stress is also apparent throughout the western portion of the navigation channel from RM 9.3 to about 8.5 (see Map 4.5-7). Sediment Trend Analysis® results suggest that the nearshore area of this iAOPC is depositional at the upstream end and then transitions to dynamic equilibrium (i.e., sediment moving into and out of the area without a net loss or gain) downstream.

The time-series bathymetric change data over the 25-month period from January 2002 through February 2004 show a large net sediment accumulation area (up to 2+ ft) from 0 to -35 ft NAVD88 at the upstream end of the iAOPC extending into the middle of the navigation channel (see Map 4.4-2). In contrast, the nearshore of the middle and downstream portions of the iAOPC, above about -25 ft NAVD88, is a mix of no change, small-scale sediment erosion, and sediment deposition areas. Widespread net sediment accumulation is evident in the navigation channel offshore the entire iAOPC, the downstream end of the large mid-channel shoal extending to about RM 10.

Periodic monitoring from July 2002 to January 2004 of beach stakes set behind the Equilon dock at elevations of +7, +9, and +14 ft NAVD88 provide information on riverbank elevation changes above the hydrosurvey coverage area (Anchor 2004). The low elevation stake showed net erosion of about 18 cm over the measurement period; this is consistent with the nearshore bathymetric change data. The middle stake showed two cycles of sediment accretion (up to 20 cm) in the summer/fall followed by erosion back to the baseline level in the winter/spring periods. The high elevation stake showed

little change through December 2002 and then small-scale erosion (8 cm) through the remainder of the observation period (to January 2004).

Consistent with the hydrodynamic characteristics noted above, the majority of the surface sediment deposits in the iAOPC consist of silt or sandy silt (Map 11.3.15-2a). Limited areas characterized by silty sand or sand occur at the upstream end of the Equilon dock and in the nearshore area between the upstream Gunderson dock and the shoreline. Silt and sandy silt also dominate the subsurface sediment cores, particularly those collected adjacent to Gunderson Areas 2 and 3. Some subsurface beds contained anthropogenic debris (i.e., apparent fishing line and plastic film in C458-1), indicating relatively recent deposits. Nearshore cores also contained sand beds ranging from <1 ft to over 6 ft thick, with grain sizes ranging from silty very fine sands to fine-to-medium well-sorted sands, and limited silt/clay deposits (Map 11.3.15-2b). While these sand beds may be hydraulically connected with sand deposits identified in the upland subsurface, they are likely not contemporaneous.

The Gunderson site riverbank is mostly armored with riprap, with a few areas of native and non-native vegetation.

Several significant in-water facilities and structures are present (Map 11.3.15-1):

- A dock that extends into the river perpendicular to the shoreline at the downstream end of the iAOPC (Area 1)
- Launchways for marine barges (central portion of Gunderson or Area 2)
- Equilon Enterprises LLC Dock and pipelines (Gunderson Area 2)
- Outfitting dock (upstream portion of Gunderson or Area 3)
- One public stormwater outfall (City of Portland Outfall 18)
- Twenty-nine private stormwater outfalls (WR-128 through WR-145, WR-147, WR-148, WR-150, WR-279 through WR-281, WR-360, WR-361, WR-363, and WR-377).

Primary in-water site uses for the Gunderson iAOPC are launchways for marine barges, unloading of raw materials including petroleum products and aggregate, and servicing of vessels. These uses have generally remained the same since the 1960s or before, though ship dismantling historically occurred near the upstream end of the iAOPC (Gunderson Area 3).

11.3.15.1.2 Upland

Upland sites adjacent to the iAOPC include the Gunderson, Equilon, and Fort James/GP Northwest Service Center properties. Each of these properties is zoned industrial. In addition, the iAOPC receives drainage from approximately 460 acres of upland through the City of Portland Outfall 18.

Gunderson

The Gunderson site (ECSI #1155) is an active industrial facility that manufactures and refurbishes railroad cars and marine barges. Current and historical operations for Gunderson are noted below:

- Area 1 is used primarily for shipping and receiving and for storage, covered and uncovered, of raw materials. By 1942, Area 1 had been developed with three small buildings (truck repair, paint room, and offices), the Demount Building, and a Quonset hut used for steel fabrication.
- Area 2 is used primarily for railcar and marine barge manufacture, painting, sandblasting, and assembly. A dock structure has been present at the Equilon dock location (Area 2) since at least 1913, when most of the remaining site property was still under water. Between 1953 and 1958, fill was placed on the shoreline landward of this dock to build launchways and to raise Area 2 above the floodplain. Fill for this development was placed by the U.S. Army Corps of Engineers during Willamette River dredging operations. During the 1950s, Area 2 was developed with the fabrication bays and by 1963 the facility had expanded to include the buildings now known as Fabrication Bays 1 and 2, and the second railcar line. By 1963, the Administration/Engineering/Maintenance Building was present. By 1977, the Marine Barge Launch with whirly cranes was developed upstream of the Equilon Dock, the Craneways Building was under construction, and the Finishing and Paint Buildings were present.
- Area 3 is a larger open area currently used for storage. It is the location for the Hazardous Materials Storage Area, the Autostack Building, the 3-Bay Building, the Stevedore Building, Scale House Building, and a dock (gantry) facility. By the 1960s, Area 3 had been filled, the outfitting dock had been constructed, and ship dismantling activities were underway. During the 1970s, Area 3 was used as an automobile salvage yard.

Equilon Properties

The Equilon Terminal Property (ECSI #169) is an active bulk petroleum terminal consisting of a dock area on Gunderson property, a pipeline corridor (a portion of which also is on the Gunderson property), and a terminal area that is located within the Outfall 18 Basin. The dock area has existed since 1913, though likely not the same structure. The pipeline corridor has been assigned ECSI #2117.

Fort James/GP Northwest Service Center

The Fort James/GP Northwest Service Center is located at the upstream end of the iAOPC, and is not on the DEQ ECSI site list. The property contains an active warehouse facility that includes a dock structure.

The discussion of additional upland facilities in the municipal stormwater Outfall 18 drainage basin includes six properties for which LWG has prepared site summaries. Their major operations are summarized below:

- **Christenson Oil (ECSI #2426):** The property is in use as a bulk petroleum facility that stores, blends, and distributes lubricating and specialty oils. Christenson Oil has occupied the property since at least 1952, and may have operated petroleum storage facilities at the site as early as the 1940s. The oldest structure appears to have been constructed in 1947. Currently, small quantities of cresols, isobutanol, and phenolic and zinc-containing lubricant additives are also handled at this site.
- **Columbia American Plating (ECSI #29):** Although currently not in use, this property was a former commercial metal plating operation. Solutions of chromium, copper, gold, nickel silver, tin, and zinc were used for plating in acid and caustic tanks.
- **McWhorter Technologies (ECSI #135):** This site consists of two parcels, separated by Yeon Avenue. The parcel south of Yeon Avenue is referred to as the McWhorter/ Eastman Manufacturing facility. The parcel north of Yeon Avenue is leased, located on the Burlington Northern Hub Center and Lake Yard property (ECSI #100), and referred to as the McWhorter/Eastman leased parcel. The leased parcel is used for drum and bulk tank storage, product staging, and transfer. Historical uses on the manufacturing facility parcel include varnish and paint manufacturing operations by McClosky Varnish from 1943 to -1989, and similar operations by McWhorter Technologies from 1989 to 2000. Current activities at the site are not precisely known. According to corporate succession research by the LWG, the property is used for drum and bulk tank storage, shipment of alkyd paint bases, and unloading of raw materials from tank cars. These uses have not been confirmed.
- **Trumbull Asphalt Plant (ECSI #1160):** The plant produces asphalt roofing and specialty products for residential, commercial, and industrial markets. Facility operations have been continuous since plant construction in the 1930s (or earlier), and general operations have remained unchanged since 1972.
- **Van Waters and Rogers (ECSI #330):** The site has been a chemical supply and distribution facility since 1946, packaging, storing, and distributing organic solvents, acids and bases, ammonia, and a wide range of other industrial materials. Operations also included chlorinated solvent recycling from 1973 to -1987.
- **Schnitzer Investment Corp (ECSI #2424):** This 2.84-acre site is currently inactive, but has included operations by a battery manufacturer (Willard Storage Battery, approximately 1952-1958), a chemical distributor (Great Western Chemical Company, 1959-1970), a retail hardware store (Ace Hardware, 1972-1975), and a bag manufacturer (Chase Bag/Chase Packaging Company and Union Camp Corporation, 1979-1994).

Other upland sites that have been identified in the DEQ ECSI database or through City source tracing work within the Outfall 18 drainage basin are described below.

- **Magnus (ECSI #69):** This is a 1-acre site currently occupied by Industrial Craters Inc., a manufacturing company. Former tenants include Magnus Co. (1930-1936), which operated a lead smelter on site, and National Lead Company (1936-1968), which operated a bearing rehabilitation plant. Lead, zinc, and brass smelting occurred onsite over its history. Lead was also used to fill cracks in the concrete floor of the building (CH2M Hill 2004a). The site is alternatively referred to as NL Industries, and Wilhelm Trucking (DEQ 2007).
- **Burlington Northern Santa Fe Railroad Lake Yard (BNSF Lake Yard; ECSI #100):** A 142-acre area including the Burlington Northern Hub Center and Portland Terminal Guild's Lake Railyard (DEQ 2007). DEQ reports chemicals in onsite soils and/or surface drainage pathways stemming from railway operations, improper waste disposal, releases from lessee operations, and unknown sources.
- **Hill Investment (Ashland Chemical; ECSI #1076):** This 3.18-acre site was formerly a warehouse operated by Nabisco, and is currently operated by Ashland Chemical Company. USTs are present on site but no other information regarding current site uses is available (DEQ 2007).
- **Carson Oil (ECSI #1405):** This 3.5-acre site is a operated as a bulk petroleum products terminal and distribution facility, located adjacent to the Columbia American Plating property. Vehicle maintenance is performed on site. DEQ considers this a low priority site for further agency action (DEQ 2007).
- **ANRFS (ABF Freight Systems, Inc.; ECSI #1820):** This site consists of a 9.3-acre, fully paved area that currently contains a truck terminal owned and operated by ABF Freight Systems, Inc. Current operations include truck painting, maintenance, fueling, washing, and loading. Trucking operations are consistent throughout the site's history. Former occupants include Woodbury Steel Company (? -1963), ANR Freight Service (1963-1993), and FTL Motor Freight Carrier (1993-2000). Chemicals currently used or stored onsite include diesel, used motor oil, antifreeze, degreaser, and various solvents (CH2M Hill 2004a).
- **Container Recovery (ECSI #4015):** This 9.1-acre site is currently owned and operated by Container Recovery, which process beverage containers for recycling operations. Additionally, a smaller building in the NE corner of the property has contained a photography studio since its construction in 1953. The Container Recovery site was initially two properties developed in the mid-1940s. Convoy Corporation built trucks and loaded them with cars as freight in the western portion of the site until the early 1960s when they assumed ownership of the eastern property as well. Previously, the eastern property was occupied by Sandberg Manufacturing, which produced furnaces and sheet metal. Ryder purchased Convoy and the entire site in the 1980s. Container Recovery assumed full control of the site in 1990 (DEQ 2007).

11.3.15.1.3 Upland Hydrogeology

Subsurface environmental investigations have been completed at the Gunderson, Equilon, BNSF Lake Yard, Van Waters and Rogers, Columbia American Plating, and Trumbull Asphalt sites.

At the Gunderson site, lithologic logs of materials collected during numerous subsurface investigations provide a comprehensive picture of the stratigraphic features that influence groundwater flow beneath the site adjacent to the river. Cross-sections of the subsurface below the Gunderson facility are presented in Figure 11.3.15-1a–d. Three principal geologic units have been identified: alluvium and younger terrace deposits, a gravel zone, and basalt bedrock.

Investigations at other sites associated with the iAOPC were much less extensive and did not encounter the deeper gravel or basalt layers. These units and their corresponding hydrogeologic characteristics for the Gunderson facility are summarized below:

- **Alluvium and Younger Terrace Deposits** – The Gunderson facility is underlain by recent alluvial deposits of the Willamette River. Portions of the site adjacent to the Willamette River were raised above the river level using dredged material beginning in the 1930s. Fill depths range up to 30 ft. The alluvial deposits consist of discontinuous zones of transitional sands, sandy silt, silts, and some clay, interfingered across the site. The unit is typically 30-40 ft thick in Area 1, but is significantly thicker in Area 2 (apparent maximum thickness of ~160 ft) and Area 3 (thickness of at least 125 ft). This shallow unit has been subcategorized into a surficial sand and fill zone (containing concrete and other debris), a predominantly silt zone, and an underlying predominantly sand zone (Squier|Kleinfelder 2005).
- **Gravel Zone** – Gravels were encountered at the base of the recent alluvial deposits in some of the borings. In the northwestern portion of Gunderson's Area 1, the gravels were typically encountered at approximately 35 feet bgs. These gravels, which contain sand, cobbles, and boulders, appear to be geologically recent alluvial deposits that underlie the onshore sand and sandy silt. Gravels were encountered at depths between 70 and 110 ft in Area 2 at an elevation that is below the base of Willamette River.
- **Basalt Bedrock** – Flows of the Columbia River Basalt Group (CRBG) are present (where encountered) directly beneath the shallow sediments and gravels. The CRBG is estimated to be about 500-700 ft thick in this area (Squier|Kleinfelder 2005). The top surface of the CRBG slopes uniformly east into the Willamette River at about 0.03 ft/ft and then steepens to about 0.1 ft/ft as the CRBG plunges below the Willamette River. Basalt was encountered in Area 1 borings at approximately 50-60 ft bgs (Figure 11.3.15-1a) and in Area 2 historical borings at depths around 150-160 ft, indicating that the depth to basalt also increases southward. It has not been determined whether this is due to steeply dipping basalt flows or to fault blocks (Squier|Kleinfelder 2005).

Groundwater occurs in all three of the geologic zones identified at the Gunderson site. The hydrologic properties of the materials in each of the zones have been evaluated using a variety of techniques, including aquifer performance tests, slug tests, and packer tests, as well as literature reviews. These evaluations have resulted in the following estimated hydraulic conductivity values (Squier|Kleinfelder 2005):

Unit	Hydraulic Conductivity (ft/day)
Alluvial sand/silt	1
Detrital gravel	100
Gravelly fractured basalt	50
Fractured basalt	10
Massive basalt	0.1
Basalt interflow zone	5

The heterogeneous nature of the subsurface at the Gunderson facility creates complex groundwater migration regimes, especially under Area 1. From periodic monitoring of groundwater flow directions and gradients below the Gunderson facility since 1991 (Squier|Kleinfelder 2005), it appears that groundwater flow direction in the shallow alluvium zone is generally north, while the flow direction in the underlying gravels appears to be generally northeastward. The horizontal groundwater gradient of the alluvium zone in the southeastern portion of the facility (0.025 ft/ft) is steeper than the gradient in the northwestern portion (0.003 ft/ft) (Squier|Kleinfelder 2005). Vertical gradients calculated for eight well pairs (March 30, 2004) indicate a relatively neutral component of vertical groundwater movement, with a downward vertical gradient in wells located closest to the Willamette River (Squier|Kleinfelder 2005).

The depth to the water table at the facility varies seasonally from approximately 7 to 25 ft bgs (Squier|Kleinfelder 2005). Recharge occurs primarily from offsite sources, but also by rainfall in the limited areas without impervious cover. Shallow and deep water levels are generally a few feet higher than the river stage, and fluctuations generally mimic those of the river. Water levels (including perched water) in Area 3 are up to 15 ft higher than water levels in Areas 1 and 2. The non-continuous perched system does not appear to be influenced by the river.

A north/south trending channelized gravel feature overlying the basalt in the western portion of the site (Figures 11.3.15-1a and -1d) appears to be a preferential pathway for the migration of groundwater (Squier|Kleinfelder 2005). The gravel feature extends toward the river and beneath the adjacent downstream property (Lakeside Industries). There is not an evident in-river discharge point for this preferential pathway (Integral 2006g).

Several seeps discharge into the iAOPC. One seep (Seep-01, also referred to as WR-149 in the City of Portland's system) has been identified in Area 3 and is attributed to

the apex of a former gully that allowed access to the river from the upland area during ship dismantling activities. The gulley was apparently filled in the 1970s and the contact between the recent fill and the original hydraulic fill appears to intercept and redirect shallow groundwater flow. Two other seeps (Seep-02 and Seep-03) related to damaged outfalls were identified along the Willamette riverbank (Squier/Kleinfelder 2005). Another seep also was identified around the backfill of Outfall 18 located near the Equilon dock during a 2002 seep reconnaissance survey (GSI 2003b).

11.3.15.2 Chemical Distribution of iCOCs

This section describes the distribution of iCOCs and potential iCOCs in environmental media at iAOPC 19. For the purpose of evaluating sources, the following discussion is limited to PCBs, cadmium, DBP, DDD, and DRH. All iCOC data for the iAOPC can be found in Appendix I.

11.3.15.2.1 Sediments

Sediment data for iAOPC 19 are based on analyses of 47 surface samples (i.e., grab samples and upper core intervals to 30 cm) and 17 subsurface cores (49 subsurface samples). Map 11.3.15-1 shows the sediment sampling locations, and Table 11.3.15-1a provides a statistical summary of the data.

PCBs

PCBs were detected in all but one of the surface sediment samples (Map 11.3.15-3 and -4). Two types of analyses were conducted: all samples were analyzed for Aroclors, and a subset was analyzed for PCB congeners. Total Aroclor concentrations in surface sediment ranged from 9.1 to 27,400 µg/kg, with a mean value of 1,060 µg/kg. Total PCB congener concentrations in the eight samples analyzed ranged from 50.4 to 35,400 µg/kg. The highest PCB concentrations in surface sediment within the iAOPC are located in nearshore areas: offshore of private outfalls WR-138, WR-139, and City Outfall 18 behind the Texaco Equilon fueling dock; immediately upstream (south) of the Equilon dock; offshore of Area 3 inside the dock structure, adjacent to outfall WR-147; and offshore of the southern end of Area 3 docks, near the Gunderson property boundary.

PCBs were detected in 40 of the 45 subsurface samples analyzed. All samples were analyzed for Aroclors and 4 were analyzed for the full set of PCB congeners. Detected total Aroclor concentrations ranged from 2.91 to 21,900 µg/kg (Map 11.3.15-5 and -6). Total PCB congeners ranged from 506 to 36,800 µg/kg. Maximum concentrations were generally higher in the subsurface than at the surface except for, most notably at the upstream end of the Equilon dock (e.g., G453) where the opposite occurred.

Maxima for total Aroclors in surface and subsurface sediment were detected in the same areas, although concentrations in the upper intervals of the cores in the northern end of the iAOPC were significantly higher than the surface concentrations. PCB Aroclor concentrations decreased with depth at most locations; concentrations in two cores adjacent to the Equilon dock on the river side increased significantly with depth. Subsurface concentrations in nearshore cores are generally higher downstream of the

Equilon dock than upstream, a trend not seen in the surface sediments. This distribution may indicate downstream migration of input from historical sources in the Equilon dock area or historical local sources near the sample locations.

Total Aroclor concentrations in surface samples collected inside the embayment formed by the Equilon dock ranged from 68.3 to 795 µg/kg, notably lower than the maximum concentration detected in sediment samples located just outside the embayment. No subsurface data exist for the area, preventing assessment of the vertical distribution of subsurface PCB (and other iCOC) concentrations inside the embayment area.

Cadmium

Cadmium was detected in 42 of the 44 surface sediment samples that were analyzed for it (Map 11.3.15-7). Concentrations ranged from 0.077 to 5.41 mg/kg, with a mean of 0.592 mg/kg. The maximum sediment within the iAOPC was located nearshore between the Equilon and Gunderson dock structures.

Cadmium was detected in all 42 of the subsurface samples analyzed for this metal. Concentrations ranged from 0.088 to 5.3 mg/kg (Map 11.3.15-8). The locations of subsurface sediment maxima coincided with those of surface maxima, between the Equilon and Gunderson dock structures. Maximum subsurface concentrations were higher than surface concentrations in two of the three cores from this area and were found in the core intervals immediately below the surface intervals. Cadmium concentrations decreased with sediment depth below the near-surface maximum.

DBP

DBP was detected in 11 of 44 surface sediment samples (Map 11.3.15-9), at concentrations ranging from 7.6 to 185 µg/kg, with a mean value of 68.5 µg/kg. DBP was detected in nearshore areas throughout the iAOPC, with the highest concentrations found in the northern areas near private outfall WR-138 and City Outfall 18, and near private outfalls WR-129 and WR-360. Elevated DBP was also reported slightly offshore near RM 9. Detection limits for several samples within the iAOPC greatly exceeded the maximum detected concentrations.

In subsurface sediments, DBP was detected in 12 of the 45 subsurface samples, at concentrations ranging from 4.5 to 91 µg/kg (Map 11.3.15-10). The highest concentration was found near the current Gunderson launchways (sample C456-C). No concentration trends were evident in subsurface sediment; the analyte was detected at various scattered locations at various sediment depths. DBP is a common laboratory contaminant, and this pattern of detections is consistent with laboratory contamination. Sediment cores were not collected in the areas where the highest DBP concentrations were found in surface sediment.

DDD

Total DDD (i.e., the sum of the 2,4' and 4,4' isomers) was detected in all but one of the surface sediment samples from this iAOPC (Map 11.3.15-11), at concentrations of 0.915 to1,370 µg/kg, with a mean value of 68.9 µg/kg. The maximum concentration—

more than 10 times as high as concentrations elsewhere in the iAOPC—was found in nearshore sediment between the Equilon and Gunderson dock structures.

In subsurface sediment, DDD was detected in 31 of 33 samples. Concentrations ranged from 0.349 to 2,980 µg/kg (Map 11.3.15-12). The subsurface maximum occurred in the same general area as the surface maximum. DDD concentrations in this area decreased with depth overall, and were highest in the surface interval or in the shallowest subsurface interval. DDD concentrations in subsurface sediment were at or below 755 µg/kg in other areas of iAOPC 19.

DRH

DRH was detected in 22 of the 24 surface sediment samples from this iAOPC (Map 11.3.15-13), within a range of 16.2 to 8,400 µg/kg and a mean of 577 µg/kg. The highest DRH concentration was found in nearshore sediment between the Equilon and Gunderson dock structures. This maximum concentration was more than 10 times as high as concentrations in surrounding sediment and sediment from other areas of the iAOPC. The analytical laboratory (Columbia Analytical Services [CAS]) indicated that the hydrocarbons in this sample "appear to be from weathered diesel fuel and unknown lubricating oil" (CAS data package K2406703). The DRH concentration was also elevated somewhat at one location near private outfalls WR-129 and WR-360, preliminarily identified by CAS as appearing: "to be due to transformer oil and unknown lubricating oil with some biological organics" (CAS data package K2406459). Locally elevated total PCB Aroclor concentrations at this location may be associated with transformer oil.

DRH was detected in 21 of 22 subsurface sediment samples, at concentrations ranging from 51 to 12,000 µg/kg (Map 11.3.15-14). The maximum subsurface concentration occurred in the same general area as the surface sediment maximum. The DRH concentrations in this nearshore area between the Equilon and Gunderson docks decreased with depth overall, and were highest in the surface interval or in the shallowest subsurface interval. In other nearshore areas, DRH concentrations in subsurface sediment were less than 500 µg/kg, and tended to increase with depth.

11.3.15.2.2 Surface Water

Surface water samples were collected at one sampling location (W019) within the iAOPC during the three Round 2A sampling events (Integral 2006l). Station W019 was located near the northern end of the iAOPC (RM 8.5), downstream of the main Gunderson and Equilon dock structures and all but four outfalls, in a nearshore amphibian habitat area (Integral 2006l). Near-bottom water samples were collected using a peristaltic pump at depths of approximately 4.4-5.5 ft below the water surface. Analytical results for samples from Station W019 are provided in Table 11.3.15-1b.

PCB Aroclors, DBP, and DDD were not detected in any of the three Round 2A samples collected at this station. Detection limits ranged from 0.0025-0.00263 µg/L for PCB Aroclors, 0.067-0.097 µg/L for DBP, 0.000481-0.0005 µg/L for DDD (Table 11.3.15-1b). Samples were not analyzed for DRH.

Cadmium and total DDT were also detected. Total and dissolved cadmium concentrations, detected during two sampling events, ranged from 0.00002 to 0.00003 mg/L. Concentrations were below detection limits during the March 2005 sampling event. DDT was detected only during the March 2005 sampling event, at a concentration of 0.00115 µg/L. For comparison, summary statistics for the entire Round 2 surface water data set are presented in Table 6.3-2.

11.3.15.2.3 Biota

Potential exposure of biota in iAOPC 19 was assessed from one sample of each of three types of invertebrate tissues: field-collected clams, laboratory-exposed clams, and laboratory-exposed mudworms. The field-collected clam sample was composited from several transects at the upstream end of the Equilon dock. Organisms tested in the laboratory were exposed to sediment composited from grab samples collected in the area covered by the transects (Windward and Integral 2006).

All iCOCs except DBP were detected in the invertebrate tissue samples from this iAOPC (Table 11.3.15-1c).

11.3.15.2.4 Transition Zone Water

Areas offshore of the Gunderson site (Area 1) were included in transition zone water sampling performed during the Round 2 groundwater pathway assessment (Integral 2006g). TZW sampling locations are shown on Map11.3.15-1. TZW sampling results are described in detail in Integral (2006g) and are summarized in Section 6.2. Several upland groundwater COIs were detected in one small nearshore area immediately of the iAOPC boundary; however, no potential TZW iCOCs were identified for iAOPC 19 based on the results of Round 2 TZW sampling and the draft human health and ecological risk evaluations (Sections 8 and 9).

Porewater samples were collected from the 0- to 10-cm intervals of two sediment samples: SD143 near the upstream end of the Equilon dock, and SD146 offshore of the current Gunderson marine barge launchways (Map 11.3.15-1). Both samples were analyzed for metals (cadmium, mercury, and silver), but none were detected. Detection limits ranged from 0.0001 mg/L (mercury) to 0.002 mg/L (cadmium).

11.3.15.3 Potential Sources of iCOCs

This section presents a summary of the current understanding of potential sources of iCOCs at iAOPC 19. Information presented is this section was obtained from site summaries unless otherwise noted. In addition to iCOCs, COIs associated with nearby upland areas are also discussed in this section. The COIs are presented to provide a comprehensive understanding of the upland issues and to support the identification of potential sources to the iAOPC. The relevance of the pathway to iCOCs is summarized at the end of each pathway discussion. Potential sources, COIs, and pathways for ECSI sites associated with these iAOPCs are summarized in Table 11.3.15-2.

11.3.15.3.1 Upland Releases

Releases have been documented at each of the following upland sites that may serve as sources of contaminants found in this iAOPC.

Gunderson

Current activities at Gunderson include raw materials receiving, metal cutting, welding, machining, sandblasting, parts cleaning, painting, and other activities related to marine barge refurbishment and railcar manufacturing. Many site operations occur outdoors and adjacent to or over the river shoreline. Historical activities were generally similar, with additional ship dismantling and automobile salvage operations occurring in the southernmost portion of the Gunderson property (Area 3). COIs from releases at the Gunderson facility include PCBs, petroleum hydrocarbons, PAHs, metals, butyltins, chlorinated VOCs (trichloroethane and its degradation products and dichloroethene), and toluene.

Equilon Property

Historical releases of petroleum product occurred from activities such as tank and pipeline flushing/cleaning, load rack drain maintenance, AST sandblasting, fuel handling, and boiler and pump building operations. Malfunctions in an oil-water separator also caused releases (e.g., of separate phase hydrocarbons). Sludge and residual products from these activities were discharged onto unpaved surfaces, including grounds adjacent to ASTs and the drainage ditch running through the Terminal facility.

The pipeline corridor represents a current potential source area. Some areas have been assessed and remediated, but the areas beneath the UPRR rail lines and Gunderson building have not (SECOR 2001). COIs related to the Equilon properties include petroleum hydrocarbons and related compounds (BTEX, PAHs, lead).

COIs at significant upland properties within the Outfall 18 drainage basin, as identified from LWG and DEQ site summaries (DEQ 2007), are summarized below. It should be noted that full site characterizations (including all potential COIs) have not been conducted at many of these sites, and therefore this information may be incomplete

- **Christenson Oil (ECSI #2426):** petroleum storage operations have resulted in releases of diesel- and oil- range petroleum hydrocarbons, PAHs, BTEX, copper, lead, and zinc.
- **Columbia American Plating (ECSI #29):** Metal cleaning and plating activities were conducted at this site between 1975 and 2003. COIs related to these activities include metals, cyanide, SVOCs, and chlorinated VOCs.
- **McWhorter Technologies (ECSI #135):** Operations at this facility and possibly neighboring facilities have resulted in release of DRH, PAHs, phthalates, pentachlorophenol, and several VOCs.

- **Trumbull Asphalt Plant (ECSI #1160):** Petroleum releases have been document at this asphalt plant. Current COIs include petroleum hydrocarbons and petroleum-related PAHs, and VOCs (BTEX).
- **Van Waters and Rogers (ECSI #330):** Chemical distribution and solvent recycling operations have resulted in the release of several VOCs; other potential site chemicals include pesticides, PAHs, and metals (DEQ 2007).
- **Schnitzer Investment Corp (ECSI #2424):** Various operations over the history of this facility have resulted in release of chlorinated VOCs and lead, which have been detected onsite; additional potential constituents include petroleum hydrocarbons and PAHs.
- **Magnus (ECSI #69):** Former lead-based operations of Magnus Co. and National National Lead Company have resulted in lead contamination of the soil and surface dust of the property (DEQ 2007).
- **Burlington Northern Railroad Lake Yard (ECSI #100):** rail yard and lessee operations at this facility have resulted in releases of diesel- and oil range petroleum hydrocarbons, PAHs, PCBs, phthalates, and metals (including iCOCs arsenic, cadmium, mercury, zinc, and others), as well as non-iCOCs including phenols, tetrachloroethene, trichloroethene, methylene chloride, acetone, methyl ethyl ketone, and possible sodium cyanide, ethylene glycol, and creosote constituents (DEQ 2007).
- **Hill Investment (Ashland Chemical; ECSI #1076):** Little information is available regarding substances used or stored as part of site operations. Chlorinated VOCs detected in site groundwater are attributed to an offsite source (DEQ 2007).
- **Carson Oil (ECSI #1405):** Petroleum-based solvents, gasoline, diesel oils, and grease are used in site operations. Petroleum releases to site soil have been documented; chlorinated VOCs detected in site groundwater likely result from offsite sources.
- **ANRFS (ABF Freight Systems, Inc.; ECSI #1820):** Site COIs include chlorinated and petroleum-based VOCs, which have been found in site groundwater. From 1996 to present ABF Freight Systems' NPDES permit has exceeded its benchmarks for oil and grease, TSS, and zinc on multiple occasions (CH2M Hill 2004a).
- **Container Recovery (ECSI #4015):** Site operations have resulted in a release of chlorinated VOCs to soil and groundwater. Previous concerns regarding migration of contaminants along the stormwater drainage pathway have been addressed (DEQ 2007).

11.3.15.3.2 Stormwater/Overland Transport

This section includes discussions of stormwater outfalls, seeps, and adjacent upland overland transport to the iAOPC.

Stormwater

Stormwater drains to the iAOPC through 30 private outfalls and one public outfall. The outfalls and the nature of their drainage basins are summarized in Section 5.

Twenty-seven of the 30 private outfalls belong to the Gunderson facility, and three are located on the Fort James/GP Northwest Service Center facility property (Map 11.3.15-1). Gunderson conducts biannual sampling of 14 of the 27 outfalls in compliance with their 1200-Z NPDES permit. In addition, between 2003 and 2005 Gunderson evaluated selected stormwater systems for an expanded suite of analytes including petroleum, PCBs, PAHs, phthalates, 16 metals, butyltins, and VOCs, as presented in the site summary addendum (Integral 2007). Diesel- and oil-range petroleum hydrocarbons, PCBs, PAHs, phthalates, metals, butyltins, and VOCs were detected in one or more samples of catch basin solids or stormwater from facility storm drains. No sample data are available for the Fort James/GP Northwest Service Center facility drains.

City Outfall 18 is located near the Equilon dock and discharges only stormwater through a 72-inch-diameter concrete pipe located near the upstream boundary of the Equilon property shoreline. The outfall drains an area of approximately 460 acres whose major land uses are industrial (41 percent) and open space (53 percent). Facility types within the Outfall 18 basin are primarily manufacturing, fabrication, and distribution operations, but recycling, waste processing, transportation, storage, offices, environmental cleanup, equipment rental and repair, gas station, petroleum terminal, truck washing, painting contractor, photo processing, vehicle repair, and retail operations were also identified (CH2M Hill 2004a).

Fifteen properties held NPDES permits to discharge to Outfall 18 as of 2003 (CH2M Hill 2004a). The GEN13 permit for Owens Corning Corporation (Trumbull Asphalt) has been terminated since that time. The results of NPDES stormwater sampling from 1995 to 2002 at 17 industrial facilities that held 1200Z or 1300J permits within the Outfall 18 basin are provided elsewhere (Appendix F of the source control pilot study report [CH2M Hill 2004a]). One or more of these samples contained detected concentrations of oil and grease, TPH, metals, and VOCs. Concentrations of oil and grease, copper, lead, zinc, and certain conventional parameters were above benchmark thresholds in one or more samples (CH2M Hill 2004a).

The City conducted MS4 permit stormwater quality monitoring from two subbasins within the Outfall 18 drainage basin during 14 storm events between 1991 and 1996 (CH2M Hill 2004a). The storm event sampling was conducted at two locations on NW Yeon Avenue near NW 35th Avenue, one primarily representing runoff from a heavy industry area, the other primarily representing a high-volume traffic corridor. A summary of minimum and maximum results for selected analytes is presented below.

	Stormwater (mg/L)		
Analyte	**# Samples**	**Min**	**Max**
Ammonia Nitrogen	14	ND	1.5
Total Oil and Grease	13	ND	16
TPH	13	ND	12
Polar Oil and Grease	13	ND	6.1
Total Metals			
Arsenic	11	ND	0.008
Cadmium	14	ND	0.016
Chromium	11	*0.008*	0.068
Lead	14	0.013	0.17
Silver	14	ND	0.0023
Mercury	11	ND	ND
Zinc	14	0.05	8.1
Dissolved Metals			
Arsenic	11	ND	0.002
Cadmium	14	ND	0.003
Chromium	11	ND	0.013
Lead	14	ND	0.009
Silver	14	ND	0.006
Mercury	11	ND	ND
Zinc	14	0.028	7.3

Note: Italicized results are considered estimates due to QA/QC review (CH2M Hill 2004a).

Outfall 18 was the focus of a 2002 pilot study performed by Portland's Bureau of Environmental Services for three purposes: 1) evaluate the impacts of discharge from City outfalls on sediment quality in the ISA, 2) identify upland sources of contaminants in the outfall basins, and 3) guide subsequent source control efforts (CH2M Hill 2004a). Major findings of the report include the following:

- A preliminary assessment of approximately 58 properties within the basin was conducted to identify potential contaminant sources. Evaluation parameters included standard industrial classification number/business type, storm drainage exposure, and historical records associated with the site (for example, spills/releases, NPDES permit benchmark exceedance, ECSIs and LUSTs). Contaminants of interest were identified for the site based on site type (e.g., metals and PAHs were assigned to transportation sites) and/or historical contaminants.
- Chemical data screening from sediment sampling identified the following chemicals near the outfall (the results of City sediment samples are included in Section 11.3.1.2 above):
  - Phthalates
  - PAHs
  - PCBs

- DDTs and metabolites
- Lead
- Mercury.

On the basis of the sediment data collected for Outfall 18, the City concluded that there was no spatial pattern showing that Outfall 18 is a conduit for significant sources of sediment contamination. The City is proceeding with Phase 2 of the evaluation.

Most of the city's sediment samples were collected inside the embayment formed by the Equilon dock (Samples PP011801-PP011809; Map 11.3.15-1). As mentioned in Section 11.3.1.2 above, no subsurface sediment data exist for this area; the distribution of chemicals in the subsurface sediment near Outfall 18, and therefore the potential historical impacts from this outfall, remain unknown.

Stormwater Pipe-related Seeps

Three seeps related to stormwater pipes have been identified along the iAOPC shoreline. A seep was identified around the backfill of Outfall 18 during a 2002 Seep Reconnaissance Survey (GSI 2003b). Seeps -02 and -03 are associated with stormwater drain pipes (formerly referred to by Gunderson as outfalls 18 and 21, respectively) that are cracked upstream of their intended terminus (type 3 seeps). As mentioned in Section 6.2.1.2, each of these three seeps was sampled once in November 2004 and again in April 2005, with samples analyzed for 31 individual parameters, including conventionals, metals, PCB Aroclors, petroleum hydrocarbons, and phthalates. Data were validated to QA1 Category 1 level (not appropriate for use in risk assessment).

In samples collected previously by Gunderson, DRH, RRH, PCBs, PAHs, phthalates, and metals were intermittently detected at Seeps -02 and –03.

11.3.15.3.3 Overwater Discharge

Many of the current and historical manufacturing activities at the Gunderson facility have been conducted at overwater facilities such as the barge launchways in Area 2 (currently used for blasting and occasional marine coatings application) and the Outfitting Dock in Area 3 (currently used for welding and touch-up painting). Contaminant pathways to the river associated with these activities include direct overwater discharge and overland sheet flow.

Several direct overwater spills involving diesel or gasoline been documented at the Equilon dock during the transfer of products from vessels to the underground pipeline corridor. No information has been identified regarding overwater discharges or spills occurring at the Fort James/GP Northwest Service Center facility at the upstream end of the iAOPC.

11.3.15.3.4 Groundwater Discharge

Upland site operations have resulted in impacts to groundwater upgradient of the iAOPC. Several groundwater plumes have been identified at upgradient facilities

(Map 5.1-1a–h), but only the chlorinated VOC plume in Area 1 is known to be discharging to the river. TZW discharge mapping and sampling conducted by the LWG in the area near the downstream boundary of the iAOPC revealed a nearshore area of groundwater discharge (Integral 2006g). The boundary of the discharge zone extends approximately 100 ft downstream of the iAOPC. Because nearby extraction wells have suppressed the groundwater gradient, discharge (flow) rates in this zone are likely to be low. Chlorinated solvents measured in TZW samples from this area likely migrated from upland groundwater to the shoreline before the remedial extraction wells were installed. The region outside the discharge zone is identified as a low- to no-flow groundwater discharge area. No potential TZW iCOCs were identified for iAOPC 19, based on the results of Round 2 TZW sampling and the draft human health and ecological risk evaluations (Sections 8 and 9).

In 1999, after a brief precipitation period, filtered and unfiltered samples of the seeping groundwater were collected from Gunderson's former access gully seep (Seep-01/WR-149). PCBs and mercury were among the analytes detected. Additional samples collected by Gunderson from this seep in 2002-2004 have intermittently contained detected concentrations of phthalates and several metals.

11.3.15.3.5 Riverbank Erosion

The Gunderson facility riverbank was developed to its current configuration through the periodic placement of fill material starting in at least the 1950s and into the 1960s. Most of the fill material is assumed to have consisted of dredged river sediment placed by the USACE. The gully in Area 3 associated with Seep-01 was filled in the 1970s; the source of the fill material is not mentioned in the site summary. The present riverbank fronting the iAOPC is predominantly riprapped with small to large imported boulders that limit erosion potential, with a few vegetated bank areas.

A riverbank survey was conducted along the iAOPC by Gunderson in 2005-2006 (Squier|Kleinfelder 2006a,b,c). Well-established vegetative cover and general uniformity of slope gradients along the much of the riverbank and shoreline areas suggest that the waterfront has been relatively stable since it was constructed, and evidence of localized riverbank erosion was observed in only a few locations (in the vicinity of the historical launchways, the Marine Blast and Paint Building, and in Area 3).

Samples of spent blasting grit lying on the surface and from the near-surface soils collected along the Marine Barge Launchways contained copper, nickel, and zinc. Heavy oil, PCBs, metals, high molecular weight PAHs, and butyltins were detected in beach samples near Area 1 outfalls WR-131 and WR-132 (near the Paint and Blast Building) and behind the Equilon dock in Area 2 (Map 11.3.15-1). Beach samples collected in the vicinity of outfalls WR-137, WR-138, and Outfall 18 in Area 2 contained detected concentrations of these constituents (except butyltins) as well as gasoline range hydrocarbons, low molecular weight PAHs, and VOCs. Heavy petroleum hydrocarbons, PCBs, PAHs, arsenic, cadmium, and lead were detected in riverbank samples collected from Area 3 during the upland RI.

11.3.15.4 Relationship of Upland Sources to the Distribution of iCOCs

Based on the in-water distribution of several iCOCs (PCBs, DDD, cadmium, and DRH) and the evaluation of chemical sources/pathways presented above, there is evidence of a link between chemicals in upland sources and those in sediment and surface water from the iAOPC. As DBP was detected in only a few iAOPC sediment samples, no links can be made between sources and in-river media for this potential iCOC.

Overall, the highest concentrations of iCOCs in sediment were generally found in the nearshore zone, close to the riverbank, where the time-series bathymetry data show predominantly stable depths or limited deepening. Low concentrations were typically detected in the dominantly depositional areas in the offshore portions of the iAOPC.

Samples collected between the upstream end of the Equilon dock and the current barge launchways contained the highest concentrations of several iCOCs, including PCBs, cadmium, DDD, and potential iCOC DRH. The concentrations of each of these iCOCs generally decreased with depth in this area, suggesting a common active source and pathway, though high PCB concentrations in the subsurface downstream of this area suggest a long-term source. Given the area's high density of outfalls, stormwater is a plausible source, but overwater releases, runoff from upland soils, and bank erosion are also possible. For example, the observed cadmium concentrations in sediment may also be attributable to overwater releases, runoff, or bank erosion in the Gunderson Marine Barge Paint and Blast Area, and DRH concentrations may stem from overwater releases from Gunderson or Equilon dock operations.

Localized, relatively elevated concentrations of PCBs, DDD, and DRH occurred in samples near the shoreline in other portions of the iAOPC as well. The abundance of stormwater outfalls along the shoreline suggests that these contaminants may reach the river via the upland stormwater systems; however, overland transport, bank erosion, and overwater releases from the outfitting dock (in Area 3) may also be attributable pathways.

Limited areas of riverbank erosion were observed in the vicinity of the historical launchways, near the Marine Blast and Paint Building, and in Area 3. iCOCs and potential iCOCs (cadmium, PCBs, and petroleum) were detected in riverbank soil samples in Area 3 during the upland RI. Localized erosion, transport, and deposition of riverbank fill materials by outfall discharges have also been observed in the vicinity of at least one outfall (Outfall 18), but data regarding concentrations in bank fill materials are limited. Based on the results of a bank survey, areas of current riverbank erosion are anticipated to be limited, but riverbank erosion may have contributed to the distribution of iCOCs in localized areas. The degree of this contribution is uncertain due to the limited riverbank soil chemistry information.

The Round 2 TZW discharge mapping investigation (Integral 2006g) identified a groundwater discharge area immediately downstream of the iAOPC, but no potential TZW iCOCs were identified for iAOPC 19 in the draft human health and ecological risk

evaluations (Sections 8 and 9). Many of the iAOPC iCOCs have been tested for in groundwater plumes or TZW known to be discharging to the river. Discharges of contaminated shallow groundwater have been identified at Seep-01 in Area 3, which likely contribute relatively low concentrations of PCBs, phthalates, and metals.

A preliminary evaluation of the relationship between sources, pathways, and iCOCs in iAOPC 19 is summarized in Figure 11.3.16-4. A preliminary assessment of the current and historical relative contributions of each source for iAOPC 19 is summarized in Table 11.3.15-3.

11.3.16 CSM for iAOPCs 20, 21, 22, and 23

This section describes the preliminary Round 2 CSM for the iAOPCs extending from RM 7.5 to RM 9.2 along the eastern shore of the river, inclusive of Swan Island Lagoon. iAOPCs 21, 22, and 23 are contiguous within the Swan Island Lagoon, and iAOPC 20 is in the main channel of the river off the upstream end of the Swan Island Peninsula (Map 11.3.16-1). Together, these iAOPCs comprise approximately 113 acres. Numerous industrial properties are adjacent to and within the stormwater basins draining into the iAOPCs. This CSM examines the physical setting of the iAOPCs and adjacent upland properties, the chemical distribution of iCOCs in in-water media, and potential sources of the iCOCs.

The iAOPCs and associated iCOCs are listed below:

- **iAOPC 20:** Total PCBs
- **iAOPC 21:** Total PCBs
- **iAOPC 22:** Total PCBs
- **iAOPC 23:** Total PCBs.

Potential iCOCs include:

- **iAOPC 21:** Arsenic, zinc, total PCB Aroclors, DBP, DRH.

Potential iCOCs are identified through less certain and/or less rigorous evaluations based on fewer lines of evidence, FPM results, or other high uncertainty lines of evidence (see Sections 8 and 9).

Map 10.5-3a–j shows the areas where this preliminary analysis identified the potential for risk for individual exposure scenarios that were considered in iAOPC development, and Table 10.5-1 identifies the iCOCs associated with the exposure scenarios. PCBs are an iCOC at all areas within the iAOPCs. The risk area for the potential iCOCs is limited to the downstream end of the peninsula in iAOPC 21.

The CSM evaluation is summarized as follows: The primary sources of iCOCs in the Swan Island Lagoon appear to be related to current and historical stormwater outfalls

and overwater activities. The highest concentrations of iCOCs in sediment were found near the Cascade General dry docks and near outfalls draining the Cascade General property. Sediment concentrations of PCBs near public outfalls (M-1, M-2, S-1, S-2), which drain large areas of Mocks Bottom and the Swan Island industrial park, were relatively low compared to high concentrations elsewhere in the lagoon. Groundwater does not appear to be a significant contributor of iCOCs in sediments. No relationship to sources is apparent at iAOPC 20. The contribution from riverbank erosion cannot be evaluated because the riverbanks adjacent to the iAOPCs have not been sampled.

11.3.16.1 Physical Setting, Infrastructure, and Operational History

In-river and upland physical characteristics, infrastructures, and operational history relevant to these iAOPCs are described in this subsection. Information on adjacent upland sites was obtained from the LWG site summaries (Integral and GSI 2004; 2005a,b,c) and updates (Integral 2007) unless otherwise noted.

11.3.16.1.1 In-River

The Swan Island area has been heavily modified since the early 1900s. The main stem of the river originally flowed east of Swan Island. Excavation and dredging initiated in 1923 relocated the main channel of the river to the west side of the island and raised the level of the island to 32 ft above mean low water. The peninsula and lagoon were created with the construction of a causeway in 1927, connecting the island to the mainland.

This group of iAOPCs includes the off-channel Swan Island Lagoon (RM 8 to 9.2) and the area offshore Portland Shipyard. The contiguous iAOPC area (i.e., iAOPCs 21, 22, and 23) is sheltered from the flows of the main lower Willamette River by Swan Island, as reflected in Map 4.5-1 which shows that bottom shear stresses are very low even during periods of relatively high flow (160,000 cfs). The inner portion of the lagoon is relatively shallow, deepening gradually downstream from the -23.2 ft NAVD88 contour about one-half the distance from the enclosed upstream end to about -30 ft NAVD88 near the mouth and in the shipyard-dry dock area. At the dry dock locations, depths extend to about -50 ft NAVD88, representing localized deep holes and likely the result of dredging with the last decade. The 2002-2004 bathymetric change data from this area show a widespread and complex mosaic of areas with no change interspersed with areas of small-scale (0.5 to 1 ft) scour. Localized areas of accretion are evident along the outer shoreline, in the shipyard berths, and in the former dry docks. Given the sheltered nature of these iAOPCs, the observed riverbed elevation changes appear to reflect the influence of vessel traffic in this relatively shallow and active water-use area.

The most recent large dredging project occurred in 1992-94 at the shipyard dry docks. The maintenance dredging was conducted because silt accumulation had reduced the bottom clearance of certain river vessels to an unacceptable level. Approximately 130,000 yd^3 cubic yards of sediment were removed from these dock areas and disposed of at Ross Island. Chemical composition of the dredged material is discussed in Section 11.3.16.3.

Sediment grain-size distribution within the iAOPCs is shown on Maps 11.3.16-2a–c. The majority of surface sediment deposits consist of sandy silts. Silty sands and sandy silts dominate the subsurface sediment (bottom depths of representative samples unknown). Trace levels of clay were found throughout the surface and subsurface sediments within the iAOPCs.

Riverbank conditions for the area are shown in Map 4.6-1. Structures and riprap line the west shore of the lagoon and the shipyard. Unclassified fill is present at the head of the slip and along the east side. Natural banks are generally present in the area of the U.S. Coast Guard Marine Safety Station.

Primary in-water site uses for these iAOPCs, excluding iAOPC 20, are ship docking, maintenance, and repair. Significant in-water facilities and structures and their associated uses are listed below:

- In-water structures along the eastern shore of the lagoon, an area locally known as Mocks Bottom:
  - U.S. Coast Guard Marine Safety Station docks (RM 8.1) – One pier and one floating dock used for servicing and launching vessels
  - U.S. Navy/Marine Corps dock (RM 8.1 - 8.2) – Uses unknown
  - Fred Devine Diving and Salvage (FDDS) dock (RM 8.3 - 8.4) – Maintenance and repair of salvage vessels; berthing of boats, barges, visiting vessels, and a floating workshop; and refueling of vessels via a small tanker truck
  - Port of Portland large overwater combination dock-barge-building and two smaller overwater structures (RM 8.4 - 8.5) – Uses unknown.
  - Becker Land's Berth 311 (RM 8.8 - 9.0) – Uses unknown
- In-water structures on Swan Island:
  - A berth area along the east side of the lagoon extending south approximately 3,000 ft from the north end of the lagoon
  - A dry dock area at the north end of the lagoon housing Pier A, Pier C, Dry Dock #1, Dry Dock #3, and seven berths
  - A berth area on the west side and extending downstream of the peninsula
  - Three smaller stand-alone berths along the southeast side of Swan Island (RM 8.6 - RM 9.1), one of which, Berth 308, is not included in Cascade General's ECSI site boundary – Uses unknown.

Dry dock uses include hull repair, maintenance, painting, and other dry lay-up ship repair tasks. Berth activities include, for example, cleaning of oil tanker ballasts, engine maintenance, outfitting, and deck painting.

Private and public stormwater drains to the iAOPCs in this area. The existing stormwater routing is shown on Supplemental Figure ANZ 2002-4190.

11.3.16.1.2 Upland

All of the properties adjacent to the iAOPCs are zoned for industrial use. Historically, Mocks Bottom was a low, swampy area within a possible ancient in-filled meander of the river. Filling of this large wetland occurred between 1931 and the 1960s. Most of the industrial development area occurred after 1960, initially along the shoreline properties. Full build-out was not completed until the 1990s.

Upland properties adjacent to the iAOPCs along Mocks Bottom include (listed downstream to upstream) University of Portland, USCG Marine Safety Station, U.S. Navy/Marine Corps, FDDS, Marine Salvage Consortium, various parcels owned by the Port of Portland, Dallas & Mavis, Becker Land, and City of Portland (at the head of Swan Island Lagoon). The majority of Swan Island is owned and operated by Cascade General, with the center of the peninsula (southeast of the fabrication area) under the ownership and control of the Port of Portland.

Predevelopment features (when available), historical operations, and current operations are highlighted below for the ECSI sites for which site summaries were prepared (i.e., Cascade General, the two Freightliner properties, USCG Marine Safety Station, and FDDS). Other ECSI sites for which site summaries were not prepared as well as non-ECSI sites are also discussed in this subsection.

Cascade General Ship Repair Yard

Cascade General (formerly Portland Shipyard; ECSI #271) comprises 94 acres and occupies most of the Swan Island Peninsula, where ships have been built, repaired, and dismantled since the 1940s. Ship repair has been the primary undertaking since the 1950s. Current activities at the Cascade General dry docks include hull repair, maintenance, painting, and other dry lay-up ship repair tasks. Current activities at the berths include cleaning of tanker vessel ballasts, engine maintenance, outfitting, and deck painting.

The Portland Municipal Airport, constructed on Swan Island in 1926, functioned until operations moved in 1941 to what is now the Portland International Airport. For 10 years after the airport moved (1942 – 1951), the U.S. Maritime Commission leased Swan Island from the Port of Portland. In the early 1940s, shipyard facilities consisting of six separate land parcels (U.S. Maritime Commission 1946) were used to build WWII Liberty ships. The main portion of the shipyard was a 250-acre tract covering the entire Swan Island peninsula as well as areas east of the lagoon for barracks and employee parking. Land east of the lagoon and north of the barracks was used during the war years as a "disposal and burn area" (U.S. Maritime Commission 1946).

In an aerial photograph of Swan Island dated February 25, 1945, one can see shops, buildings, eight assembly platforms, an outfitting dock, a dry dock repair basin, a

floating dry dock, and deperming and degaussing stations. The docks were located at the downstream end of the peninsula.

After the war, the area was leased to a number of industrial tenants. Their activities included steel fabrication and storage, ship dismantling and scrapping, wood products manufacturing, equipment manufacturing, maritime supply sales, printing, chemical and soap storage, war surplus storage, fire extinguisher service and storage, paint storage, aluminum oil tank manufacturing, service station operation, sheet metal work, roofing supply storage, and general office storage.

The eight assembly platforms were filled with dredged materials between 1948 and 1957. The current configuration of four dry docks at the end of the peninsula was completed by 1979.

U.S. Coast Guard

The 7.4-acre USCG Marine Safety Station (ECSI #1338) is situated at the base of the Swan Island Bluff and on the northeastern bank of the mouth of the Swan Island Lagoon in Mocks Bottom. Between 1906 and 1931 the site was used by lumber companies. The area appears to have been used for shipyard worker parking during the war. The Coast Guard station was constructed in 1972-1974. Most of the 7.4 acres is paved or covered with buildings.

Fred Devine Diving and Salvage Co.

The area currently occupied by FDDS (ECSI #2365) was leased in the 1940s by the U.S. Navy, which used the waterfront as an outfitting basin and the upland areas as an employee parking lot. FDDS has been the main tenant at the site since 1973. The primary activities are warehousing and outdoor storage of equipment for marine salvage, wreck removal, high-capacity and heavy oil pumping, underwater inspection and repair, environmental dredging and sampling, and receipt and delivery of ship stores. Portions of the site were also leased by environmental contractors in the 1990s. Pacific Coast Environmental stored equipment and, from time to time, liquids related to tank cleaning. Smith Environmental Services stored equipment for industrial washing, hazardous waste profiling, transportation, and disposal. Occasionally, both contractors stored hazardous wastes onsite.

Freightliner

Freightliner's two facilities are located at the base of a 130-ft vegetated bluff in Mocks Bottom, within stormwater outfall basins draining into the iAOPCs. The 25-acre Truck Manufacturing Plant (TMP; ECSI #2366) site lies approximately 1,400 ft east-northeast of the lagoon and the 10.3-acre TMP2 site lies 400 ft or more east-southeast of the lagoon. The TMP was constructed in 1969 by the Port of Portland on previously undeveloped land that had been filled to its current elevation of 23.2 ft NAV88. TMP2 (ECSI #115) was constructed in 1951 on leased vacant land presumably filled by the USACE to its current elevation of approximately 33.2 ft NAV88. Both sites are largely paved or covered with buildings.

The only historical land use associated with these properties appears to be the manufacture of truck tractors and parts, including truck assembly, painting, welding, and finish detailing. Additional activity at TMP2 between 1970 and 2002 included component machining, zinc- and iron-phosphate metal pretreatment, and electrostatic priming. In 2002, TMP2 was reengineered for truck subassembly and warehousing.

Other ECSI and Non-ECSI Facilities

The historical and current operations at the ECSI and non-ECSI facilities adjacent to the iAOPCs have not been not well-documented; available information is summarized below:

- The U.S. Navy/Marine Corps property is used for training and operations. Specific information on site history and uses has not been reviewed.
- The Dallas & Mavis property is owned and operated by the trucking company GI Trucking (ECSI #1840). Specific site history and uses are unknown.
- The Becker Land LLC site consists of 5.77 acres of upland property and 2.28 acres of embankment adjacent to the Swan Island Lagoon. The upland area contains a truck terminal, a 15,000-ft^2 cross-dock facility, a 4,800-ft^2shop, and paved areas. The property also includes the Berth 311 dock structure. The site was purchased from the Port of Portland in 2005 by Becker Trucking, Inc., who had been a sub-tenant since 2000 (DJC 2005).
- NW Paper Box is adjacent to the southeast edge of the M-2 basin on land formerly operated by Island Holdings (ECSI #260).
- The unpaved and undeveloped portion of the Port of Portland-owned property on Swan Island is not currently in use. Historical use of this property has not been reviewed.
- The paved portion of the port-owned property located southwest of N. Channel Avenue serves as a parking lot for shipyard workers.
- The paved and developed portion of the port-owned property located between N. Lagoon Avenue and Swan Island Lagoon was formerly leased by Foss Environmental; this property is not currently in use.

11.3.16.1.3 Upland Hydrogeology

Subsurface investigations have been conducted at the Freightliner TMP and USCG sites in the Mocks Bottom area, and at the Freightliner TMP2 and Cascade General sites near or on Swan Island. Over the years, the topography of the uplands adjacent to the iAOPCs and surrounding area has been modified by filling, generally with material dredged from the Willamette River between 1931 and the 1960s. Throughout the area, this fill material is present to a minimum depth of 15 to 20 ft bgs. Underlying the fill material is Pleistocene or recent alluvium consisting of alternating layers of sediments ranging from clay to fine sand. Coarse-grained gravels (Pleistocene flood gravels or Troutdale Formation) were encountered at 95 ft bgs at the USCG site. Additional detail

appears in cross sections that have been prepared for the Cascade General (Figure 11.3.16-1a–c), Freightliner TMP2 (Figure 11.3.16-2a,b), and TMP (Figure 11.3.16-3a–d) sites.

Aerial photos of Mocks Bottom show a wetland and slough cutting across the current location of the Coast Guard facility, and draining into the river. A shallow water-bearing unit occurs in fill and the sandy alluvium beneath the USCG site, with groundwater encountered at 7 to 15 ft bgs. At the Freightliner TMP site, depth to groundwater ranges from 10 to 17 ft bgs. Groundwater generally flows south toward the Swan Island Lagoon. Deeper water-bearing zones appear to occur in the coarse-grained facies of the catastrophic flood deposits or the Troutdale Formation below approximately 112 ft bgs. Horizontal and vertical hydraulic gradients and velocity have not been estimated for the shallow or deeper water-bearing zones.

At Swan Island, shallow groundwater elevations (7-31 ft bgs) are highest near the interior, and decrease both to the north toward Swan Island Lagoon and to the west and south toward the Willamette River. There is no laterally continuous silt layer that separates the water-bearing units, and the fill and lower alluvium act as a single water-bearing unit. Most wells show a hydraulic connection to the river.

A groundwater seep was observed on Cascade General's property at the base of the riverbank over silty clay soil. Approximately 20 ft long, it occurs over the rocky beach above the high tide level. The exact location of the seep was not identified in Cascade General's site summary report.

11.3.16.2 Chemical Distribution of iCOCs

This section describes the distribution of iCOCs in environmental media within the Swan Island iAOPCs. Sediment, surface water, transition zone water, and biota sampling locations are shown in Map 11.3.16-1. Data summaries of the findings are provided in Tables 11.3.16-1a–d. All iCOC data for the Swan Island iAOPCs can be found in Appendix I.

11.3.16.2.1 Sediments

Table 11.3.16-1a provides statistical summaries of iCOCs and potential iCOCs for sediment in iAOPCs 20 through 23. The only iCOC for iAOPCs 20, 22 and 23 is total PCBs.

iAOPC 20

Two surface sediment samples and one subsurface sediment sample were analyzed for PCB Aroclors. Concentrations of total detected Aroclors in surface sediment ranged from 156 to 183 µg/kg, with a mean value of 170 µg/kg. Total PCBs for the sample analyzed for total detected congeners was 108 µg/kg. The surface sediment samples were located approximately 200 ft offshore of outfall WR-163 (Maps 11.3.16-3 and -4).

In the subsurface sample, the detected total Aroclor concentration of 48 µg/kg (Map 11.3.16-5a) was lower than that in the collocated surface sample. No subsurface samples were analyzed for congeners.

iAOPC 21

PCBs

Concentrations of total detected Aroclors ranged from 16 to 1,430 µg/kg, with a mean value of 255 µg/kg in the 26 surface sediment samples analyzed. Total PCBs for the seven surface sediment samples analyzed for total detected congeners (sum of 15 congeners) ranged from 23.6 to 725 µg/kg. The highest surface sediment total PCB concentrations were measured in samples from the central dry dock area and adjacent to the Coast Guard facility, approximately 200 ft offshore of the docks (Maps 11.3.16-3 and 11.3.16-4).

Aroclors were detected in every core sample analyzed. The highest concentration of total Aroclors in the 28 subsurface samples analyzed was 3,840 µg/kg; it was detected in the central and eastern areas of the dry docks (Map 11.3.16-5b). The maximum subsurface concentrations were generally similar to the collocated surface concentrations except in the central and eastern dry dock area, where they were higher in the upper intervals of the cores than in collocated surface samples. Aroclor concentrations decreased with depth in all cores. No subsurface samples were analyzed for PCB congeners.

Arsenic

The maximum detected concentration of arsenic in surface sediment was 17 mg/kg (Map 11.3.16-7). The highest concentrations were found within the central and eastern dry dock areas and adjacent to the USCG facility.

The maximum concentration of arsenic in subsurface sediment was 44.5 mg/kg (Map 11.3.16-8); subsurface concentrations were generally similar to the collocated surface concentrations except in the central dry dock area, where they were higher in the upper intervals of the cores than in collocated surface samples. Arsenic concentrations decreased with depth in all cores. The distributions of higher subsurface concentrations were similar to those of surface sediments. Arsenic concentrations were the lowest in the bottom core sample interval at all locations.

DBP

DBP concentrations in the 27 surface sediment samples analyzed ranged from 11 to 350 µg/kg, with a mean of 55.1 µg/kg. The highest concentration was in the central dry dock area (Map 11.3.16-9). Twenty-seven subsurface sediment samples were also analyzed; DBP concentrations ranged from 5.5 to 230 µg/kg, with a mean of 56.1 µg/kg (Map 11.3.16-10). The highest concentration was also located in the central dry dock.

Surface sediment concentrations were generally equal to or higher than the maximum concentrations in collocated core samples. The highest subsurface concentration is an exception.

DRH

DRH was detected in all 10 surface sediment samples analyzed. Concentrations ranged from 99.5 to 406 µg/kg, with a mean value of 171 µg/kg (Map 11.3.16-11). The highest surface sediment concentrations of DRH were found in the central dry dock areas.

DRH was detected in all six subsurface samples analyzed. Concentrations ranged from 21 to 880 mg/kg, with a mean of 200 mg/kg (Map 11.3.16-12). The highest concentration was found in the central dry dock area. The distribution of the highest concentrations of subsurface DRH generally correlates to that of high surface concentrations, although the uppermost intervals of the cores in the central dry dock areas had higher concentrations than the collocated surface sediment. DRH concentrations were significantly lower in the deepest intervals analyzed in individual cores.

iAOPC 22

Aroclors were detected in 28 of 31 surface samples from iAOPC 22 at concentrations ranging from 8.79 to 2,500 µg/kg, with a mean value of 397 µg/kg (Map 11.3.16-3). Total PCBs in the four samples analyzed for total detected congeners (sum of 15 congeners) ranged from 130 to 656 µg/kg, with a mean of 462 µg/kg (Map 11.3.16-4). The highest surface sediment total PCB concentrations were found along the central and western side of the iAOPC, adjacent to the Cascade General large vessel moorage docks. The eastern shore of iAOPC 22 had lower concentrations of PCBs, except for one sample adjacent to municipal Outfall M-1 and a second sample adjacent to the former USACE docks between the Coast Guard and FDDS properties.

PCBs were detected in 13 of 29 subsurface sediment samples from 13 cores (Map 11.3.16-5c). Detected total Aroclor concentrations in subsurface sediment samples ranged from 6.24 to 1,340 µg/kg, with a mean value of 543 µg/kg. In the two subsurface samples analyzed for congeners, total PCBs were 291 and 571 µg/kg (Map 11.3.16-6c). Maximum subsurface concentrations were generally similar to or lower than the collocated surface concentrations. In two sediment core locations, however—one mid-lagoon near RM 8.5 and the other adjacent to Cascade General outfall WR-62—concentrations were higher in the upper intervals of the core than in collocated surface samples. Aroclor concentrations decreased with depth in all cores. The highest concentrations of subsurface total Aroclors were detected in the eastern portion of the iAOPC, adjacent to the Cascade General large vessel moorage.

iAOPC 23

PCB Aroclors were detected in 25 of 28 surface sediment samples at concentrations ranging from 2.39 to 880 µg/kg, and a mean value of 141 µg/kg (Map 11.3.16-3). Total PCBs for the 20 samples analyzed for total detected congeners (sum of 15 congeners) ranged from 0.629 to 256 µg/kg, with a mean of 39 µg/kg (Map 11.3.16-4). The highest surface sediment total PCB concentrations were for samples from the western side of the iAOPC. One surface sediment sample in the north central portion of the iAOPC was also comparatively elevated. Concentrations in samples from the eastern and southern shorelines of iAOPC 23 were generally lower.

PCBs were detected in 24 of 30 subsurface samples. Detected total Aroclor concentrations ranged from 22.2 to 1,230 µg/kg (Map 11.3.16-5c), with a mean value of 245 µg/kg. Maximum subsurface concentrations were generally higher than the collocated surface concentrations. In two sediment core locations, however—C426 and C415 located on the western shoreline—concentrations were lower in the cores than in collocated surface sediment. Aroclor concentrations decreased with depth in all cores, except in the four cores in the two south corners of the lagoon and one core mid-lagoon (PSY07), where concentrations increased with depth. The highest concentration of subsurface total Aroclors was detected in the upper interval of core C421 located on the central eastern shoreline.

11.3.16.2.2 Aroclor Distribution

The relative distribution of Aroclors in sediment samples is shown in Figure 6.1-48a–i. Samples from within the Swan Island Lagoon have a higher proportion of Aroclor 1254 than samples from the main stem of the river, which are dominated by Aroclor 1260. This is most apparent in the downstream area (iAOPC 21) and to a lesser extent in the upstream area (iAOPC 23). The middle reach (iAOPC 22) has dominant Aroclor 1260 distributions in some samples. (With only two data points for iAOPC 20, no trends can be discerned.) Although not definitive, these Aroclor distributions suggest local sources of PCBs in the lagoon area.

11.3.16.2.3 Surface Water

Surface water samples were collected from two locations within iAOPC 23 (W020 and W021) and one location in iAOPC 22 (see Section 6 and Integral 2006l). Station W020, located near the eastern shore of the lagoon just downstream of the boat ramp, lies within a human use area (Map 11.3.16-1); integrated water column samples were collected using a peristaltic pump. Station W021, located near the eastern shore of the lagoon on the downstream end of iAOPC 23, lies within an amphibian habitat; near-bottom water samples were collected using a peristaltic pump. Analytical results are summarized in Table 11.3.16-1b.

PCB Aroclors were not detected in any surface water sample from Round 2A at either station in iAOPC 23, at detection limits of 0.0025 to 0.0026 µg/L. Station W018 located near outfall WR-58 adjacent to the pier at Cascade General lies within an amphibian habitat area; high-volume near-bottom samples were collected using an XAD column and filter for all three Round 2A sampling events. The XAD column and filter (0amp.5 µm) s les were analyzed for PCB congeners. The analytical results are summarized in Table 11.3.16-1b. Total PCB congeners ranged from 162 to 567 pg/L in the XAD column samples and from 277 to 1,120 pg/L in the XAD filter samples. PCB Aroclor concentrations were derived from the PCB congener data by the laboratory using various combinations of individual PCB congeners to identify and quantitate Aroclors. The derived Aroclor concentrations are included in Table 11.3.16-1b. TEQs, ranging from 0.00165 to 0.0176 pg/L in the XAD columns and filters, were calculated from the dioxin-like PCB congeners reported by the laboratory (Table 11.3.16-1b).

11.3.16.2.4 Transition Zone Water

Porewater samples were collected in iAOPC 21 from the 0- to 10-cm intervals of two non-LWG sediment samples: SD128, offshore of the easternmost dry dock (Map 11.3.16-1), and SD133, in the berth on the western end of the dry docks. Arsenic was detected in both samples at concentrations 0.004 to 0.007 mg/L. Zinc was detected at concentrations of 0.073 and 0.179 mg/L (Table 11.2.16-1c).

11.3.16.2.5 Biota

Tissues from clams (field-collected and laboratory-exposed), the mudworm *Lumbriculus variegatus* (laboratory-exposed), crayfish, epibenthic organisms (sampled from artificial substrates), and sculpin are available to represent exposure of biota in iAOPCs 21, 22, and 23 (Table 11.3.16-1d). Laboratory-exposed organisms were not collected in the field; more precisely, they were exposed in laboratory bioassays to sediment that had been collected in the field. Biological samples were not collected in iAOPC 20. The following tissues were sampled at each iAOPC.

- **iAOPC 21** – Clams were sampled at two locations (FC022 and FC023), mudworms and clams in laboratory bioassays were exposed to sediment sampled at two locations (BT022 and BT023), epibenthic organisms were sampled at one location (MIT007), and sculpin was sampled at one location (08R003).
- **iAOPC 22** – Clams were sampled at one location (FC026), mudworms and clams in laboratory bioassays were exposed to sediment sampled at one location (BT026), and fish was sampled at one location (08R010).
- **iAOPC 23** – Clams were sampled at one location (FC029), mudworms and clams in laboratory bioassays were exposed to sediment sampled at one location, crayfish was sampled at two locations (09R001), and sculpin was sampled at one location (09R001).

PCBs

Total PCB Aroclors and total PCB congeners were analyzed in all but a few samples. PCB congeners were not analyzed in fish (largescale sucker) at iAOPC 22 or in crayfish or sculpin at iAOPC 23. Where analyzed, PCBs were detected in all samples.

DBP

DBP was analyzed only in the clam tissue sample collected in iAOPC 21. This sample was located near the Coast Guard dock structures along the eastern shore of the lagoon. The average concentration in the sample and its duplicate was 0.82 mg/kg.

Arsenic

Tissue samples analyzed for arsenic were collected only at locations in iAOPC 21. Analysis was conducted on the clam, laboratory clam, mudworm, and sculpin. Arsenic was detected in all samples, with the highest concentrations found in the mudworm tissue sample (0.985 mg/kg) from offshore of the east side of the lagoon downstream of the Coast Guard docks.

11.3.16.3 Potential Sources of iCOCs

This section presents a summary of the current understanding of potential sources of iCOCs to three contiguous iAOPCs (21, 22, and 23) within Swan Island Lagoon as well as iAOPC 20, located along the main stem of the river (Map 11.3.16-1). These iAOPCs are adjacent to several ECSI and non-ECSI sites in the Swan Island Lagoon and along the peninsula. Site summaries have been prepared for Cascade General, U.S. Coast Guard, Freightliner TMP and TMP2, and FDDS properties.

Information presented in this subsection was obtained from site summaries unless otherwise noted. In addition to iCOCs, COIs associated with nearby upland areas are also discussed in this section. The COIs are presented to provide a comprehensive understanding of the upland issues and to support the identification of potential sources to the iAOPCs. The relevance of the pathway to iCOCs is summarized at the end of each pathway discussion. Potential sources, COIs, and pathways for ECSI sites associated with these iAOPCs are summarized in Table 11.3.16-2. Upland investigations of soil and groundwater have been performed at all of the ECSI sites discussed here except FDDS.

11.3.16.3.1 Upland Releases

During World War II, Swan Island was occupied by a 250-acre shipyard owned by Port of Portland and leased to the U.S. Maritime Commission. Construction, conversion, and repair of oil tankers were performed for the U.S. Navy by the Kaiser Company. An outfitting basin, outboard ways, and dry dock facilities were located beyond the harbor line, under permit by the USACE.

Industrial processes at the shipyard included sandblasting, metal plating and surface finishing, painting, fiberglass construction, machining, and metal working. The operations conducted on the site involved building ships with Maritime Commission-owned equipment, machinery, and raw materials. Hazardous substances likely to have been discharged to the surface waters and sediments include but are not necessarily limited to lead, zinc, copper, chromium, mercury, other heavy metals, grease and oils, abrasives, solvents, cutting fluids, organic compounds, organotins, resins, fiberglass, cyanide, and used paints (EPA 1997c). Typical wastestreams associated with work at the shipyard included air emissions, wastewater, residual wastes, sanitary sewage, and stormwater runoff. PCBs are known to be present in many components of ships (e.g., Pape 2004), such as paints, rubber products, electrical cable insulation, bulkhead insulation, ventilation gaskets, and lubricants.

iAOPC 20

This iAOPC includes the offshore area along the main stem of the river in the vicinity of outfall WR-163. WWII shipbuilding operations did not occur in this iAOPC. The N. Channel Avenue fabrication site, which is located downstream and adjacent to the iAOPC, is currently being investigated by the Port of Portland under DEQ's Cleanup Program. Between 1986 and 1990, ARCO built major modules at the N. Channel Avenue site to support oil exploration activities in Alaska. Fabrication, finish painting, and the application of fire retardant were conducted on concrete pads in the center of

the area, with materials, administrative modular trailers, and equipment stored around the perimeter. Petroleum, fuel, and solvents were stored in tanks and totes during the ARCO construction project.

iAOPC 21

iAOPC 21 includes the overwater portions of the Cascade General Shipyard and extends across the mouth of the Swan Island Lagoon to include the USGS Marine Safety Station. Cascade General repairs and maintains ships at dry docks and berths along the perimeter of the shipyard. Sources with potentially complete pathways to the river include overwater activities at the shipyard and stormwater outfalls that drain localized areas along various berths. Potential COIs associated with these activities include TPH, PAHs, PCBs, phthalates, metals, and butyltins (EPA 1997c). In samples collected before and after the 1992-1994 dredging project, the following compounds were detected: PCBs (<17,000 µg/kg), tributyltin (<268,000 µg/kg), metals (copper <5,340 mg/kg), phthalates (<23,000 µg/kg), and PAHs (<26,000 µg/kg) (DEQ 1998). Sediment with the highest concentrations listed above appears to have been removed with the dredging, but post-dredge sampling does not indicate total removal of all COIs. Cascade General treats stormwater from the dry docks by mechanical and chemical means before, depending upon analytical results, pumping it to the city sewer system or discharging it to the Willamette River under Cascade General's NPDES permit. No information was reviewed regarding the dates that stormwater controls were initiated.

The USCG Marine Safety Station supports the CGC *Bluebell*, a 100-ft buoy tender, as well as several small vessels for enforcement, search, and rescue. Upland site activities include light maintenance of skiffs and vehicles (e.g., washing), storage and maintenance of buoys and navigational equipment (e.g., "limited" sandblasting in a self-contained booth, painting "touch-ups," cleaning operations), and storage of fuel. Sources with potentially complete pathways to the river include the garage (in which equipment and pesticides are stored), buoy storage yard, former fuel storage area, and buried product lines, Mount Jefferson Building, former drum storage area, and stormwater outfalls. Potential COIs associated with these activities include VOCs, SVOCs, PAHs, metals, and pesticides. The effect of past practices on soils is not known because soil investigations have not been conducted at the USGC station.

iAOPC 22

This iAOPC is adjacent to upland areas and several berths along the lagoon side of Cascade General and other Port of Portland properties, and extends east across the middle portion of the Swan Island Lagoon to U.S. Navy, FDDS, and Port of Portland property. The Freightliner TMP and FDDS facilities also drain to this iAOPC.

Sources at the Cascade General facility with potentially complete pathways to the river include the ballast water treatment plant, Building 73 (currently used for sandblasting and painting), the former paint shed and blast booth area, former substations (some contained PCBs), catch basins, and stormwater outfalls. Potential COIs from this portion of the Cascade General site include VOCs, TPH, PAHs, metals, PCBs, and butyltins.

FDDS primarily uses their site for warehousing and outdoor storage of equipment for marine salvage, wreck removal, high-capacity and heavy oil pumping, underwater inspections and repair, environmental dredging and sampling, and receipt and delivery of ship stores. Sources with potentially complete pathways to the river identified at the FDDS site include the warehouse where boats and diving gear are maintained, an oil/water separator that receives flow from the warehouse, solvents and cleaners used by former tenants in the warehouse, two diesel ASTs, former USTs, a storage area northeast of the warehouse, transformers that may contain PCBs, catch basin sediment, overwater spills from docks, and discharges from moored vessels. Potential COIs associated with these activities include VOCs, SVOCs, TPH, PAHs, phthalates, metals, PCBs, and butyltins. Catch basin sediment samples collected in 2002 confirmed the presence of SVOCs, PAHs, TPH, metals, and phthalates. Because detection limits were elevated at 500 µg/kg) for the catch basin sediment analyses, PCBs cannot be eliminated as a COI.

City stormwater Outfall M-1 is also located within iAOPC 22. The FDDS and Freightliner TMP sites are two of approximately 40 upland properties located in the M-1 basin. The Freightliner TMP facility is used for truck assembly, painting, welding, and finish detailing. Sources with potentially complete pathways to the river from the Freightliner property include contaminated dredged fill material (low levels of arsenic in fill; MFA 2003a,b); former USTs and AST for solvents and thinners; the former wheel paint booth, vapor degreaser, etch booth, and compactor; contaminated soil and groundwater in the vicinity of the former USTs, paint booth, and compactor; and stormwater drainage to Outfall M-1. Potential COIs associated with Freightliner TMP include VOCs, SVOCs, TPH, and metals.

iAOPC 23

This iAOPC encompasses the head of the Swan Island Lagoon and includes a portion of the Cascade General Shipyard, and other industrial and port-owned properties. Potential sources within this portion of the shipyard include the N. Channel Avenue fabrication site and several berths. ARCO used the fabrication site from 1986 to 1990 for construction of modular units. Fabrication, finish painting, and fire retardant application took place on concrete pads in the center of the area, with petroleum, fuel, and solvents stored in tanks and totes. It is unknown whether the fire retardants contained PCBs. Potential COIs associated with these operations in this portion of the Cascade General site include TPH, VOCs, PAHs, metals, PCBs, and butyltins.

GI Trucking (ECSI #1840), within the public Outfall M-2 basin, is included in the ECSI database for known or potential contamination by diesel and bunker fuel. NW Paper Box, adjacent to the southeast edge of the M-2 basin on land formerly operated by Island Holdings (ECSI #260), has known or potential contamination by arsenic, chromium, PCB, 2,4-D, and other pesticides; PCBs were detected at low levels (13-28 µg/kg) and DEQ issued a *No Further Action* at this site in 1993. NW Paper Box drains to outfalls WR-15 and -16.

Two ECSI sites are located within the public Outfall M-3 basin: Fred Meyer (ECSI #44), and Freightliner TMP2 (ECSI #115). Known or potential contaminants associated with Fred Meyer include PCBs, organic solvents, phenols, 1,2-dichlorobenzene, bis(2-ethylhexyl)phthalate, and dioxin/furans. PCBs were associated with the dismantling of oil-filled transformers and other electrical equipment, and past operating practices for copper wire reclamation; releases occurred from 1960 to 1968. The area was paved in 1988 to prevent migration. DEQ issued a *No Further Action* at this site in 1992.

The Freightliner TMP2 has been used for the manufacture of truck trailers and parts. In 2002, the TMP2 plant was reengineered for truck subassembly and warehousing. Several hazardous materials were used at the former TMP2 plant: natural and synthetic oils, machining coolants, solvent-based thinners, primers, paints, inorganic acids and bases, and welding gases. The following hazardous materials are used in current operations: diesel fuel, natural and synthetic oils, engine and machining coolants, adhesives, glues, solvent-based thinners, primers, paints, inorganic acids and bases, welding gases, and refrigerants. Sources with the potential to impact in-water media include contaminated dredged fill material (low levels of arsenic have been detected in the fill; MFA 2003a,b), contaminated soil and groundwater from former USTs, former wet filter paint booths, and stormwater discharges to Outfall M-3. COIs associated with these activities include VOCs, SVOCs, TPH, and metals.

11.3.16.3.2 Stormwater/Overland Transport

The upland areas adjacent to iAOPCs 20, 21, 22, and 23 are dominated by impervious surfaces, where stormwater travels directly overland or through conveyance systems to the river. In areas with porous surfaces, stormwater infiltrates directly into the ground or is routed to dry wells, sumps, and other infiltration devices.

There are approximately 60 stormwater outfalls in the Swan Island Lagoon, many of unknown status. The storm drains and catch basins that make up the stormwater conveyance systems in the Swan Island iAOPCs connect to pipes with outfalls along the lagoon or river. The outfalls and drainage basins for the Swan Island iAOPCs are listed in Table5-3. The existing stormwater routing for the Swan Island and Mocks Bottom area is shown in Supplemental Figure ANZ 2002-4190.

Stormwater discharges from the port-owned area and from the City conveyance system are regulated under Municipal Separate Storm Sewer System (MS4) Discharge Permit No. 101314 (Municipal Permit). Two sites (Cascade General and Becker Trucking [discharging to outfalls WR-68, WR-185, and WR-186]) are regulated under NPDES General Permit 1200-Z (Section 5).

DEQ is in the process of conducting stormwater pathway evaluations at several sites, including Cascade General, FDDS, and the Freightliner TMP and TMP2 facilities.

iAOPC 20
This iAOPC is located southeast of the Swan Island Shipyard along the main stem of the river. A single outfall (WR-163) discharges to the iAOPC, but no information for it is currently available.

iAOPC 21
Eight outfalls discharge into iAOPC 21: four at the shipyard and four adjacent to the Coast Guard Station. Cascade General routinely exceeds its NPDES stormwater benchmarks for copper and lead (Jurries 2006, pers. comm.).

iAOPC 22
Approximately 21 outfalls discharge into iAOPC 22: two along the east shore (Outfalls M-1 and outfall WR-70) and the remainder along the west shore (including Outfall S-1 and multiple Cascade General outfalls). Available information on the outfalls is summarized below.

Outfall M-1 is a 60-inch-diameter pipe on the east side of the Swan Island Lagoon between the FDDS and Port of Portland properties, near the center of iAOPC 22. The outfall basin drains approximately 174 acres, mostly warehousing and distribution operations. Five properties in the basin hold NPDES 1200-Z permits and one facility holds a 100-J permit. This outfall was the focus of a 2002 pilot study by the City of Portland Bureau of Environmental Services to 1) evaluate the impacts of discharge from City outfalls on sediment quality, 2) identify upland sources of contaminants in the outfall basins, and 3) guide subsequent source control efforts (CH2M Hill 2003). Phase I of the pilot project found that contaminant concentrations in sediment near Outfall M-1 exceeded screening benchmarks[86] for phthalates, PAHs, PCBs, chromium, and zinc. Phase I results also determined that the spatial distribution of organic and inorganic chemicals is not strongly influenced by total organic carbon content or by grain size. Selected chemicals appear to co-occur at the outfall, suggesting a common source of release (CH2M Hill 2003). The FDDS and Freightliner TMP2 sites are two of approximately 40 upland properties located in the M-1 basin. Based on the results of the pilot study, the city ranked Outfall M-1 as a high priority for source investigation (CH2M Hill 2004b).

NPDES limits for total suspended solids, oil and grease, and metals are intermittently exceeded in the Freightliner TMP2 wastestream (Jurries 2006, pers. comm.).

In samples of catch basin sediment collected at the FDDS property in 2002, SVOCs, PAHs, TPH, metals, and phthalates were detected. All metals and several PAHs

[86]The detected concentrations and detection limits for each of the analytes were compared to two sediment benchmark values: the DEQ High Toxicity Screening Level for freshwater receptors presented in the external review draft of the *Guidance for Evaluation of Sediment at State Cleanup Sites* (DEQ 2002), and the Apparent Portland Harbor Sediment Baseline Maximum Values presented in Table 1 of *DEQ Notification Letters to Portland Harbor Property Owners* (DEQ 1999a).

exceeded DEQ's screening level values. The phthalates detected in the catch basin sediment (i.e., BEHP and butylbenzyl phthalate) are of concern to DEQ because sediment samples near the discharge point of municipal Outfall M-1 contained higher phthalate concentrations than other river sediments. Lead concentrations were also elevated. DEQ has concluded that paint-related waste appears to be a possible source of contamination in the catch basin and outfall sediment.

City stormwater Outfall S-1 is 36-inch-diameter pipe on the west side of the lagoon at the upstream end of iAOPC 22. It drains 25 acres of industrial property, much of which is owned by Cascade General. On the basis of sediment data, the City of Portland concluded that this outfall does not appear to be a significant source of contamination to the lagoon (CH2M Hill 2004b). There are no known contaminated overland transport pathways from iAOPCs 21 and 22 to the river. The adjacent uplands owned by Cascade General and operated as a shipyard are almost entirely paved with asphalt or concrete or covered with buildings. The adjacent uplands owned by the Port of Portland are partially paved with asphalt; the remainder is unpaved and undeveloped, but does not drain to the Willamette River.

iAOPC 23

Approximately 33 outfalls drain into iAOPC 23. City Outfalls S-2 and M-3 drain to the iAOPC at the head of the lagoon, M-2 drains into the east side of the lagoon, and a dense array of private outfalls drains into the perimeter of the lagoon. Available information on the outfalls is summarized below.

City Outfall M-2 is a 60-inch-diameter pipe located on Becker Trucking property on the east side of Swan Island Lagoon. Outfall M-2 drains approximately 118 acres of primarily light industrial land, used mostly for warehousing and trucking operations (CH2M Hill 2004b). Four properties discharge to the municipal system under 1200-Z permits, and one property routes its drainage to a dry well. One ECSI site within the M-2 basin (GI Trucking, ECSI #1840) is listed for known or potential contamination by diesel and bunker fuel. The City determined that sediment contaminants detected in the vicinity of Outfall M-2 did not exceed screening levels (CH2M Hill 2004b).

City stormwater Outfall M-3 is a 60-inch-diameter pipe at the head of the Swan Island Lagoon. Land uses within the 111-acre basin are a combination of vacant and industrial properties (CH2M Hill 2004b). There are four facilities with 1200-Z permits. Two ECSI sites are located within the basin: Fred Meyer (ECSI #44) and Freightliner TMP Plant (ECSI #115); see the Upland Releases – iAOPC 23 subsection, above, for a description of the known or potential site contaminants. Zinc has regularly exceeded its stormwater benchmark at the Freightliner TMP facility. The City has ranked Outfall M-3 a high priority for source investigation based on considerably elevated sediment concentrations of HPAH, LPAH, and phthalates, and slightly elevated concentrations of DDT (CH2M Hill 2004b). Concentrations of PAHs and phthalates are also elevated in sediment near outfall WR-16.

City stormwater Outfall S-2 is 36-inch-diameter pipe located in the Swan Island Shipyard on the west side of the lagoon. On the basis of adjacent sediment data, the City of Portland concluded that this outfall does not appear to be a significant source of contamination (CH2M Hill 2004b).

No information is available for any of the private stormwater outfalls.

There are no known contaminated overland transport pathways from iAOPC 23 to the river. The portion of the adjacent uplands owned by the Port of Portland is partially paved with asphalt; the unpaved and undeveloped remainder does not drain to the Willamette River. However, most of the site is flat and inclines naturally at the edge of the property.

Another ECSI site, NW Paper Box, is located adjacent to the southeast edge of the basin on land formerly operated by Island Holdings (ECSI #260), with known or potential contamination by arsenic, chromium, PCB, 2,4-D, and other pesticides. Drainage from NW Paper Box discharges into the lagoon through outfalls WR-15 and WR-16.

11.3.16.3.3 Overwater Discharges

Shipbuilding, dismantling, and repair have been underway at the Swan Island Lagoon since the early 1940s. As reported by EPA (1997c), substances released by these WWII-era activities were likely to include but not necessarily be limited to lead, zinc, copper, chromium, mercury, other heavy metals, grease and oils, abrasives, solvents, cutting fluids, organic compounds, butyltins, resins, fiberglass, cyanide, used paints, and similar materials. The largest releases are expected to be associated with area at the downstream end of the peninsula within iAOPC 21 that was formerly used for ship assembly and later converted to the existing dry docks. Historical shipbuilding and repair activities were likely conducted at the locations of existing docks on the east side of the lagoon within iAOPCs 21 and 22, but no information on this area has been obtained. The magnitude of release is expected to have decreased dramatically with time as the level of activity declined and other controls have been implemented. No large overwater releases were included in spill records (ERIS) for Cascade General since 1995, but there are several reports for releases of hydraulic oil, lead paint, fuel (several small releases), and sandblasting dust as well as a report for a vessel fire in dry dock. Small overwater spills have been documented at the Coast Guard station, which is also located within iAOPC 21.

The FDDS dock, located within iAOPC 22, is primarily used to berth work boats, barges, and a floating workshop, but also is used by moorage tenants for private vessels. Vessels at the dock are refueled by a small tanker truck. No large overwater releases have been reported for FDDS. The Port of Portland also has a dock in this iAOPC.

Within iAOPC 23 near the head the lagoon, Becker Trucking also has a large dock, but information about activities at this dock was not available.

11.3.16.3.4 Groundwater Discharge

Groundwater investigations have been conducted at Cascade General and the two Freightliner sites.

iAOPC 20

There is no groundwater information for iAOPC 20.

iAOPCs 21 and 22

At Cascade General, the maximum concentrations of all metals, VOCs, and PAHs detected during the first and latest round of annual groundwater sampling performed in December 2003 are below DEQ Level II Screening Level Values and Ambient Water Quality Criteria for fish protection and fish consumption only (Bridgewater 2006), except for arsenic, carbon disulfide, and TCE. The distribution of scattered exceedances in groundwater suggests that impacts are localized; no mobile plume appears to be present. There does not appear to be a current and significant contribution of impacted groundwater to the river from the Cascade General site.

Groundwater investigations at the TMP site have identified two localized plumes of VOCs, both of which appear to be limited to the site boundaries and are more than 1,400 ft from the lagoon.

iAOPC 23

Localized VOC groundwater contaminants have been detected at the Freightliner TMP2 site. VOCs have also been detected downgradient of the site near the property at the head of Swan Island Lagoon. The possible relationship between the TMP2 site and the VOCs at the adjacent property is currently under investigation; however, TMP2 does not appear to be the source of VOCs (primarily vinyl chloride) (Romero 2006, pers. comm.), whose origin remains unknown. DEQ has not issued a determination regarding the need for or content of further action at either of the Freightliner sites.

11.3.16.3.5 Riverbank Erosion

As shown on Map 5.1-2, the shoreline is a mixture of natural bank (Coast Guard shoreline within iAOPC 21), unclassified fill (iAOPCs 22 and 23), river beach (on the east side and head of the lagoon, iAOPC 23), structures and riprap (along the remaining portions of the shoreline in iAOPCs 21, 22, and 23), and combinations of natural bank and unclassified fill (iAOPC 20). Cascade General reports that there is no evidence of riverbank erosion along the limited portions of shoreline that are not covered with piers, berths, and other structures. The upland RI is ongoing at this point, however, and erodible soils are being considered in the source control evaluation. No riverbank sampling has been conducted at the FDDS or U.S. Coast Guard sites.

11.3.16.4 Relationship of Upland Sources to Distribution of iCOCs

The in-water distribution of PCBs, DRH, DBP, and arsenic, and the foregoing evaluation of chemical sources and pathways constitute evidence of a link between these iCOCs in the upland areas and those in sediment and biota from the three contiguous iAOPCs (21, 22, 23) in the Swan Island Lagoon area. PCBs were detected

in sediment and biota. PCB congeners also were detected in surface water in the picogram to nanogram per liter range in iAOPC 22 using a high-volume sample collection technique. PCBs were not detected in surface water for samples in iAOPC 23, but the detection limits were relatively high. Surface water and biota samples were not collected in iAOPC 20.

Overwater activities and stormwater runoff are current and historical pathways to the river and appear to be the principal contributors of iCOCs in iAOPCs 21, 22, and 23. Generally, the highest concentrations of PCBs have been detected in surface and subsurface sediment in the area of the dry docks in iAOPC 21. Individual Aroclors there are dominated by Aroclor 1254, unlike the distribution on the main stem of the river in this area, which is primarily Aroclor 1260. The PCB concentrations and relative distributions suggest the PCB source is local. The highest concentrations of arsenic, and potential iCOCs DBP and DRH, were also found in surface sediment in the dry dock areas. The highest concentrations in subsurface sediment were in the upper core intervals, suggesting relatively recent inputs or dredging-based re-exposure of deeper and older sediments.

Within iAOPCs 22 and 23, total PCBs were higher on the west side of the lagoon, in the vicinity of Cascade General stormwater outfalls and historical overwater activities. Overall, iAOPC 23 had the lowest PCB concentrations within Swan Island Lagoon. iCOC trends relative to potential sources at iAOPC 20 could not be established because there are few sediment data points.

Although low concentrations of some iCOCs have been detected in groundwater and porewater samples from the Cascade General site, groundwater is not considered a significant historical or current pathway by which iCOCs reach in-water media in any of the Swan Island Lagoon iAOPCs.

Riverbank investigations have not been performed within Swan Island Lagoon or at iAOPC 20. Large portions of the shoreline are composed of dredged fill. Arsenic (an iCOC for iAOPC 21) has been detected at low concentrations in the fill on some properties in the Mocks Bottom area. However, there are no distinct patterns in the spatial distribution of sediment concentrations indicating that riverbank erosion is a significant source of iCOCs to these iAOPCs.

A preliminary evaluation of the relationship between sources, pathways, and iCOCs in iAOPCs 21, 22, and 23 is summarized in Figure 11.3.16-4. Preliminary assessments of the current and historical relative contributions of each source for iAOPCs 21, 22, and 23 are summarized in Table 11.3.16-3. Migration pathways for iAOPC 20 are not evaluated due to lack of information.

11.3.17 CSM for iAOPC 24

This section describes the preliminary Round 2 CSM for iAOPC 24, which is a small (5.3 acres) area of potential concern associated with Balch Creek Cove (also known as

Fireboat Cove) (Map 11.3.2-1). This CSM examines the physical setting of the iAOPC and adjacent upland properties, the chemical distribution of iCOCs in in-water media, and potential sources of the iCOCs. One iCOC has been identified for this iAOPC:

- Total PCBs.

Map 10.5-3a–j shows the areas where this preliminary analysis identified the potential for risk for individual exposure scenarios that were considered in iAOPC development, and Table 10.5-1 identifies the iCOCs associated with the exposure scenarios. PCBs are an iCOC at all areas within the iAOPC.

iAOPC 24 is adjacent to several facilities including Sause Brothers and Port of Portland Terminal 2. Both WR-235 (Port facility) and WR-258 (Fire Bureau) and municipal (City of Portland Outfalls 16 and 17) outfalls discharge into Balch Creek Cove. There is limited information about facilities within the municipal drainage basins; however, one industry within the basin is known to have released PCBs into the stormwater system. Overall, the information on the types of industrial activities within the drainage basins is limited. There is a potential link between one facility and the iAOPC; however, no information is available to confirm or refute links between other potential upland sources and the iAOPC.

11.3.17.1 Physical Setting, Infrastructure, and Operational History

In-river and upland physical characteristics, infrastructure, and operational history relevant to this iAOPC are briefly described in this subsection. Information on adjacent upland sites was obtained from the LWG site summaries (Integral and GSI 2004; 2005a,b,c) and updates (Integral 2007) unless otherwise noted.

iAOPC 24 is adjacent to several parcels within Balch Creek Cove (Sause Brothers, Port of Portland, and Williams and Pierce). GE Decommissioning (ECSI #4003) and a portion of the Burlington Northern Railroad Lake Yard site (ECSI #100) discharge stormwater via Outfall 17; no ECSI sites discharge to the Outfall 16 drainage basin. Outfall WR-235 drains stormwater from a 14.6-acre area within the northern portion of Terminal 2. WR-258 drains a small area from the City's Fire Bureau facility. Little additional information is available about industries within the drainage basins for Outfalls 16 and 17, which discharge to iAOPC 24.

11.3.17.1.1 In-River

iAOPC 24 is located in Balch Creek Cove along the western side of the LWR at approximately RM 9.7 (Map 11.3.2-1). Information from the site summaries for the adjacent downstream, (Gunderson) and upstream facilities (Port of Portland Terminal 2) is used to describe the sediment in this area.

The off-channel and sheltered Balch Creek Cove is characterized by low natural flows and shear stresses (see Map 4.5-1) and fine-grained sediments (Map 11.3.2-2a,b). The time-series bathymetric change data from January 2002 through February 2004 show net sediment accumulation in much of the cove, with some areas of no change. A

localized an area of sediment scour is evident just off the central dock, likely due to propwash. No bathymetric change data could be obtained in the inner portion of the cove because the shallow water depth interfered with access by the hydrosurvey vessel.

Maintenance dredging and capping was conducted at Fire Bureau Station 6 facility in January 2005 to remove sediment buildup from beneath the fireboat docking area (Map 11.3.2-2). No information on sediment sampling that may have been associated with the dredging has been reviewed.

The riverbank downstream of the iAOPC is primarily armored with riprap, with a few areas of native and non-native vegetation. Upstream of the iAOPC, the shoreline consists of a series of marine vessel dock and berth structures operated by the Port.

Significant in-water facilities/structures and their associated uses are as follows (Map 11.3.2-1):

- Fireboat dock
- Commercial dock (Sause Brothers)
- Port dock – vessel dock and berth structures
- Four public stormwater outfalls (Outfall 16, Outfall 17, WR-235, and WR-258).

11.3.17.1.2 Upland

Upland sites adjacent to iAOPC 24 include parcels owned or operated by Port of Portland Terminal 2, City of Portland Fire Bureau, Sause Brothers, and Williams and Pierce. The latter three are non-ECSI sites and individual site summaries have not been prepared.

The T2 facility is either paved or covered with buildings. The entire shoreline is developed as a marine terminal with no natural areas. Based on aerial photos, the remaining parcels can be characterized as a combination of paved and vegetated areas (natural vegetation is primarily along the shoreline). Upland areas along the river were primarily created from fill and are typically flat, grading to the river (or cove) only along the shoreline.

The drainage basins for each of the outfalls, including ECSI sites, are summarized below:

- **Outfall 16**: No known ECSI site drains to this outfall. According to the Portland Harbor Outfall GIS map layer (City of Portland 2006b), 62-acres (Table 5.1-3) of industrial area discharge into the stormwater conveyance system.
- **Outfall 17:** This drainage basin covers several thousand acres of industrial, residential, mixed use, and park land, of which the majority of the area has undergone stormwater/sanitary sewer separation. Stormwater from about 1,836

acres discharges to this outfall. Several hundred acres are not separated and occasionally discharge combined sewage and stormwater at this same location. Stormwater from two ECSI sites, GE Decommissioning (ECSI# 4003) and a portion of stormwater from Burlington Northern Railroad Lake Yard (ECSI #100) drain to this outfall. GE Decommissioning is an electrical service and repair facility located within the Guild Lake Industrial Sanctuary. The mostly flat site is 100 percent paved (approximately 3-acre basin area). A portion of site stormwater is routed to an oil/water separator and is discharged to the sanitary sewer. Remaining stormwater discharges to public sewer lines that ultimately empty into the Willamette River at Outfall 17. There was no site summary prepared for Burlington Northern Railroad site.

- **WR-258:** The drainage basin is associated with the City's fireboat station.
- **WR-235:** This drainage basin collects stormwater from the northern portion (approximately 15 acres) of Terminal 2.

11.3.17.1.3 Upland Hydrogeology

Subsurface environmental site investigations are limited to the Port of Portland Terminal 2 facility. Soils from borings were described as sand and silty sand to approximately 36 ft bgs, with zones of clayey silt and silt clay several feet in thickness. The subsurface explorations also determined that groundwater was at depths of 21.5 to 36 ft bgs.

11.3.17.2 Chemical Distribution of iCOCs

This section describes the distribution of PCBs (the only iCOC) in environmental media for iAOPC 24. Map 11.3.2-1 shows the sediment sampling locations, Table 11.3.17-1a–c summarizes analytical data, and all iCOC data for the iAOPC can be found in Appendix I.

11.3.17.2.4 Sediments

Table 11.3.17-1a provides a statistical summary of iCOCs for sediment in iAOPC 24. Sediment sampling locations for total PCBs within iAOPC 24 include 8 surface samples and 10 subsurface samples collected from 4 cores (Maps 11.3.2-1).

PCBs were detected in all surface samples. Two types of analyses were conducted for these samples, Aroclors (Map 11.3.2-3) and congeners (Map 11.3.2-4). The concentration of total Aroclors ranged from 98 to 600 µg/kg, with a mean value of 264 µg/kg. Total PCBs congeners ranged from 7.01 to 524 µg/kg, with a mean of 255 µg/kg. The surface sediment samples with the highest total PCB concentrations were in the nearshore adjacent to Outfall 17.

PCBs were detected in 8 of the 10 subsurface samples analyzed. All samples were analyzed for Aroclors, and 1 sample was analyzed for a subset of congeners. The total Aroclor concentrations ranged from 26 to 971 µg/kg (Map 11.3.2-5 and -6), with a mean value of 392 µg/kg. The single subsurface congener value was 953 µg/kg, and it

was collocated with the 971-µg/kg total Aroclor sample. PCB Aroclors were not detected in the deepest interval analyzed in two of three cores collected in the iAOPC.

11.3.17.2.5 Surface Water

Surface water samples were collected at one location in iAOPC 24 during sampling events of November 2004, March 2005, and July 2005 (Integral 2006). Station W022, located near the Portland Fireboat moorage, adjacent to Outfall 17 and outfall WR-258, falls within in a nearshore amphibian habitat area (Map 11.3.2-1). Near-bottom water samples were collected using a peristaltic pump at depths of approximately 1.5 to 10.3 ft below the water surface. Analytical results are summarized in Table 11.3.17-1b and reported in Appendix I.

PCB Aroclors were not detected at a detection limit of 0.00125 to 0.0025 µg/L in November 2004 or March 2005. Aroclors 1248 and 1254 were detected at concentrations of 0.00217 µg/L and 0.0025 µg/L, respectively, in July 2005.

11.3.17.2.6 Transition Zone Water

No porewater or transition zone water samples were analyzed at iAOPC 24.

11.3.17.2.7 Biota

Invertebrate tissue samples for clams (*Corbicula* spp.; field-collected and laboratory-exposed), crayfish (whole body), laboratory-exposed worms (*Lumbriculus variegatus*), epibenthic invertebrates (from artificial substrates), and sculpin are available to potentially represent exposure of biota to iAOPC 24 sources.

Total Aroclor and congener analyses were conducted on all biological samples from this iAOPC and were detected in all samples. The tissue chemistry data is compiled in Table 11.3.17-1c. The highest concentrations of total PCB Aroclors and congeners were measured in laboratory-exposed worms at 930 µg/kg and 1,450 µg/kg, respectively. The lowest concentrations of total PCB Aroclors and congeners were measured in lab-exposed clams (43.2 µg/kg and 60 µg/kg).

11.3.17.3 Potential Sources of iCOCs

This section presents a summary of the current understanding of potential sources of iCOCs to iAOPC 24.

11.3.17.3.8 Upland Releases

Limited information is currently available on upland releases or waste disposal practices within the drainage basins associated with Outfalls 16 and 17. Historical practices at the GE Decommissioning facility appear to have introduced oil and PCB-contaminated liquids and sediments into the onsite storm drainage system (discussed in the Section 11.3.17.3.3 below).

About 5,000 yd3 of petroleum-contaminated soil were excavated in the Burlington Northern Lake Yard from a former locomotive-fueling area in 1994-95 and bioremediated at the site. Soils in the excavation pit contained up to 16,000 mg/kg

diesel fuel. Apparent antifreeze was observed seeping into the excavation pit at the time; it was not analyzed, and no source was determined. The bioremediated soils were landfilled onsite, after remediation was confirmed by diesel fuel analyses. Later analyses indicated that oil was also present in the excavation pit. PCB 1260 was also detected in the subsurface at a low concentration. Several pockets of subsurface soil with up to 16,000 mg/kg diesel fuel and 4,400 mg/kg oil remain at the excavation site. Excavated soils may not have been adequately remediated or tested.

11.3.17.3.9 Overwater Discharge

Terminal 2 is located upstream and within the iAOPC. From the time the facility started operating, overwater activities included the loading and unloading of break-bulks and containers. Break-bulk historically handled at the facility included steel, lumber, logs and lesser quantities of other bulk materials, including small quantities of grain and bulk minerals. Current overwater activities consist of the infrequent loading and unloading of bulk products. Reported spills associated with the facility include releases of hydraulic oil, paints and thinners, lube and diesel oil, and inappropriate dredging activities.

No information is available that documents discharge of PCBs from overwater activities in the vicinity of the iAOPC.

11.3.17.3.10 Stormwater/Overland Transport

Stormwater investigations have been conducted at the GE Decommissioning site draining into City Outfall 17. BES conducted sediment sampling within the sewer lines upstream of Outfall 17 in March 2002. During the Portland Harbor Investigation (October 2002), PCBs were detected in sediment near Outfall 17. In 2002, the City collected three samples. One sample, collected within the sewer line just downstream of the site's lateral connection to the municipal system, contained PCBs at a concentration of 6,770 µg/kg. PCBs were not-detected upstream of any lateral connection from the GE site. In subsequent samples by BES (on GE's behalf in 2004), an additional 7 samples were collected in the public system. Of the total 10 samples, 80 percent had PCBs detected. Precise hydrodynamic conditions in the Outfall Basin 17 public conveyance system are uncertain, making inline data interpretation difficult, though four of the samples were collected from locations clearly upstream of the GE facility; PCB concentrations ranged from not detected to 944 µg/kg (PCB Aroclor 1260) and 1,240 µg/kg (PCB Aroclor 1254)..

In a follow-up investigation, catch basin samples were collected from each of the six onsite catch basins and submitted for analysis of PCBs as Aroclors. PCB Aroclor 1260 was detected in all samples at concentrations ranging from 3,100 to 98,200 µg/kg. Aroclor 1242 was also detected in one catch basin at a concentration of 3,550 µg/kg. Several PAHs and metals were also detected in legacy sediment at concentrations exceeding the applicable DEQ screening level values. Extensive catch basin and storm sewer cleanout was conducted, resulting in removal of approximately 4,000 gallons of sewer cleanout waste consisting of 95 percent wash water and 5 percent soils, as well as over 133 tons of soil and debris. Additional monitoring data to confirm the efficacy of

the cleanout are not available and there is a potential that some legacy sediment remains in the onsite and offsite storm drain piping.

Stormwater drains a portion of the Burlington Northern Lake Yard and discharges to Outfall 17, WR-235 drains stormwater from a 14.6-acre area within the northern portion of Terminal 2, and WR-258 drains a small area from the City's Fire Bureau facility. No information on stormwater sampling has been reviewed for these drainages.

11.3.17.3.11 Groundwater Discharge

Groundwater monitoring has been conducted at several facilities in the vicinity of the iAOPC, but there are no plumes that appear to discharge to or near the iAOPC. The degree of groundwater infiltration to the stormwater system from industries within the drainage basins is unknown.

At the GE Decommissioning site, a soil sample with a PCB concentration of 742,000 µg/kg was collected at a depth of 8 ft and may indicate impacted groundwater. The relationship between impacted groundwater and the subsurface storm drains is currently under investigation.

11.3.17.3.12 Riverbank Erosion

The riverbank susceptibility to bank erosion is unknown. No information is available for iAOPC 24, but Map 4.6-1 shows the shoreline as being mostly riprapped with a beach forming at the toe of the riprap.

11.3.17.3.13 Sediment Transport

It is unknown to what degree sediment transport has contributed to the distribution of PCBs within the iAOPC. Samples located immediately upstream of the iAOPC are 2 orders of magnitude less in PCB concentrations.

11.3.17.4 Relationship of Upland Sources to the Distribution of iCOCs

Based on the evaluation of historical chemical sources/pathways presented above and in the in-water distribution of PCBs for iAOPC 24, there is evidence of a link between upland sources and concentrations in sediment, biota, and surface water samples in iAOPC 24.

There are records documenting the use and release of PCBs at the GE Decommissioning site discharging to the Outfall 17 stormwater system, and PCBs were detected in soil at the Burlington Northern Lake Yard. With the exception of these sites, the DEQ on-line ECSI database has no record of PCB use or spills to storm drains associated with the facilities within the outfall drainage basins. There are areas of sediment deposition noted at this iAOPC, and sediment transport from up- or downstream areas may have contributed to the PCB distribution in these iAOPCs. Groundwater is not likely to be a contributor of PCBs, and no sampling has been conducted in riverbank soils adjacent to the iAOPC.

A preliminary evaluation of the relationship between sources, pathways, and iCOCs in iAOPC 24 is summarized in Figure 11.3.17-1. A preliminary assessment of the current and historical relative contributions of each source for iAOPC 24 is summarized in Table 11.3.17-2.

11.3.18 CSM for iAOPC 25

This section describes the preliminary Round 2 CSM for iAOPC 25, which is a small (6 acres) area of potential concern on the east bank at RM 9.9 (Map 11.3.2-1). This CSM examines the physical setting of the iAOPC and adjacent upland properties, the chemical distribution of iCOCs in in-water media, and potential sources of the iCOCs.

One iCOC has been identified for this iAOPC:

- Total PCBs.

Map 10.5-3a–j shows the areas where this preliminary analysis identified the potential for risk for individual exposure scenarios that were considered in iAOPC development, and Table 10.5-1 identifies the iCOCs associated with the exposure scenarios. PCBs are an iCOC at all areas within the iAOPC.

This CSM may be summarized as follows: The iAOPC is adjacent to industrial properties and one public and one private outfall drain to the iAOPC. The information on the types of industrial activities and chemicals used at adjacent sites and within the drainage basins that discharge to the iAOPC is too limited to either conclude or refute that there is a link between potential upland sources and PCB contamination in the iAOPC.

11.3.18.1 Physical Setting, Infrastructure, and Operational History

In-river and upland physical characteristics, infrastructure, and operational history relevant to this iAOPC are briefly described in this subsection. Information on adjacent upland sites was obtained from the LWG site summaries (Integral and GSI 2004, 2005a,b,c) and updates (Integral 2007) unless otherwise noted.

11.3.18.1.1 In-River

iAOPC 25 is located along the eastern side of the LWR at approximately RM 9.9 (Map 11.3.2-1). The nearest ECSI sites to iAOPC 25 are the former Goldendale Aluminum (ECSI #2440), now Ash Grove Cement, and UPRR Albina Yard (ECSI #178), which is located to the east and southeast of the iAOPC on the eastern side of Port Center Way.

iAOPC 25 is located at the downstream end of the relatively high energy zone from RM 11 to 10 (see Section 4.5.1). The river widens and turns west at RM 10, transitioning from a predominantly transport environment upstream to a depositional one downstream. The 2002-2004 bathymetric change data show that the nearshore, channel-slope portion of iAOPC 25 is a mix of no change and slightly scoured areas. The offshore portion of iAOPC 25 is at the upstream end of a large area of sediment

accumulation that extends downstream from this area for approximately 2 miles (see Map 4.4-2). Grain size (percent fines) in the vicinity of the iAOPC is shown in Map 11.3.2-2a,b.

The banks of the river along the adjacent Ash Grove (formerly Goldendale) shoreline are shown on Map 5.1-2 to be rip-rapped with a beach area immediately downstream or just within the iAOPC.

When operated by Goldendale Aluminum, historical overwater features included a dock where the following activities occurred:

- Barge refueling
- Alumina and pitch unloading.

The facility was acquired by Ash Grove Cement in 2006, and the dock is currently used for importing Portland cement.

11.3.18.1.2 Upland

Adjacent upland sites include land owned by the City of Portland and Ash Grove Cement (previously Goldendale Aluminum. Conditions at the Goldendale facility are used to describe the upland conditions in the vicinity of the iAOPC. This information is described in the site summary and is briefly summarized in this subsection.

The Goldendale Aluminum facility was acquired by Ash Grove Cement in early 2006. The 8-acre site is relatively flat, and is bordered by the river to the west, and the Union Pacific Railroad (UPRR) Albina rail yard to the north, east, and south. The former Goldendale Aluminum facility consisted of an administrative building, an unloader building and air conveyance equipment, three alumina storage silos, a garage, a storage building, a shop, a railcar load-out building and rail lines, and a dock with a concrete pier and mooring dolphins. Goldendale Aluminum leased the riverbed from Oregon DSL for marine industrial uses. The northern and central portions of the facility are paved, and the southern portion is covered with gravel. The riverbank is rip-rapped and mostly vegetated. Site stormwater is currently drained by a single private outfall and overland flow discharges to the river. Ash Grove Cement began using the facility in September 2006 to import Portland cement.

11.3.18.1.3 Upland Hydrogeology

Limited geologic and hydrogeologic data has been collected in the area of the iAOPC. Boring logs from the Goldendale Aluminum site indicate sand with some minor gravel to the total depth explored (25 ft). Depth to groundwater appears to range from 20 to 22 ft bgs and the inferred direction of groundwater flow is west toward the Willamette River.

11.3.18.2 Chemical Distribution of iCOCs

This section describes the distribution of PCBs (the only iCOC) for iAOPC 25. Map 11.3.2-1 shows the sediment sampling locations, and all iCOC data for the iAOPC can be found in Appendix I.

11.3.18.2.1 Sediments

Table 11.3.18-1 provides a statistical summary of iCOCs for sediment in iAOPC 25. Sediment sampling locations for total PCBs within iAOPC 25 include 2 surface samples and 1 subsurface sample collected from a single core.

PCBs were detected in both surface sediment samples. Only PCB Aroclors were analyzed in these samples (Map 11.3.2-3). The measured concentrations were 46.1 and 109 µg/kg. The surface sediment sample with the highest total PCB concentration was located offshore in the navigation channel near the center of the iAOPC. Sediment concentrations adjacent to the iAOPC are generally lower than within the iAOPC, with the exception of one nearshore upstream sediment sample near the downstream end of the Ash Grove dock and off of private outfall WR-218 that was reported at 550 µg/kg.

PCBs Aroclors were detected in the single subsurface sample analyzed at a concentration of 60 µg/kg (Map 11.3.2-5). This sample was a 0-7 ft vertically composited core from the central portion of the iAOPC.

11.3.18.2.2 Surface Water

Surface water samples were not collected within iAOPC 25.

11.3.18.2.3 Transition Zone Water

Porewater and TZW samples were not collected within iAOPC 25.

11.3.18.2.4 Biota

Biota water samples were not collected within iAOPC 25.

11.3.18.3 Potential Sources of iCOCs

This section presents a summary of the current understanding of potential sources of iCOCs to iAOPC 25.

11.3.18.3.1 Upland Releases

Limited information is currently available on upland releases or waste disposal practices at adjacent upland sites or sites within the drainage basins associated with Outfall 47, WR-218 and WR-240. The upland parcels adjacent to the iAOPC have been the site of industrial activities since the early 1900s; however, little is known about the specific industrial activities or chemical use. Aerial photographs show that the area was filled by 1969 and remained vacant until 2003 when the City started construction of a pump station.

11.3.18.3.2 Overwater Discharge

There are currently no structures or activities adjacent to iAOPC that would suggest that this is a pathway for the iAOPC. No information is available that documents historical discharge of PCBs from overwater activities in the vicinity of the iAOPC.

11.3.18.3.3 Stormwater/Overland Transport

The majority of the land use within the current stormwater basin associated with Outfall 47 is industrial. Discharge from the 21-acre Outfall 47 drainage basin (Table 4.1-3) is considered a controlled CSO; prior to controls being implemented in 2006, stormwater from a portion of the UPRR site drained to the outfall. The stormwater discharges from the rail yard are now directed to the Columbia Boulevard wastewater treatment plant. Prior to 2006 when the combined flows were diverted to the wastewater treatment plant, approximately 300 acres of predominantly residential use also discharged through Outfall 47. No information on stormwater sampling within the Outfall 47 basin has been reviewed.

Stormwater from private outfall WR-218 is discharged from 60 acres of the UPRR facility upstream of the iAOPC. Stormwater from WR-218 is considered a potential source of PAHs, TPH, and metals. PCBs were not detected in stormwater collected in 2002 from the UPRR facility. WR-240 appears to drain a rock sump on the Goldendale Aluminum property. This is an unpermitted outfall, and no information on basin area or stormwater sampling has been reviewed.

11.3.18.3.4 Groundwater Discharge

No other information is available to discuss groundwater quality for site adjacent to the iAOPC. The degree of groundwater infiltration to the stormwater system from industries within the drainage basins is unknown.

11.3.18.3.5 Riverbank Erosion

Map 4.6-1 shows the shoreline as being mostly riprapped with some shoreline vegetation, which would tend to limit erosion. The banks of the river along the Goldendale Aluminum shoreline are reportedly vegetated with grass. Significant bank erosion was noted during the 1996 record flood, but the relationship to these banks and the iAOPC is not known. No data are available to indicate whether bank soils are contaminated.

11.3.18.3.6 Sediment Transport

This iAOPC exists in an area transitioning from transport to depositional. It is unknown to what degree sediment transport has contributed to the distribution of PCBs within the iAOPC. Based on surface sediment chemistry, PCB concentrations in the vicinity of the iAOPC are generally lower than within the iAOPC. One exception is a single nearshore sample upstream of the iAOPC that had PCB concentrations greater than within the iAOPC.

11.3.18.4 Relationship of Upland Sources to the Distribution of iCOCs

Based on the evaluation of historical chemical sources/pathways presented above and in the in-water distribution of PCBs for iAOPC 25, there is little evidence of links between upland or in-water sources and PCB concentrations in sediment at iAOPC 25. However, data to support or refute such links are very limited.

A preliminary evaluation of the relationship between sources, pathways, and iCOCs in iAOPC 11 is summarized in Figure 11.3.18-1. A preliminary assessment of the current and historical relative contributions of each source for iAOPC 25 is summarized in Table 11.3.18-2.

11.3.19 CSM for iAOPC 26

This section provides the preliminary Round 2 CSM for iAOPC 26, which includes a 6.3-acre area located at approximately RM 10.3 on the western shore of the river, adjacent to the Sulzer Bingham Pumps and the Port of Portland Terminal 2 properties (Map 11.3.19-1). This CSM examines the physical setting of the iAOPC and the adjacent upland properties, the chemical distribution of iCOCs in in-water media, and potential sources of the iCOCs.

One iCOC has been identified for this iAOPC:

- Total PCBs.

Map 10.5-3a –j shows the risk areas for individual exposure scenarios that were considered in iAOPC development, and Table 10.5-1 identifies the iCOCs associated with the exposure scenarios. PCBs are an iCOC at all areas within the iAOPC.

The relative concentrations of PCBs in surface sediment samples appear to be elevated in iAOPC 26 when compared to surface sediment adjacent to the iAOPC, suggesting local source(s). Maximum concentrations of PCBs in surface sediment were similar to the subsurface PCB concentrations in underlying core samples, indicating that the sources to the iAOPC were relatively active at the time of sampling. Stormwater runoff and outfall discharge, which function as both present and historical pathways to the river, may be important contributors of PCBs to in-water media. Groundwater and riverbank erosion do not appear to be significant sources of PCBs. Overwater activities may have been a historical source of PCBs to in-water media.

11.3.19.1 Physical Setting, Infrastructure, and Operational History

In-river and upland physical characteristics, infrastructure, and operational history relevant to iAOPC 26 are briefly described in this subsection. Information on adjacent upland sites was obtained from the LWG site summaries (Integral and GSI 2004; 2005a,b,c) and updates (Integral 2007) unless otherwise noted.

11.3.19.1.1 In-River

iAOPC 26 is near the downstream end of the relatively high-energy upper Study Area reach (RM 11 to 10) described in Section 4.5.1. The navigation channel in this area extends nearly from riverbank to riverbank and modeled high flow bed shear is relatively high throughout this reach (Map 11.3.19-1 and Map 4.5-1). The nearshore portion of the iAOPC drops steeply from the river edge to the channel boundary over a horizontal distance of about 100 ft and the in-channel remainder of the iAOPC is relatively flat.

The Sediment Trend Analysis® results indicate that this section of the river is predominantly in dynamic equilibrium (i.e., sediment moves into and out of the area without a net loss or gain). Time-series bathymetric change data over the 25-month period from January 2002 through February 2004 indicate a continuous swath of sediment scour (greater than 1 ft in places) from the shoreline/channel slope to approximately the -30 ft NAVD88 contour across the entire river frontage at the site (Map 11.3.19-1). The gently sloping offshore portion of the iAOPC in the channel alternates between areas of no change and sediment scour of up to 1 ft in extent over this time frame.

Surface sediment textures in this iAOPC appear to be somewhat transitional from sand-dominated to silts based on contoured grain-size (see Map 4.4-3). Map 11.3.19-2a,b shows surface and subsurface sediment textures in the vicinity of the iAOPC. Surface sediments in the three samples ranged from coarse to fine material. Sediments in a single composite core sample from 0-7.5 ft consisted of 74 percent fines.

Sulzer Pumps and Terminal 2 docks span most of the shoreline within this iAOPC. Information regarding the lease of submerged lands and/or overwater structures was not found in Oregon DSL files. Several large pieces of metal slag are located along the Willamette riverbank, at and above the surface water level.

The upstream end of Terminal 2 is located adjacent to the downstream half of iAOPC 26. The terminal area has been the site of numerous dredging activities throughout its operational history. From 1980 to 2002, 12 separate dredging projects (primarily maintenance, but some construction activities) have been associated with the four berths. Approximately 400,000 yards of dredged sediment have been removed during this time period.

Significant in-water facilities/structures adjacent to the iAOPC and their current associated uses are as follows (Map 11.3.19-1):

- Sulzer Pumps dock—used for temporary moorage
- Terminal 2 dock—mostly inactive.

11.3.19.1.2 Upland

Terminal 2 bounds the northern (downstream) portion and Sulzer Pumps the southern portion of iAOPC 26. The land use zoning for these sites is industrial. Site summaries prepared by LWG for Port of Portland Terminal 2 and Sulzer Pumps describe upland conditions at these sites and are briefly summarized in the subsections below.

Port of Portland Terminal 2

Port of Portland Terminal 2 (ECSI #2769) occupies 49 acres along the western bank of the Willamette River between RM 9.7 and 10.7. The site is largely inactive.

Land features and the operational history of Terminal 2 include:

- Portions of the existing Terminal 2 property have been used as a sawmill (1901-1919) and a shipyard (1900s-1949), including three shipways with four attendant craneways. The shipyard was used throughout World War II for conversion, maintenance, and repair of government ships.
- After the war, Terminal 2 was acquired by the City of Portland Commission of Public Docks (CPD) for use as a public marine terminal. The Port assumed ownership of the terminal in 1971 after its merger with the CPD.
- From 1985 to 2004, the terminal was operated by Stevedoring Services of America (SSA) under an exclusive operating agreement with the Port of Portland. Operations included infrequent cargo handling, storage, and equipment maintenance. Periodic maintenance performed by SSA included work on passenger vehicles, forklifts, yard vehicles, toploaders, miscellaneous equipment, and motors related to terminal operations, as well as fueling of the equipment.
- Existing outfalls at the site discharge downstream of iAOPC 26.

Sulzer Bingham Pumps

The Sulzer Pumps site (ECSI #1235) occupies approximately 24.1 acres (including 2.2 acres of pier area) along the western bank of the Willamette River between RM 10.2 and 10.7. The Sulzer facility produces engineered pumps primarily for the hydrocarbon processing and oil and gas production markets, using processes such as metal fabrication and machining, pump testing, and painting.

Land features and the operational history of Sulzer Pumps property include:

- The property was developed in the early 1900s and has been in continual operation since that time. In 1908, Willamette Iron and Steel Works occupied the site. Based on aerial photos, the facility appears to have been built on pilings over the river.
- During World War II, steam locomotives and ships were manufactured onsite.

- By 1947, the area had been infilled to near its current extent, and most of the structures present today had been constructed. Site features at that time included a boiler shop, several machine shops, welding stations, paint shop, and a sheet metal shop. Aerial photos show rolling welding sheds on a wharf area over the Willamette River.
- Existing outfalls at the site discharge upstream of iAOPC 26
- Three outfalls, believed to be no longer in service, discharged to iAOPC 26

11.3.19.1.3 Upland Hydrogeology

The general site stratigraphy at the Terminal 2 site from the ground surface downward consists of sand and silty sand to approximately 36 ft bgs with zones of clayey silt and silty clay.

The general site stratigraphy at the Sulzer Pumps site from the ground surface downward consists of recent fill underlain by Quaternary alluvium. The fill consists of sand and layers of silt and sand mixed with brick and wood debris up to 22.5 ft bgs. Below 22.5 ft, interbedded sandy silt to silty clay/gravel was encountered, which is interpreted to represent Quaternary alluvial deposits. The base of the Quaternary alluvial deposits was not encountered (total depth explored was 37.5 ft bgs).

The depth to groundwater at Terminal 2 site was reported at 21.5 to 22 ft bgs and between 20 and 36 ft bgs.

Groundwater at the Sulzer Pumps site is present within the Quaternary alluvium at depths ranging from 18.5 to 28 ft bgs. Information on the groundwater flow rate and direction, vertical gradients, and aquifer parameters was not available for this site.

11.3.19.2 Chemical Distribution of iCOCs

This section describes the distribution of iCOCs in sediment at iAOPC 26. iCOCs within the iAOPC include total PCBs. All iCOC data for the iAOPC can be found in Appendix I.

11.3.19.2.1 Sediments

The sediment data for iAOPC 26 include three surface samples and one subsurface core (one subsurface sample) (Map 11.3.19-1; Table 11.3.19-1). This section describes the distribution of PCBs in surface and subsurface sediments within the iAOPC.

PCBs

All sediment samples collected in this iAOPC were analyzed for PCB Aroclors. One surface sediment sample was also analyzed for PCB congeners. PCB Aroclors were detected in all three surface sediment samples (Map 11.3.19-3) at concentrations ranging from 41 to 898 µg/kg, with a mean value of 362 µg/kg. PCB congeners were detected at 338 µg/kg (Map 11.3.19-4) in the sample that was collocated with the sample containing 898 µg/kg total PCB Aroclors. The highest PCB concentration was detected immediately adjacent to the downstream end of the Sulzer dock.

The subsurface sediment sample is from a core located near the center of the iAOPC in the navigation channel. This single vertically composited sample was analyzed for Aroclors only. The total Aroclor concentration was 880 µg/kg (Map 11.3.19-5). This subsurface concentration is comparable to the highest surface concentrations, and was higher than the proximal surface concentrations. A vertically composited core sample collected just upstream of the iAOPC had a total PCB Arcolor concentration of 2,400 µg/kg.

11.3.19.2.2 Surface Water

No surface water samples were collected within or near iAOPC 26 during Round 2.

11.3.19.2.3 Transition Zone Water

No porewater samples were analyzed for the iCOCs at this iAOPC. TZW samples collected in the iAOPC are discussed in the CSM for iAOPC 19 (see Section 11.3.15).

11.3.19.2.4 Biota

No tissue samples were collected within iAOPC 26.

11.3.19.3 Potential Sources of iCOCs

This section presents a summary of the current understanding of potential sources of iCOCs to iAOPC 26. Information presented is this section was obtained from site summaries unless otherwise noted. In addition to iCOCs, COIs associated with nearby upland areas are also discussed in this section. The COIs are presented to provide a comprehensive understanding of the upland issues and to support the identification of potential sources to the iAOPC. The relevance of the pathway to iCOCs is summarized at the end of each pathway discussion. Potential sources, COIs, and pathways are summarized in Table 11.2.19-2.

11.3.19.3.1 Upland Releases

The Willamette Iron and Steel Company (WISCO) used Terminal 2 and the Sulzer Pumps property for shipyard activities for an unknown period ending in 1949. In 1941-1942, the WISCO facility was expanded to 79 acres, with government ownership of approximately 36 acres. The WISCO shipyard was used throughout the war for conversion, maintenance, and repair of government ships. WISCO constructed minesweepers, minelayers, escort vessels, and patrol vessels, and repaired various operating vessels. Many of the manufacturing operations associated with the shipyard were located on the Sulzer Pumps property and included outfitting operations, a sheet metal fabrication shed, a cable storage building, a machine shop, a paint shop, a coppersmith shop, and the main industrial building. Operations conducted at Terminal 2 consisted of three shipways with four attendant craneways located at the southern (upstream) end of the property (Integral 2007).

Based on studies of WWII-era shipyards conducted by U.S. EPA (1997), discharges of hazardous substances to the surface waters and sediments were likely to include, but were not necessarily limited to, lead, zinc, copper, chromium, mercury and other heavy metals; grease and oils; abrasives; solvents; cutting fluids; organic compounds;

organotins; resins; fiberglass; cyanide; and used paints. Typical waste streams associated with these processes included air emissions, wastewater, residual wastes, sanitary sewer wastes, and stormwater runoff.

Port of Portland Terminal 2

Current operations at the Terminal 2 facility involve infrequent cargo handling, storage, and equipment maintenance. Historically, higher volumes of these products were loaded and unloaded. Periodic equipment maintenance is conducted by SSA and includes work on passenger vehicles, forklifts, yard vehicles, toploaders, miscellaneous equipment and motors related to terminal operations and fueling of the equipment. Maintenance is conducted in or near the gearlocker building. Waste generated in this operation is collected and contained for offsite disposal or recycling. Known or suspected upland sources include the gearlocker building, the Building 3060 and Building 3070 areas, former petroleum USTs, and former WISCO shipyard and Oceanic Terminal operations. Potential COIs associated with these historical and current sources include TPH, PAHs, PCBs, metals, and butyltins.

Sulzer Bingham Pumps

Sulzer Pumps produces engineered pumps primarily for the hydrocarbon processing and oil and gas production markets using processes such as metal fabrication and machining, pump testing, and painting. Site features include a manufacturing/fabrication building, main office, pattern shop, sandblast and paint area, hazardous waste storage area, pump manufacturing warehouse, testing laboratory, three electrical transformer stations, oil storage shed and 500-gallon waste oil aboveground storage tank (AST), waste storage shed, 500-gallon diesel fuel AST at the pier, and four monitoring wells near the western corner of the site. An underground oil pipeline extends from the Willamette River along the southeast property line to PGE Station E.

Potential sources at the Sulzer site include former and existing USTs, historical sandblasting areas, hazardous waste storage area (including radioisotopes), electrical substations, catch basins and storm sewers, former WISCO shipyard, and metal slag along the riverbank. Potential COIs associated with these historical and current sources include TPH, VOCs, SVOCs, PAHs, metals, and PCBs. In March 2004, the sandblasting operations were moved from an area adjacent to the river to the east end of the NE Operations building. Sandblast grit and debris is now contained in an enclosed space, reducing the potential for future airborne releases.

11.3.19.3.2 Stormwater/Overland Transport

The outfalls and drainage basins for the WISCO era have not been evaluated. Potential contaminants found in stormwater, industrial wastewater, and overland sheet runoff during this time were likely associated with sandblasting, metal plating and surface finishing, painting, fiberglass construction, and machining and metal working activities at the shipyard. These could have included VOCs, SVOCs, PCBs, PAHs, TPH, metals, cyanide, and butyltins.

Stormwater is currently collected at the Terminal 2 facility by a series of catch basins and is discharged to the Willamette River through two outfalls located downstream of the iAOPC.

On the Sulzer Pumps property, site stormwater is collected by catch basins in six drainage areas that discharge to eight outfalls, all located upstream of iAOPC 26. Historically, there were 16 outfalls on the Sulzer property, seven of which are no longer in service.

Catch basins sampled across the site during the XPA (GeoDesign 2004) contained diesel- and oil-range petroleum hydrocarbons, PAHs, chromium, copper, lead, and zinc at concentrations greater than DEQ screening level values. Sediment adjacent to Outfalls WR-2, WR-3, and WR-4 also contained concentrations of these constituents above applicable screening levels. In 2005, Sulzer Pumps performed an extensive cleanup of the site, including the cleaning of catch basins and storm drains. Analytical results from stormwater outfalls (WR-4 and WR-2) and catch basin sampling following these activities were screened against JSCS screening levels. The following constituents were detected at concentrations exceeding the screening levels: benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene (GeoDesign 2005).

On May 7, 2006, stormwater samples were collected during a storm event from outfalls or the last catch basin in the drainage prior to the outfall. Phenanthrene was the only PAH detected. Zinc, copper, and lead were detected above the JSCS ecological screening levels (GeoDesign 2006).

No information has been reviewed indicating that PCBs have been sampled in stormwater features. According to the XPA (GeoDesign 2004), PCBs were detected in transformer oil samples from all six substations onsite at concentrations ranging from 3 to 78 mg/kg. Oil stains were observed on the ground adjacent to substations 2 and 4. GeoDesign recommended characterization and remediation of the area adjacent to substation 2.

11.3.19.3.3 Overwater Discharge

In the early 1900s, during the WISCO tenure on the Terminal 2 and Sulzer Pumps properties, some operations were carried on pilings over the river. Any accidental releases or spills associated with the WISCO operations directly entered the river during this time. By 1947, the area had been infilled to near its current extent, and most of the structures present today had been constructed. Since that time, overwater activities have included the loading and unloading of containers and break-bulk (which included steel, lumber, logs and lesser quantities of other bulk materials, including small quantities of grain and bulk minerals). Current overwater activities consist of the infrequent loading and unloading of bulk products. Overwater spills, primarily of unknown volumes of petroleum products, have been documented at the Terminal 2 facility since 1978.

The current Sulzer facility includes a 2.2-acre dock that extends along the shoreline. A 500-gallon diesel AST is currently located on the dock. The dock is currently used for temporary moorage.

11.3.19.3.4 Groundwater

Except for groundwater sampling associated with the demolition of Building 3060 at Terminal 2, no upland groundwater investigations have been performed at this facility. Diesel and PAHs were detected, but downgradient samples were below method reporting limits.

Groundwater on the Sulzer Pumps property has been affected by releases from the heating oil UST area, former waste oil UST area, PGE pipeline, and from unspecified historical uses of the site. Map 5.1-1a–h shows the location of the identified plumes and areas of isolated groundwater contamination at the site. A potential pathway between groundwater and the river exists in the following areas: 1) near the former waste oil tank area, 2) the PGE pipeline, and 3) in the northern corner of the site. The groundwater contaminant plume associated with the former gasoline UST, which is located approximately 800 ft from the river, appears to have expanded beneath the current component factory at one time. The downgradient extent of the gasoline constituents has not been fully characterized; however, an active groundwater extraction and treatment system is in place.

VOCs and PAHs exceed generic risk-based screening criteria at the former waste oil UST, heating oil UST, and northwest corner of the site near the river. Elevated levels of petroleum hydrocarbons and PAHs were detected near the PGE pipeline. Information regarding the elevation of groundwater relative to the stormwater outfalls is not sufficient to assess whether stormwater drain pipes, the PGE pipeline, or backfill act as preferential groundwater pathways to the river. Therefore, it is not known whether the identified groundwater plumes at the site are a current source of contamination to the Willamette River.

11.3.19.3.5 Riverbank Erosion

Potential impacts from eroding metal slab along the northern bank were evaluated by analyzing the metal slag and adjacent sediment. Samples were collected in 2003 as part of the XPA (GeoDesign 2004) and analyzed for the Contract Laboratory Program Target Analyte List metals (22 metals plus cyanide). Some metals were detected in adjacent sediment samples at concentrations greater than background levels and freshwater sediment screening level values. Samples were not analyzed for PCBs.

No riverbank samples have been collected on the Terminal 2 portion of the iAOPC. A dock extends along most of the Terminal 2 property, and the extent of any bank erosion is unknown.

11.3.19.4 Relationship of Upland Sources to Distribution of iCOCs

iAOPC 26 and its surrounding area have a long history of heavy industrial use. WWII shipbuilding operations are potential sources of PCBs (i.e., the only iCOC at iAOPC 26)

to the river, but specific sources or pathways for in-water impacts are obscured due to significant changes in land configuration and land use after the shipbuilding era.

The relative concentrations of PCB Aroclors in surface sediment samples appear to be elevated in iAOPC 26 when compared to surface sediment adjacent to the iAOPC, suggesting local source(s). Maximum concentrations of PCBs in surface sediment were similar to the subsurface concentrations, suggesting that the sources to the iAOPC were relatively active at the time of sampling. The highest PCB Aroclor concentration in surface sediment was found in a sample collected adjacent to the downstream terminus of the Sulzer dock, indicating a possible link with historical stormwater discharges and overwater activities in this area. Stormwater runoff and outfall discharge upstream of the iAOPC, which function as both present and historical pathways to the river, may be important contributors of PCBs. The closest active outfall is located approximately 200 ft upstream from the iAOPC. Elevated PCB concentrations were measured in core samples offshore of this outfall as well as offshore of outfalls farther upstream. Insufficient data have been collected to determine whether the identified groundwater plumes at the Sulzer Pumps site are a current source of PCBs to the Willamette River.

Overwater activities still occur within the iAOPC, but operations have dwindled substantially since the WWII years. Overwater activity was likely an important pathway during those years, but the impact is not easily quantifiable.

Although the river reach in and around this iAOPC is not generally depositional in nature, sediment transport is also a potential source of PCBs to iAOPC 26.

A preliminary evaluation of the relationship between sources, pathways, and iCOCs in iAOPC 26 is summarized in Figure 11.3.19-1. A preliminary assessment of the current and historical relative contributions of each source for iAOPC 26 is summarized in Table 11.3.19-3.

11.3.20 CSM for iAOPC 27

This section describes the preliminary Round 2 CSM for iAOPC 27, which is a small (5.3 acres) area of potential concern adjacent to several private outfalls (WR-283, -282, and -291) and City of Portland Outfall 45 (Map 11.3.2-1). This CSM examines the physical setting of the iAOPC and adjacent upland properties, the chemical distribution of iCOCs in in-water media, and potential sources of the iCOCs.

One iCOC has been identified for this iAOPC:

- Total PCBs.

Map 10.5-3a–j shows the areas where this preliminary analysis identified the potential for risk for individual exposure scenarios that were considered in iAOPC development, and Table 10.5-1 identifies the iCOCs associated with the exposure scenarios. PCBs are an iCOC at all areas within the iAOPC.

This CSM may be summarized as follows: iAOPC 27 is adjacent to industrial facilities and several private outfalls and a public storm drain outfall that receive stormwater from industrial properties. There is no information regarding PCB releases from the adjacent parcels. Overall, the information on the types of industrial activities and chemical uses at facilities within the basins draining to the iAOPC is too limited to either conclude or refute that there is a link between potential upland sources and PCB contamination in the iAOPC.

11.3.20.1 Physical Setting, Infrastructure, and Operational History

In-river and upland physical characteristics, infrastructure, and operational history relevant to this iAOPC are briefly described in this subsection. Information on adjacent upland sites was obtained from the LWG site summaries (Integral and GSI 2004, 2005a,b,c) and updates (Integral 2007) unless otherwise noted.

iAOPC 27 is adjacent to parcels owned by Sakrete of Pacific Northwest and Herman Stan, with no other information available about parcels within the drainage basins for iAOPC 27. No ECSI sites discharge to iAOPC 27.

11.3.20.1.1 In-River

iAOPC 27 is located along the eastern side of the LWR at approximately RM 11 (Map 11.3.2-1). Information on in-river conditions was obtained from Section 4 of this report.

RM 11 is a narrow, channelized portion of the river characterized by relatively high flows and bottom shear stresses (Map 4.5-1). The riverbed slopes steeply from the bank to channel depth approximately 100 ft offshore. The outer portion of iAOPC 27 is the upstream end of depression that appears to be a former borrow area. The 2002-2004 bathymetric change data show sediment accumulation around the dock structure located over the inshore portion of this iAOPC. Areas of sediment scour and then no change are evident as one moves from the toe of the channel slope offshore into the channel (Map 11.3.2-1). The Sediment Trend Analysis® results indicate this area is in dynamic equilibrium and surface sediment texture is dominated by sandy sediments (Maps 4.4-3 and 11.3.2-2a,b).

There is a dock associated with the Sakrete facility located within the iAOPC, but no information is available on activities related to the dock.

11.3.20.1.2 Upland

There are no ECSI sites adjacent to or draining to this iAOPC. Sites adjacent to the iAOPC are owned or operated by Herman Stan and Sakrete of Pacific Northwest. The City of Portland GIS outfall layer provided to the LWG (City of Portland 2006b) shows that Outfall 45 discharges stormwater from a 10.1-acre (Table 5.1-3) industrial area and private outfalls WR- 282, -283, and -291 discharge stormwater from the Sakrete facility. Information on drainage areas for these private outfalls is not currently available.

11.3.20.1.3 Upland Hydrogeology

No geologic or hydrogeologic data have been collected in the area of this iAOPC.

11.3.20.2 Chemical Distribution of iCOCs

This section describes the distribution of PCBs (the only iCOC) for iAOPC 27. Map 11.3.2-1 shows the sediment sampling locations, and all iCOC data for the iAOPC can be found in Appendix I.

11.3.20.2.1 Sediments

Table 11.3.20-1 provides a statistical summary of iCOCs for sediment in iAOPC 27. Sediment sampling locations for total PCBs within iAOPC 27 include 3 surface samples (Maps 11.3.2-1).

PCBs were detected in the three surface sediment samples collected in this iAOPC. Aroclors were analyzed in all samples (Map 11.3.2-3) with congeners also analyzed in one of these samples (Map 11.3.2-4). The concentration of total Aroclors ranged from 14 to 190 µg/kg. The total PCB congeners value was 32.3 µg/kg, which corresponded closely with Aroclor total of 28.1 µg/kg in the same sample. The surface sediment sample with the highest PCB concentration was located at the toe of the slope offshore of the dock structure and outfalls WR-282 and WR-291.

11.3.20.2.2 Surface Water

Surface water samples were not collected within iAOPC 27 during Round 2.

11.3.20.2.3 Transition Zone Water

Porewater and TZW samples were not collected within iAOPC 27 during Round 2.

11.3.20.2.4 Biota

Biota samples were not collected within iAOPC 27 during Round 2.

11.3.20.3 Potential Sources of iCOCs

This section presents a summary of the current understanding of potential sources of iCOCs to iAOPC 27. The upland parcels adjacent to the iAOPC have been the site of industrial activities since the early 1900s; however, little is known about the specific industrial activities or chemical use within the individual drainage basins. The drainage basins for Outfall 45 and the private outfalls are characterized as entirely industrial. PCBs have had many industrial applications (paints, sealants, coolants, lubricants, hydraulic and dielectric fluids, etc.) so some PCB sources would be anticipated in this industrial drainage area.

11.3.20.3.1 Upland Releases

No information is currently available on upland releases or waste disposal practices at facilities that may discharge to iAOPC 27.

11.3.20.3.2 Stormwater/Overland Transport

No information on the four stormwater outfalls draining to this iAOPC has been reviewed.

11.3.20.3.3 Overwater Discharge

There is a dock associated with the Sakrete facility along the inshore portion of the iAOPC, but no information is available on its use, so its potential as a current pathway is unknown. Similarly, no information is available that documents discharge of PCBs from historical overwater activities in or near the iAOPC.

11.3.20.3.4 Groundwater Discharge

No information is available on groundwater quality within the drainage basins associated with outfalls discharging to this iAOPC. The degree of groundwater infiltration to the stormwater system from industries within the drainage basins is unknown. Several seeps have been observed along the shoreline in the vicinity of the iAOPC, but no seep water quality samples are available.

11.3.20.3.5 Riverbank Erosion

The susceptibility of the riverbank to erosion is unknown. Map 11.3.2-1 indicates the upstream shoreline area is behind the dock structure while a vegetated riverbank appears to be adjacent to the downstream portion of the iAOPC.

11.3.20.3.6 Sediment Transport

iAOPC 27 is in a relatively dynamic area. It is unknown to what degree sediment transport has contributed to the distribution of PCBs within the iAOPC. This iAOPC is at the upstream end of the Study Area and there are limited data to evaluate the effect of sediment transport on the characteristics of the iAOPC. Most surface sediment samples in the vicinity of the iAOPC (including one upstream sample, SD01) were reported at concentrations about an order of magnitude lower than the maximum sample value within the iAOPC.

11.3.20.4 Relationship of Upland Sources to the Distribution of iCOCs

Based on the evaluation of historical chemical sources/pathways presented above and in the in-water distribution of the iCOC (PCBs) for iAOPC 27, there is little evidence of links between upland or in-water sources and concentrations in sediment. However, data to support or refute such links are very limited. In general, runoff and discharges from industrial areas would be anticipated to be potential historical sources of PCBs, given their widespread and diverse industrial applications.

A preliminary evaluation of the relationship between sources, pathways, and iCOCs in iAOPC 11 is summarized in Figure 11.3.20-1. A preliminary assessment of the current and historical relative contributions of each source for iAOPC 27 is summarized in Table 11.3.20-2.

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EXECUTIVE SUMMARY

SECTION 12 – DATA GAPS

As a result of data collection and analysis through Round 2, data needs to complete the RI/FS are identified in Section 12. These data focus on:

- Sediment traps
- Surface sediments
- Subsurface sediments
- Surface water
- Stormwater
- Lamprey and sturgeon tissue
- Lamprey and benthic toxicity.

Of these data needs, sediment trap, surface sediment, subsurface sediment, surface water, stormwater, lamprey and sturgeon tissue, and lamprey toxicity data are already being addressed through Round 3A data collection activities. Additional surface sediment and subsurface sediment data along with benthic toxicity data have been identified as Round 3B data needs. The data needs are evaluated on both a area-wide and site-specific basis.

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12.0 DATA GAPS AND ADDITIONAL DATA NEEDS

The overall approach and objective of the Comprehensive Round 2 Report is to evaluate the existing environmental data set for the Study Area and surrounding reaches and identify the data needed to complete the RI/FS. The data collected and compiled by the LWG through Round 2 of the RI/FS, the initial evaluation of risks to human and ecological receptors, and the iAOPCs resulting from the initial risk evaluations have been presented in previous sections of this Comprehensive Round 2 Report. Those evaluations have resulted in the identification of the data needed to complete the RI/FS.

At the end of Round 2, the Portland Harbor data set includes more than 3,000 surface and subsurface sediment chemistry samples, over 200 TZW samples, approximately 130 surface water samples, and about 150 tissue samples (including more than 2,000 individual fish, shellfish, and benthic invertebrates) collected from the Study Area. The samples represent data of acceptable quality for use in the RI/FS that have been collected by the LWG in Round 1 or Round 2, or by EPA and other parties investigating sediment contamination in Portland Harbor prior to the AOC. Sampling that has been conducted for the current RI/FS was designed based on gaps observed in existing information.

The Round 2 data set was used in the evaluations presented in this Comprehensive Round 2 Report, which in turn were used to identify the remaining data needs for the RI/FS. The primary data needs identified at the conclusion of Round 2 are presented in Tables 12.0-1 and 12.0-2 and are as follows:

- Sediment trap data
- Surface sediment data
- Subsurface sediment data
- Surface water data
- Stormwater data
- Lamprey and sturgeon tissue data
- Lamprey and benthic toxicity data.

Other specific data needs were also identified (e.g., side scan sonar). Of these data needs, sediment trap, surface sediment, subsurface sediment, surface water, stormwater, lamprey and sturgeon tissue, and lamprey toxicity data are already being addressed through Round 3A data collection activities. Additional surface sediment and subsurface sediment data along with benthic toxicity data have been identified as Round 3B data needs.

The additional data identified are specifically those needed to complete the RI/FS for the Site. It is recognized that data needs for source control and remedial design/remedial action (RD/RA) activities may also exist. The iAOPCs that were

identified to facilitate the data gaps analysis for the RI/FS may also be a tool for DEQ to focus source control efforts. Specific RD/RA data needs cannot be entirely determined until after the FS. While data needs for source control and RD/RA activities may exist, those needs are not identified here unless the data are also needed for the RI/FS.

This section briefly compiles the relevant findings of the Comprehensive Round 2 Report and presents the data gaps analyses based on those findings that resulted in the identification of the data needed to complete the RI, including the baseline risk assessments, and the FS. The data needs are evaluated on both a Harbor-wide and area-specific basis.

12.1 SUMMARY OF FINDINGS OF THE ROUND 2 REPORT

This Comprehensive Round 2 Report presents the data collected and compiled by the LWG through Round 2 of the RI/FS, provides an initial evaluation of risks to human and ecological receptors based on those data, and identifies iAOPCs resulting from the initial risk evaluations, as well as potential sources to those iAOPCs. The major conclusions of the Comprehensive Round 2 Report are summarized here to help focus and provide context for the subsequent evaluations of data needs.

12.1.1 Nature and Extent

The nature and extent of chemicals in sediment, TZW, surface water, and biota are detailed in Section 6 and associated appendices. The Comprehensive Round 2 data set includes all LWG data collected through Round 2 of the RI/FS and other existing data from the LWR collected between May 1997 and December 2005 and determined to be of suitable quality.

The nature and extent of the COPCs identified from the human health and ecological risk screening steps (see Appendix F and G of this report) were examined. Key COPCs include arsenic, mercury, PCBs (reported as both Aroclors and congeners), DDx isomers, PAH compounds, petroleum, some phthalates, and dioxins/furans. These data provide extensive spatial coverage of the Study Area and indicate that highly elevated COPC levels are, in general, localized in their distribution within the Study Area and are generally located near upland properties that are known or suspected historical or current sources. Sediment and tissue data available from areas outside the Study Area, including upriver (RM 15.3 to 26), the downtown corridor (RM 11 to 15.3), downstream (RM 0-2), the upper Multnomah Channel, and the riparian zone "above" the in-water site, show much lower concentrations of most organic COPCs than the Study Area. Conversely, metal concentrations are comparable between the Study Area and upstream and downstream areas.

12.1.2 Human Health Risk

The Round 2 HHRA, summarized in Section 8 and presented in full in Appendix F, evaluated risks to human health resulting from exposure to chemicals in sediment, water, and biota within the Study Area. The Round 2 HHRA concluded that the fish consumption exposure scenarios result in estimated risks that exceed EPA target risk levels and are generally orders of magnitude higher than the other exposure scenarios evaluated. For the fish consumption scenarios, PCBs result in the highest cancer and noncancer risks, with approximately 85 percent of the cancer risk due to PCBs and the PCB noncancer hazard 80 times higher than any other chemical. While tissue concentrations within the Study Area are higher than upstream tissue concentrations, the Round 2 HHRA found that risks from consumption of fish collected upstream of the Study Area also exceed EPA target risk levels.

12.1.3 Ecological Risk

The Round 2 ERA, summarized in Section 9 and presented in detail in Appendix G, identified chemicals and exposure pathways that have the potential to drive risks for ecological receptors within the Study Area. Receptors addressed in this Round 2 ERA include benthic invertebrates, fish, wildlife (i.e., fish-eating birds and mammals, and shorebirds that feed on invertebrates in the sediment), amphibians and reptiles, and aquatic plants. iCOCs were identified in the Round 2 ERA, including seven metals, total and individual PAHs[87] two phthalates, two TPHs, one dioxin TEQ, eight pesticides[88], three conventional parameters, cyanide and PCBs. The predicted toxicity line of evidence (floating percentile model; FPM LOE) for the benthic community identified the highest number of iCOCs, while no iCOCs were identified for amphibians or aquatic plants. The Round 2 iCOCs are summarized in Section 9, Table 9.4-1.

12.1.4 Initial Areas of Potential Concern

iAOPCs represent areas that may be resulting in or contributing to unacceptable risks and are intended to facilitate the data gaps analysis. The iAOPCs and the process used to identify them are presented in Section 10. A total of 28 individual iAOPCs were identified over the entire Study Area. In addition, a site-wide iAOPC was identified due to risks from PCBs for certain fish consumption scenarios for human receptors. The individual iAOPCs ranged in size from under 0.2 acre to just over 40 acres. In general, individual iAOPCs were the result of risks associated with two or more human health scenarios or ecological receptors. In general, the higher the concentrations of iCOCs in an iAOPC, the more scenarios or receptors associated with the identification of the iAOPC. PCBs are the most widespread chemical causing the identification of iAOPCs,

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[87] PAHs identified for benthic invertebrates as iCOCs included the following: 2-methylnaphthalene, acenaphthene, anthracene, BAP, BAA, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, fluoranthene, fluorene, indeno(1,2,3-cd)pyrene, naphthalene, phenanthrene, pyrene, and total PAHs.

[88] DDTs identified for benthic invertebrates as iCOCs based on the FPM included sum DDD, sum DDE, and sum DDT. DDTs identified for benthic invertebrates as iCOCs based on LOEs other than the FPM included 2,4'-DDD, 2,4'-DDT, 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT.

and PCB risks are present in almost every iAOPC. In comparison, other chemicals sporadically contribute on a localized basis to iAOPC development.

12.1.5 Key Findings from Round 2 Report

The following summarizes the key findings of the round 2 Report:

- The existing Round 2 data set is adequate to:
  - Identify the portions of the Study Area that represent relatively discrete areas of contamination at levels that present potentially unacceptable risk to human health or ecological receptors
  - Identify iCOCs, pathways and exposure media that are most likely to represent unacceptable risk to humans or ecological receptors that contact contaminated areas of the Site.
- PCBs are the most widespread chemical resulting in unacceptable risks for both human and ecological receptors. The magnitude of risk from PCBs is generally significantly higher than from other chemicals. Other chemicals result in unacceptable risks on a localized basis associated with specific upland properties or overwater activities.
- Additional data are necessary to completely characterize fate and transport of iCOCs to adequately support analysis of remedial action alternatives in the FS. These include limited bed sediment, suspended sediment, surface water, and stormwater data collection that are primarily needed to address site boundary, background, upstream contaminant loading, and iAOPC-specific data needs.
- The additional data collection proposed for Round 3 will augment the existing data set and is expected to be sufficient to complete the RI/FS.

12.2 SITE-WIDE DATA NEEDS

While individual iAOPCs were identified to focus data collection, data for the Site in general are potentially needed to complete the RI/FS. This section presents those data needs that have been identified as site-wide, and not related to specific iAOPCs. The data needs that are identified in this section are summarized in Table 12.0-1.

12.2.1 Nature and Extent

Nature and extent data needs have been identified to address the Site boundary, establish background conditions, and evaluate subsurface sediment. The data needs related to the Site boundary and subsurface sediment are discussed in the following subsection. Data needs related to background are discussed in Section 12.0-2.

12.2.1.1 Site Boundary

Per the SOW, one of the critical objectives of the RI/FS is to provide sufficient information to allow EPA to define the Site boundaries. There are three site-wide nature and extent boundaries: upstream, downstream (which include both the main stem of the LWR and the upstream end of Multnomah Channel), and the lateral or vertical elevation boundary that separates the in-water Study Area from the adjacent uplands along its entire length. These data are being collected to assist EPA in defining Site boundaries.

12.2.1.1.1 Upstream and Downstream Boundaries

The upstream and downstream Site boundary data collection needs for surface water and sediments that are being addressed in Round 3A are listed below:

- Surface and subsurface sediment samples between RM 1 and RM 2 to support definition of the downstream Site boundary on the LWR
- A precision bathymetric survey in the upper Multnomah Channel to provide an accurate map of that reach and to help identify potential depositional areas in the upper channel (Round 3 data evaluation needs will follow this data collection)
- Surface and sediment samples at two potentially contaminated areas upstream of the Study Area between RM 11.2 and 12.2 to assess these areas as potential sources of contamination to the Study Area.

The details of these sampling efforts are contained in the EPA-approved Round 3A Surface Water FSP (Integral 2006o) and Upstream and Downstream Round 3A Sediment FSP (Integral 2006d). The Round 3A surface water program is being implemented in 2006 and early 2007 and includes water sampling at the upstream and downstream (including Multnomah Channel) ends of the Study Area to support Site boundary definition. Based on the evaluations conducted herein, no other data needs related to upstream and downstream boundary definition have been identified based on the Round 2 data evaluation. However, following the evaluation of the Round 3A Multnomah Channel bathymetric data, additional sediment sampling in the upper channel may be identified for Round 3B.

12.2.1.1.2 Lateral Boundary

The riparian zone for the Portland Harbor Study Area has been defined as riverbank areas between approximately +13 to + 20 ft NAVD 88 (EPA 2006g). DEQ (2003a) has defined the in-water/upland boundary at +13.3 NAVD88 or approximately the lower boundary of this riparian zone. Section 6.1.2.3 summarizes the available data compiled for this zone (+13 to +22 NAVD88) as part of this Round 2 effort. The data set is limited in both total quantity (maximum of 22 samples for any analyte) and in spatial coverage. On a site-wide basis, however, the paucity of riparian zone data does not represent a data need as the vertical Site boundary is defined and the riparian zone is outside of the in-water Site. Potential riparian zone data needs relative to iAOPC-specific FS or source identification questions are discussed in Section 12.3 (iAOPC section).

12.2.1.2 Subsurface Sediment

As noted in Section 5, the review of source information in this report focuses on current source conditions consistent with the requirements of the SOW (EPA 2001a and amendments). A comprehensive review of historical discharges to the Study Area has not been conducted. However, in some areas, it is likely that historical discharges have resulted in substantial chemical concentrations in sediments at depth that are now buried below cleaner surface sediments. Such areas would not have been identified in the current iAOPC process because this process was based on surface sediment risks. Consequently, an additional data evaluation need is to conduct a more thorough review of information related to any historical discharges combined with physical sediment transport modeling erosion predictions during flood events (work that is ongoing) and identify locations 1) that are not within any currently defined iAOPCs, 2) where subsurface sediments have not been sampled, 3) where historical discharges were likely, and 4) where subsurface sediments are likely to be exposed over time. This evaluation will be conducted in time to incorporate in the Round 3B Sediment FSP so that any areas of potentially buried contamination that have not already been subject to coring can be identified and included in that FSP. Note that the review of the volume extent in and around currently identified iAOPCs (as discussed in Section 12.3.3) already includes a review of the potential for any buried and uncharacterized contamination in and around these areas. Thus, any additional coring data needs identified by the historical discharge information evaluation would include areas away from currently identified iAOPCs.

12.2.2 Upstream Contribution and Naturally Occurring Background Concentrations

As described throughout this Comprehensive Round 2 Report, it is important to evaluate whether "background" conditions have been adequately characterized because the chemical concentrations in sediment or surface water that are entering the Site will be used in the FS in the development of PRGs for remedial action. The upstream contribution of chemicals will also be used to evaluate recontamination potential in remediated areas. Additionally, in accordance with EPA (2002) guidance, the contribution of these "background concentrations" to chemical concentrations and risks associated with the Site will be discussed during risk characterization of the baseline risk assessments. For example, information on upstream fish tissue concentrations may be important for communicating health risks associated with human consumption of fish caught in the Study Area.

The final determination of background conditions for the RI/FS will consist of a line-of-evidence approach that will evolve from the preliminary approach used in this Comprehensive Round 2 Report through Round 3 data collection and the final RI/FS. For purposes of this report, existing upriver bedded surface sediment data were compiled to provide preliminary "background" or upriver concentrations (see Section 6.1.3). The final determination of upstream background values will involve evaluation of multiple data types, including bedded surface sediment from both above and below the downtown reach (e.g., around RM 11 and RM 16), sediment trap, surface water, and

tissue data. In addition to the upstream background, some additional non-CERCLA related inputs of contaminants (e.g., from diffuse non-point sources such as atmospheric deposition) may enter the Site through stormwater discharges within the Study Area itself. This component will be assessed as part of the Round 3A stormwater sampling effort.

12.2.2.3 Sediments

Because PRGs will be established for sediment and background concentrations may be used to refine cleanup levels, a quantitative determination of background sediment concentrations is necessary. In this report, preliminary background concentrations were developed by compiling all upriver sediment data for all COPCs that had been identified during the human health and ecological risk screening process for use in the preliminary risk evaluation (see Table 6.1-16). Across all COPCs targeted, total sample sizes ranged from 2 to 42 and the total number of detected values ranged from 0 to 30. Given the limited number of upriver samples for at least some of the COPCs, additional upriver bedded sediment data have been identified as a data need (see Table 12.0-1). An analyte-by-analyte assessment of the existing data set and statistical evaluation of the data will be done to determine sample numbers and target analyses for the additional upriver sediment samples. These additional data will supplement the existing upriver sediment data set for use as one line of evidence in the determination of sediment background concentrations for the RI/FS.

An additional line of evidence in the determination of sediment background concentrations is settling sediment chemical concentration data. These data are also needed to evaluate recontamination potential. As part of the Round 3A sampling effort, sediment traps have been deployed to collect settling sediment mass and associated chemical concentration data. These data will address the need for background settling sediment data. Another Round 3A sampling effort is the collection of collocated sediment chemistry and geochronology (i.e., radioisotopes) cores in several upper Study Area long-term, depositional areas. These samples are designed to provide empirical information on contaminant loading to the Study Area over time and a range of hydrologic conditions.

12.2.2.4 Surface Water

Because PRGs will be established for surface water and background concentrations may be used to refine cleanup levels, a quantitative determination of background surface water concentrations is necessary. Three surface water sampling events were completed as part of Round 2. Additional low-detection-limit data under specific flow and runoff conditions are being acquired as part of the Round 3A sampling effort. Combined, these data will address the need for background surface water data.

12.2.2.5 Biota

PRGs will not be established for tissue. However, unacceptable risks were found associated with the tissue data, so background concentrations in tissue are important for consideration during risk characterization and in risk communication. Given the use for

background tissue data, a statistically robust data set is not necessary. Six smallmouth bass tissue composites and three brown bullhead composites, each consisting of five individual fish, were collected during Round 1 at upstream locations and analyzed for the same analytes as the tissue collected from the Study Area. These upstream tissue samples will address the need for background tissue data.

12.2.3 Human Health Risk

To evaluate data needs that may be necessary to complete the baseline HHRA, uncertainties that could have an impact on the conclusions of the Round 2 HHRA, and thus a potentially significant impact on risk management decisions, were identified. The following uncertainties, which are discussed in detail in Section 7.0 of Appendix F, were determined to rise to this level of significance and were the focus of the data gaps evaluation for completion of the baseline HHRA:

- ***Exposure parameters for fish consumption exposure scenarios.*** The ingestion parameters used were negotiated with EPA and its partners and provide a high degree of protectiveness to the exposure scenarios being evaluated. EPA and its partners have been clear that Site-specific fish consumption studies would not be accepted, so this uncertainty cannot be resolved through additional data collection. Additional discussions with EPA and its partners are needed to assess how the conservative assumptions used in the Round 2 HHRA could be refined for the baseline HHRA.
- ***Using the maximum concentration to represent exposure.*** The maximum concentration was used to represent exposure when there were less than 5 samples with detections for a given analyte because the software used to calculate exposure point concentrations (ProUCL) does not handle data sets with a large number of non-detects. Thus, this is an uncertainty for analytes that were infrequently detected in environmental media, primarily tissue, at the Study Area. Because additional tissue collection may not provide sufficient numbers of detected concentrations of a given chemical, it is proposed that alternative statistical procedures be evaluated to handle non-detects and limited data sets and estimate appropriate exposure concentrations.
- ***Risks from background.*** As described in Section 12.2.2, data collection to establish background levels is currently underway or being proposed. The upstream sediment, surface water, and sediment trap data will be used to account for background when establishing remedial goals. There are upstream fish tissue data available of adequate data quality that can be used to provide context for Site risks for purposes of risk communication. Therefore, no additional data collection is recommended to address this uncertainty.

Based on the uncertainty assessment and data gaps evaluation, no additional data collection beyond that which is already underway is needed to complete the baseline HHRA. However, additional data collected during Round 3 that are appropriate for human exposures will be used to refine the risk estimates in the baseline HHRA.

Additional evaluation of existing tissue data and exposure factors, particularly for fish consumption scenarios, will be completed prior to the baseline HHRA.

12.2.4 Ecological Risk

Data needs affecting the risk evaluation results for ecological receptors and the significance of spatial extent of ecological risks were identified as part of the Round 2 ERA and this Comprehensive Round 2 Report. Data needs are discussed in Appendix G and Section 9. Data needs represent information or data required to complete the BERA (see Section 9, Table 9.5-1). Filling those information needs will address key uncertainties that affect the outcome of the risk evaluation and the spatial scale over which risks need to be assessed to support the selection of a remedy for the Portland Harbor Superfund Site. Data needs were correctly anticipated for the BERA and all but one will be filled by Round 3 sampling that has been conducted or is being planned. Based on the Round 2 ERA, a data need in selected indeterminate areas of benthic risk was identified. Additional toxicity testing is recommended in four areas identified as either indeterminate or where there may be spatial data gaps in the delineation of iAOPCs (see Section 12.3).

Data needs identified by EPA that will be filled during Round 3 sampling include:

- ***Tissue concentrations in lamprey ammocoetes.*** This data need was identified by the LWG; however, the magnitude of the effort was defined by EPA and its partners. Lamprey ammocoete tissue was collected for analysis and comparison to tissue-based TRVs. This data gap was filled by the Round 3 sampling event conducted in Fall 2006.
- ***Toxicity of selected chemicals in water to lamprey ammocoetes.*** Lamprey ammocoete toxicity tests in water will be conducted to determine appropriate toxicological thresholds. The Round 3 sampling event was initiated in Fall 2006, and toxicity testing is expected to be completed in Spring 2007.
- ***Tissue concentrations in pre-breeding sturgeon.*** Pre-breeding sturgeon tissue will be collected for analysis and comparison to tissue-based TRVs. This will include the analysis of TBT in whole-body tissue. Observations on external/physical conditions of pre-breeding sturgeon collected in the field will be made. The Round 3 sampling event will be conducted in Winter/Spring 2007. If the sturgeon collection effort is unsuccessful, the available fish tissue data would be considered representative of exposure for benthic fish receptors in the Study Area. Additionally, non-LWG-collected sturgeon fillet data could be evaluated for use in risk calculations.

Data needs identified by the LWG for the RI/FS that will be filled during Round 3 sampling include:

- ***Effects of flow conditions on surface water concentrations.*** Additional surface water samples will be collected to better understand any influence of flow

conditions on surface water concentrations for applicable receptor groups (e.g., fish, benthic invertebrates, amphibians/reptiles, and aquatic plants) and will be incorporated into an updated analysis for relevant aquatic receptors. The Round 3 sampling event is currently being conducted.

- ***Stormwater sampling.*** Stormwater data will be collected to better understand the magnitude of stormwater impacts within the Study Area. Major components of the stormwater sampling effort include flow-weighted composite water samples from three stormwater events, sediment trap deployment, and continuous flow monitoring at each sediment sampling site for the duration of the deployment period. The stormwater collection event is expected to occur in early 2007.

Key uncertainties include those related to the data and assumptions used to assess risks. Further analysis of existing data and additional review of existing literature, including regional data, toxicological data, and other information will be used to refine exposure estimates, toxicological thresholds and ultimately, risk estimates. These include:

- ***Re-evaluation of TPH measures as sediment quality values.*** The uncertainties associated with any correlation of the available TPH measures (DRH, RRH) to toxicity in the FPM have been well-documented and submitted to the EPA under separate cover (LWG 2006b). In particular, the existing TPH measures represent mixtures of hydrocarbons with an unknown, variable composition of constituents of variable toxicities and cannot be used reliably to establish a sediment quality value. If, despite this analysis, EPA's recommendation is to utilize a TPH correlation in the BERA (in the FPM or other approach), it is critical that appropriate data be collected and that a scientifically robust analysis be completed addressing the merits of this application. The alternative to TPH would most likely be one or more PAH exposure metrics, for which additional data collection is not anticipated. Specific metrics would be selected in collaboration with EPA (as part of the Scientific/Management Decision Point for Step 4 in the ERAGS Ecological Risk Assessment Process).
- ***Conduct a TRV search for benthic invertebrate tissue residues.*** The TRVs used in the tissue residue LOEs (both empirical and predicted) were based on the aquatic TRVs provided by EPA. The majority of these TRVs are derived as AWQCs multiplied with BCFs and therefore best suited as conservative screening values. This analysis will occur prior to the BERA.
- ***Re-evaluate Round 2 fish and wildlife TRVs to determine whether they are appropriate for the BERA.*** Additional literature searching for TRVs for benthic invertebrates will provide more reliable toxicity thresholds for evaluating benthic risk receptors in the BERA. This analysis will occur prior to the BERA.
- ***Conduct additional literature investigations as part of the BERA to evaluate the ecological significance of exposure populations or subpopulations of receptors within the Site.*** Direct-measurement regional data will be evaluated on wildlife populations of selected ecological receptors in the LWR, if such data

are available. This analysis will occur prior to the BERA. For some receptors, regional or local data may be available that will help determine whether risks predicted by the ERA are actually observed in local wildlife populations. Such information will be discussed in the risk characterization.

- ***Evaluate appropriate SUF and spatial scale assumptions for selected wildlife receptors.*** Additional literature will be reviewed to determine appropriate SUF and spatial scale assumptions to be used in the BERA. This analysis will occur prior to the BERA to reduce uncertainties in estimates for wildlife.
- ***Evaluate further the ecological relevance of shorebird exposure assumptions (i.e., shorebird beach habitat use in the Study Area, the use of laboratory-exposed worm tissue to represent shorebird prey).*** This analysis will occur prior to the BERA to reduce uncertainties in risk estimates for shorebirds.

12.2.5 Fate and Transport Data Needs

To complete the RI/FS, a number of fate and transport evaluations have been identified in coordination with EPA. These evaluations, modeling approaches, and the objectives related to each evaluation and model are described in detail in Section 7.3. In summary, EPA and the LWG have worked together to develop a Study Area fate and transport model, termed the "Hybrid Model," to meet the objectives described in Section 7.3. A Model Development Report describing Hybrid Model development and any remaining detailed data needs to run, calibrate, and validate the model is being developed and will be submitted to EPA shortly after submittal of the Comprehensive Round 2 Report. This section provides an overview of the potential data needs that will be presented in more detail in the Model Development Report.

The Hybrid Model includes three model components. The general data needs for each of these components to meet the objectives discussed in Section 7.3 are described below.

12.2.5.1 Hydrodynamic and Sediment Transport Model

This model was developed by the LWG and describes the movement of water and sediments around the Site. This model has been developed in several phases during the project and is most recently described in WEST Consultants (2006). Data have been collected to calibrate this model in two phases, and the second phase of data collection and final calibration of the model was completed in 2006. No further data needs are expected to be identified in the Model Development Report to use this model in the modeling process described in Section 7.3.

12.2.5.2 The Abiotic Chemical Fate and Transport Model

This model was developed by EPA and partner agencies describing the movement of chemical masses around the Site (Hope 2006). This model is currently under development in a form that can interface with the other Hybrid Model components. The model requires a series of inputs, most of which will come from Site-specific data.

Although the exact data set to be used for every input has not yet been determined, the known and expected general sources of important data are:

- Surface and subsurface sediment chemistry data collected and compiled through Round 2 (as presented in this report)
- Surface water chemistry data collected through Round 3A (currently underway)
- Sediment trap data collected through Round 3A (currently underway)
- Stormwater data collected by the LWG through Round 3A (currently underway)
- Physical and chemical properties of the chemicals in the model (e.g., partitioning coefficients and biodegradation rates); these will primarily come from literature values.

Data from sediment trap, stormwater, and surface water sampling will contribute to understanding of iCOC sources to overall chemical load in the surface water column. This information, in turn, will contribute to understanding the main iCOC sources to tissue in fish and other aquatic organisms that are important sources of exposures to humans and wildlife.

Note that groundwater chemistry data collected through Round 3A is not expected to be input into the model for reasons that will be described in more detail in the Model Development Report. In summary, groundwater transport of chemicals to the river is not expected to be major factor in determining site-wide long-term fate and transport outcomes for the river.

12.2.5.3 The Food Web Model

This model was developed by EPA and its partner agencies and Windward Environmental to describe chemical retention and movement between organisms and abiotic media and across trophic levels (Windward 2004a). No new data are needed beyond what exist or are being collected in Round 3A. As an element of the Hybrid Model, the food web model is to be coupled with the abiotic Chemical Fate And Transport Model and so it shares those data needs identified in Section 12.2.5.2. The other known and expected sources of important data, beyond what was identified for the abiotic Chemical Fate And Transport Model, are:

- Fish tissue chemistry data collected through Round 2, which is used to calibrate the model
- Physical (e.g. temperature), chemical (e.g. biological uptake rates), and biological (e.g., dietary make up, lipid contents) properties determined from either extant Site-specific data and/or literature values.

12.2.6 Feasibility Study Data Needs

Data needs were developed using the FS development process outlined in the Programmatic Work Plan (Integral et al. 2004b) and subsequent planning documents

discussed with EPA, most notably the Draft FS Framework document (Anchor 2006b). As described in these documents, the FS purpose is to reach a conclusion regarding the question, "What is the best way to clean up the Site?" Thus, all FS data needs ultimately relate to answering this single question.

Most relevant to identifying FS data needs is differentiating between the level of understanding necessary to complete the FS versus the understanding needed for RD/RA phases of work. FS information must be sufficient to evaluate and determine remedial alternatives consistent with EPA guidance and FS evaluation criteria with reasonable certainty to support a Record of Decision. More detailed evaluations of the exact design requirements of various aspects of the remedy will be part of the Remedial Design phase of work.

At an FS-appropriate level of detail, the following information must be available to (1) identify areas and volumes that need to be remediated and (2) define and evaluate remedial alternatives for the FS:

- Chemical concentrations of concern (i.e., PRGs)
- Sediment areas and volumes that will be subject to cleanup (i.e., AOPCs/SMAs)
- Predictions of the long-term risk outcomes subsequent to implementation of various remedial alternatives (e.g., recontamination potential and natural recovery)
- Physical/chemical system properties sufficient to define remedial alternatives (e.g., sediment characteristics, hydrodynamic forces, areas of erosion and deposition, presence of debris, and treatability characteristics)
- Locations and nature of present and future water-dependent Site uses
- FS-appropriate level of understanding of important ongoing chemical sources (e.g., sediment resuspension and movement, upstream sources, stormwater). In some cases this will require a better understanding of historical sources to confirm assumptions that currently observed contamination in sediments no longer has a current loading source. With respect to stormwater, this will require refinement of the accuracy of the map of existing outfalls to the Study Area.[89]

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[89] It is recognized that data needs for source control and RD/RA activities may also exist. The iAOPCs that were identified to facilitate the data gaps analysis for the RI/FS may also be a tool for DEQ to focus source control efforts. Specific RD/RA data needs cannot be entirely determined until after the FS. An important example of a potential data need for source control and RD/RA activities is sampling information on bank soils that may erode and present recontamination potential at some future SMAs. Because bank erosion is an area-specific condition dependent on both the erodibility and chemical concentrations of any given bank area, the data to understand these localized sources will need to be evaluated as a part of the remedial design process for each SMA. Bank erosion and chemistry data will need to be collected by individual upland property owners under the direction of

PRGs and SMAs are necessary to identify the areas and volumes that remedial alternatives will address. (Note that understanding erosive areas is also central to area identification, because these areas may contain buried chemicals that could be exposed in the future.) Predictions of long-term risk outcomes are needed to understand the final effectiveness of various remedial alternatives that may be applied to those areas. Physical system properties and information on water-dependent uses are needed to understand whether alternatives are buildable and feasible. Finally, sources must be understood at sufficient detail to understand their overall impact on long-term risk outcomes of remedial alternatives (e.g., contribution to recontamination) and the major sources that will need to be addressed in conjunction with sediment remedial design to reduce overall in-river risks.

Based on these general information needs, the FS data needs fall into the following categories:

- Studies and evaluations called for in the Programmatic Work Plan as a part of the overall FS development process:
  - Site use information
  - Treatability studies (as needed)
  - Presence of debris (side-scan sonar)
  - Fate and transport data needs
- Data needs identified based on Round 2 data analyses conducted in this report:
  - Sediment area extent
  - Sediment volume extent
  - Sediment physical/geotechnical properties.

This first category of data needs applies to the entire Study Area and is addressed in the following subsections, except FS fate and transport data needs, which are discussed in Section 12.2.5. They are most relevant to issues of defining and evaluating remedial alternatives.

The second category of data needs applies to each iAOPC identified in this report and is addressed in Section 12.3.3. They are most relevant to defining the areas and volumes that need to be addressed by remedial alternatives.

12.2.6.1 FS Site Use Information

As described in the Programmatic Work Plan, it will be necessary to collect information from various shoreline property owners along the river to understand current, potential future, and planned shoreline site uses. This information is necessary to accurately

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DEQ, so that the data are available in time for the remedial design process. For the purposes of the FS, it will be assumed that potential bank erosion sources will be controlled before remedial action proceeds.

define feasible remedial alternatives along the river for the purposes of the FS evaluations. This will include information such as draft, navigation, vessel maneuvering requirements around existing docks, and shoreline access points. Also, planned or potential future dock or other water-dependent access developments and their draft and navigation requirements will be determined.

This task will be conducted by interviewing major landowners along the shoreline, reviewing both dredging records and existing maintenance dredging permits, and reviewing the City of Portland Comprehensive Plan and Port of Portland Marine Master Plan to determine areas that are or will be routinely maintained for navigation. It should be realized that in many cases landowners may be uncertain about potential future uses and/or unwilling to provide this information for commercial reasons. Consequently, information gaps may exist after this effort, and assumptions may have to be made in some areas for FS purposes.

12.2.6.2 Treatability Studies (as needed)

A technical memorandum on treatment technologies is currently in preparation. This memorandum will review various available treatment technologies for sediments and, as necessary, will identify any bench-scale or pilot studies that may be needed in order to complete the FS. It is anticipated that in most, if not all, cases, such treatability studies will not be needed for the purposes of FS evaluation but may be needed for remedial design at some areas of the Site if the FS determines that specific treatment alternatives are feasible for those areas. This is because, in most cases, there is sufficient literature information on the limitations and requirements of such treatment technologies, at least on a bench scale, to understand and evaluate the cost, effectiveness, and feasibility of such options at an FS level of detail. Similarly, extensive information is available through Round 2 data regarding the range of physical and chemical characteristics of sediments in and around iAOPCs to understand how those sediments might perform under various treatment conditions.

12.2.6.3 Presence of Debris (side scan sonar)

Once final AOPCs have been determined, it will be necessary to conduct side-scan sonar of each of these AOPCs to determine the presence, nature, and extent of any debris in the sediment surface (e.g., submerged logs and structures) in these areas. This information will be used directly in the FS evaluation of the feasibility of capping and dredging options, both of which are affected in terms of cost, logistics, and environmental effectiveness by the presence of large amounts of debris.

12.2.7 Site-wide iAOPC

A site-wide iAOPC was identified due to widespread concentrations of PCBs in sediment and in the water column that result in unacceptable risks to human health from fish consumption. PCBs in fish tissue are the chemical and exposure medium that are predicted to have the highest contribution to risks to human health at the Site based on the results of the Round 2 HHRA. Because upstream fish tissue concentrations also result in risks that exceed EPA target risk levels, it will be necessary to evaluate

remedial options with the objective of reducing risks rather than achieving target risk levels.

To evaluate remedial options that will reduce risks, the significant source(s) of PCBs in tissue need to be determined. That involves understanding the contributions from both surface water and sediment to PCBs in fish tissue. Once the relationship between sediment, surface water, and tissue is understood, the relative contributions from upstream, desorption of PCBs from contaminated sediment, resuspension of contaminated sediment, stormwater, and groundwater to PCBs concentrations in surface water need to be determined.

The FWM (described in detail in Appendix E) developed for the Site has an overall predictive accuracy within the acceptable range identified with EPA (within a factor of two to five) and is performing adequately for evaluating contributions from sediment and water. Based on the results of the FWM, surface water contributes between approximately 5 and 20 percent of the PCB concentration in tissue, which results in risks that exceed EPA target risk levels for some of the fish consumption scenarios. The FWM data needs are discussed further in Section 12.2.5.3.

Upstream data needs, which include settling sediment, surface water, and upstream bedded surface and subsurface sediment, are described in Section 12.2.2. With these data, the relative contributions from upstream can be determined. Stormwater samples are being collected during Round 3A and will provide information needed to understand the relative contribution from stormwater. The ongoing Round 3A settling sediment and surface water data collection efforts and fate and transport evaluations will provide information needed to understand the relationship between sediment concentrations and surface water column concentrations. Groundwater is not a significant transport medium for PCBs, and the relative loading from groundwater is expected to be negligible relative to other potential contributions. Therefore, there is no need to evaluate groundwater further in assessing the potential contributions to PCBs in fish tissue. The data collection and evaluation efforts currently planned will provide the data needed to determine the relative contributions from sediment and surface water, as well as relative contributions to those media, to PCBs in fish tissue.

With the exception of the site-wide iAOPC for PCBs, other risks resulted in the identification of individual iAOPCs and are not considered Harbor-wide risk management issues. Some iCOCs are present at multiple iAOPCs, but these are mostly indicative of either local sources, or physical factors (e.g., depositional areas) that result in locally elevated concentrations. In these situations, it is anticipated that risk will be managed based on individual iAOPCs. The data needs and evaluations for the individual iAOPCs are discussed further in Section 12.3.3.

12.3 AREA-SPECIFIC DATA NEEDS

This section presents data that are needed only for specific locations within the Study Area. Data gaps were analyzed relative to the iAOPCs. Data needs were identified both for areas that were not identified as iAOPCs and for iAOPCs. The data needs that are identified in this section are summarized in Table 12.0-2.

12.3.1 Data Needs for Areas that Are Not iAOPCs

As discussed in Section 10, the mapping analysis used to define iAOPCs resulted in some areas mapped using the information from the risk assessments that are not included within any iAOPC. These areas are reviewed here as they may relate to any remaining data needs to complete the RI/FS.

As noted in Section 10, there are 37 relatively small, isolated, and discrete mapped areas outside of the iAOPCs. These areas and the risk-based information used to identify them are shown in Maps 12.3-1a through 12.3-1j. In each case, these 37 areas were identified based on one (or more) of the following four types of risk information:

- Human health beach exposures only (various chemicals)
- Human health area-specific fish consumption (PCBs)
- Ecological otter fish consumption exposures (PCBs)
- Ecological benthic toxicity at one station (uncertain chemicals) at RM 10.5.

The path forward regarding each of these types of areas is discussed below.

12.3.1.1 Human Health Beach Areas

Beaches were identified as a mapped area if the risk for the beach exceeded the risk from the default background arsenic concentration from regional guidance. Additional analysis of the chemical concentrations at the beaches shown in Map 12.3-1 will not further clarify the potential risks associated with these beaches. Consequently, no data collection needs exist for these beaches. However, proposed evaluations of background conditions discussed above will provide further context regarding the risks from naturally occurring arsenic levels at these beaches. Based on such evaluations, risk management decisions for these beaches will be discussed in the FS, and EPA will need to make risk management decisions regarding any risk reductions potentially realized by remediating these beaches.

12.3.1.2 PCB Human Health and Ecological Fish Consumption Areas

Both of these types of mapped areas are shown on Maps 12.3-1a –12.3.1j. Combined, these areas comprise 34 of the 37 areas shown in Map 12.3-1. These areas are scattered across the entire Study Area and represent the locations that were mapped through the hill topping analysis from a Study Area- or RM-wide risk perspective, rather than posing location-specific risks. Because of the broad and scattered pattern of these areas,

the risks appear to be a function of the widespread presence of relatively low levels of PCBs throughout the Study Area and the contribution from PCBs in the water column. This pattern of low-level PCB contamination and water column contribution to PCB risks was also found for other human health fish consumption scenarios that resulted in the designation of a site-wide iAOPC for PCBs.

Due to the nature of these mapped areas, additional data collection in and around these areas would not be expected to generate any new information that would alter conclusions about the widespread PCB-related risks throughout the Study Area. The future collection of additional PCB data in surface sediment (for other purposes noted previously in this section) will result in new site-wide and area-wide SWACs, which will change the results of the hill topping analysis and the areas identified through such an analysis. Site-wide PCB levels contributing to the identification of these areas will be examined further in additional data analyses for the RI/FS, including assessment of the hill-topping techniques (with any additional PCB sediment data), as well as other methods for identifying remediation that would address PCB risks. From such analyses, more practical approaches to PCB remediation, such as remediating more contiguous areas already associated with iAOPCs rather than scattered areas, or addressing water column contributions, can be developed. These approaches will include a review of:

- Widespread PCB contamination in sediments and water in general
- Appropriate measures to address that contamination in the context of overall risk reduction from PCBs
- Risk reduction from PCB remediation as compared to background PCB risk levels.

12.3.1.3 Ecological Benthic Toxicity

12.3.1.3.1 Non-iAOPC Benthic Toxicity Area

As noted above and in Section 10, one station associated with benthic toxicity was noted at RM 10.5 but not included in any iAOPC. This location is adjacent to an area of indeterminate benthic toxicity where additional bioassays are being recommended, and it is combined with that indeterminate area for the purpose of discussing data needs.

12.3.1.3.2 Indeterminate Benthic Toxicity Areas

In addition to the issue of benthic toxicity at one isolated station noted above, there are areas where risk determinations were indeterminate for benthic toxicity, and these areas were not included in any iAOPC (Maps 12.3-2 and 12.3-3). Based on analysis of other benthic community LOEs and spatial distribution relative to iAOPCs for other ecological receptors and human health risk scenarios, it was determined that additional toxicity testing data are warranted for assessing benthic community risks in four of these areas:

- ***The west side of the river between RM 10.5 and RM 11.*** This indeterminate area is adjacent to the non-iAOPC benthic toxicity area identified above, so

these locations are combined for the purpose of discussing data needs. Four additional benthic toxicity tests are recommended to confirm or refute the presence of a spatially significant cluster of benthic toxicity in this area.

- ***The area on the west side of the river between RM 10 and RM 11, between iAOPCs 19 and 24.*** Three additional benthic toxicity tests are recommended to confirm or refute the presence of a spatially significant cluster of benthic toxicity in this area.
- ***The area around RM 9 contiguous with iAOPC 19.*** Two additional benthic toxicity tests are recommended to confirm or refute the presence of a spatially significant cluster of benthic toxicity in this area.
- ***The area between RM 9 and RM 8 extending from near the downstream end of iAOPC 19 to the area offshore of iAOPC 18.*** Three additional benthic toxicity tests are recommended to confirm or refute the presence of a spatially significant cluster of benthic toxicity in this area.

12.3.2 Transition Zone Water

Three of the 12 sites identified in Round 2 as high priority "Category A" sites[90] for groundwater pathway evaluation were not included in the Round 2 TZW sampling program (Integral et al. 2005): Time Oil Northwest Terminal, the former PEO site, currently owned by Schnitzer Investment Corporation, and OSM. Time Oil was recommended for no further action in the program because groundwater data collected from shoreline wells installed by Time Oil in the fall of 2004 demonstrated that iCOCs in upland groundwater are not being transported to in-river exposure points via groundwater (Landau Associates 2006a). To date, data collected during eight sampling events at these Time Oil wells further confirm this conclusion (Landau Associates 2006b). Also, no LNAPL is present in the shoreline wells and there are no known groundwater seeps at the Time Oil site. Consequently, there are no TZW data gaps identified for the Time Oil Northwest Terminal.

The PEO site was not included in the Round 2 TZW sampling program because upland site characterization data (nature and extent of iCOCs, groundwater flow patterns, stratigraphy) were insufficient at the time to indicate the likelihood of a complete groundwater pathway. Upland characterization data would also be needed to support design of an in-river TZW sampling plan. Groundwater data have not been collected at the PEO site since 1998, and to date, shoreline wells have not been installed. Therefore, upland data are still insufficient to evaluate the likelihood of a complete groundwater pathway to the river offshore of the PEO site. These upland data are needed to

[90] Representatives of EPA, DEQ, and the LWG met on January 7, 2005 to review the 21 Category A sites (defined in GSI et al. [2004] as sites where COIs in groundwater have been confirmed to or have a reasonable potential to discharge to the river) and identify a subset of high priority sites that would be carried forward into the site-specific scoping process for the Round 2 Groundwater Pathway Assessment. This process yielded the 12 high-priority Category A sites.

determine the need, if any, for in-water (TZW) sampling and designing in-river discharge mapping and sampling plans. It is the LWG's understanding that Schnitzer and DEQ are currently negotiating the scope of additional upland groundwater characterization work.

Potential TZW data needs for the OSM site are discussed in the data needs presentation for iAOPC 1 (Section 12.3.3.1).

TZW investigation is not considered necessary offshore of any other upland sites adjacent to the Study Area. While other sites adjacent to the Study Area have known upland groundwater impacts, none aside from the 12 high-priority sites were determined to present a reasonable likelihood of a complete groundwater transport pathway for upland groundwater COIs to reach in-water exposure media. Additionally, given that very low TZW concentrations were measured offshore of several of the high priority sites, it is reasonable to conclude that these lower priority sites do not merit in-river TZW investigation for the purposes of completing the RI/FS.

12.3.3 Feasibility Study Data Needs for iAOPCs

This section discusses FS data needs related to each iAOPC, as summarized in Table 12.0-2. As discussed in Section 2.5.2, these data needs primarily focus on identifying areas and volumes that may need to be addressed by remedial alternatives in the FS. In addition, sediment physical characteristics used in the evaluation of remedial alternatives are also discussed for each area. Also, as noted in Section 12.2.6 even though iAOPCs may not necessarily become SMAs, FS data needs were evaluated for all iAOPCs to ensure that the necessary information is collected for the RI/FS. If subsequent analysis for the RI indicates that some of these iAOPCs are not AOPCs or that the location and extent of those AOPCs shifts, it is possible that some of the data collected per the discussions below will not be heavily used in the FS.

12.3.3.1 iAOPC 1

12.3.3.1.1 Area Extent

The upstream and downstream margins of iAOPC 1 are estimated by relatively large polygons that are included for ecological otter risks (downstream end) and human health area-specific fish consumption (upstream end) for PCBs. Additional surface sediment station(s) will be sampled on both these margins to assess the PCB extent in these areas. Because PCBs are the risk drivers for these areas, the analyte list can be confined to PCB congeners.

In addition, there are portions of the iAOPC that extend into or near the navigation channel. Some of the polygons making up these areas are also the result of otter and human health shellfish risks. Consequently, surface sediment sampling along this margin will be conducted. The analyte list will be confined to PCB congeners and shellfish iCOCs present in this area. Additionally, this area will be evaluated for its actual potential to have shellfish habitat to refine the likelihood that substantial

populations of shellfish (consistent with the shellfish exposure assumptions) would be expected to be present now or in the future.

12.3.3.1.2 Volume Extent

The depth of PCB contamination in and around the margins of the iAOPC is not well characterized. Except for five offshore cores grouped around the center of the iAOPC, all the cores are set extremely close to shore. Consequently, some of the marginal surface sediment stations noted above will be extended to 16-ft vibracores with sampling for PCBs similar to the Round 2 coring scheme. Deeper cores (20-ft vibracores) are not indicated due to the general pattern already shown in existing cores of less contamination with depth, particularly at greater distances from the shoreline.

12.3.3.1.3 Physical/Geotechnical Data Needs

The full suite of conventional physical parameters (i.e., grain size, water content, TOC, specific gravity) will be measured at each of the additional station samples proposed above. This area contains substantial deposits of relatively fine-grained material (up to 80 percent fines). As Atterberg limit results are already available from six fine-grain-deposit areas at various depths in and around this iAOPC, the only geotechnical data needed for this area will be vane shear and seepage-induced consolidation tests at a representative location(s) for soft sediments in the area.

12.3.3.1.4 Transition Zone Water

An upland site contiguous with iAOPC 1, OSM, was identified in Round 2 as a high priority "Category A" site for groundwater pathway evaluation.[91] The area offshore of OSM was not included in the Round 2 TZW sampling program because insufficient site data existed at the time to indicate the presence of a complete groundwater pathway and support design of an in-river TZW sampling plan. Subsequent to this determination, OSM conducted a beach well investigation in 2005 and a geochemical analysis of metals in groundwater at the site. The results indicate that there is not a complete transport pathway for COIs in upland groundwater to reach in-water exposure media. Therefore, no Round 3 TZW data needs exist for iAOPC 1

12.3.3.2 iAOPC 2

12.3.3.2.1 Area Extent

iAOPC 2 is estimated by a single station based on a PCB concentration that was hill topped for human health area-specific fish consumption and ecological otter risks. Thus, this site falls into that subcategory of iAOPCs discussed in Section 10 that appear to be present entirely as a function of the PCB hill-topping process. Thus, additional extensive data collection within this iAOPC will not be conducted.

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[91] Representatives of EPA, DEQ, and the LWG met on January 7, 2005 to review the 21 Category A sites (defined in GSI et al. (2004) as sites where COIs in groundwater have been confirmed to or have a reasonable potential to discharge to the river) and identify a subset of high priority sites that would be carried forward into the site-specific scoping process for the Round 2 Groundwater Pathway Assessment. This process yielded the 12 high-priority Category A sites.

Additional site-wide data collection for PCBs in sediments might alter this location as a hill topped site for PCBs and eliminate it as an iAOPC. Additional analysis of existing data and the hill topping results will be conducted to determine whether such an outcome is likely.

If the above existing data analyses indicate that this iAOPC is likely to remain for the RI, some sediment data collection will be conducted for Round 3B. This iAOPC is estimated by a small group of sediment stations just downstream of outfall OF-53A. Thus, one surface sediment station away from this grouping and within the iAOPC analyzed for PCBs will be sampled.

12.3.3.2.2 Volume Extent

The two cores in this area (one inside and one just outside the existing iAOPC downstream margin) indicate low-level and decreasing PCB concentrations with depth. Consequently, contamination in this area appears to be a surface phenomenon and no additional coring will be conducted.

12.3.3.2.3 Physical/Geotechnical Data Needs

The full suite of conventional physical parameters will be measured at the additional station noted above, if sampled. Because of the small size and relatively sandy nature of this iAOPC, geotechnical samples will not be collected here.

12.3.3.3 iAOPC 3

12.3.3.3.1 Area Extent

iAOPC 3 is within the Schnitzer Slip and is estimated by a large number of surface sediment stations. There are relatively few large polygons or poorly estimated margins in or around this iAOPC. Consequently, no area-related data needs are present here.

12.3.3.3.2 Volume Extent

There are also a large number of cores within the iAOPC. In general, these cores reach depths that show substantially reduced concentrations of all iCOCs. Consequently, no volume-related data needs are present for the iAOPC.

12.3.3.3.3 Physical/Geotechnical Data Needs

The surface sediments are generally not silty within the iAOPC, although some pockets of finer sediments exist at depth in some areas. There are three Atterberg limit results in surface and subsurface sediment in this area. Consequently, no additional geotechnical data will be collected for the FS here.

12.3.3.4 iAOPC 4

12.3.3.4.1 Area Extent

iAOPC 4 is at the mouth of Schnitzer Slip and has relatively low sample density, especially in the following areas:

- At the mouth of the slip a large polygon is estimated by one station.

- A lobe extends outward into the main navigation channel due to the lack of any offshore station.
- In addition, the large polygon on the upstream margin is estimated by one station and is present due solely to human health shellfish consumption risks.

Consequently, surface stations sampled for PCBs and iCOCs relevant to other risks in these polygons would better estimate sediment chemicals in this region. Potential actual shellfish habitat for the upstream margin polygon, similar to the discussion for iAOPC 1, will also be reviewed to assist in the understanding of potential risks here.

12.3.3.4.2 Volume Extent

Coring data throughout this area indicates decreasing PCB concentrations (the primary iCOC) with depth, and contamination appears mostly a surface phenomenon. Consequently, additional coring data are unnecessary here.

12.3.3.4.3 Physical/Geotechnical Data Needs

The full suite of conventional physical parameters will be taken at the additional locations noted above, if sampled. The surface and subsurface sediments in this area are generally in the 40- to 75-percent fines range with some finer localized deposits. There is one Atterberg limit result available just outside this iAOPC at station G098. An additional Atterberg limit test targeted to areas of any finer deposits will be conducted in this area. Given that the locations of very fine deposits appear to be relatively limited, additional geotechnical tests will not be conducted for the FS.

12.3.3.5 iAOPC 5

12.3.3.5.1 Area Extent

iAOPC 5 is a shoreline area identified by PCB-related risks only that extends out into the river channel along portions of the iAOPC due to lack of channel-ward surface sediment samples in this area. These channel-ward extensions are estimated by a site-specific sculpin PCB risk area as well as otter and human health area-specific and site-wide PCB risks identified through hill-topping procedures. In addition, a relatively large upstream polygon is estimated by one station based on a human health area-specific fish consumption hill top analysis. Consequently, these marginal areas should be refined by additional surface sediment samples for PCBs in these areas. Also, additional analysis of existing PCB data and the hill topping results might alter some or all of these polygons as hill topped locations for PCBs (as described for iAOPC 2 above).

12.3.3.5.2 Volume Extent

Coring data throughout this area indicate decreasing PCB concentrations (the only iCOC) with depth, and contamination appears mostly a surface phenomenon. Consequently, additional coring data are unnecessary to estimate volumes in this iAOPC.

12.3.3.5.3 Physical/Geotechnical Data Needs

The full suite of conventional physical parameters will be measured at the additional locations noted above, if sampled. The surface and subsurface sediments in this area are generally in the 50- to 85-percent fines range with some much sandier deposits. No Atterberg limit tests have been conducted in or around this area. Consequently, some Atterberg limit samples targeting the limited areas of very fine deposits in this area may be warranted.

12.3.3.6 iAOPC 6

12.3.3.6.1 Area Extent

iAOPC 6 is a very small area along the western shore of the Site that is present solely due to the results of the benthic toxicity analysis. There are numerous surface sediment stations surrounding the iAOPC in all directions. Consequently, no further surface sediment sampling is necessary for this iAOPC.

12.3.3.6.2 Volume Extent

This area is also well surrounded by core data. Where deeper cores (e.g., targeting 20 ft below mudline [bml]) were sampled near this area, they show decreasing iCOC concentrations, particularly at the bottom of the cores. However, the one core actually within the iAOPC does not extend to these depths, and one deeper core within this iAOPC will be collected to help estimate the lower limit of contamination in this general area.

12.3.3.6.3 Physical/Geotechnical Data Needs

The full suite of conventional physical parameters will be measured at the additional location noted above. The surface and subsurface sediments vary in and around this iAOPC, with substantial deposits in the 75- to 90-percent fines range. Atterberg limit samples were taken near this iAOPC, which will likely be representative of the consolidation characteristics of fines in this general area. Consequently, no Atterberg limit tests are recommended for this iAOPC. However, because deeper sediments in and immediately around this iAOPC contain relatively thick layers of up to 90 percent fines, additional vane shear and seepage-induced consolidation tests will be conducted for the FS.

12.3.3.6.4 Transition Zone Water

An upland site contiguous with iAOPC 6, ARCO Terminal 22T, was identified in Round 2 as a high priority "Category A" site for groundwater pathway evaluation. Round 2 TZW data collected offshore of this site are adequate to complete the RI/FS. Therefore, no Round 3 TZW data needs exist for iAOPC 6.

12.3.3.7 T4 iAOPC

This iAOPC includes an area entirely within the ongoing T4 Early Action being conducted by the Port of Portland. This Early Action is currently in the 60 percent design phase and is well beyond the determination of any FS-level data needs. Consequently, the information related to risks used to estimate this iAOPC as contained

within this report will be referred to the Port of Portland for consideration in the final design process currently underway.

12.3.3.8 iAOPC 7

12.3.3.8.1 Area Extent

This iAOPC extends along a substantial portion of eastern shoreline and extends out into the channel in several places. These channel-ward extensions are due to the low sampling station density along this outer margin. In addition, the entire downstream half of the iAOPC is present due to hill topped PCB risks for human health area-specific fish consumption (the vast majority) and otter (one isolated location). The most downstream polygon is quite large due to a lack of a nearby station in this direction. Consequently, selected surface sediment stations along these margins of the iAOPC for PCBs and iCOCs related to benthic toxicity will be sampled. Also, as described above for iAOPC 2, additional analysis of existing PCB data and the hill topping results might alter some or all of these polygons as hill-topped locations for PCBs, particularly around the downstream half of the iAOPC.

12.3.3.8.2 Volume Extent

Coring data are relatively sporadic around the upstream half of the iAOPC in the channel-ward and upstream directions. Extending some of the above surface locations to cores of 16-ft depth is necessary to assist in estimating volumes around this area. Existing cores in and around the iAOPC to 16 ft bml show a clear trend of decreasing chemical concentrations with depth, and therefore, deeper coring is not needed to estimate volumes.

12.3.3.8.3 Physical/Geotechnical Data Needs

The full suite of conventional physical parameters will be measured at the additional location noted above. A substantial majority of the surface and subsurface sediments in this area are 65 percent fines or greater. Three Atterberg limit results are already available within this iAOPC. Consequently, no additional Atterberg limit or other geotechnical tests will be conducted around this iAOPC for the FS.

12.3.3.9 iAOPC 8

12.3.3.9.1 Area Extent

This is a very small iAOPC estimated by two surface sediment stations due to PCB-related risks from human health area-specific and site-wide fish consumption as well as ecological otter risks. The iAOPC is small because it is well-bounded by surface sediment stations and no further surface sediment sampling will be conducted. The iAOPC is present due to two relatively high PCB total Aroclor results (220 and 350 µg/kg) in surface sediments. For this reason, it is unlikely that additional analysis of existing PCB hill topping results would result in a reduction or elimination of this iAOPC.

12.3.3.9.2 Volume Extent

Within this iAOPC there is only one 3-ft-deep core, which is from a previous study. Although nearby cores generally indicate no PCB concentrations at depth that are similar to the surface sediment concentrations, they may not be representative of the conditions within this relatively isolated area of PCBs. Consequently, one core to 16 ft bml will be sampled to help estimate volumes in and around this iAOPC.

12.3.3.9.3 Physical/Geotechnical Data Needs

The full suite of conventional physical parameters will be measured at the additional location noted above. All of the surface and subsurface sediments in and around this iAOPC are below 71 percent fines, with less than 25 percent fines measured at several locations. Consequently, geotechnical testing for properties associated with more fine-grained sediments is not needed for this iAOPC.

12.3.3.10 iAOPC 9

12.3.3.10.1 Area Extent

This is a very small iAOPC estimated by three surface sediment stations due to PCB human health area-specific fish consumption and sculpin risks from DDT. The iAOPC is small because it is well-bounded by surface sediment stations and no further surface sediment sampling in or around this AOPC will be conducted. However, additional analysis of existing PCB data and the hill topping results might alter two of these polygons as hill-topped locations for PCBs (as described for iAOPC 2 above) and could substantially alter the size of this iAOPC.

12.3.3.10.2 Volume Extent

This iAOPC is bounded on two sides by two deeper (>16-ft-deep) sediment cores that show decreasing iCOC concentrations with depth. Within these cores are iCOC concentrations that are relatively similar to surface concentrations seen within the iAOPC. Consequently, these cores can be used to estimate sediment volume in and around this iAOPC as needed for the FS.

12.3.3.10.3 Physical/Geotechnical Data Needs

The surface and subsurface sediments in this area are not particularly silty and vary between deposits that are somewhat greater than 50 percent fines to somewhat less than 50 percent fines. For this reason, no Atterberg limit results have been obtained in this general area and no additional geotechnical data will be collected.

12.3.3.11 iAOPC 10

12.3.3.11.1 Area Extent

This iAOPC extends along a substantial portion of the shoreline. A human health beach risk area for arsenic occurs in one portion of this iAOPC. The remainder of the iAOPC is estimated from PCB-related risk areas through hill topping for human health Site-wide and area-specific fish consumption and ecological risks to otter. In some areas, the iAOPC extends channel-ward due a relatively low density of sampling stations in this direction. This also occurs to some extent in the upstream direction. Consequently,

selected additional surface sediment samples in some of these marginal areas would help better estimate risks in this area. Also, additional analysis of existing PCB data and the hill topping results might alter several of these polygons as hill-topped locations for PCBs (as described for iAOPC 2 above) and could substantially alter the size or shape of this iAOPC, particularly for polygons caused by the human health area-specific fish consumption hill top analysis, as these are the most widespread in this iAOPC.

12.3.3.11.2 Volume Extent

There are three cores within this iAOPC. Two of them show PCB concentrations decreasing with depth. The third, toward the middle of the iAOPC, does not. Because there is also a relative horizontal gap in the distribution of cores toward the middle of the iAOPC, an additional core in this vicinity to approximately 20 ft bml will be collected to help estimate volumes associated with PCBs in and around this iAOPC.

12.3.3.11.3 Physical/Geotechnical Data Needs

The full suite of conventional physical parameters will be measured at the additional location noted above. Surface sediments contain generally less than 40 percent fines in and around this area. However, the upstream half of the iAOPC contains subsurface sediment deposits in the 65- to 92-percent fines range. Two Atterberg limit samples are available for surface sediments in the iAOPC, but both were found to be non-plastic due to the relatively low fines content in surface sediment throughout this area. Consequently, additional samples from a core location targeting the area of known deposits of silty sediments will be collected and analyzed for Atterberg limits, vane shear, and seepage-induced consolidation.

12.3.3.12 iAOPC 11

12.3.3.12.1 Area Extent

This iAOPC extends along a substantial portion of western shoreline. This iAOPC is estimated by a combination of:

- TPH/PAH human health and benthic toxicity risks, which occur mostly in the downstream two-thirds of the iAOPC
- PCB/DDT, which occur sporadically but more often in the upstream one-third of the iAOPC for
  - Human health site-wide and area-specific fish consumption (PCBs)
  - Ecological sculpin, bass, and otter risks (DDT and PCBs).

There is a relatively high density of surface sediment sampling stations throughout and around the iAOPC, except there is a relative gap between stations located at the toe of the slope of the navigation channel and samples taken in the middle of the channel along much of the iAOPC. Some stations along this margin would help better estimate risks in and around this iAOPC. Also, additional analysis of existing PCB data and the

hill topping results in the upstream third of this iAOPC might alter some of these polygons as hill-topped locations for PCBs (as described for iAOPC 2 above).

12.3.3.12.2 Volume Extent

Similar to the surface sediment data, the subsurface coring information is relatively dense in and around this iAOPC. In many cases, these cores show a pattern of decreasing iCOC concentrations with depth. However, there are a few notable exceptions to this pattern occurring sporadically throughout the iAOPC. Consequently, a few additional cores will be collected extending beyond 20 ft (using an alternative technique to vibracoring) to help better estimate the lower limit of iCOCs in this area. In addition, a few of the marginal surface sediment stations noted above will be extended to 20-ft vibracores to assist in the estimation of sediment volumes in and around this iAOPC.

12.3.3.12.3 Physical/Geotechnical Data Needs

The full suite of conventional physical parameters will be measured at the additional locations noted above. Most of the surface sediments in the vicinity of this iAOPC tend toward greater than 50 percent fines with some areas on the downstream end having greater than 80 percent fines. Deposits of both relatively sandy (less than 25 percent fines) and relatively silty (greater than 80 percent fines) occur at depth, again with downstream areas tending to be siltier. Several Atterberg limit results already exist in both surface and subsurface sediments in and near the iAOPC. Consequently, the only additional geotechnical tests needed are vane shear and seepage-induced consolidation tests at a few key locations. These tests will be incorporated into the cores noted for volumetric evaluations above.

12.3.3.12.4 Transition Zone Water

Two upland sites contiguous with iAOPC 11, Gasco and Siltronic, were identified in Round 2 as high priority "Category A" sites for groundwater pathway evaluation. Because of the abundance of TZW data collected offshore of Siltronic in Round 2 and in separate investigations conducted by Siltronic, no additional TZW data are needed offshore of the Siltronic site to complete the RI/FS.

The Round 2 Groundwater Pathway Assessment investigation offshore of the Gasco site focused on the nearshore areas of the site, recognizing that NW Natural intends to perform an in-water study in the areas farther offshore. The Round 2 investigation was further reduced in scope by access limitations associated with the concurrent removal action around the former tar body at the time of sampling. Consequently, groundwater discharge and TZW chemistry are only partially characterized offshore of the Gasco site at this time. NW Natural's ongoing 2007 in-water investigation is expected to address data gaps in the intermediate and offshore areas related to both the delineation of groundwater discharge zones and TZW chemistry. Therefore, at this time, no additional data gaps for TZW delineation are identified for iAOPC 11 to support the RI/FS.

12.3.3.13 iAOPC 12

12.3.3.13.1 Area Extent

This iAOPC is located in the middle of the river channel and is estimated by the hill topping analysis of PCBs for human health site-wide and area-specific fish consumption and ecological otter risks. Because of its location within the channel, the surface sediment sampling density in and around this iAOPC is relatively low as compared to many of the shoreline iAOPCs. For this reason, some limited marginal surface sediment samples for PCBs will be collected in this area to help estimate risks in and around this iAOPC.

12.3.3.13.2 Volume Extent

There are two deeper cores within this iAOPC, located on the upstream and downstream ends of the area. Both these cores show decreasing PCB concentrations with depth. In addition, there are a number of additional cores immediately to the east that, in most cases, show a similar pattern with depth. Consequently, these results appear to be adequate to estimate volumes related to PCB concentrations in and around this iAOPC.

12.3.3.13.3 Physical/Geotechnical Data Needs

The full suite of conventional physical parameters will be measured at the additional locations noted above. Surface sediments in this iAOPC range from 20 to 80 percent fines, and subsurface sediments have an even wider range that varies widely across sampling depths. There is one Atterberg limit surface sediment sample on the upstream end of the iAOPC. The deposits of fine material appear to be associated with higher concentrations of PCBs. Consequently, an additional sample of subsurface fine deposits on the downstream end of the iAOPC for Atterberg limits and seepage-induced consolidation will be analyzed.

12.3.3.14 iAOPC 13

12.3.3.14.1 Area Extent

This iAOPC extends from a cove area on the eastern shore out toward the navigation channel. This iAOPC is composed of risk areas for three out of the five mapped human health risk scenarios and five of the five mapped ecological receptors and includes iCOCs such as PCBs for multiple scenario/receptors and dioxin, DDTs, mercury, and TPH for one scenario/receptor. The surface sediment sampling density in the cove portion of the area is relatively dense. Given the number of scenario/receptors mapped for this iAOPC, it appears unlikely that re-analysis of the PCB hill topping results would cause any substantial revision to the configuration of this iAOPC. However, the widely spaced sampling locations at the channel-ward edge of the iAOPC result in relatively large Thiessen polygons that extend into the main channel of the river. Added sampling of surface sediments in this area would help to refine the boundary of iAOPC relative to the navigation channel and iAOPC 12.

12.3.3.14.2 Volume Extent

There is also a relatively high density of coring stations in and around this iAOPC, with the exception of the most channel-ward area. In addition, the M&B cap extends

through this area and should not be penetrated with cores. Overall, the pattern at most cores is one of decreasing iCOC concentrations with depth. However, this pattern is not observed at stations C277 and C291, both at the downstream margin of the area, for either PCBs or TPH. Consequently, it appears that buried subsurface contamination could extend outward and downstream of the area around this iAOPC, and limited selected cores (20-ft deep vibracores) in this area would help estimate volumes in and around this iAOPC.

12.3.3.14.3 Physical/Geotechnical Data Needs

The full suite of conventional physical parameters will be measured at the additional locations noted above. With some exceptions, substantial deposits of fine material (greater than 75 percent fines) occur extensively in both surface and subsurface sediments throughout this iAOPC. Several Atterberg limit results exist within surface and subsurface samples in and near the iAOPC. Consequently, the only additional geotechnical sampling needed will be conducted for shear stress and seepage-induced consolidation in a few subsurface locations targeting areas with high fines deposits.

12.3.3.15 iAOPC 14

12.3.3.15.1 Area Extent

This iAOPC extends along a substantial portion of the western shoreline. It includes risks for all but one of the ten human health and ecological risks mapped in iAOPC development for chemicals such as dioxin, DDx, PCBs, aldrin, and HCH. There is a relatively high density of surface sediment samples in and near much of this iAOPC. However, in a few locations a small number of surface stations determine some larger polygons extending well into the channel and along the downstream margin of the iAOPC. In these cases, a few selected surface sediment stations sampled for relevant iCOCs would help better estimate risks in and around this area. Given the number of scenario/receptors mapped for this iAOPC, it appears unlikely that re-analysis of the PCB hill topping results would cause any substantial revision to the configuration of this iAOPC.

12.3.3.15.2 Volume Extent

This iAOPC has a relatively high density of cores throughout and near the iAOPC providing good coverage of the area. Extending surface sediment stations recommended above to cores in one or two locations would also provide some additional information on volumes along the channel-ward margin of the area. The existing cores show a general pattern of decreasing iCOC concentrations with depth at most locations. However, a few notable exceptions to this pattern occur sporadically throughout the iAOPC. Consequently, additional cores extending beyond 20 ft (using an alternative technique to vibracoring) will be collected to help better estimate the lower limit of iCOCs in and around this iAOPC. This will not include areas where deep cores (approximately 30 ft deep or more) have already been collected.

12.3.3.15.3 Physical/Geotechnical Data Needs

The full suite of conventional physical parameters will be measured at the additional locations noted above, if sampled. There is a diverse pattern of both relatively sandy and silty deposits occurring within this iAOPC in surface sediments, and particularly in subsurface sediments. Several Atterberg limit samples have been analyzed in siltier deposits within and around the iAOPC. Consequently, only additional vane sheer and seepage-induced consolidation tests will be conducted in silty deposits from one or two selected samples from the above new locations.

12.3.3.15.4 Transition Zone Water

Two upland sites contiguous with iAOPC 14, Rhone Poulenc and Arkema, were identified in Round 2 as high priority "Category A" sites for groundwater pathway evaluation. Round 2 TZW data collected offshore of these sites are adequate to complete the RI/FS. Therefore, no Round 3 TZW data needs exist for iAOPC 14.

12.3.3.16 iAOPC 15

12.3.3.16.1 Area Extent

This iAOPC is located in a cove on the eastern shore of the river. It includes human health area-specific risks for dioxin and benthic toxicity in non-overlapping areas. The iAOPC is relatively well estimated by surface sediment arsenic concentrations but very poorly estimated for dioxin (two stations) in surface sediments. Consequently, some additional selected samples for arsenic and dioxin both within and along some margins of the iAOPC will be collected to help better estimate the risks in and around this area.

12.3.3.16.2 Volume Extent

There are no cores either within or near this iAOPC. Consequently, approximately two cores in selected locations (16-ft deep vibracores), sampled using the Round 2 approach, would provide an approximate volume associated with the iCOCs in and around this area.

12.3.3.16.3 Physical/Geotechnical Data Needs

The full suite of conventional physical parameters will be measured at the additional locations noted above, if sampled. Surface sediments in this area are relatively sandy. Subject to field observations from the cores noted above finding substantial deposits of finer material, Atterberg limits will be analyzed in these samples. Additional geotechnical tests will not be conducted due to the limited size of this iAOPC and can be estimated for the FS from Atterberg limit and grain size data, should substantial deposits of fines be encountered.

12.3.3.17 iAOPC 16

12.3.3.17.1 Area Extent

This iAOPC is located in a cove on the eastern shore of the river. It includes PCB human health area-specific and site-wide risks as well as ecological otter risks. The iAOPC is present due to the various hill topping analyses for these scenarios/receptors and the presence of one relatively high PCB detection in surface sediments.

Consequently, additional selected surface sediment samples for PCBs will be collected to estimate risks in and around this iAOPC.

12.3.3.17.2 Volume Extent

There are no cores within this iAOPC and only one in the general vicinity. Consequently, approximately two cores in selected locations (16-ft vibracores), sampled using the Round 2 approach, will be analyzed to help provide an estimate of volumes in and around this area.

12.3.3.17.3 Physical/Geotechnical Data Needs

The full suite of conventional physical parameters will be measured at the additional locations noted above, if sampled. Surface sediments in this area have relatively high fines content, with some sandier areas localized in this iAOPC. Subject to field observations from the cores noted above finding substantial deposits of finer material, Atterberg limits will be analyzed in these samples. Additional geotechnical tests will not be conducted due to the limited size of this iAOPC and can be estimated for the FS from Atterberg limit and grain-size data should substantial deposits of fines be encountered.

12.3.3.18 iAOPC 17

12.3.3.18.1 Area Extent

This iAOPC is located in a cove on the western shore of the river. It includes PCB human health area-specific and site-wide risks as well as ecological bass, sculpin, and shorebird risks for PCBs, dioxin, and DDx. Benthic toxicity for unknown chemicals was exhibited at two sampling locations by one of four toxicity indicators. This iAOPC forms two lobes. The upstream lobe is primarily determined by two PCB results, and the downstream lobe is primarily determined by a few dioxin and DDT results and a benthic toxicity cluster. In both cases, relatively few sampling stations result in large polygons that form each lobe. A few stations sampled for iCOCs for this area across both lobes would help provide a better estimate of risks in and around this iAOPC. Given the number of scenarios/receptors mapped for this iAOPC, it appears unlikely that re-analysis of the PCB hill topping results would cause any substantial revision to the configuration of this iAOPC.

12.3.3.18.2 Volume Extent

There is a dense distribution of cores in the upstream lobe, all of which show a pattern of decreasing iCOC concentrations with depth. In the downstream lobe there is only one core, which shows an increasing dioxin concentration with depth. Consequently, one or two additional cores (20 ft deep) in and around this downstream lobe will be sampled to help better estimate the volumes in and around this iAOPC.

12.3.3.18.3 Physical/Geotechnical Data Needs

The full suite of conventional physical parameters will be measured at the additional locations noted above. Surface sediments in this area range from relatively sandy to silty but subsurface sediments generally have high fines content, where data are

available. No Atterberg limit sample results are available in this area. Subject to field observations from the cores noted above finding substantial deposits of finer material, Atterberg limits will be analyzed in these samples. Additional geotechnical vane shear and seepage-induced consolidation tests will be conducted on one of these samples.

12.3.3.18.4 Transition Zone Water

An upland site contiguous with iAOPC 17, the Willbridge bulk fuel facility was identified in Round 2 as a high priority "Category A" site for groundwater pathway evaluation. Round 2 TZW data collected offshore of this site are adequate to complete the RI/FS. Therefore, no Round 3 TZW data needs exist for iAOPC 17.

12.3.3.19 iAOPC 18

12.3.3.19.1 Area Extent

This iAOPC is located in a cove on the western shore of the river. It includes PCB human health area-specific and site-wide risks as well as ecological otter, bass, and sculpin risks. It also includes one area of benthic toxicity associated with ammonia. The shape of this iAOPC is mostly due to the various PCB hill topping analyses for these scenarios/receptors, although sculpin and benthic toxicity were determined on a station-specific basis. Most of the surface sediment stations are clustered nearshore within this iAOPC and its outward extent is mainly estimated by two stations with a relatively large gap between. Consequently, one or two additional surface sediment samples within or around the outward margins of this iAOPC would help better estimate risks in this area. Also, additional analysis of existing PCB data and the hill topping results, particularly for area-specific human health fish consumption might alter a few of the polygons as hill-topped locations for PCBs (as described for iAOPC 2 above).

12.3.3.19.2 Volume Extent

There are two cores nearshore within this iAOPC that both show decreasing PCB concentrations within depths of about 16 ft. However, there is no core on the outer margin of the iAOPC. Consequently, one of the above surface sediment sampling stations will be extended to a core (16-ft vibracore) to help estimate the volumes in this area.

12.3.3.19.3 Physical/Geotechnical Data Needs

The full suite of conventional physical parameters will be measured at the additional locations noted above, if sampled. Surface sediments in this area are relatively sandy, but there are isolated instances of subsurface silty deposits. There is one Atterberg limit sample within or near this iAOPC, and it was found to be non-plastic. Subject to field observations from the core or surface samples noted above finding substantial deposits of finer material, Atterberg limits will be analyzed in these samples. Additional geotechnical tests will not be conducted due to the limited size of this iAOPC and can be estimated for the FS from Atterberg limit and grain size data should substantial deposits of fines be encountered.

12.3.3.20 iAOPC 19

12.3.3.20.1 Area Extent

This iAOPC extends along a substantial portion of the western shoreline. It includes PCB human health and ecological risks for eight of the ten measures mapped. Risks due to DDx, aldrin, metals, TPH, and other iCOCs are also present, including areas associated with benthic toxicity. There is a relatively dense distribution of surface sediment stations throughout this area. In one location, the iAOPC extends well out into the channel for otter PCB hill-topped risks. However, there are approximately seven surface sediment stations within this channel area. One or two selected surface sediment samples for PCBs along the outer margins of this iAOPC might reduce or confirm risks in this area. Additional analysis of existing PCB data and the otter hill topping results may also alter a few of the polygons as hill-topped locations for PCBs (as described for iAOPC 2 above) within this iAOPC. This is particularly true given that the PCB concentrations in much of this area are relatively low. Such an analysis will also be conducted for the downstream third of the iAOPC, which is mostly present due to the human health area-specific fish consumption hill topping analysis.

12.3.3.20.2 Volume Extent

There is a relatively high density of cores both within and around this iAOPC. Consequently, additional coring to help estimate volumes is not warranted. There is an overall pattern of decreasing iCOC concentrations with depth throughout the iAOPC, but there are several notable exceptions including C441, which is just outside the downstream margin of the iAOPC. Consequently, deep cores in a few selected locations would help better estimate volumes associated with iCOCs in and around this iAOPC.

12.3.3.20.3 Physical/Geotechnical Data Needs

The full suite of conventional physical parameters will be measured at the additional locations noted above. Surface and subsurface sediments throughout this iAOPC have very high fines content. There are Atterberg limit samples within and near this iAOPC. Coring at two selected locations where substantial silt deposits are known to exist will be conducted and the samples subjected to additional vane shear and seepage-induced consolidation tests.

12.3.3.20.4 Transition Zone Water

An upland site contiguous with iAOPC 19, Gunderson Area 1, was identified in Round 2 as a high priority "Category A" site for groundwater pathway evaluation. Round 2 TZW data collected offshore of this site are adequate to complete the RI/FS. Therefore, no Round 3 TZW data needs exist for iAOPC 19.

12.3.3.21 iAOPC 20

12.3.3.21.1 Area Extent

This iAOPC is located along a small portion of the eastern shoreline. It includes only hill-topped PCB risk areas for human health site-wide and area-specific fish consumption and ecological otter risks. It is estimated by two surface sediment stations.

The most channel-ward station is not bounded by any station in that direction, and thus, the iAOPC extends into mid-channel. One to two additional surface sediment samples for PCBs along this margin will be collected to provide a better estimate of risks in and around this iAOPC. Also, additional analysis of existing PCB data and the hill topping results will be conducted and may alter the configuration of this iAOPC (as described for iAOPC 2 above). However, given the levels of PCBs detected here, such an outcome may be unlikely.

12.3.3.21.2 Volume Extent

There are no cores within or near this iAOPC. Consequently, one core (16-ft vibracore) will be located within the current iAOPC to help estimate sediment volumes.

12.3.3.21.3 Physical/Geotechnical Data Needs

The full suite of conventional physical parameters will be measured at the additional locations noted above No Atterberg limit samples are present within or near this iAOPC. Subject to field observations from the core or surface sample noted above finding substantial deposits of finer material, Atterberg limits will be analyzed in these samples. Additional geotechnical tests will not be conducted due to the limited size of this iAOPC and can be estimated for the FS from Atterberg limit and grain-size data should substantial deposits of fines be encountered.

12.3.3.22 iAOPCs 21, 22, and 23

12.3.3.22.1 Area Extent

Together, these iAOPCs make up the Swan Island Lagoon and shipyard areas of the Site. The iAOPC boundaries are mostly estimated based on PCB concentrations compared to iPRGs associated with a number of human health scenarios and ecological receptors. In addition, benthic toxicity from metals, DBP, and TPH was also found in some areas. The high density of surface sediment samples throughout this area also provides a good estimate of the extent of iAOPC 21 at the mouth of the lagoon. Consequently, additional surface sediment samples will not be collected. Given the number of scenario/receptors mapped for these iAOPCs and the high levels of PCBs found in some locations, it appears unlikely that re-analysis of the PCB hill topping results would cause any substantial revision to the configuration of these iAOPCs.

12.3.3.22.2 Volume Extent

These iAOPCs have a relatively high density of cores throughout providing good coverage of the area. The cores show a general pattern of decreasing iCOC concentrations with depth at most locations. However, there are a few notable exceptions to this pattern within iAOPCs 22 and 23 only. Consequently, it is recommended that additional cores extending to 20-ft depth (e.g., vibracore) be collected to better estimate the lower limit of iCOCs in selected areas of this iAOPC.

12.3.3.22.3 Physical/Geotechnical Data Needs

The full suite of conventional physical parameters will be measured at the additional core samples noted above. Atterberg limit samples are present within these iAOPCs.

Coring at two selected locations where substantial silt deposits are known to exist will be conducted and the samples subjected to additional vane shear and seepage-induced consolidation tests.

12.3.3.23 iAOPC 24

12.3.3.23.1 Area Extent

This iAOPC covers a narrow cove area on the western shoreline and is entirely estimated by PCB related risks for human health area-specific and site-wide fish consumption as well as ecological risks for otter, bass, sculpin, and shorebirds. There is a high density of surface sediment samples, with the exception of the outer/downstream quarter of the iAOPC. Consequently, one additional surface sediment sample in or near this area for PCBs will be collected to help estimate risks in this area. Given the number of scenario/receptors mapped for this iAOPCs and the concentrations of PCBs found in some samples, it appears unlikely that re-analysis of the PCB hill topping results would cause any substantial revision to the configuration of these iAOPCs.

12.3.3.23.2 Volume Extent

There is one deep core within this area that shows a decreasing PCB concentration at the deepest interval at approximately 10-ft depth. One additional core within this iAOPC (20-ft deep vibracore) will be collected to confirm this overall pattern and help provide a better estimate of volumes associated with PCBs in and around this area.

12.3.3.23.3 Physical/Geotechnical Data Needs

The full suite of conventional physical parameters will be measured at the sample locations noted above. There is one surface Atterberg limit sample within this area that was found to be non-plastic. However, overall, the surface and subsurface sediments tend to be in excess of 50 percent fines. Subject to field observations from the samples noted above finding substantial deposits of finer material, Atterberg limits will be analyzed in some of these samples. Additional geotechnical tests will not be conducted due to the limited size of this iAOPC and can be estimated for the FS from Atterberg limit and grain-size data should substantial deposits of fines be encountered.

12.3.3.24 iAOPC 25

12.3.3.24.1 Area Extent

This iAOPC extends outward from the shoreline in a relatively narrow band on the eastern shore. It is entirely estimated by PCB-related hill-topped risks for human health area-specific fish consumption and ecological otter risks. This iAOPC is estimated by PCBs found in two surface sediment samples. The iAOPC is essentially unbounded on the channel-ward side, and an additional surface sediment sample for PCBs in this area would help better estimate risks in and around this iAOPC. Also, additional analysis of existing PCB data and the hill topping results may alter one of these polygons as hill-topped locations for PCBs (as described for iAOPC 2 above).

12.3.3.24.2 Volume Extent

There is one relatively shallow undifferentiated core in the channel area off of this iAOPC. Consequently, at least one 20-ft core in or near this iAOPC will be collected to better estimate the volumes in and around this area. The exact number and location of any such cores would be determined after the reanalysis of the PCB hill topping evaluation, to ensure that the most useful location(s) are selected.

12.3.3.24.3 Physical/Geotechnical Data Needs

The full suite of conventional physical parameters will be measured at the sample locations noted above. There are no Atterberg limit samples within this area and overall the surface and subsurface sediments tend to range around 50 to 70 percent fines. Subject to field observations from the samples noted above finding substantial deposits of finer material, Atterberg limits will be analyzed in some of these samples. Additional geotechnical tests will not be conducted due to the limited size of this iAOPC and can be estimated for the FS from Atterberg limit and grain-size data should substantial deposits of fines be encountered.

12.3.3.25 iAOPC 26

12.3.3.25.1 Area Extent

This iAOPC extends outward from the shoreline in a relatively narrow band on the western shore. It is entirely estimated by PCB-related risks for human health area-specific and site-wide fish consumption as well as ecological otter, sculpin, and bass risks. This iAOPC is estimated by PCBs found in three surface sediment samples. The iAOPC is essentially unbounded on the channel-ward and downstream sides, and substantial PCB concentrations occur in large polygons in the channel just upstream of this iAOPC. Consequently, additional surface sediment samples for PCBs around and upstream of this area would help better estimate PCB risks in and around this iAOPC. Also, additional analysis of existing PCB data and the hill topping results may alter one of these polygons as hill-topped locations for PCBs (as described for iAOPC 2 above). However, it appears that a number of PCB detections in and around this iAOPC are sufficiently high that some form of iAOPC will be present in this area.

12.3.3.25.2 Volume Extent

There is one relatively shallow undifferentiated core near the channel area within this iAOPC. Consequently, one or two 20-ft cores in and around this iAOPC will be collected to help estimate volumes in and around this iAOPC.

12.3.3.25.3 Physical/Geotechnical Data Needs

The full suite of conventional physical parameters will be measured at the sample locations noted above. There are no Atterberg limit samples within this area and overall the surface and subsurface sediments tend to vary, but a deposit of 74 percent fines was found in the one core in this area. Subject to field observations from the samples noted above finding substantial deposits of finer material, Atterberg limits will be analyzed in some of these samples. Additional geotechnical tests will not be conducted due to the

limited size of this iAOPC and can be estimated for the FS from Atterberg limit and grain-size data, should substantial deposits of fines be encountered.

12.3.3.26 iAOPC 27

12.3.3.26.1 Area Extent

This iAOPC extends outward from the shoreline in a relatively narrow band on the eastern shore. It is entirely estimated by PCB-related hill-topped risks for human health area-specific fish consumption as well as ecological otter risks. This iAOPC is estimated by PCBs found at three surface sediment samples. The iAOPC extends well into the channel due to one of these samples, which had the lowest PCB concentration within the area. An additional surface sediment sample for PCBs in or near this area would help better estimate risks in and around this iAOPC. Also, additional analysis of existing PCB data and the hill topping results would likely alter one or two of the polygons with lower PCB concentrations as hill-topped locations for PCBs (as described for iAOPC 2 above). Consequently, determination of the location and need for the additional surface sediment sample should be done after the reevaluation of the hill topping results.

12.3.3.26.2 Volume Extent

There are no cores within this area. Consequently, at least one 20-ft core in this area may be collected to help estimate volumes in and around this iAOPC. Determination of the location and need for the additional core will be done after the reevaluation of the hill topping results.

12.3.3.26.3 Physical/Geotechnical Data Needs

The full suite of conventional physical parameters will be measured at the sample locations noted above. There are no Atterberg limit samples within this area, and overall the surface and subsurface sediments tend to vary. Subject to field observations from the samples noted above finding substantial deposits of finer material, Atterberg limits will be analyzed in some of these samples. Additional geotechnical tests will not be conducted due to the limited size of this iAOPC and can be estimated for the FS from Atterberg limit and grain-size data, should substantial deposits of fines be encountered.

13.0 NEXT STEPS

The Comprehensive Round 2 Report is a comprehensive evaluation of the extensive and state-of-the-art work done over the past five years by the LWG at the Portland Harbor Superfund Site Study Area. It also analyzes historical data that meet the EPA-mandated quality assurance criteria. The Round 2 Report is designed to be a tool that the LWG and EPA can use to confirm and define data gaps that need to be filled in order to complete the RI/FS. The LWG recognizes that there are several different methods that can be used to evaluate these data; however, the data gap analysis provided in Section 12 is an accurate representation of outstanding project data needs. The report will also provide a sound basis for the development of field sampling plans for the final year of RI data collection.

As detailed in Section 12, the analysis of data presented in this report concludes that the majority of data needed to complete the RI/FS have been collected. The LWG understands that the remaining data gaps will be addressed in the upcoming Round 3 effort. The LWG will work diligently with EPA to arrive at a mutually understood and acceptable data collection effort. Work is already underway to fill many of these data gaps through the ongoing Round 3A efforts. The LWG is also prepared to establish a clear path forward for Round 3B and to develop a schedule to complete the draft RI/FS.

The LWG expects that technical considerations will be incorporated into the data gap analysis and vetted in discussions between LWG and EPA and its partners. The LWG also expects EPA to provide a short list of written comments on specific aspects of the Round 2 Report that need clarification or resolution as part of developing the Round 3B field effort. These comments will be managed as part of the development of Round 3B field sampling plans. Finally, the LWG understands that EPA will provide a comprehensive set of comments on the Round 2 Report to be managed and resolved in the development of the draft RI/FS. No revision to the Round 2 Report is anticipated.

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15.0 GLOSSARY OF TERMS

A

Absorption: The uptake of water, other fluids, or dissolved chemicals by a cell or an organism (as tree roots absorb dissolved nutrients in soil).

Acceptable Levels: Levels of chemicals in media that do not cause unacceptable adverse risk to either ecological or human health receptors.

Adsorption: The process of adhering a chemical on the surface of a solid material as a chemical transport mechanism.

Alluvial: Relating to sediment deposited by flowing water.

Anthropogenic: Natural and human-made substances present in the environment as a result of human activities.

Aqueous: Composed of liquid water medium.

Aquifer: An underground geological formation, or group of formations, containing usable and practicably extractible quantities of water. Aquifers are sources of groundwater for wells and springs.

Area of Potential Concern: An area of sediments that potentially contributes to unacceptable risks within a site.

Assessment Endpoint: In ecological risk assessments, an explicit expression of the environmental value to be protected. It includes both an ecological entity and specific attribute thereof. For example, osprey are a valued ecological entity; reproduction and population maintenance of osprey, the attribute, form an assessment endpoint.

Attenuation: The process by which a chemical is reduced in concentration over time, through absorption, adsorption, degradation, dilution, or transformation.

B

Background: Constituents or locations that are not influenced by the releases from a site, either naturally occurring or anthropogenic.

Bed Load: Sediment particles resting on or near the channel bottom that are pushed or rolled along by the flow of water.

Benthic Invertebrates: Organisms without vertebrae dwelling either in the sediment or on the sediment in streams and rivers.

Bioavailability: Degree of ability to be absorbed and ready to interact in organism metabolism.

Biota: The animal and plant life of a given region.

Biota-Sediment Accumulation Factor (BSAF): The relationships used to describe the accumulation of sediment-associated organic compounds or metals in tissues of ecological receptors. BSAFs are calculated from paired sets of chemical concentrations in sediment and tissue and can be calculated in two ways: 1) from the slope of the line that results from plotting paired sediment and tissue concentrations, or 2) as the average of BSAF values calculated for each paired data set (see Appendix E for details on the site-specific BSAFs developed for Portland Harbor).

Blowdown: Water discharged from boilers to control water quality and maintain boiler function. Boiler blowdown contains various concentrations of suspended and dissolved solids and, sometimes, sludge; it may also contain boiler treatment chemicals.

C

Carcinogen: Any substance that can cause or aggravate cancer.

Central Tendency: An estimate of the average exposure that may potentially be experienced by the population.

Characterization of Ecological Effects: A step in the ecological risk assessment process that evaluates the ability of a stressor to cause adverse effects under given circumstances.

Characterization of Exposure: A step in the ecological risk assessment process that evaluates the interaction of a stressor with one or more receptors.

Cleanup: Actions taken to deal with a release or threat of release of a hazardous substance that could affect humans or the environment. The term "cleanup" is sometimes used interchangeably with the terms remedial action, removal action, response action, natural attenuation, or corrective action.

Columbia River Datum (CRD): A vertical datum established for the Columbia River from the lower river to the Bonneville Dam and on the Willamette from the Columbia up to Willamette Falls. At the Morrison Street bridge gauge, the CRD is 1.85 feet above NVGD29/47.

Combined Sewer Overflow: Discharge of a mixture of stormwater and domestic wastewater when the flow capacity of a sewer system is exceeded during rainstorms.

Community: In ecology, an assemblage of populations of different species within a specified location in space and time. Sometimes, a particular subgrouping may be specified, such as the benthic community in a river.

Confined Aquifer: An aquifer in which groundwater is confined under pressure that is significantly greater than atmospheric pressure.

Chemical(s) of Concern (COC): Chemicals identified through the baseline risk assessment that are judged to cause unacceptable adverse effects to human health and/or ecological receptors.

Chemical(s) of Interest (COI): Chemicals that have been detected at a site but have not been screened in the risk assessment process.

Chemical(s) of Potential Concern (COPC): Chemicals of interest that have been screened-in for evaluation in the Round 2 risk assessment process.

D

Data Quality Objectives (DQOs): Qualitative and quantitative statements of the overall level of uncertainty that a decision-maker will accept in results or decisions based on environmental data. They provide the framework for planning and managing environmental data operations consistent with user's needs.

Dermal Absorption: Process by which a chemical penetrates the skin and enters the body as an internal dose.

Dermal Contact: Contact between a chemical and the skin.

Detection Limit: The lowest concentration of a chemical that can reliably be distinguished, with a stated level of confidence, from a zero concentration.

Dredging: Removal of mud and sediment from the bottom of water bodies.

E

Early Action: A non-time critical removal action pursuant to 40 CFR 300.415(b)(4).

Ecological Exposure: Exposure of a non-human organism to a stressor.

Ecological Risk Assessment: The application of a formal framework, analytical process, or model to estimate the effects of human actions(s) on a natural resource and to interpret the significance of those effects in light of the uncertainties identified in each component of the assessment process. Such analysis includes initial problem formulation, exposure and effects assessments, and risk characterization.

Ecosystem: The interacting system of a biological community and its non-living environmental surroundings.

Effluent: Wastewater--treated or untreated--that flows out of a treatment plant or industrial outfall. Generally refers to wastes discharged into surface waters.

Environmental Exposure: The interaction of a stressor with a human or ecological receptor.

Erosion: The removal of soil or sediment by wind or water.

Exposure Assessment: Identifying the pathways by which chemicals may reach receptors and estimating how much of a chemical an individual is likely to be exposed to.

Exposure Pathway: The path from sources of chemicals through environmental media to human or ecological receptors.

Exposure Point Concentration (EPC): The conservative estimate of the concentration of a chemical in an environmental medium (e.g., sediment) to which a receptor may reasonably be exposed over the entire frequency and duration of exposure.

Exposure Route: The way a chemical enters an organism after contact (e.g., ingestion).

Exposure: The interaction of a stressor with a human or ecological receptor.

F

Flood Stage: A river stage established by the National Weather Service (NWS) above which flood damage may occur. The NWS defines flood stage for the Willamette River at Portland as 18.0 feet CRD.

Food Web Model (FWM): A model that describes interconnecting feeding relationships and simulates chemical bioaccumulation from environmental media (see Appendix E for description of the food web model developed for Portland Harbor).

G

Groundwater: Fresh water found beneath the earth's surface, usually in aquifers, that supplies wells and springs.

Groundwater Discharge: Groundwater entering surface water or exiting to the ground surface.

H

Habitat: The place where a population or community (e.g., human, animal, plant, microorganism) lives and its surroundings, both living and non-living.

Hazard Index: An indication of the potential for cumulative noncancer effects that is derived by summing the individual chemical hazard quotients.

Hazard Quotient: An indication of the potential for noncancer effects from a given chemical that is derived by dividing the estimated dose of a chemical by the reference dose for that chemical.

Hazardous Substance: Any substance defined as a “hazardous substance” under CERCLA or ORS Chapter 465.

Hydraulic Gradient: In general, the direction of groundwater flow due to changes in the depth of the water table.

Hydrogeology: The geology of groundwater, with particular emphasis on the chemistry and movement of water.

I

Initial Area of Potential Concern (iAOPC): An area of sediments that potentially contributes to unacceptable risks within the Study Area identified through preliminary evaluations prior to the remedial investigation report.

Initial Chemical of Concern (iCOC): Chemicals identified as part of the Comprehensive Round 2 Report that are judged to have the potential to cause unacceptable adverse effects to human health and/or ecological receptors.

Initial Preliminary Remediation Goal (iPRG): A numeric matrix-specific (e.g., sediments, water, air) chemical value that should achieve target risk levels and that can be used to help identify iAOPCs (see definition) developed prior the remedial investigation report.

Initial Study Area (ISA): The 5.7-mile stretch of the Willamette River from approximately the southern tip of Sauvie Island at river mile 3.5 to the southern end of Swan Island at river mile 9.2, and adjacent areas logically associated with an evaluation of the in-water portion of this stretch of the river. The ISA does not include upland sources of contamination being investigated or cleaned up pursuant to ORS 465 as implemented by the Oregon Department of Environmental Quality.

L

Light Non-Aqueous Phase Liquid (LNAPL): A non-aqueous phase liquid with a specific gravity less than 1.0. Because the specific gravity of water is 1.0, most LNAPLs float on top of the water table. Most common petroleum hydrocarbon fuels and lubricating oils are LNAPLs.

Line of Evidence (LOE): A specific measure, based on empirical data or a model prediction, that is used to assess potential risks to ecological receptors.

Lipid Solubility: The maximum concentration of a chemical that will dissolve in fatty substances. Lipid soluble substances are insoluble in water. They will very selectively disperse through the environment via uptake in living tissue.

Lower Willamette River (LWR): The stretch of the Willamette River from the confluence with the Columbia River (river mile 0) to Willamette Falls (approximately river mile 26).

Lowest Observed Adverse Effect Level (LOAEL): The lowest level of a stressor that causes statistically and biologically significant differences in test samples as compared to other samples subjected to no stressor.

M

Matrix: The sample material in which the chemicals of interest are found (e.g., water, sediment, tissue).

Mean High River Stage: The arithmetic mean of the maximum (e.g., highest daily measurement) observed river stage data in a given period (e.g., monthly mean high river stage).

Mean Sea Level (MSL): MSL is a tidal datum determined over a 19-year National Tidal Datum Epoch. It pertains to local mean sea level and should not be confused with the fixed datums of North American Vertical Datum of 1988 (NAVD88) or the National Geodetic Vertical Datum of 1929 (NGVD29). Data referencing MSL as the vertical datum in the Portland Harbor is technically on NGVD29/47.

Media: Specific environments such as air, water, and soil that are the subject of regulatory concern and activities.

Mean High Water (MHW): A tidal datum. The average of all the high water heights observed over the National Tidal Datum Epoch (19-year period).

Mean Low Water (MLW): A tidal datum. The average of all the low water heights observed over the National Tidal Datum Epoch (19-year period).

Method Detection Limit (MDL): See *Detection Limit.*

Municipal Discharge: Discharge of effluent from wastewater treatment plants that receive wastewater from households, commercial establishments, and industries in the coastal drainage basin. Combined sewer/separate storm overflows are included in this category.

N

North American Vertical Datum of 1988 (NAVD88): This vertical datum is the national standard geodetic reference for heights. NAVD88 is a fixed datum derived from local mean sea level observations at Father Point/Rimouski, Quebec, Canada. NAVD88 replaced NGVD29/47 as the national standard geodetic reference for heights.

National Geodetic Vertical Datum of 1929 and Supplemental Adjustment of 1947 (NGVD29/47): NGVD29/47 is a fixed datum adopted and adjusted in 1947 as a national standard geodetic reference for heights prior to June 24, 1993 and is now considered superseded by NAVD88. NGVD29 is sometimes referred to as Sea Level Datum of 1929 or as Mean Sea Level (MSL) on some early issues of U.S. Geological Survey topographic quads. NGVD29 was originally derived from a general adjustment of the first-order leveling networks of the U.S. and Canada after holding mean sea level observed at 26 long-term tide stations as fixed. Historical data referencing MSL as the vertical datum in Portland Harbor is technically on NGVD29/47.

Naturally Occurring: Substances present in the environment in forms that have not been influenced by human activity.

Nature and Extent: Characterization of chemical distribution within a site.

No Observable Adverse Effect Level (NOAEL): An exposure level at which there are no statistically or biologically significant increases in the frequency or severity of adverse effects between the exposed population and its appropriate control. Some effects may be produced at this level, but they are not considered adverse or precursors to adverse effects.

No Observed Effect Concentration (NOEC): Exposure concentrations at which there are no statistically or biological significant differences in the frequency or severity of any effect in the exposed or control populations.

Non-Point Sources: Diffuse pollution sources (i.e., without a single point of origin or not introduced into a receiving stream from a specific outlet).

O

Operable Unit: A discrete action that comprises an incremental step toward comprehensively addressing site problems. This discrete portion of a remedial response manages migration or eliminates or mitigates a release, threat of release, or pathway of exposure.

Ordinary High Water or High Water: Defined as the vegetation line or the line the water impresses on the soil by covering it for sufficient periods to deprive it of vegetation. It is established by field observation of seasonally high river levels by the U.S. Army Corps of Engineers and designates the jurisdictional limits of the Corps regulatory program. From Willamette RM 0 to 16, the ordinary high-water level ranges from 14.7 to 15.2 feet CRD (USACE 1991). The Oregon Division of State Lands defines the ordinary high water line (OHWL) as a line on the bank or shore to which high water ordinarily rises annually in season. The OHWL excludes exceptionally high-water levels caused by large floods (e.g., 100-year events).

P

Pathway: The physical course a chemical or pollutant takes from its source to the exposed organism.

Perched Water: Zone of unpressurized water held above the water table by impermeable rock or sediment.

Permeability: The rate at which liquids pass through soil or other materials in a specified direction.

Plume: A visible or measurable discharge of a contaminant from a given point of origin.

Point Source: A stationary location or fixed facility from which pollutants are discharged.

Population: A group of interbreeding organisms (i.e., members of the species) occupying a particular space; the number of humans or other living creatures in a designated area.

Porewater: Water existing in the interstices of submerged sediments.

Portland River Datum (PRD): Datum of reference plane from which river stage is measured on the Willamette River at Portland at the Morrison Bridge gauge. PRD equals 1.55 feet above NGVD29/47 or MSL, and the PRD gauge reports water levels 0.30 foot above CRD levels at this location.

Potential Initial Chemical of Concern (Potential iCOC): Potential iCOCs are differentiated from iCOCs in that they were identified through less certain and/or less rigorous evaluations based on fewer lines of evidence.

Pre-AOC: Events including sampling and other studies that occurred prior to signing of the AOC for the Site.

Preliminary Background Concentrations: Concentrations of chemicals in bedded sediments from the upriver reach of the LWR (RM 15.3 to 26). The primary use of these preliminary

background concentrations in the Round 2 data evaluation is to support the definition of initial AOPCs.

Preliminary Remediation Goal (PRG): A numeric matrix-specific (e.g., sediments, water, air) chemical value that should achieve target risk levels, and that can be used to identify AOPCs (see definition) for a remedial investigation.

Principal Threat: Those source materials considered highly toxic or highly mobile that generally cannot be reliably contained or would present a significant risk to human health or the environment should exposure occur.

Q

Quality Assurance/Quality Control (QA/QC): A system of procedures, checks, audits, and corrective actions to ensure that all EPA research design and performance, environmental monitoring and sampling, and other technical and reporting activities are of the highest achievable quality.

R

Reasonable Maximum Exposure: An estimate of the highest exposure that is reasonably expected to occur for a given population.

Receptor: Human or ecological entity to be evaluated in a risk assessment.

Recharge Area: A land area in which water reaches the zone of saturation from surface infiltration (e.g., where rainwater soaks through the earth to reach an aquifer).

Recharge: The process by which groundwater is added to a zone of saturation, usually by percolation from the soil surface (e.g., the recharge of an aquifer).

Remedial Action (RA): The actual construction or implementation phase of a Superfund site cleanup that follows remedial design.

Riparian Zone: The portion of riverbank between approximately +13 feet to +22 feet NAVD88 vertical elevation.

Risk: A measure of the probability that an adverse effect to human health or ecological receptors will occur as a result of a release of a hazardous substance.

Risk Assessment: Qualitative and quantitative evaluation of the risk posed to human health or the environment by the actual or threatened release of specific chemical(s).

Risk Characterization: The last phase of the risk assessment process that estimates the potential for adverse human or ecological effects to occur from exposure to a stressor and evaluates the uncertainty associated with the estimate.

Risk Estimate: A description of the probability that organisms exposed to a specific dose of a chemical will develop an adverse effect (e.g., cancer).

Risk Management: The process of evaluating and selecting alternative regulatory and non-regulatory responses to risk. The selection process necessarily requires the consideration of legal, economic, and behavioral factors.

Risk Reduction: Lessening the unacceptable risks from chemicals by lowering their concentrations, mobility, bioavailability, toxicity, or exposure to receptors.

River Stage: Height of a river measured relative to a datum or specific elevation.

Round 1: RI/FS field work performed during 2002. Initially termed Round 1A and Round 1 to denote separation of several months between sampling events.

Round 2: RI/FS field work conducted from July 2003 through December 2005, following EPA approval of the Programmatic Work Plan.

Round 3A: RI/FS field work conducted in 2006 and 2007 and that was scoped before completion of the Comprehensive Round 2 Report.

Round 3B: RI/FS field work proposed for 2007 that will be scoped and conducted following completion of the Comprehensive Round 2 Report.

S

Saturated Zone: The area below the water table where all open spaces are filled with water under pressure equal to or greater than that of the atmosphere.

Sediment Management Area (SMA): Areas and volumes of sediments contributing to unacceptable risks segregated into discrete units for the purposes of the identification and evaluation of remedial technologies in the feasibility study.

Sediment Quality Value (SQV): A sediment chemical concentration threshold that represents some documented correlation with effects on benthic invertebrates. SQVs are usually presented as a pair, with the lower concentration indicating a threshold below which adverse biological effects rarely occur and the upper concentration indicating a threshold above which adverse biological effects frequently occur.

Silt: Sedimentary materials composed of fine- or intermediate-sized mineral particles.

Site: The Portland Harbor NPL site.

Solubility: The amount of mass of a compound that will dissolve in a unit volume of solution. Aqueous solubility is the maximum concentration of a chemical that will dissolve in pure water at a reference temperature.

Sorption: The action of soaking up or attracting substances.

Spatially-Weighted Average Concentration (SWAC): A spatially weighted sediment chemical concentration calculated as the sum of the product (by sampling location) of normalized Thiessen polygon areas and sediment concentrations.**Storm Sewer:** A system of pipes (separate from sanitary sewers) that carries water runoff from buildings and land surfaces.

Stressors: Physical, chemical, or biological entities that can induce adverse effects on ecosystems or human health.

Study Area: The stretch of the Willamette River extending from approximately river mile 2 to river mile 11. Some samples as far downstream as river mile 1.9 were included in the risk assessments and delineation of iAOPCs.

Surface Runoff: Precipitation, snowmelt, or irrigation water in excess of what can infiltrate the soil surface and be stored in surface depressions.

Surface Water: All water naturally open to the atmosphere (e.g., rivers, lakes, reservoirs, ponds, streams, impoundments, seas, estuaries).

T

Threshold: The lowest dose or concentration of a chemical at which a specified measurable effect is observed and below which it is not observed.

Transition Zone: The interval where both groundwater and surface water comprise some percentage of the water occupying pore space in sediments.

Transition Zone Water (TZW): The groundwater/surface water transition zone (also known as the hyporheic zone) is the interval where a mixture of groundwater and surface water compose some percentage of the water occupying interstitial space in the sediments.

Trophic Levels: A functional classification of species that is based on feeding relationships.

Toxicity Reference Value:. A chemical concentration threshold that represents some level of documented effect on a particular organism from exposure to the chemical (i.e., the minimum concentration at which adverse effects have been observed, or the maximum concentration at which no adverse effects have been observed).

Toxicity Testing: Biological testing (usually with an invertebrate, fish, or small mammal) to determine the adverse effects of a compound or effluent.

Toxicity: The concentration at which a substance or mixture of substances can cause adverse effects in humans or animals.

U

Unconfined Aquifer: An aquifer containing water that is not under pressure; and where the water level in a well is the same as the water table outside the well.

Unsaturated Zone: The area above the water table where soil pores are not fully saturated, although some water may be present.

Urban Runoff: Stormwater from urban environments, including industrial, residential, commercial, vacant, and transportation land uses.

V

Vadose Zone: The zone between land surface and the water table within which the moisture content is less than saturation (except in the capillary fringe) and pressure is less than atmospheric. Soil pore space also typically contains air or other gases. The capillary fringe is included in the vadose zone.

Volatile: Any substance that evaporates readily.

W

Water Quality Criteria: Standards of water quality not to be exceeded under the Clean Water Act.

Weight of Scientific Evidence: Considerations in assessing the interpretation of published information about toxicity—such as quality of testing methods, size, and power of study design; consistency of results across studies; and biological plausibility of exposure-response relationships and statistical associations.

Willamette River Flood Stage: Defined as +18 feet CRD on the lower Willamette River.

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