Lower Duwamish Waterway Group

Port of Seattle / City of Seattle / King County / The Boeing Company

Lower Duwamish Waterway Remedial Investigation

DATA REPORT:
CHEMICAL ANALYSES OF FISH, CRAB, AND CLAM TISSUE SAMPLES AND CO-LOCATED SEDIMENT SAMPLES COLLECTED IN 2007
FINAL

For submittal to

The U.S. Environmental Protection Agency
Region 10
Seattle, WA

The Washington State Department of Ecology
Northwest Field Office
Bellevue, WA

March 5, 2009

Prepared by: Wind Ward environmental LLC

200 West Mercer Street, Suite 401 ♦ Seattle, Washington ♦ 98119

Table of Contents

Additional Supporting Documentation

The following appendices, which consist of detailed validation reports and scanned versions of original field and laboratory documents, may be viewed at http://www.ldwg.org/rifs_docs.htm; the links are found in the Data Report section under the heading Task 10: Results of Phase 2 fieldwork. A compact disc version of these materials is included with this report.

List of Tables

List of Figures

List of Maps

Acronyms

Acronym	Definition
ARI	Analytical Resources, Inc.
ASTM	American Society for Testing and Materials
Axys	Axys Analytical Services, Ltd.
Brooks Rand	Brooks Rand Laboratory
CCV	continuing calibration verification
COC	chain of custody
DCM	dichloromethane
dw	dry weight
EPA	US Environmental Protection Agency
ID	identification
LDC	Laboratory Data Consultants, Inc.
LCS	laboratory control sample
LDW	Lower Duwamish Waterway
MS/MSD	matrix spike/matrix spike duplicate
PCB	polychlorinated biphenyl
QA/QC	quality assurance/quality control
QAPP	quality assurance project plan
RI	remedial investigation
RM	river mile
RPD	relative percent difference
RSD	relative standard deviation
SDG	sample delivery group
TEF	toxic equivalency factor
TEQ	toxic equivalent
Windward	Windward Environmental LLC
ww	wet weight

1.0 Introduction

This data report presents the results of the sampling event for the chemical analyses of fish, crab, and clam tissue samples conducted in 2007 to augment data collected in 2004 and 2005 for the remedial investigation (RI) for the Lower Duwamish Waterway (LDW). The quality assurance project plan (QAPP) for this 2007 sampling event was prepared as an addendum to the initial fish and crab QAPP (Windward 2004c) and benthic invertebrate QAPP (Windward 2004b). The QAPP addendum for this 2007 sampling event (Windward 2007c) presented the design for this study, including details on project organization, field data collection, laboratory analyses, and data management.

Field catch results and the results of the chemical analyses of fish, crab, and clam composite tissue samples are provided in this report as well as results of chemical analyses of sediment samples co-located with clam composite tissue samples. Fish and crab samples were analyzed for polychlorinated biphenyls (PCBs) as Aroclors, total solids, and lipids; a subset of the samples were also analyzed for PCB congeners. Clam composite samples were analyzed for total and inorganic arsenic, total solids, and lipids; a subset of the samples were also analyzed for PCBs as Aroclors. Co-located sediment samples were analyzed for total arsenic and total solids.

The data from this sampling event will be included in the RI in the nature and extent evaluation of PCBs and arsenic, including the temporal evaluations. These data will not be used to recalculate baseline ecological or human health risks (Windward 2007a, 2007b), revise risk conclusions presented in those documents, or re-calibrate the food web model presented in the RI. The cleanup alternatives in the feasibility study will be based on the baseline risk assessments and food web model presented in the RI report, which, as noted previously, will not be modified to incorporate the 2007 data.

The remainder of this report is organized into the following sections:

- Section 2 – Fish and crab tissue sampling and processing
- Section 3 – Analytical methods
- Section 4 – Chemical analysis results
- Section 5 – References

The text is supported by the following appendices:

- Appendix A – PCB congener data
- Appendix B – Compositing information
- Appendix C – PCB Aroclor and congener plots
- Appendix D – Data management

- Appendix E – ARI and Brooks Rand tissue preparation notes
- Appendix F – Data validation reports
- Appendix G – Form 1s
- Appendix H – Field forms, field notes, and navigation report
- Appendix I – Chain-of-custody forms

2.0 Fish, Crab, and Clam Tissue Sampling and Processing

This section describes the methods used to collect and process fish, crab, and clam tissue samples and sediment samples co-located with clam tissue samples. The field procedures used to collect these samples are described in detail in the fish and crab QAPP (Windward 2004c), the benthic invertebrate QAPP (Windward 2004b), and the QAPP addendum (Windward 2007c). Section 2.1 presents the fish and crab tissue sampling and processing methods; Section 2.2 presents the clam tissue and co-located sampling and processing methods; and Section 2.3 describes field deviations from the QAPP.

2.1 LDW Fish and Crab Tissue Sampling and Processing

Fish and crab sampling took place over seven days, September 4 through 7, 2007 and September 10 through 12, 2007. This section discusses the species targeted for collection, sampling areas, sampling methods, and the catch results.

2.1.1 Targeted species and collection areas

As presented in Section 3.1 of the QAPP addendum (Windward 2007c), species targeted for collection were English sole (≥ 200 mm), shiner surfperch (≥ 80 mm), and Dungeness crab (≥ 90 mm). The minimum sizes of fish and crabs noted above were selected to represent the preferred prey size of piscivorous wildlife receptors of concern and reasonable sizes of seafood consumed by humans (Windward 2004c).

Fish and crab tissue samples were collected from four distinct tissue sampling areas (Areas T1, T2, T3, and T4), as described in the QAPP addendum (Windward 2007c), Areas T1, T2, and T3 were divided into six subareas (A to F). Area T4 was divided into five subareas (A to E) because of its shape and the difficulty in sampling upstream of river mile (RM) 4.8 (Figure 2-1). These subareas were identified for the purpose of collecting shiner surfperch,[1] which are believed to have smaller home range areas than English sole and crabs. As specified in the QAPP addendum (Windward 2007c), no

[1] Pacific staghorn sculpin were also collected from subareas in previous sampling efforts; however, sculpin were not targeted for chemical analyses in 2007.

sampling was conducted in subarea T4-E in 2007 because only one shiner surfperch of target size was collected in this subarea in 2004 and no English sole were found in this subarea in 2004. In addition, trawling was not practicable in this subarea because of submerged logs and debris. Starry flounder were collected as a surrogate species for English sole in Area T4 when insufficient numbers of English sole were collected to meet target specimen numbers. Slender crabs were collected as a surrogate species for Dungeness crabs in Areas T1 and T2 because insufficient numbers of Dungeness crabs were collected in these areas. Hereafter, target species refers to both target species and their surrogates.

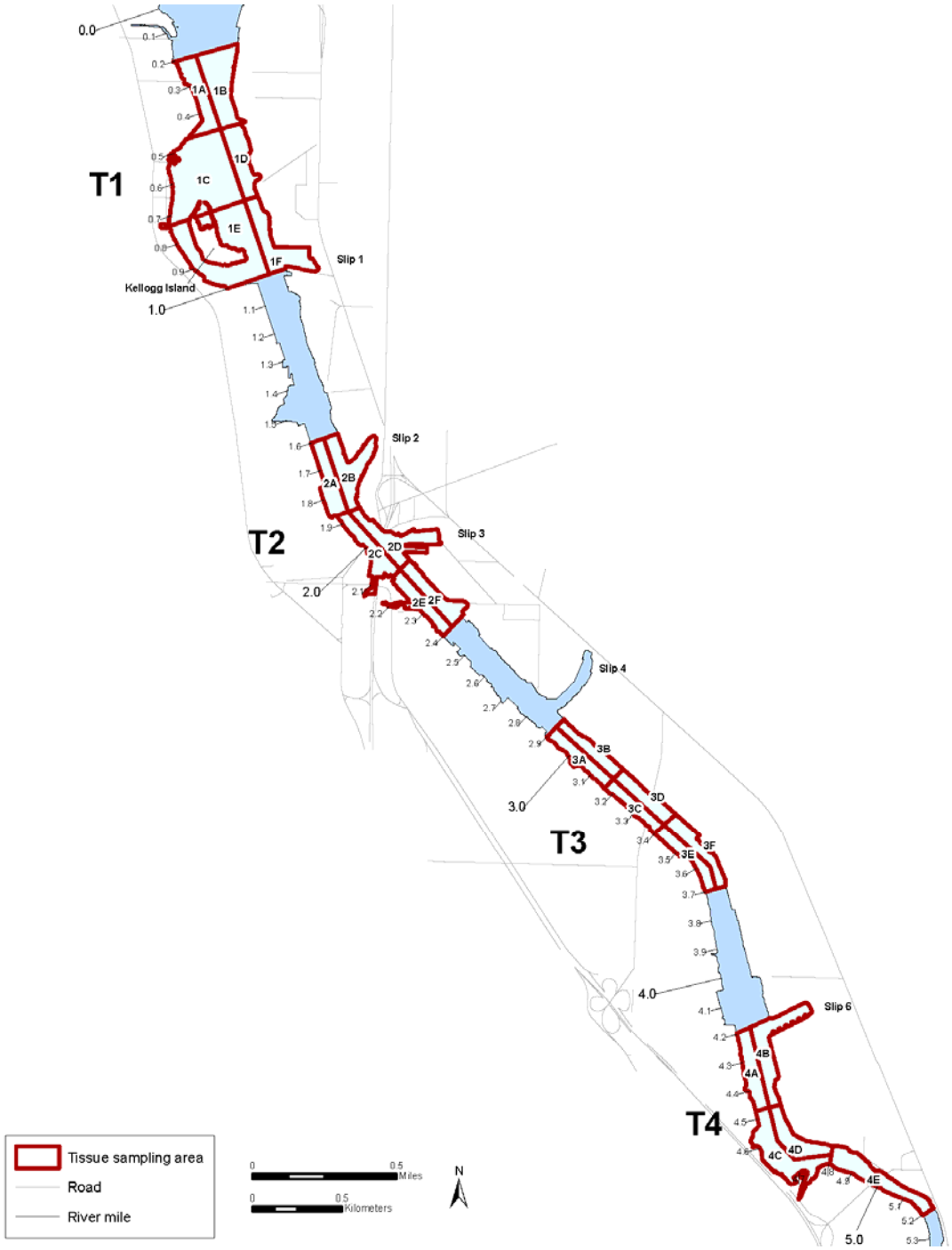

Figure 2-1. Fish and crab tissue collection areas in the LDW

2.1.2 Collection methods

Fish and crabs were collected using two different collection methods: a high-rise otter trawl for all fish species and crab traps for crabs. The rationale for the sampling locations and the field procedures used to collect the fish and crab samples is described in detail in the QAPP (Windward 2004c) and QAPP addendum (Windward 2007c)

2.1.2.1 High-rise otter trawl

Trawling was conducted in the LDW for seven days, from September 4 through 7, 2007 and from September 10 through 12, 2007. All trawling was conducted using the research vessel *Kittiwake*, captained by Charles Eaton (Bio-Marine Enterprises). Specifications of the high-rise otter trawl are presented in the QAPP (Windward 2004c).

Trawling began and ended within the boundaries of a given subarea and generally progressed against the flow of the waterway. During ebb tides, trawls were conducted from downstream to upstream. During flood tides that caused flow reversal, trawls were conducted from upstream to downstream. Within each subarea, trawling was focused on areas outside of the navigation channel to capture fish in shallower habitats. However, vessel draft and trawl depth limitations constrained trawling to waters deeper than 6 ft at the time of trawling. If multiple trawls outside the navigation channel failed to yield sufficient numbers of target species, trawls were also conducted within the navigation channel. Some trawls were conducted over more than one subarea within a sampling area to target English sole, which were targeted within areas, rather than subareas. The numbers of trawls conducted in each subarea, both inside and outside the navigation channel, are presented in Table 2-1, and trawling locations are shown on Maps 2-1 through 2-4.

Table 2-1. Number of trawls conducted inside and outside the navigation channel in each LDW sampling area

Area	Subarea[b]	Number of Trawls[a]		
		Inside Channel	Outside Channel	Total
T1	A	2	1	3
	B	0	14	14
	C	1	5	6
	D	1	4	5
	E	0	6	6
	F	2	5	7
	M	na	na	2
T1 Total				**43**

Area	Subarea[b]	Number of Trawls[a]		
		Inside Channel	Outside Channel	Total
T2	A	1	0	1
	B	2	2	4
	C	3	0	3
	D	1	0	1
	E	1	0	1
	F	3	0	3
	M	3	0	3
T2 Total				**16**
T3	A	4	2	6
	B	3	1	4
	C	1	0	1
	D	1	0	1
	E	4	0	4
	F	2	1	3
	M	12	0	12
T3 Total				**31**
T4	A	4	1	5
	B	3	0	3
	C	1	1	2
	D	0	1	1
	E	0	0	0
	M	8	0	8
T4 Total				**19**
Grand Total				**109**

[a] The locations of trawl transects in relation to channel bathymetry are shown on Maps 2-1 through 2-4.

[b] Trawls within the six subareas were identified with the letters A through F; trawls conducted over multiple subareas were identified with the letter M.

LDW – Lower Duwamish Waterway

2.1.2.2 Crab traps

Crab traps were deployed in Areas T1 and T4 on September 11 and 12, 2007. Traps were not deployed in Areas T2 or T3 because target numbers of crabs in those areas were collected in trawls. All traps were Ladner 30-in. rubber-wrapped stainless steel crab traps. Bait was placed in a mesh bait bag and tied to the inside of the trap so the bags could not be opened and the contents consumed.

Eighteen traps were dispersed throughout Area T4. Two traps were deployed in Area T1 to supplement the number of Dungeness crabs that were captured in the trawls from this area. Trap deployment times typically ranged from approximately 3 to 4 hours, although nine traps were left overnight in Area T4. The locations of traps are shown on Maps 2-5 and 2-6.

2.1.2.3 Field sample processing

Upon completion of an individual trawl or trap, the catch was sorted by species and size into holding trays that contained site water. Prior to release within their area of capture, non-target species were identified to the lowest practical taxonomic level, numbers of each species were counted (or estimated if a species was present in large numbers), and these data were recorded on the non-target species tally form (Appendix H).

Individual specimens of target fish or crabs were rinsed in site water to remove any foreign matter from the external surface. The target species were then grouped by species and general size class and placed in clean holding trays to prevent contamination. All fish and crabs were inspected carefully to ensure that their skin or shells had not been damaged by the sampling equipment; specimens with broken skin or shells were not included in composite tissue samples. Each fish or crab within the selected target species was measured to determine that the actual total length was greater than the minimum target length for that species. Large fish were killed by placing them in a zip-lock bag and giving them a sharp blow to the head on the side of the processing table. Small fish were killed by placing them on ice, as recommended by the US Environmental Protection Agency (EPA; 2000). Crabs were killed in the field by placing them on dry ice (Windward 2007c). After target numbers were met in a given area or subarea, additional specimens of target size captured (but not collected) during sampling were measured, enumerated, and returned to the LDW.

Individual specimens of the same species from a particular sampling area and equipment deployment (i.e., a single trawl or trap) were kept together in one large re-sealable plastic bag with the date, time, effort number, species, and collection method recorded on the outside of the bag in indelible ink. The bagged and iced fish and crabs were transported in coolers to Windward, where they were stored frozen or at 4˚ C (±2˚ C). The specimens were then transported to Analytical Resources, Inc. (ARI) for final processing.

The date, time, and location of each effort were recorded in the field notebook, the target species collection form, the non-target species tally form, and the navigation report. Completed field forms are presented in Appendix H.

2.1.3 Catch results

A total of 438 fish and crab specimens of target species and size were collected and processed from 77 successful trawls and 1 successful crab trap set. Target numbers of fish and crabs specified in the QAPP addendum (Windward 2007c) were met or

exceeded for all species in each pertinent area or subarea. Catch results for all target fish and crab species collected and processed from each area and subarea of the LDW are presented in Table 2-3. Compositing information, including the specimen identification (ID), length, and weight for each target specimen included in a composite sample, are presented in Appendix B.[2]

Table 2-3. Target species catch results by area and subarea

Area	Subarea[a]	Number of Specimens Retained					
		English Sole	Starry Flounder	Shiner Surfperch	Dungeness Crab	Slender Crab	Total
T1	A	21	0	10	0	2	33
	B	4	0	10	1	0	15
	C	0	0	10	0	1	11
	D	0	0	10	1	0	11
	E	13	0	11	1	9	34
	F	8	0	12	1	3	24
T1 Total		**46**	**0**	**63**	**4**	**15**	**128**
T2	A	45	0	10	0	0	55
	B	0	0	10	0	5	15
	C	0	0	10	0	3	13
	D	0	0	10	0	0	10
	E	0	0	10	0	0	10
	F	0	0	10	0	2	12
	M	0	0	0	0	5	5
T2 Total		**45**	**0**	**60**	**0**	**15**	**120**
T3	A	11	0	10	6	0	27
	B	1	0	10	2	0	13
	C	0	0	10	4	0	14
	D	1	0	10	2	0	13
	E	3	0	10	0	0	13
	F	5	0	10	2	0	17
	M	25	2	0	0	0	27
T3 Total		**46**	**2**	**60**	**16**	**0**	**124**
T4	A	1	1	10	0	0	12
	B	3	2	10	1	0	16
	C	0	0	10	0	0	10

[2] As described in Section 2.1.4.2, the sample ID for each specimen contains characters that identify the area and subarea where the specimen was captured, the collection method, the effort number, and the species.

Area	Subarea[a]	Number of Specimens Retained					
		English Sole	Starry Flounder	Shiner Surfperch	Dungeness Crab	Slender Crab	Total
	D	0	0	10	0	0	10
	M	1	17	0	0	0	18
T4 Total		**5**	**20**	**40**	**1**	**0**	**66**
Total		**142**	**22**	**223**	**21**	**30**	**438**

[a] Trawls within the six subareas were identified with the letters A through F; trawls conducted over multiple subareas were identified with the letter M.

Non-target fish and crab species captured in the LDW were identified, recorded, and returned to the subareas where they were collected. A total of 26 fish species and 31 types of invertebrates classified to the lowest taxonomic level practicable were collected from the LDW, including both target and non-target species. The numbers of each species captured for each collection method are presented in Table 2-4 for fish and in Table 2-5 for invertebrates.

Table 2-4. Numbers of individual fish species captured in the LDW using trawls and crab traps

Species	Scientific Name	Number of Specimens Captured		
		Otter Trawl	Crab Trap	Total
American shad	*Alosa sapidissima*	3	0	3
Big skate	*Raja binoculata*	3	0	3
Brown rock fish	*Sebastes auriculatus*	1	0	1
Buffalo sculpin	*Enophrys bison*	4	0	4
English sole	*Parophrys vetulus*	711	1	712
Longfin smelt	*Spirinchus thaleichthys*	236	0	236
Pacific herring	*Clupea pallasii marisalbi*	40	0	40
Pacific staghorn sculpin	*Leptocottus armatus*	494	0	494
Pacific tomcod	*Microgadus proximus*	115	0	115
Padded sculpin	*Artedius fenestralis*	3	0	3
Pile perch	*Rhacochilus vacca*	285	0	285
Pink salmon	*Oncorhynchus gorbuscha*	4	0	4
Prickly sculpin	*Cottus asper*	10	0	10
Ratfish	*Hydrolagus colliei*	1	0	1
Rock sole	*Lepidopsetta bilineata*	60	0	60
Roughback sculpin	*Chitonotus pugetensis*	41	0	41
Sand sole	*Psettichthys melanostictus*	33	0	33
Shiner surfperch	*Cymatogaster aggregata*	1,921	0	1,921
Snake prickleback	*Lumpenus sagitta*	10	0	10

Species	Scientific Name	Number of Specimens Captured		
		Otter Trawl	Crab Trap	Total
Speckled sanddab	*Citharichthys stigmaeus*	1	0	1
Starry flounder	*Platichthys stellatus*	1,274	0	1,274
Steelhead	*Oncorhynchus mykiss*	2	0	2
Striped perch	*Embiotoca lateralis*	4	0	4
Unidentified sculpin	*Cottus* sp.	4	0	4
Whitespotted greenling	*Hexagrammos stelleri*	8	0	8
Total		**5,268**	**1**	**5,269**

Table 2-5. Numbers of individual invertebrate species captured in the LDW using trawls and traps

Species	Scientific Name	Number of Specimens Captured		
		Otter trawl	Crab Trap	Total
Amphipod	*Amphipoda* sp.	2	0	2
Clam, bent-nose	*Macoma* sp.	2	0	2
Cockle clams	*Clinocardium* sp.	2	0	2
Crab	*unknown*	2	0	2
Crangon shrimp	*Crangon* sp.	154	0	154
Decorator crab	*Loxorhynchus crispatus*	17	0	17
Dock shrimp	*Pandalus danae*	28	0	28
Dungeness crab	*Cancer magister*	90	1	91
Frilled dogwinkle	*Nucella lamellosa*	2	0	2
Burrowing clam	unknown	5	0	5
Hermit crab	*Pagurus* sp.	4	0	4
Jellyfish	unknown	5	0	5
Kelp crab	*Pugettia producta*	5	0	5
Lion's mane jellyfish	*Cyanea capillata*	3	0	3
Moon snail	*Polinices lewisii*	1	0	1
Mottled sea star	*Evasterias troschelii*	14	0	14
Nudibranch	*Armina californica*	57	0	57
Nudibranch	*Tritonia diomedea*	5	0	5
Nudibranch	unknown	93	0	93
Pacific lyre crab	*Hyas lyratus*	2	0	2
Polychaete (worm)	unknown	1	0	1
Plumose anemone	*Metridium senile*	73	0	73
Red rock crab	*Cancer productus*	10	4	14

Species	Scientific Name	Number of Specimens Captured		
		Otter trawl	Crab Trap	Total
Sea pen	unknown	4	0	4
Sea star	*Pisaster* sp.	28	0	28
Sea star	unknown	2	0	2
Sea star, sunflower	*Pycnopodia helianthoides*	22	0	22
Slender crab	*Cancer gracilis*	160	5	165
Solaster star	*Solaster stimpsoni*	1	0	1
Squid	unknown	1	0	1
Tunicate	unknown	2	0	2
Total		**797**	**10**	**807**

2.1.4 Sample processing, identification, and compositing

This section presents methods used to process fish and crabs following collection in the field. Specimen and sample ID numbers are described for individual fish and crabs and also for the composite tissue samples. In addition, the compositing scheme is described.

2.1.4.1 Laboratory sample processing

At the end of each day, all sample labels were checked against field forms, and sample ID numbers were recorded on COC forms. COC forms were placed together with samples collected that day into heavy-duty plastic garbage bags, which were then sealed and stored overnight at less than 4°C in the Windward processing laboratory. Prior to transport to ARI, samples were securely packed inside a cooler with ice packs and were kept on ice. In general, samples collected Monday through Thursday (September 4 through September 6, 2007 and September 10 through September 12, 2007) were transported in coolers the day following collection from Windward to ARI. Samples collected on Friday (September 7, 2007) were refrigerated and held at Windward over the weekend, and were transported to ARI on the following Monday (September 10, 2007).

Initial processing of samples (i.e., weighing, measuring, and packaging) was conducted by Windward personnel at ARI. Fish and crabs were weighed using an analytical scale accurate to 0.1 g, measured, and individually packaged. Each target specimen was individually wrapped in heavy-duty aluminum foil, enclosed in a resealable plastic bag with an ID label (also enclosed in a resealable bag), and immediately transferred into coolers with wet ice. Crabs were double-wrapped in heavy-duty aluminum foil to minimize punctures prior to placing them in the plastic bag.

All relevant information for each individually wrapped and labeled specimen was recorded on the target fish and crab species collection forms (Appendix H). Relevant information included the specimen ID, length, weight, gender (when differences between the sexes were visually discernable, such as with gravid females), sample date, time, and location number. The demands of sample processing made a close inspection of all specimens for external abnormalities impossible.

After initial processing, samples were assigned a specific storage area at ARI. Custody was turned over to ARI at that time and signed COC forms were filed at ARI. All individual specimens were frozen within 72 hours. Fish were processed (weighed/measured) immediately after collection and delivered to the lab either that same day or the next. of collection and were kept frozen at -20°C until fish were homogenized and composite samples were created. The homogenization process began on October 10, 2007.

All fish and crab tissue preparation, including filleting of fish, dissection of crabs, and homogenization of tissues, was conducted at ARI following standard operating procedures. Specimens were formed into composite samples prior to homogenization. Large fish were chopped into small pieces and included in their entirety in the composite sample. For fillet samples, partially thawed whole fish were filleted (skin on), and the fillets were then homogenized. Crabs were dissected, and the hepatopancreas and edible meat tissues were combined into the relevant composite samples prior to homogenization (Appendix B). Laboratory notes for tissue preparation are presented in Appendix E. Frozen subsamples of homogenized composite fish and crab tissue samples were shipped via FedEx to Axys Analytical Services, Ltd. (Axys) for PCB congener analyses.

2.1.4.2 Sample identification

Unique alphanumeric sample ID numbers were assigned to each individual target fish or crab specimen and recorded on the target fish and crab species form (Appendix H).[3] Table 2-6 presents the ID scheme for individual fish and crab specimens.

Table 2-6. ID scheme for individual fish and crab specimens

IDENTIFIER	DESCRIPTION
LDW	Identifies the project area.
07	Identifies the year collected.
T1, T2, T3, or T4	Identifies the sampling area.
A, B, C, D, E, F	Identifies the sampling subarea. Multiple relevant subarea letters were applied to specimens collected from trawls that traversed multiple subareas.

[3] No sample ID numbers were assigned to specimens of non-target species.

IDENTIFIER	DESCRIPTION
TR or CT followed by sequential three-digit number	Identifies the collection method (trawl or crab trap, respectively) and the effort as a unique number over all areas (e.g., the 15th trawl after the start of sampling would be TR015).
ES, SF, SS, DC, or SC	Identifies the species type (English sole, starry flounder, shiner surfperch, Dungeness crab, or slender crab, respectively).
Sequential number	Identifies the specimen captured in the sampling event from a given area or subarea

ID - identification

LDW – Lower Duwamish Waterway

Thus, for example, the 28th English sole captured in the 13th trawl of Area T1 in subarea A was identified as LDW-07-T1-A-TR013-ES-28. After individual fish and crab specimens were combined to form composite samples, as discussed in Section 2.1.4.3, composite sample IDs were assigned as shown in Table 2-7.

Table 2-7. ID scheme for fish and crab composite tissue samples

IDENTIFIER	DESCRIPTION
LDW	Identifies the project area.
07	Identifies the year collected.
T1, T2, T3, or T4	Identifies the sampling area.
A, B, C, D, E, F, or M	Identifies the sampling subarea; M identifier was used if specimens from multiple subareas were included in the composite sample.
PS, ES, SF, SS, DC, or SC	Identifies the species type (Pacific staghorn sculpin, English sole, starry flounder, shiner surfperch, Dungeness crab, or slender crab, respectively).
WB, FL, EM, or HP	Identifies whole-body, fillet, edible meat, or hepatopancreas samples, respectively.
comp	Indicates the sample as a composite of individual specimens
sequential number	Identifies the composite number for a specific species and sampling area combination.

ID - identification

LDW – Lower Duwamish Waterway

Thus, for example, the second composite whole-body English sole sample, which contained specimens from multiple subareas within Area T1, was identified as LDW-07-T1-M-ES-WB-comp-2.

2.1.4.3 Compositing scheme

Fish and crab tissue samples were chemically analyzed as composite samples, which were created by homogenizing individual specimens together. The compositing plan was developed with and approved by EPA. Most of the specimens retained for analysis were included in composite samples. The numbers and types of composite samples created and chemically analyzed are presented in Table 2-8. Appendix B

presents length and weight data for each individual specimen included in the composite samples, as well as gender data for crabs.

Table 2-8. Numbers of fish and crab composite tissue samples collected from the LDW

Species Name	Total Length (MM)	Sample Type	Number Of Composite Tissue Samples By Area			
			T1	T2	T3	T4
English sole	≥ 200	whole body	6	6	6	1
		fillet (skin on)	3	3	3	0
Starry flounder	≥ 200	whole body	0	0	0	3
		fillet (skin on)	0	0	0	1
Shiner surfperch	≥ 80	whole body	6	6	6	4
Dungeness crab	≥ 90	edible meat	1	0	3	0
		hepatopancreas	1	0	3	0
Slender crab	≥ 90	edible meat	3	3	0	0
		hepatopancreas	3	3	0	0

LDW – Lower Duwamish Waterway

The compositing plan took into consideration both sampling area and specimen length.[4] For English sole, starry flounder, and crabs, specimens were grouped by area for formation of the composite samples. Shiner surfperch specimens were grouped by subarea. A summary of each of the composite samples is presented in Table 2-9. Comprehensive compositing information is presented in Appendix B.

Table 2-9. Summary of composite tissue samples

SPECIES	AREA	SAMPLE IDS	NUMBER OF INDIVIDUALS	AVERAGE LENGTH (mm)	MINIMUM LENGTH (mm)	MAXIMUM LENGTH (mm)
English sole	T1	LDW-07-T1-M-ES-FL-comp1	5	246	200	306
		LDW-07-T1-M-ES-FL-comp2	5	230	201	270
		LDW-07-T1-M-ES-FL-comp3	5	243	209	293
		LDW-07-T1-M-ES-WB-comp1	5	252	204	331
		LDW-07-T1-M-ES-WB-comp2	5	243	200	276
		LDW-07-T1-M-ES-WB-comp3	5	246	214	296
		LDW-07-T1-M-ES-WB-comp4	5	243	204	297

[4] For slender crab, weight rather than length was taken into consideration.

Species	Area	Sample IDs	Number of Individuals	Average Length (mm)	Minimum Length (mm)	Maximum Length (mm)
		LDW-07-T1-M-ES-WB-comp5	5	241	207	287
		LDW-07-T1-M-ES-WB-comp6	5	233	211	280
	T1 total		***45***	***242***	***200***	***331***
	T2	LDW-07-T2-M-ES-FL-comp1	5	248	202	346
		LDW-07-T2-M-ES-FL-comp2	5	224	200	250
		LDW-07-T2-M-ES-FL-comp3	5	229	201	290
		LDW-07-T2-M-ES-WB-comp1	5	221	200	255
		LDW-07-T2-M-ES-WB-comp2	5	251	200	395
		LDW-07-T2-M-ES-WB-comp3	5	226	207	265
		LDW-07-T2-M-ES-WB-comp4	5	231	200	280
		LDW-07-T2-M-ES-WB-comp5	5	225	205	269
		LDW-07-T2-M-ES-WB-comp6	5	234	200	297
	T2 total		***45***	***232***	***200***	***395***
	T3	LDW-07-T3-M-ES-FL-comp1	5	235	205	290
		LDW-07-T3-M-ES-FL-comp2	5	271	212	359
		LDW-07-T3-M-ES-FL-comp3	5	266	209	373
		LDW-07-T3-M-ES-WB-comp1	5	263	211	339
		LDW-07-T3-M-ES-WB-comp2	5	262	211	327
		LDW-07-T3-M-ES-WB-comp3	5	263	209	371
		LDW-07-T3-M-ES-WB-comp4	5	251	201	342
		LDW-07-T3-M-ES-WB-comp5	5	261	215	335
		LDW-07-T3-M-ES-WB-comp6	5	262	200	387
	T3 total		***45***	***259***	***200***	***387***
	T4	LDW-07-T4-M-ES-WB-comp1	5	257	208	296
	T4 total		***5***	***257***	***208***	***296***
English sole total			**140**	**245**	**200**	**395**
Starry flounder	T4	LDW-07-T4-M-SF-FL-comp1	5	245	196	296
		LDW-07-T4-M-SF-WB-comp1	5	241	203	305
		LDW-07-T4-M-SF-WB-comp2	5	222	200	275
		LDW-07-T4-M-SF-WB-comp3	5	243	204	292
	T4 total		***20***	***238***	***196***	***305***
Starry flounder total			**20**	**238**	**196**	**305**

Species	Area	Sample IDs	Number of Individuals	Average Length (mm)	Minimum Length (mm)	Maximum Length (mm)
Shiner surfperch	T1	LDW-07-T1-A-SS-WB-comp1	10	106	91	120
		LDW-07-T1-B-SS-WB-comp1	10	115	96	129
		LDW-07-T1-C-SS-WB-comp1	10	106	95	118
		LDW-07-T1-D-SS-WB-comp1	10	107	92	125
		LDW-07-T1-E-SS-WB-comp1	10	114	92	140
		LDW-07-T1-F-SS-WB-comp1	10	116	93	140
	T1 total		***60***	***111***	***91***	***140***
	T2	LDW-07-T2-A-SS-WB-comp1	10	119	97	145
		LDW-07-T2-B-SS-WB-comp1	10	109	95	130
		LDW-07-T2-C-SS-WB-comp1	10	115	95	132
		LDW-07-T2-D-SS-WB-comp1	10	119	92	140
		LDW-07-T2-E-SS-WB-comp1	10	111	97	122
		LDW-07-T2-F-SS-WB-comp1	10	119	91	140
	T2 total		***60***	***115***	***91***	***145***
	T3	LDW-07-T3-A-SS-WB-comp1	10	112	99	123
		LDW-07-T3-B-SS-WB-comp1	10	115	100	136
		LDW-07-T3-C-SS-WB-comp1	10	114	95	147
		LDW-07-T3-D-SS-WB-comp1	10	124	110	149
		LDW-07-T3-E-SS-WB-comp1	10	127	111	141
		LDW-07-T3-F-SS-WB-comp1	10	107	95	120
	T3 total		***60***	***117***	***95***	***149***
	T4	LDW-07-T4-A-SS-WB-comp1	10	115	92	138
		LDW-07-T4-B-SS-WB-comp1	10	120	105	141
		LDW-07-T4-C-SS-WB-comp1	10	111	90	140
		LDW-07-T4-D-SS-WB-comp1	10	116	99	134
	T4 total		***40***	***116***	***90***	***141***
Shiner surfperch total			**220**	**114**	**90**	**149**
Dungeness crab	T1	LDW-07-T1-M-DC-EM-comp1 LDW-07-T1-M-DC-HP-comp1	4	109	91	135
	T1 total		***4***	***109***	***91***	***135***
	T3	LDW-07-T3-M-DC-EM-comp1 LDW-07-T3-M-DC-HP-comp1	5	124	114	136

Species	Area	Sample IDs	Number of Individuals	Average Length (mm)	Minimum Length (mm)	Maximum Length (mm)
		LDW-07-T3-M-DC-EM-comp2 LDW-07-T3-M-DC-HP-comp2	5	121	110	132
		LDW-07-T3-M-DC-EM-comp3 LDW-07-T3-M-DC-HP-comp3	5	125	112	135
	T3 total		***15***	***123***	***110***	***136***
Dungeness crab total			**19**	**120**	**91**	**136**
Slender crab	T1	LDW-07-T1-M-SC-EM-comp1 LDW-07-T1-M-SC-HP-comp1	5	96	90	100
		LDW-07-T1-M-SC-EM-comp2 LDW-07-T1-M-SC-HP-comp2	5	96	90	101
		LDW-07-T1-M-SC-EM-comp3 LDW-07-T1-M-SC-HP-comp3	5	96	90	102
	T1 total		***15***	***96***	***90***	***102***
	T2	LDW-07-T2-M-SC-EM-comp1 LDW-07-T2-M-SC-HP-comp1	5	92	90	97
		LDW-07-T2-M-SC-EM-comp2 LDW-07-T2-M-SC-HP-comp2	5	96	90	108
		LDW-07-T2-M-SC-EM-comp3 LDW-07-T2-M-SC-HP-comp3	5	94	88	98
	T2 total		***15***	***94***	***88***	***108***
Slender crab total			**30**	**95**	**88**	**108**

To create composite tissue samples for English sole and starry flounder, five individuals were assigned to each composite tissue sample by dividing all the specimens of a given species from a given area into five size classes and randomly selecting one individual from each size class per composite tissue sample. Gender was not considered during compositing of English sole, starry flounder samples, to be consistent with methods used in 2004 and 2005.

Composite crab tissue samples were created using the same approach described above except gender was considered. Composite tissue samples of Dungeness crabs from Area T3 included 8 males and 8 females, to be consistent with methods used in 2004 and 2005. For the Dungeness crab samples from Area T3, males and females were distributed into three size classes and randomly distributed to samples as described above. Gender was not considered in creating the single Dungeness crab composite tissue sample from Area T1 because all specimens captured were included in the sample. Gender was not considered in creation of the slender crab composite tissue samples because all specimens retained for analysis were males.

For shiner surfperch, with the exceptions noted in Table 2-10, composite samples were created for each subarea using all 10 specimens collected from a given subarea. Gender was not considered in compositing shiner surfperch samples to be consistent with methods used in 2004 and 2005.

Some of the specimens collected were not used in creating composite tissue samples. These specimens are summarized in Table 2-10.

Table 2-10. Individual fish and crab specimens excluded from composite tissue samples

Species	Area	Subarea	Number of Individuals	Min Length (mm)	Max Length (mm)
Dungeness crab	T3	F	1[a]	110	110
	T4	B	1[b]	122	122
English sole	T1	A	1[a]	200	200
	T3	DEF	1[a]	181	181
Shiner surfperch	T1	E	1[a]	140	140
	T1	F	2[a]	72	72
Starry flounder	T3	BD	1[c]	291	291
	T3	AC	1[c]	270	270

[a] These fish specimens were less than the targeted length and/or they were not needed to meet the targeted number of specimens for a composite tissue sample.

[b] No Dungeness crab composite tissue samples were created for Area T4 because not enough crabs were collected.

[c] Starry flounder samples from Area T3 were not needed as surrogates for English sole because a sufficient number of English sole were captured from Area T3.

2.2 LDW Clam Tissue and Co-located Sediment Sampling and Processing

Clams and co-located sediment samples were collected from the LDW during low tide from August 24 through 28, 2007. This section describes the species targeted for collection, sampling locations, sampling collection and processing methods, the catch results, and the sample ID scheme.

2.2.1 Targeted species and collection areas

As discussed in the QAPP addendum (Windward 2007c), Eastern soft-shelled clams (*Mya arenaria)* were targeted for collection. Fifteen intertidal locations in the LDW were sampled (Figure 2-7; Table 2-11). The sampling locations and design were the same as those used in 2004 (Windward 2004b), with the following exceptions:

- One composite tissue sample from depurated clams and one composite tissue sample from non-depurated clams were created for each location sampled to

evaluate the potential effect of depuration on chemical concentrations. In 2004, none of the clam specimens were depurated prior to homogenization (Windward 2005).

- Two new intertidal clam sampling locations (C11 from RM 2.9 to RM 3.4 and C12 from RM 3.8 to RM 4.0) were added. Although the habitat quality was low (Windward 2004a), C11 was added to evaluate abundance and tissue concentrations of clams from the beach adjacent to Duwamish Waterway Park, a location easily accessed by the public. Location C12 was added because this beach has medium habitat quality (Windward 2004a) and elevated arsenic concentrations in surface sediment (Windward 2007a).
- Although two samples were collected from location C7 in 2004, only one sample was collected from C7 in 2007 because this beach is similar in size to the smaller beaches.

Table 2-11. Clam sampling location coordinates in the LDW

Clamming Area	Collection Date	Clam Sampling Location[a,b]	
		X	Y
C1	8/25/2007	1266011	210326
C2-1	8/24/2007	1266665	207534
C2-2	8/25/2007	1266846	206986
C3-1	8/24/2007	1265929	207871
C3-2	8/24/2007	1265860	207283
C4	8/25/2007	1267954	203985
C5	8/26/2007	1269239	202501
C6	8/25/2007	1269713	200959
C7	8/26/2007	1273505	199265
C8	8/26/2007	1273526	199371
C9	8/25/2007	1272381[c]	198314[c]
C10-1	8/27/2007	1275519[c]	195412[c]
C10-2	8/26/2007	1275851	194249
C11	8/27/2007	1273045[c]	197703[c]
C12	8/28/2007	1276108	194752

[a] State plane coordinates (WA State Plane N, US feet) based on the North American Datum (NAD) of 1983.

[b] GPS coordinates represent the approximate mid-point of each clam sampling location.

[c] Coordinates are estimates because the GPS equipment was not functioning properly at the time these locations were sampled.

LDW – Lower Duwamish Waterway

2.2.2 Collection methods

Clams were collected according to the catch per unit effort (CPUE) method used in 2004 (Windward 2004b). The method involved three field crew members actively searching for and collecting clams from locations within the intertidal area with the highest clam abundance, as determined by evidence of siphon holes. Sufficient numbers of clams were collected for two composite tissue samples (one depurated and one non-depurated) at each location (i.e., at least 20 clams with shell widths of at least 2 cm were collected for each composite tissue sample). The collection effort for the two composite tissue samples was a function of the length of the beach, the substrate (avoiding, when possible, soft mud that made digging difficult), and the availability of clams on the beach.

The collection effort targeted siphon holes. When a siphon hole was located, a hole was initiated with a shovel to retrieve the clam. In many cases, hand digging was also required to retrieve clams without breaking shells. At each of the holes where undamaged clams were collected, approximately 50 mL of the first shovelful of sediment was collected into a 50 mL beaker. All of the 50 mL aliquots of sediment from the hole where each clam was collected were composited and homogenized in the field. This homogenized sediment was used to fill one 4-oz glass jar (for planned analyses) and one 8-oz glass jar (to archive for potential additional analyses), leaving a minimum of 1 cm of headspace to prevent breakage during shipping and storage. All containers were sealed and appropriately labeled. Excess sediment was left at the beach where it was collected. A field duplicate sediment sample was collected at sampling location C10-2, selected in the field by the field coordinator.

All clams collected at each sampling location were rinsed in a decontaminated plastic bucket with site water until visible traces of sediment were removed. These buckets with clams were then filled with site water and transported to Windward for further processing. Buckets were labeled in indelible ink with the location name, time, and date. All other pertinent information was recorded in the field notebook and field collection forms (Appendix H).

2.2.3 Sample processing

At the Windward laboratory, clams were removed from the buckets, measured to the nearest 1 mm and weighed to the nearest 1 g, and recorded on the Clam Collection Form (Appendix H). Two composite tissue samples of at least 20 clams each were randomly selected from each sampling area; one for a non-depurated sample and one for a depurated sample (Table 2-12). A total of 631 clams of target size were collected and processed. Target numbers of clams specified in the QAPP addendum (Windward 2007c) were met or exceeded for each location. Average lengths ranged from 67 to 81 mm across the sampling areas, and average weights ranged from 43 to 67 g. Length and weight data for each clam specimen are presented in Appendix B.

Table 2-12. Average weights and lengths of clams collected at each sampling location, and numbers of clams in each composite tissue sample

Sampling Location	Average Length[a] (mm)	Average Weight[a] (g)	Number of Clams in Depurated Composite Tissue Sample	Number of Clams in Non-Depurated Composite Tissue Sample
C1	73	48	21	22
C2-1	73	49	20	21
C2-2	78	60	20	21
C3-1	70	48	20	20
C3-2	67	43	20	21
C4	69	44	20	21
C5	81	67	21	21
C6	80	64	21	22
C7	70	49	21	21
C8	70	43	20	22
C9	79	63	20	21
C10-1	77	58	23	23
C10-2	75	51	20	20
C11	81	63	22	22
C12	71	45	22	22

[a] Average lengths and weights are for all clams (depurated and non-depurated) collected at each location.

All non-depurated clams from a given location were kept together in one zip-lock bag and stored in a cooler on ice with the date, time, effort number, species, and collection method recorded on the outside of the bag in indelible ink.

The clams selected for depuration were also kept together in one zip-lock bag (unsealed) and placed in a cooler on ice with the date, time, effort number, species, and collection method recorded on the outside of the bag in indelible ink. These clams were transported within an hour of processing to the Port of Seattle boathouse at Terminal 91. Clams were depurated at the boathouse for 24 hours according to modified American Society for Testing and Materials (ASTM) guidelines (ASTM 2001). Specifically, clams and a label sealed in a zip-lock bag were placed in decontaminated plastic jars that were perforated on all sides to allow minimally interrupted water flow. Jars were filled no more than two-thirds full with clams to minimize crowding, and then placed within a nylon frame to exclude potential predators. The frame was then suspended in the water 3 to 5 ft beneath the boathouse for 24 (±2) hours. During depuration, clams from different sampling areas were separated to the extent possible to minimize potential cross contamination. After the depuration period, clams from each location were placed together in one zip-lock bag labeled with the date, time, effort number, species, and collection method. The bagged clams were placed in a cooler on wet ice and transported back to Windward.

The bagged clams (both depurated and non-depurated samples) were wrapped in bubble wrap to prevent breakage and placed in a cooler on wet ice for transportation to Brooks Rand Laboratory (Brooks Rand). Clam samples were transported to Brooks Rand within 24 hrs of processing or held at 4 (±2) °C until the next business day. The co-located sediment samples collected with the clam samples were transported to Brooks Rand along with the clam samples.

Clams within each bag were shucked and homogenized together to form separate composite tissue samples at Brooks Rand following their standard operating procedures. Laboratory notes regarding tissue preparation are presented in Appendix E. All composite clam tissue samples were analyzed for total arsenic, inorganic arsenic, and total solids by Brooks Rand. Subsamples of clam tissue from each homogenized composite sample were frozen and then sent to ARI for lipid analyses (all samples) and PCB Aroclor analyses (subset of samples). The remaining tissue samples were archived frozen at each laboratory for possible future analyses.

Sediment in the 4-oz jars was analyzed for total solids and total arsenic by Brooks Rand, and sediment remaining after those analyses was archived frozen at Brooks Rand. The 8-oz jars of sediment were archived frozen at ARI for possible future analysis.

2.2.4 Sample identification scheme

Unique alphanumeric sample ID numbers were assigned to each composite clam tissue sample and each co-located sediment sample (Tables 2-13 and 2-14). For example, the depurated clam tissue sample consisting of composited individual clams collected from location C10-1 was identified as LDW-07-C10-1-comp-dep. The co-located sediment sample from location C1 was identified as LDW-07-C1-S.

Table 2-13. ID scheme for composite clam tissue samples

IDENTIFIER	DESCRIPTION
LDW	Identifies the project area
07	Identifies the year collected
C1 to C12[a]	Identifies the sampling area
comp	Indicates the sample as being composited
dep	Identifies the sample as being depurated when applicable

Note: Sequential numbers were added to identify individual specimens during the weighing and measuring process, as documented in Appendix B.

[a] In areas with two locations, the location identifier was followed by the number 1 or 2 (e.g., C10-1 and C10-2).

Table 2-14. ID scheme for co-located sediment samples

IDENTIFIER	DESCRIPTION
LDW	Identifies the project area

IDENTIFIER	DESCRIPTION
07	Identifies the year collected
C1 to C12[a]	Identifies the sampling location
S	Identifies sediment sample
FD	Identifies the field duplicate sample when applicable

[a] In areas with two locations, the location identifier was followed by the number 1 or 2 (e.g., C10-1 and C10-2).

2.3 FIELD DEVIATIONS FROM THE QAPP

Field deviations from the QAPP (Windward 2004b, 2007c) included minor modifications to collection and processing methods. These field deviations did not affect the data quality and are discussed in detail below.

Fish and crab tissue sampling

- The targeted numbers of composite tissue samples for English sole whole body (three) and fillets (one) in Area T4 were not met. Therefore, three starry flounder whole-body samples and one fillet sample were used as surrogates (Table 2-8). The single composite English sole whole-body tissue sample that was collected from Area T4 was retained for analysis.
- The targeted numbers of composite tissue samples for Dungeness crabs in Areas T1 (three), T2 (three), and T4 (one) were not met. Samples of slender crabs collected from Areas T1 and T2 (three samples from each area) were used as surrogates (Table 2-8). No crab sample was created from Area T4 because there was an insufficient number of crabs of either species to create a composite tissue sample. The single composite Dungeness crab tissue sample that was collected from Area T1 was retained for analysis.
- One slender crab (87 mm) was included in a composite tissue sample (edible meat composite sample LDW-07-T2-M-SC-EM-comp2 and the corresponding hepatopancreas composite sample LDW-07-T2-M-SC-HP-comp2) even though it was under the targeted length of 90 mm. It was included because no other specimen met the size requirement.
- The scale used for fish and crab specimens weighing over 300 g was accurate to 1 g rather than 0.5 g as specified in the QAPP.
- English sole gender data were not collected.

Clam and co-located sediment sampling

- For most locations (all except C10-1, C11, and C12), clams were randomly separated for the depurated or non-depurated composite tissue samples in the Windward lab rather than in the field, as specified in the QAPP. Clams were weighed using a scale accurate to 1 g rather than to 0.5 g.

- The total number of clams collected was 631 instead of 600, with 20 to 23 clams per composite sample. Extra clams were collected to insure that sufficient unbroken individuals were kept and available for processing.
- The ID scheme used for clamming and co-located sediment sampling locations that had two samples per location (C2, C3, and C10) was changed from using an a or b to distinguish between the two locations to using a 1 or 2.
- Only 36 clams were collected from location C8 on August 26, 2007, along with co-located sediment samples. An additional 6 clams were collected the following day, August 27, 2007, from the same area to obtain a sufficient number of clams for the composite tissue samples. Because clams collected on the first day represented over 80% of the total for that location, it was determined that additional sediment would not be collected along with the six additional clams collected on the second day.

3.0 Analytical Methods

The methods and procedures used to prepare and chemically analyze the composite tissue and sediment samples are described briefly in this section and in detail in the QAPPs (Windward 2004b, 2004c) and QAPP addendum (Windward 2007c). This section also discusses laboratory deviations from the QAPP.

Individual fish, crab, and clam specimens were hand-delivered to ARI or Brooks Rand where they were homogenized into composite tissue samples according to the compositing scheme presented in Section 2.1.4.3 for fish and crabs and in Section 2.2.4.3 for clams. Windward personnel oversaw the initial homogenization procedures to ensure that the correct specimens were included in the composite tissue samples created at ARI. Individual specimens used in each composite tissue sample are presented in Appendix B. Co-located sediment samples in the 4-oz jars were delivered to Brooks Rand for chemical analysis and samples in the 8-oz jars were delivered to ARI for archiving.

3.1 Tissue and Co-located Sediment Analytical Methods

3.1.1 Tissue analytical methods

All fish and crab tissue samples were analyzed for PCBs (as Aroclors). Following the Aroclor analyses, a subset of fish and crab tissue samples was selected for PCB congener analysis. Provided sufficient tissue mass remained following the PCB

Aroclor analyses,[5] samples for PCB congener analysis were selected to provide spatial coverage, to represent a range of total PCB concentrations based on the PCB Aroclor results, and to include any samples with differing percentages of specific PCB Aroclors.

All clam tissue samples were analyzed for both total and inorganic arsenic and a subset of the samples were analyzed for PCBs (as Aroclors). Clam tissue samples analyzed for PCB Aroclors were identified in the QAPP addendum (Windward 2007c); the sample locations were selected to cover the range of total PCB concentrations in 2004 clam samples and to provide spatial coverage. All tissue samples were analyzed for lipids and total solids. The data validation reports (Appendix F) provide a complete list of the individual samples in each sample delivery group (SDG).

The analytical methods are identified in Table 3-1. The analytical methods followed by ARI, Brooks Rand, and Axys adhered to the most recent EPA quality assurance/ quality control (QA/QC) guidelines and standard analysis protocols (EPA 2002; PSEP 1997b). Aliquots from each fish and crab tissue sample have been archived frozen at ARI and aliquots from each clam sample have been archived frozen at Brooks Rand.

Table 3-1. Analytical methods for fish, crab, and clam tissue analyses

Analyte	Method	Reference	Laboratory that Conducted the Analysis
PCB congeners	HRGC/HRMS	EPA 1668	Axys
PCBs as Aroclors	GC/ECD	EPA 8082	ARI
Total arsenic	ICP-MS	EPA 6020	Brooks Rand
Inorganic arsenic	HG-AFS	EPA 1632	Brooks Rand
Lipids	DCM extraction gravimetric	NOAA (1993)	ARI
Total solids	Oven-dried	NOAA (1993) or PSEP (1997a)	Brooks Rand (clam tissue) and ARI (fish and crab tissue)

ARI – Analytical Resources, Inc.

Axys – Axys Analytical Services, Ltd.

DCM –dichloromethane

GC/ECD – gas chromatography/electron capture detection

GC/MS – gas chromatography/mass spectrometry

HG-AFS – hydride generation atomic fluorescence spectrometry

HRGC/HRMS – high resolution gas chromatography/high resolution mass spectrometry

ICP-MS – inductively coupled plasma mass spectrometry

PCB – polychlorinated biphenyl

[5] Several crab hepatopancreas samples had insufficient remaining sample volume for PCB congener analysis.

3.1.2 Co-located sediment analytical methods

All co-located sediment samples were analyzed for total arsenic and total solids at Brooks Rand. The analytical methods are identified in Table 3-2. The analytical methods followed by Brooks Rand adhered to the most recent EPA QA/QC guidelines and standard analysis protocols (EPA 2002; PSEP 1997b). Separate sample jars from each co-located sediment sample were archived frozen at ARI. All methods selected represent standard methods used for the analysis of total arsenic and total solids in sediment.

Table 3-2. Analytical methods for co-located sediment analyses

PARAMETER	METHOD	REFERENCE	LABORATORY THAT CONDUCTED THE ANALYSIS
Total arsenic	ICP-MS	EPA 6020	Brooks Rand
Total solids	oven-dried	PSEP (1986)	Brooks Rand

ICP-MS – inductively coupled plasma mass spectrometry

3.2 LABORATORY DEVIATIONS FROM THE QAPP

The number of samples analyzed for PCB congeners was greater than the number specified in the QAPP addendum (Windward 2007c). In addition to the samples selected in consultation with EPA, LDWG selected an additional seven samples for PCB congener analysis (three shiner surfperch whole-body samples [one each from Areas T1, T2, and T3], three English sole whole-body samples [one each from Areas T1, T2, and T3], and one slender crab edible-meat sample [from Area T1]). These additional samples were analyzed to facilitate the comparison of total PCB concentrations based on the analysis of PCB Aroclors versus the total PCB concentrations based on the analysis of PCB congeners.

There were no other laboratory deviations from the methods and procedures described in the QAPP s (Windward 2004b, 2004c) and QAPP addendum (Windward 2007c).

4.0 Results of Chemical Analyses

This section presents results of the chemical analyses and data validation of the fish and crab tissue samples and the clam tissue samples and co-located sediment samples. Laboratory report forms are presented in Appendix G. The approach used to average laboratory replicates, and the methods for calculating concentrations of total PCBs and toxic equivalents (TEQs) are presented in Appendix D. The number of significant figures shown for each concentration was as reported by the analytical laboratories.

QA review of the chemistry data was conducted in accordance with the QA/QC requirements and technical specifications of the methods and the national functional

guidelines for organic and inorganic data review (EPA 1999, 2002). Laboratory Data Consultants, Inc. (LDC) conducted the data validation. The results of the data validation are summarized in Section 4.2 and presented in full in Appendix F.

4.1 TISSUE AND SEDIMENT CHEMISTRY RESULTS

This section presents analytical chemistry results for PCB Aroclors analyzed in fish, crab, and clam tissue samples; for PCB congeners analyzed in a subset of fish and crab tissue samples; and for arsenic analyzed in clam tissue samples and in co-located sediment samples. Results for conventional parameters (i.e., lipids and total solids) are also presented.

4.1.1 PCB Aroclors

Table 4-1 presents a summary of the individual PCB Aroclor concentrations and the concentrations for each tissue type. Aroclors 1248, 1254, and 1260 were detected in fish, crab, or clam tissue samples; at least one of these Aroclors was detected in every tissue sample. Aroclors 1254 and 1260 were the most frequently detected Aroclors. Aroclor 1248 was detected in a relatively small number of samples: four English sole fillet samples, six slender crab edible meat samples, and three Dungeness crab edible meat samples.

Table 4-1. Detection frequencies and concentrations of PCBs (as individual Aroclors or Aroclor sums) in fish, crab, and clam composite tissue samples

Analyte	Unit	Detection Frequency	Detected Concentration			Reporting Limit[a]	
			Minimum	Maximum	Mean[b]	Minimum	Maximum
English sole – whole body							
Aroclor-1016	µg/kg ww	0/19	nd	nd	nd	40	100
Aroclor-1221	µg/kg ww	0/19	nd	nd	nd	40	100
Aroclor-1232	µg/kg ww	0/19	nd	nd	nd	40	100
Aroclor-1242	µg/kg ww	0/19	nd	nd	nd	40	100
Aroclor-1248	µg/kg ww	0/19	nd	nd	nd	40	150
Aroclor-1254	µg/kg ww	19/19	210	1,000 J	410	na	na
Aroclor-1260	µg/kg ww	19/19	93	620 J	280	na	na
Total PCBs[c]	µg/kg ww	19/19	300	1,600 J	680	na	na
English sole – fillet (skin on)							
Aroclor-1016	µg/kg ww	0/9	nd	nd	nd	40	40
Aroclor-1221	µg/kg ww	0/9	nd	nd	nd	40	40
Aroclor-1232	µg/kg ww	0/9	nd	nd	nd	40	40
Aroclor-1242	µg/kg ww	0/9	nd	nd	nd	40	40
Aroclor-1248	µg/kg ww	4/9	55	61	58	40	40
Aroclor-1254	µg/kg ww	9/9	120	300	210	na	na

Analyte	Unit	Detection Frequency	Detected Concentration			Reporting Limit[a]	
			Minimum	Maximum	Mean[b]	Minimum	Maximum
Aroclor-1260	µg/kg ww	9/9	52	150	110	na	na
Total PCBs[c]	µg/kg ww	9/9	170	500	350	na	na
Shiner surfperch – whole body							
Aroclor-1016	µg/kg ww	0/22	nd	nd	nd	59	60
Aroclor-1221	µg/kg ww	0/22	nd	nd	nd	59	60
Aroclor-1232	µg/kg ww	0/22	nd	nd	nd	59	60
Aroclor-1242	µg/kg ww	0/22	nd	nd	nd	59	60
Aroclor-1248	µg/kg ww	0/22	nd	nd	nd	59	60
Aroclor-1254	µg/kg ww	22/22	86 J	420 J	190	na	na
Aroclor-1260	µg/kg ww	22/22	110 J	910 J	270	na	na
Total PCBs[c]	µg/kg ww	22/22	200 J	1,330 J	450	na	na
Starry flounder – whole body							
Aroclor-1016	µg/kg ww	0/3	nd	nd	nd	40	40
Aroclor-1221	µg/kg ww	0/3	nd	nd	nd	40	40
Aroclor-1232	µg/kg ww	0/3	nd	nd	nd	40	40
Aroclor-1242	µg/kg ww	0/3	nd	nd	nd	40	40
Aroclor-1248	µg/kg ww	0/3	nd	nd	nd	40	40
Aroclor-1254	µg/kg ww	3/3	80	110	94	na	na
Aroclor-1260	µg/kg ww	3/3	76	130	95	na	na
Total PCBs[c]	µg/kg ww	3/3	156	240	190	na	na
Starry flounder – fillet (skin on)							
Aroclor-1016	µg/kg ww	0/1	nd	nd	nd	40	40
Aroclor-1221	µg/kg ww	0/1	nd	nd	nd	40	40
Aroclor-1232	µg/kg ww	0/1	nd	nd	nd	40	40
Aroclor-1242	µg/kg ww	0/1	nd	nd	nd	40	40
Aroclor-1248	µg/kg ww	0/1	nd	nd	nd	40	40
Aroclor-1254	µg/kg ww	1/1	63	63	63	na	na
Aroclor-1260	µg/kg ww	0/1	nd	nd	nd	40	40
Total PCBs[c]	µg/kg ww	1/1	63	63	63	na	na
Dungeness crab – edible meat							
Aroclor-1016	µg/kg ww	0/4	nd	nd	nd	4.0	4.0
Aroclor-1221	µg/kg ww	0/4	nd	nd	nd	4.0	4.0
Aroclor-1232	µg/kg ww	0/4	nd	nd	nd	4.0	4.0
Aroclor-1242	µg/kg ww	0/4	nd	nd	nd	4.0	4.0
Aroclor-1248	µg/kg ww	3/4	8.5	9.9 J	9.1	4.0	4.0
Aroclor-1254	µg/kg ww	4/4	10	24 J	18	na	na
Aroclor-1260	µg/kg ww	4/4	4.7	17 J	11	na	na
Total PCBs[c]	µg/kg ww	4/4	15	51 J	36	na	na

Analyte	Unit	Detection Frequency	Detected Concentration			Reporting Limit[a]	
			Minimum	Maximum	Mean[b]	Minimum	Maximum
Dungeness crab – hepatopancreas							
Aroclor-1016	µg/kg ww	0/4	nd	nd	nd	40	40
Aroclor-1221	µg/kg ww	0/4	nd	nd	nd	40	40
Aroclor-1232	µg/kg ww	0/4	nd	nd	nd	40	40
Aroclor-1242	µg/kg ww	0/4	nd	nd	nd	40	40
Aroclor-1248	µg/kg ww	0/4	nd	nd	nd	40	80
Aroclor-1254	µg/kg ww	4/4	180	550	310	na	na
Aroclor-1260	µg/kg ww	4/4	100	470	250	na	na
Total PCBs[c]	µg/kg ww	4/4	280	1,020	560	na	na
Slender crab – edible meat							
Aroclor-1016	µg/kg ww	0/6	nd	nd	nd	4.0	4.0
Aroclor-1221	µg/kg ww	0/6	nd	nd	nd	4.0	4.0
Aroclor-1232	µg/kg ww	0/6	nd	nd	nd	4.0	4.0
Aroclor-1242	µg/kg ww	0/6	nd	nd	nd	4.0	4.0
Aroclor-1248	µg/kg ww	6/6	5.4	8.4	7.2	na	na
Aroclor-1254	µg/kg ww	6/6	14	26	22	na	na
Aroclor-1260	µg/kg ww	6/6	6.4	17	12	na	na
Total PCBs[c]	µg/kg ww	6/6	27	48 J	41	na	na
Slender crab – hepatopancreas							
Aroclor-1016	µg/kg ww	0/6	nd	nd	nd	40	60
Aroclor-1221	µg/kg ww	0/6	nd	nd	nd	40	60
Aroclor-1232	µg/kg ww	0/6	nd	nd	nd	40	60
Aroclor-1242	µg/kg ww	0/6	nd	nd	nd	40	60
Aroclor-1248	µg/kg ww	0/6	nd	nd	nd	40	90
Aroclor-1254	µg/kg ww	6/6	160	360	240	na	na
Aroclor-1260	µg/kg ww	6/6	90	300	160	na	na
Total PCBs[c]	µg/kg ww	6/6	250	660	400	na	na
Clams – non-depurated, edible meat							
Aroclor-1016	µg/kg ww	0/6	nd	nd	nd	20	20
Aroclor-1221	µg/kg ww	0/6	nd	nd	nd	20	20
Aroclor-1232	µg/kg ww	0/6	nd	nd	nd	20	20
Aroclor-1242	µg/kg ww	0/6	nd	nd	nd	20	120
Aroclor-1248	µg/kg ww	0/6	nd	nd	nd	20	20
Aroclor-1254	µg/kg ww	6/6	15 J	310	83	na	na
Aroclor-1260	µg/kg ww	1/6	170	170	170	20	20
Total PCBs[c]	µg/kg ww	6/6	15 J	310	110	na	na
Clams – depurated, edible meat							
Aroclor-1016	µg/kg ww	0/6	nd	nd	nd	20	20
Aroclor-1221	µg/kg ww	0/6	nd	nd	nd	20	20

Analyte	Unit	Detection Frequency	Detected Concentration			Reporting Limit[a]	
			Minimum	Maximum	Mean[b]	Minimum	Maximum
Aroclor-1232	µg/kg ww	0/6	nd	nd	nd	20	20
Aroclor-1242	µg/kg ww	0/6	nd	nd	nd	20	99
Aroclor-1248	µg/kg ww	0/6	nd	nd	nd	20	20
Aroclor-1254	µg/kg ww	6/6	14 J	190	66	na	na
Aroclor-1260	µg/kg ww	1/6	200	200	200	20	20
Total PCBs[c]	µg/kg ww	6/6	14 J	270	98	na	na

[a] Range of reporting limits for non-detect samples.

[b] Mean concentrations are the average of only the detected concentrations.

[c] The method for calculating total PCBs is presented in Appendix D.

na – not applicable

nd – not detected

J – estimated concentration

PCB – polychlorinated biphenyl

ww – wet weight

Total PCB concentrations (based on Aroclor sums) ranged from 156 to 1,600 µg/kg ww in fish whole-body composite samples, 63 to 500 µg/kg ww in English sole and starry flounder fillet composite samples, 15 to 51 µg/kg ww in crab edible meat composite samples, 250 to 1,020 µg/kg ww in crab hepatopancreas composite samples, and 14 to 310 µg/kg ww in clam composite samples (including both depurated and non-depurated).

In whole-body fish, mean total PCB concentrations were highest in English sole (680 µg/kg ww; n=19), followed by shiner surfperch (450 µg/kg ww; n=22), and starry flounder (190 µg/kg ww; n=3). The mean total PCB concentration in the 9 English sole fillet samples was lower than the mean concentration in the 19 English sole whole-body composite samples (350 and 680 µg/kg ww, respectively). The total PCB concentration in the one starry flounder fillet sample (63 µg/kg ww) was lower than the mean concentration in the three starry flounder whole-body composite samples (190 µg/kg ww).In the four Dungeness crab and six slender crab samples, mean total PCB concentrations in hepatopancreas (560 and 400 µg/kg ww, respectively) were higher than in edible meat (36 and 41 µg/kg ww, respectively). Mean total PCB concentrations in the six depurated and six non-depurated clam samples were similar to each other (98 and 110 µg/kg ww, respectively).

Table 4-2 presents all individual Aroclor, total PCB, lipid, and solids data for each fish, crab, and clam composite sample analyzed. Both wet weight and lipid-normalized total PCB concentrations are also presented. The highest total PCB concentrations in English sole and shiner surfperch whole-body composite samples were collected from Area T3 (1,600 and 1,330 µg/kg ww, respectively). The lowest total PCB concentration in whole-body English sole was in a composite sample from Area T4 (300 µg/kg ww) and the lowest concentration in whole-body shiner surfperch was in a composite

Table 4-2. Summary of PCB Aroclor concentrations in fish, crab, and clam composite tissue samples, including wet weight and lipid-normalized total PCB concentrations (Aroclor sums)

Sample ID	Aroclor 1016 (µg/kg ww)	Aroclor 1221 (µg/kg ww)	Aroclor 1232 (µg/kg ww)	Aroclor 1242 (µg/kg ww)	Aroclor 1248 (µg/kg ww)	Aroclor 1254 (µg/kg ww)	Aroclor 1260 (µg/kg ww)	Total PCBs (µg/kg ww)[a]	Lipids (% ww)	Lipid-Normalized Total PCBs (mg/kg lipid)[b]	Total Solids (% ww)
English sole – whole body											
Area T1											
LDW-07-T1-M-ES-WB-comp1	60 U	60 U	60 U	60 U	60 U	240	170	410	4.62	8.9	23.27
LDW-07-T1-M-ES-WB-comp2	100 U	100 U	100 U	100 U	100 U	460	320	780	7.20	11	25.99
LDW-07-T1-M-ES-WB-comp3	60 U	60 U	60 U	60 U	60 U	240	220	460	6.85	6.7	25.48
LDW-07-T1-M-ES-WB-comp4	100 U	100 U	100 U	100 U	100 U	440	280	720	6.50	11	27.81
LDW-07-T1-M-ES-WB-comp5	60 U	60 U	60 U	60 U	60 U	220	200	420	3.83	11	24.66
LDW-07-T1-M-ES-WB-comp6	60 U	60 U	60 U	60 U	60 U	230	130	360	7.22	5.0	26.95
Area T2											
LDW-07-T2-A-ES-WB-comp1	60 U	60 U	60 U	60 U	60 U	310	240	550	5.46	10	26.63
LDW-07-T2-A-ES-WB-comp2	100 U	100 U	100 U	100 UJ	100 UJ	540 J	330 J	870 J	9.00	9.7 J	29.45
LDW-07-T2-A-ES-WB-comp3	100 U	100 U	100 U	100 U	100 U	350	280	630	5.82	11	27.42
LDW-07-T2-A-ES-WB-comp4	100 U	100 U	100 U	100 U	100 U	450	300	750	8.07	9.3	28.33
LDW-07-T2-A-ES-WB-comp5	60 U	60 U	60 U	60 U	60 U	240	140	380	4.46	8.5	24.13
LDW-07-T2-A-ES-WB-comp6	100 U	100 U	100 U	100 U	100 U	530	450	980	5.82	17	26.49
Area T3											
LDW-07-T3-M-ES-WB-comp1	40 U	40 U	40 U	40 U	40 U	610 J	300	910 J	4.43	21 J	23.03
LDW-07-T3-M-ES-WB-comp2	40 U	40 U	40 U	40 U	40 U	380 J	280	660 J	2.34	28 J	20.47
LDW-07-T3-M-ES-WB-comp3	40 U	40 U	40 U	40 U	40 U	500 J	260	760 J	6.64	11 J	26.44
LDW-07-T3-M-ES-WB-comp4	40 U	40 U	40 U	40 U	40 U	1,000 J	620 J	1,600 J	10.9	15 J	27.55
LDW-07-T3-M-ES-WB-comp5	60 U	60 U	60 U	60 U	150 U	460 J	370 J	830 J	9.90	8.4 J	27.55

Table 4-2, cont.. Summary of PCB Aroclor concentrations in fish, crab, and clam composite tissue samples, including wet weight and lipid-normalized total PCB concentrations (Aroclor sums)

Sample ID	Aroclor 1016 (µg/kg ww)	Aroclor 1221 (µg/kg ww)	Aroclor 1232 (µg/kg ww)	Aroclor 1242 (µg/kg ww)	Aroclor 1248 (µg/kg ww)	Aroclor 1254 (µg/kg ww)	Aroclor 1260 (µg/kg ww)	Total PCBs (µg/kg ww)[a]	Lipids (% ww)	Lipid-Normalized Total PCBs (mg/kg lipid)[b]	Total Solids (% ww)
LDW-07-T3-M-ES-WB-comp6	40 U	40 U	40 U	40 U	40 U	320	280	600	4.40	14	21.56
Area T4											
LDW-07-T4-M-ES-WB-comp1	40 U	40 U	40 U	40 U	80 U	210	93	300	4.62	6.5	23.04
English sole – fillet with skin											
Area T1											
LDW-07-T1-M-ES-FL-comp1	40 U	40 U	40 U	40 U	40 U	170	95	270	3.00	9.0	24.11
LDW-07-T1-M-ES-FL-comp2	40 U	40 U	40 U	40 U	58	300	140	500	4.11	12	23.87
LDW-07-T1-M-ES-FL-comp3	40 U	40 U	40 U	40 U	40 U	160	97	260	2.85	9.1	22.50
Area T2											
LDW-07-T2-A-ES-FL-comp1	40 U	40 U	40 U	40 U	40 U	220	130	350	3.14	11	23.17
LDW-07-T2-A-ES-FL-comp2	40 U	40 U	40 U	40 U	40 U	120	52	170	2.14	7.9	22.56
LDW-07-T2-A-ES-FL-comp3	40 U	40 U	40 U	40 U	56	210	90	360	3.63	9.9	23.02
Area T3											
LDW-07-T3-M-ES-FL-comp1	40 U	40 U	40 U	40 U	61	280	150	490	3.26	15	23.82
LDW-07-T3-M-ES-FL-comp2	40 U	40 U	40 U	40 U	55	220	100	380	2.96	13	22.78
LDW-07-T3-M-ES-FL-comp3	40 U	40 U	40 U	40 U	40 U	220	120	340	1.77	19	19.64
Shiner perch – whole body											
Area T1											
LDW-07-T1-A-SS-WB-comp1	60 U	60 U	60 U	60 UJ	60 UJ	86 J	110 J	200 J	2.57	7.8 J	24.58
LDW-07-T1-B-SS-WB-comp1	60 U	60 U	60 U	60 UJ	60 UJ	94 J	130 J	220 J	2.20	10 J	23.82
LDW-07-T1-C-SS-WB-comp1	60 U	60 U	60 U	60 UJ	60 UJ	150 J	210 J	360 J	4.94	7.3 J	25.68
LDW-07-T1-D-SS-WB-comp1	60 U	60 U	60 U	60 U	60 U	110	140	250	1.80	14	25.79
LDW-07-T1-E-SS-WB-comp1	60 U	60 U	60 U	60 UJ	60 UJ	130 J	140 J	270 J	3.99	6.8 J	25.74

Table 4-2, cont.. Summary of PCB Aroclor concentrations in fish, crab, and clam composite tissue samples, including wet weight and lipid-normalized total PCB concentrations (Aroclor sums)

Sample ID	Aroclor 1016 (µg/kg ww)	Aroclor 1221 (µg/kg ww)	Aroclor 1232 (µg/kg ww)	Aroclor 1242 (µg/kg ww)	Aroclor 1248 (µg/kg ww)	Aroclor 1254 (µg/kg ww)	Aroclor 1260 (µg/kg ww)	Total PCBs (µg/kg ww)[a]	Lipids (% ww)	Lipid-Normalized Total PCBs (mg/kg lipid)[b]	Total Solids (% ww)
LDW-07-T1-F-SS-WB-comp1	60 U	60 U	60 U	60 UJ	60 UJ	140 J	170 J	310 J	3.30	9.4 J	26.06
Area T2											
LDW-07-T2-A-SS-WB-comp1	60 U	60 U	60 U	60 UJ	60 UJ	150 J	170 J	320 J	2.90	11 J	24.30
LDW-07-T2-B-SS-WB-comp1	60 U	60 U	60 U	60 UJ	60 UJ	140 J	150 J	290 J	4.40	6.6 J	25.47
LDW-07-T2-C-SS-WB-comp1	60 U	60 U	60 U	60 UJ	60 UJ	190 J	210 J	400 J	3.32	12 J	24.38
LDW-07-T2-D-SS-WB-comp1	60 U	60 U	60 U	60 UJ	60 UJ	200 J	200 J	400 J	4.86	8.2 J	26.67
LDW-07-T2-E-SS-WB-comp1	60 U	60 U	60 U	60 UJ	60 UJ	250 J	220 J	470 J	4.46	11 J	25.10
LDW-07-T2-F-SS-WB-comp1	60 U	60 U	60 U	60 UJ	60 UJ	290 J	320 J	610 J	4.31	14 J	24.15
Area T3											
LDW-07-T3-A-SS-WB-comp1	60 U	60 U	60 U	60 UJ	60 UJ	170 J	260 J	430 J	3.70	12 J	24.04
LDW-07-T3-B-SS-WB-comp1	60 U	60 U	60 U	60 UJ	60 UJ	290 J	490 J	780 J	4.41	18 J	25.86
LDW-07-T3-C-SS-WB-comp1	60 U	60 U	60 U	60 UJ	60 UJ	200 J	320 J	520 J	4.54	11 J	25.61
LDW-07-T3-D-SS-WB-comp1	60 U	60 U	60 U	60 UJ	60 UJ	300 J	480 J	780 J	3.79	21 J	27.42
LDW-07-T3-E-SS-WB-comp1	60 U	60 U	60 U	60 UJ	60 UJ	200 J	540 J	740 J	3.43	22 J	25.78
LDW-07-T3-F-SS-WB-comp1	60 U	60 U	60 U	60 UJ	60 UJ	420 J	910 J	1,330 J	4.94	27 J	24.87
Area T4											
LDW-07-T4-A-SS-WB-comp1	59 U	59 U	59 U	59 UJ	59 UJ	130 J	130 J	260 J	4.78	5.4 J	25.41
LDW-07-T4-B-SS-WB-comp1	60 U	60 U	60 U	60 UJ	60 UJ	140 J	160 J	300 J	3.62	8.3 J	24.38
LDW-07-T4-C-SS-WB-comp1	59 U	59 U	59 U	59 UJ	59 UJ	130 J	160 J	290 J	4.16	7.0 J	24.91
LDW-07-T4-D-SS-WB-comp1	59 U	59 U	59 U	59 UJ	59 UJ	170 J	240 J	410 J	4.77	8.6 J	26.09
Starry flounder – whole body											
Area T4											
LDW-07-T4-M-SF-WB-comp1	40 U	40 U	40 U	40 U	40 U	110	130	240	3.29	7.3	21.45

Table 4-2, cont.. Summary of PCB Aroclor concentrations in fish, crab, and clam composite tissue samples, including wet weight and lipid-normalized total PCB concentrations (Aroclor sums)

Sample ID	Aroclor 1016 (µg/kg ww)	Aroclor 1221 (µg/kg ww)	Aroclor 1232 (µg/kg ww)	Aroclor 1242 (µg/kg ww)	Aroclor 1248 (µg/kg ww)	Aroclor 1254 (µg/kg ww)	Aroclor 1260 (µg/kg ww)	Total PCBs (µg/kg ww)[a]	Lipids (% ww)	Lipid-Normalized Total PCBs (mg/kg lipid)[b]	Total Solids (% ww)
LDW-07-T4-M-SF-WB-comp2	40 U	40 U	40 U	40 U	40 U	91	79	170	0.917	19	18.21
LDW-07-T4-M-SF-WB-comp3	40 U	40 U	40 U	40 U	40 U	80	76	156	1.64	9.5	21.04
Starry flounder – fillet with skin											
Area T4											
LDW-07-T4-M-SF-FL-comp1	40 U	40 U	40 U	40 U	40 U	63	40 U	63	2.23	2.8	20.81
Dungeness crab – hepatopancreas											
Area T1											
LDW-07-T1-M-DC-HP-comp1	40 U	40 U	40 U	40 U	40 U	180	100	280	3.72	7.5	15.42
Area T3											
LDW-07-T3-M-DC-HP-comp1	40 U	40 U	40 U	40 U	40 U	220	200	420	4.56	9.2	17.54
LDW-07-T3-M-DC-HP-comp2	40 U	40 U	40 U	40 U	80 U	300	220	520	6.00	8.7	20.40
LDW-07-T3-M-DC-HP-comp3	40 U	40 U	40 U	40 U	40 U	550	470	1,020	6.87	15	24.61
Dungeness crab – edible meat											
Area T1											
LDW-07-T1-M-DC-EM-comp1	4.0 U	4.0 U	4.0 U	4.0 U	4.0 U	10	4.7	15	0.440	3.4	15.80
Area T3											
LDW-07-T3-M-DC-EM-comp1	4.0 U	4.0 U	4.0 U	4.0 U	8.5	19	11	39	0.508	7.7	17.94
LDW-07-T3-M-DC-EM-comp2	4.0 U	4.0 U	4.0 U	4.0 U	9.0	20	11	40	0.644	6.2	18.67
LDW-07-T3-M-DC-EM-comp3	4.0 U	4.0 U	4.0 U	4.0 UJ	9.9 J	24 J	17 J	51 J	0.531	9.6 J	19.71
Slender crab – hepatopancreas											
Area T1											
LDW-07-T1-M-SC-HP-comp1	60 U	60 U	60 U	60 U	90 U	310	170	480	2.79	17	13.00

Table 4-2, cont.. Summary of PCB Aroclor concentrations in fish, crab, and clam composite tissue samples, including wet weight and lipid-normalized total PCB concentrations (Aroclor sums)

Sample ID	Aroclor 1016 (µg/kg ww)	Aroclor 1221 (µg/kg ww)	Aroclor 1232 (µg/kg ww)	Aroclor 1242 (µg/kg ww)	Aroclor 1248 (µg/kg ww)	Aroclor 1254 (µg/kg ww)	Aroclor 1260 (µg/kg ww)	Total PCBs (µg/kg ww)[a]	Lipids (% ww)	Lipid-Normalized Total PCBs (mg/kg lipid)[b]	Total Solids (% ww)
LDW-07-T1-M-SC-HP-comp2	60 U	60 U	60 U	60 U	90 U	280	200	480	1.71	28	19.09
LDW-07-T1-M-SC-HP-comp3	60 U	60 U	60 U	60 U	60 U	360	300	660	1.64	40	13.36
Area T2											
LDW-07-T2-M-SC-HP-comp1	40 U	40 U	40 U	40 U	40 U	160	90	250	3.90	6.4	11.66
LDW-07-T2-M-SC-HP-comp2	40 U	40 U	40 U	40 U	40 U	170	98	270	4.10	6.6	14.76
LDW-07-T2-M-SC-HP-comp3	40 U	40 U	40 U	40 U	40 U	170	97	270	3.07	8.8	16.37
Slender crab – edible meat											
Area T1											
LDW-07-T1-M-SC-EM-comp1	4.0 U	4.0 U	4.0 U	4.0 U	7.6	21	12	41	0.444	9.2	20.96
LDW-07-T1-M-SC-EM-comp2	4.0 U	4.0 U	4.0 U	4.0 U	7.2	22	12	41	0.428	9.6	21.07
LDW-07-T1-M-SC-EM-comp3	4.0 U	4.0 U	4.0 U	4.0 U	5.4	26 J	17	48 J	0.408	12 J	21.71
Area T2											
LDW-07-T2-M-SC-EM-comp1	4.0 U	4.0 U	4.0 U	4.0 U	8.4	21	11	40	0.592	6.8	20.86
LDW-07-T2-M-SC-EM-comp2	4.0 U	4.0 U	4.0 U	4.0 U	6.2	14	6.4	27	0.452	6.0	19.34
LDW-07-T2-M-SC-EM-comp3	4.0 U	4.0 U	4.0 U	4.0 U	8.2 J	26	12	46 J	0.628	7.3 J	21.03
Softshell clam – soft tissues, not including shell; non- depurated											
LDW-07-C2-1-comp	20 U	20 U	20 U	20 U	20 U	15 J	20 U	15 J	0.739	2.0 J	19.590
LDW-07-C6-comp	20 U	20 U	20 U	20 U	20 U	20	20 U	20	0.817	2.4	19.160
LDW-07-C7-comp	20 U	20 U	20 U	50 U	20 U	74	20 U	74	0.954	7.8	17.780
LDW-07-C8-comp	20 U	20 U	20 U	120 U	20 U	310	20 U	310	0.775	40	18.74
LDW-07-C9-comp	20 U	20 U	20 U	20 U	20 U	19 J	20 U	19 J	1.03	1.8 J	19.900
LDW-07-C10-1-comp	20 U	20 U	20 U	20 U	20 U	62	170	230	0.858	27	18.520

Table 4-2, cont.. Summary of PCB Aroclor concentrations in fish, crab, and clam composite tissue samples, including wet weight and lipid-normalized total PCB concentrations (Aroclor sums)

Sample ID	Aroclor 1016 (µg/kg ww)	Aroclor 1221 (µg/kg ww)	Aroclor 1232 (µg/kg ww)	Aroclor 1242 (µg/kg ww)	Aroclor 1248 (µg/kg ww)	Aroclor 1254 (µg/kg ww)	Aroclor 1260 (µg/kg ww)	Total PCBs (µg/kg ww)[a]	Lipids (% ww)	Lipid-Normalized Total PCBs (mg/kg lipid)[b]	Total Solids (% ww)
Softshell clam – soft tissues, not including shell; depurated											
LDW-07-C2-1-comp-dep	20 U	20 U	20 U	20 U	20 U	14 J	20 U	14 J	0.835	1.7 J	22.800
LDW-07-C6-comp-dep	20 U	20 U	20 U	20 U	20 U	17 J	20 U	17 J	0.878	1.9 J	23.930
LDW-07-C7-comp-dep	20 U	20 U	20 U	40 U	20 U	67	20 U	67	0.755	8.9	20.270
LDW-07-C8-comp-dep	20 U	20 U	20 U	99 U	20 U	190	20 U	190	0.974	20	23.18
LDW-07-C9-comp-dep	20 U	20 U	20 U	20 U	20 U	32	20 U	32	1.10	2.9	22.22
LDW-07-C10-1-comp-dep	20 U	20 U	20 U	20 U	20 U	73	200	270	0.920	29	21.26

[a] The method for calculating total PCBs is presented in Appendix D.

[b] Lipid-normalized concentrations (in units of mg PCBs/kg lipid) represent the wet-weight total PCB concentration (in units of mg/kg ww) divided by the decimal fraction corresponding to the percent lipid (e.g., 2.0% lipid = 0.02).

J – estimated concentration

PCB – polychlorinated biphenyl

U – not detected at the reporting limit shown

ww – wet weight

sample from Area T1 (200 µg/kg ww). Whole-body starry flounder samples were collected only from Area T4; the lowest total PCB concentration detected in any of the whole-body fish samples was in one of these starry founder composite samples (156 µg/kg ww).

Total PCB concentrations in English sole fillet samples were not highly variable; the lowest concentration was in a composite sample from Area T2 (170 µg/kg ww) and the highest concentration was in a composite sample from Area T1 (500 µg/kg ww). Only one starry flounder fillet composite sample was collected; this sample was from Area T4 and had a lower concentration (63 µg/kg ww) than any of the English sole fillet composite samples.

Dungeness crabs were collected in Areas T1 and T3. The highest total PCB concentrations in both hepatopancreas and edible meat of Dungeness crab were in composite samples from Area T3 (1,020 and 51 µg/kg ww, respectively) and the lowest concentrations were from Area T1 (280 and 15 µg/kg ww, respectively). Slender crabs were collected in Areas T1 and T2. The highest total PCB concentrations in both hepatopancreas and edible meat of slender crab were in composite samples from Area T1 (660 and 48 µg/kg ww, respectively) and the lowest concentrations were from Area T2 (250 and 27 µg/kg ww, respectively).

The highest total PCB concentrations detected in clams were in both the depurated and non-depurated composite samples collected from location C-8 in Slip 4 (190 and 310 µg/kg ww, respectively). The lowest concentrations were in depurated and non-depurated clams from location C-2-1 at the northern tip of Kellogg Island (14 and 15 µg/kg ww, respectively).

Table 4-2 also presents the lipid and total solids content (in percent wet weight) in each fish, crab, and clam composite sample. Lipid contents ranged from 2.34 to 10.9% in whole-body English sole, 1.8 to 4.94% in whole-body shiner surfperch, and 0.917 to 3.29% in whole-body starry flounder. Lipid content in English sole fillet samples (which ranged from 1.77 to 4.11%) was generally lower than in English sole whole-body samples. Lipid content in crab hepatopancreas samples (1.64 to 6.87%) was higher than in edible meat samples (0.408 to 0.644%). Lipid contents in clam samples ranged from 0.739 to 1.10%. Total solids content in all samples ranged from 11.66 to 29.45%.

In whole-body fish, lipid-normalized total PCB concentrations ranged from 5.0 to 28 mg/kg lipid in English sole and starry flounder and from 5.4 to 26.9 mg/kg lipid in shiner surfperch (Table 4-2). In English sole and starry flounder fillets, lipid-normalized total PCB concentrations ranged from 2.8 to 19 mg/kg lipid.

In crabs, lipid-normalized total PCB concentrations ranged from 3.4 to 12 mg/kg lipid in edible meat and from 6.4 to 40 mg/kg lipid in hepatopancreas. In clams, lipid-normalized total PCB concentrations ranged from 1.7 to 40 mg/kg lipid.

4.1.2 PCB congeners

This section presents the results of the PCB congener analyses for only the coplanar PCB congeners and total PCBs based on detected congener sums in the fish and crab tissue samples. The results for all 209 individual PCB congeners analyzed in fish and crab tissue samples are presented in Appendix A. TEQs in tissue were calculated using World Health Organization (WHO) toxic equivalence factors (TEFs) for mammals, which are available for coplanar PCB congeners PCB-077, PCB-081, PCB-105, PCB-114, PCB-118, PCB-123, PCB-126, PCB-156, PCB-157, PCB-167, PCB-169, and PCB-189 (Van den Berg et al. 2006). Methods for TEQ calculations are described in Appendix D. TEQs were calculated for the purposes of comparisons among the data; results were not used in the baseline risk assessment.

In many samples, two or more PCB congeners could not be separated analytically. In these samples, the congeners co-elute and the concentration of the combined congeners is reported as one value. The laboratory responsible for the PCB congener analyses (Axys Analytical Services, Ltd.) has the convention of assigning the concentration of the co-eluting congener to the congener with the lowest IUPAC number. For example, PCB-156 and PCB-157 co-elute and the concentration is reported as PCB-156. PCB-157 is reported as C156 to indicate that it is a component of a co-elution. This convention has been followed in presenting PCB congener data throughout this data report.

All of the coplanar PCB congeners were detected in all of the fish tissue samples and in the one crab hepatopancreas sample analyzed (Table 4-3). In crab edible meat, the only coplanar PCB congeners not detected were PCB-169 (not detected in the two Dungeness crab samples or in the two slender crab samples) and PCB-081 and PCB-126 (not detected in the two Dungeness crab samples).

Table 4-3. Detection frequencies and concentration ranges of coplanar PCB congeners in fish and crab composite tissue samples

Analyte	Unit	Detection Frequency	Detected Concentration			Reporting Limit[a]	
			Minimum	Maximum	Mean[b]	Minimum	Maximum
English sole – whole body							
PCB-077	ng/kg ww	6/6	181	1,030	452	na	na
PCB-081	ng/kg ww	6/6	18.0	87.3	40.0	na	na
PCB-105	ng/kg ww	6/6	9,030	37,400 J	18,400	na	na
PCB-114	ng/kg ww	6/6	708	2,700	1,310	na	na
PCB-118	ng/kg ww	6/6	31,100	136,000	65,800	na	na
PCB-123	ng/kg ww	6/6	480	2,090	1,040	na	na
PCB-126	ng/kg ww	6/6	41.7	184	96.2	na	na
PCB-156	ng/kg ww	6/6	5,000 C	20,500 C	10,600	na	na
PCB-157	ng/kg ww	6/6	C156	C156	C156	na	na
PCB-167	ng/kg ww	6/6	2,010	8,870	4,810	na	na
PCB-169	ng/kg ww	6/6	2.18	7.95	4.87	na	na
PCB-189	ng/kg ww	6/6	408	1,270	709	na	na

Analyte	Unit	Detection Frequency	Detected Concentration			Reporting Limit[a]	
			Minimum	Maximum	Mean[b]	Minimum	Maximum
Total PCBs[c]	µg/kg ww	6/6	774 J	2,928 J	1,520	na	na
PCB TEQ[d]	ng/kg ww	6/6	5.74	25.0 J	12.9	na	na
Shiner surfperch – whole body							
PCB-077	ng/kg ww	6/6	230	588	419	na	na
PCB-081	ng/kg ww	6/6	20.0	48.7	34.6	na	na
PCB-105	ng/kg ww	6/6	5,050	17,000	10,300	na	na
PCB-114	ng/kg ww	6/6	371	1,360	790	na	na
PCB-118	ng/kg ww	6/6	18,200	53,900	33,800	na	na
PCB-123	ng/kg ww	6/6	342	889	569	na	na
PCB-126	ng/kg ww	6/6	45.2	96.1	69.3	na	na
PCB-156	ng/kg ww	6/6	4,180 C	14,100 C	8,190	na	na
PCB-157	ng/kg ww	6/6	C156	C156	C156	na	na
PCB-167	ng/kg ww	6/6	1,890	5,860	3,630	na	na
PCB-169	ng/kg ww	6/6	1.75	5.11	3.39	na	na
PCB-189	ng/kg ww	6/6	304	1,980	856	na	na
Total PCBs[c]	µg/kg ww	6/6	401.6 J	2,462 J	1,020	na	na
PCB TEQ[d]	ng/kg ww	6/6	5.54 J	12.2	8.83	na	na
Dungeness crab – edible meat							
PCB-077	ng/kg ww	2/2	78.3	85.0	81.7	na	na
PCB-081	ng/kg ww	0/2	nd	nd	nd	5.21	5.40
PCB-105	ng/kg ww	2/2	835	1,190	1,010	na	na
PCB-114	ng/kg ww	2/2	56.9	82.0	69.5	na	na
PCB-118	ng/kg ww	2/2	2,350	3,760	3,060	na	na
PCB-123	ng/kg ww	2/2	40.9	47.1	44.0	na	na
PCB-126	ng/kg ww	0/2	nd	nd	nd	7.39	9.89
PCB-156	ng/kg ww	2/2	357 C	583 C	470	na	na
PCB-157	ng/kg ww	2/2	C156	C156	C156	na	na
PCB-167	ng/kg ww	2/2	150	226	188	na	na
PCB-169	ng/kg ww	0/2	nd	nd	nd	3.98	5.31
PCB-189	ng/kg ww	2/2	23.3	38.2	30.8	na	na
Total PCBs[c]	µg/kg ww	2/2	49.45 J	86.2 J	67.8	na	na
PCB TEQ[d]	ng/kg ww	2/2	0.553	0.761	0.657	na	na
Dungeness crab – hepatopancreas							
PCB-077	ng/kg ww	1/1	688	688	688	na	na
PCB-081	ng/kg ww	1/1	41.4	41.4	41.4	na	na
PCB-105	ng/kg ww	1/1	9,470	9,470	9,470	na	na
PCB-114	ng/kg ww	1/1	606	606	606	na	na
PCB-118	ng/kg ww	1/1	26,800	26,800	26,800	na	na
PCB-123	ng/kg ww	1/1	494	494	494	na	na
PCB-126	ng/kg ww	1/1	72.4	72.4	72.4	na	na
PCB-156	ng/kg ww	1/1	4,740 C	4,740 C	4,740	na	na
PCB-157	ng/kg ww	1/1	C156	C156	C156	na	na
PCB-167	ng/kg ww	1/1	1,980	1,980	1,980	na	na
PCB-169	ng/kg ww	1/1	4.67	4.67	4.67	na	na

Analyte	Unit	Detection Frequency	Detected Concentration			Reporting Limit[a]	
			Minimum	Maximum	Mean[b]	Minimum	Maximum
PCB-189	ng/kg ww	1/1	372	372	372	na	na
Total PCBs[c]	µg/kg ww	1/1	612.1 J	612.1 J	612	na	na
PCB TEQ[d]	ng/kg ww	1/1	8.80	8.80	8.80	na	na
Slender crab – edible meat							
PCB-077	ng/kg ww	2/2	129	137	133	na	na
PCB-081	ng/kg ww	2/2	7.14	8.20	7.67	na	na
PCB-105	ng/kg ww	2/2	1,620	1,830	1,730	na	na
PCB-114	ng/kg ww	2/2	111	119	115	na	na
PCB-118	ng/kg ww	2/2	4,530	5,540	5,040	na	na
PCB-123	ng/kg ww	2/2	71.8	98.4	85.1	na	na
PCB-126	ng/kg ww	2/2	8.68	10.1	9.39	na	na
PCB-156	ng/kg ww	2/2	662 C	1,000 C	831	na	na
PCB-157	ng/kg ww	2/2	C156	C156	C156	na	na
PCB-167	ng/kg ww	2/2	267	423	345	na	na
PCB-169	ng/kg ww	0/2	nd	nd	nd	4.49	6.56
PCB-189	ng/kg ww	2/2	33.4	51.2	42.3	na	na
Total PCBs[c]	µg/kg ww	2/2	86.2 J	112 J	99. 1	na	na
PCB TEQ[d]	ng/kg ww	2/2	1.17	1.40	1.29	na	na

[a] Range of reporting limits for non-detect samples.

[b] Mean concentrations are the average of only the detected concentrations.

[c] The method for calculating total PCBs is presented in Appendix D.

[d] The method for calculating PCB TEQs is presented in Appendix D.

C – concentration represents a co-elution

C156 - PCB-156 and PCB-157 co-elute; the combined concentration is presented as the concentration of PCB-156

J – estimated concentration

na – not applicable

nd – not detected

PCB – polychlorinated biphenyl

ww – wet weight

WHO – World Health Organization

The concentrations of the individual coplanar PCB congener and total PCB concentrations (based on the sum of the detected concentrations of all 209 individual PCB congeners) for all fish tissue samples are presented in Table 4-4. Total PCB concentrations ranged from 774 to 2,928 µg/kg ww in English sole whole-body composite samples (n=6) and from 401.6 to 2,462 µg/kg ww in shiner surfperch whole-body composite samples (n=6). The highest total PCB concentrations in both English sole and shiner surfperch whole-body tissue were in samples collected from Area T3 (Table 4-4). Total PCB concentrations were lower in crab edible meat samples (ranging from 49.45 to 112 µg/kg ww) than in whole-body fish samples. The total PCB concentration was 612.1 µg/kg ww in the only crab hepatopancreas sample.

Table 4-4. Coplanar PCB congener concentrations in fish and crab composite samples, including both wet weight and lipid-normalized total PCB concentrations (PCB congener sum)

Sample ID	Coplanar PCB Congener Concentrations (ng/kg ww)												Total PCB Concentration[a] (µg/kg ww)	Lipid (%)	Lipid-Normalized total PCB Concentration (mg/kg lipid)[b]
	PCB-077	PCB-081	PCB-105	PCB-114	PCB-118	PCB-123	PCB-126	PCB-156	PCB-157	PCB-167	PCB-169	PCB-189			
English sole – whole body															
LDW-07-T1-M-ES-WB-comp3	291	29.1	12,800	855	44,800	702	77.7	8,130 C	C156	4,470	4.46	635	1,165 J	6.85	17.01
LDW-07-T1-M-ES-WB-comp5	181	18.0	9,610	727	31,100	480	41.7	5,000 C	C156	2,010	2.18	408	774 J	3.83	20.2
LDW-07-T2-A-ES-WB-comp2	533	48.0	19,900	1,570	75,400	1,230	113	11,600 C	C156	5,320	5.66	625	1,632 J	9.00	18.13
LDW-07-T2-A-ES-WB-comp4	420	37.4	21,800	1,270	68,800	1,200	110	11,300 C	C156	4,910	5.50	762	1,603 J	8.07	19.86
LDW-07-T3-M-ES-WB-comp4	1,030	87.3	37,400 J	2,700	136,000	2,090	184	20,500 C	C156	8,870	7.95	1,270	2,928 J	10.9	26.86
LDW-07-T3-M-ES-WB-comp6	255	20.4	9,030	708	38,900	537	50.7	6,820 C	C156	3,300	3.44	553	1,032 J	4.40	23.45
Shiner surfperch – whole body															
LDW-07-T1-B-SS-WB-comp1	588	48.7	14,500	1,110	45,600	720	96.1	9,750 C	C156	4,140	4.16	835	974 J	2.20	44.3
LDW-07-T1-C-SS-WB-comp1	449	41.9	7,830	548	24,600	465	59.1	5,840 C	C156	2,570	1.75	376	504.1 J	4.94	10.2
LDW-07-T2-B-SS-WB-comp1	314	26.8	5,050	371	18,200	342	45.2	4,180 C	C156	1,890	2.19 J	304	401.6 J	4.40	9.127
LDW-07-T2-E-SS-WB-comp1	431	31.1	10,500	810	35,400	590	61.5	6,820 C	C156	2,960	2.26	500	648.3 J	4.46	14.54
LDW-07-T3-E-SS-WB-comp1	230	20.0	6,770	538	25,200	406	62.9	8,420 C	C156	4,330	4.88	1,140	1,103 J	3.43	32.16
LDW-07-T3-F-SS-WB-comp1	501	39.1	17,000	1,360	53,900	889	91.2	14,100 C	C156	5,860	5.11	1,980	2,462 J	4.94	49.84
Dungeness crab – edible meat															
LDW-07-T1-M-DC-EM-comp1	85.0	5.40 U	835	56.9	2,350	40.9	7.39 U	357 C	C156	150	3.98 U	23.3	49.45 J	0.440	11.24
LDW-07-T3-M-DC-EM-comp3	78.3	5.21 U	1,190	82.0	3,760	47.1	9.89 UJ	583 C	C156	226	5.31 U	38.2	86.2 J	0.531	16.23
Dungeness crab – hepatopancreas															
LDW-07-T1-M-DC-HP-comp1	688	41.4	9,470	606	26,800	494	72.4	4,740 C	C156	1,980	4.67	372	612.1 J	3.72	16.45
Slender crab – edible meat															
LDW-07-T1-M-SC-EM-comp2	137	8.20	1,830	119	5,540	98.4	10.1	1,000 C	C156	423	6.56 U	51.2	112 J	0.428	26.17
LDW-07-T2-M-SC-EM-comp1	129	7.14	1,620	111	4,530	71.8	8.68	662 C	C156	267	4.49 U	33.4	86.2 J	0.592	14.56

[a] Total PCBs are calculated as the sum of all 209 individual PCB congeners. The method for calculating total PCBs is presented in Appendix D.

[b] Lipid-normalized concentrations (in units of mg/kg lipid) represent the wet-weight total PCB concentration (calculated as the sum or all 209 individual PCB congeners in units of mg/kg ww) divided by the decimal fraction corresponding to the percent lipid (e.g., 2.0% lipid = 0.02).

C – concentration represents a co-elution

C156 - PCB-156 and PCB-157 co-elute; the combined concentration is presented as the concentration of PCB-156

ID - identification

J – estimated concentration

PCB – polychlorinated biphenyl

U – not detected at the reporting limit shown

ww – wet weight

Lipid-normalized total PCB concentrations (based on the sum of all 209 individual PCB congeners) are also presented in Table 4-4. Lipid-normalized total PCB concentrations ranged from 17.01 to 26.86 mg/kg lipid in English sole whole-body samples, from 9.127 to 49.84 mg/kg lipid in shiner surfperch whole-body samples, and from 11.24 to 26.17 mg/kg lipid in crab edible meat samples. In the one crab hepatopancreas sample, the lipid-normalized total PCB concentration was 16.45 mg/kg lipid.

Plots of total PCB concentrations in tissue as the sum of the detected PCB congeners versus the sum of the detected Aroclors are presented in Appendix C. In addition, Appendix C presents plots showing patterns of the individual PCB congeners contributing most to the total PCB concentration in the various tissue types.

PCB TEQs were calculated using the WHO mammalian TEFs (Van den Berg et al. 2006) and one-half the RL as the value for undetected PCB congeners (Table 4-5; refer to Appendix D for details on calculation of TEQs). Mammalian PCB TEQs ranged from 5.54 to 25.0 ng/kg ww in whole-body fish samples and from 0.553 to 1.40 ng/kg ww in crab edible meat samples. The mammalian PCB TEQ in the one crab hepatopancreas sample was 8.80 ng/kg ww. The highest PCB TEQs in both English sole and shiner surfperch whole-body tissue (25.0 and 12.2 ng/kg ww, respectively) were in samples collected from Area T3 (Table 4-5). Mammalian PCB TEQs and total PCB concentrations for fish tissue samples are presented graphically in Appendix C.

Table 4-5. Mammalian TEQs in fish and crab composite tissue samples

SAMPLE ID	MAMMALIAN PCB TEQ[a] (ng/kg ww)
English sole – whole body	
LDW-07-T1-M-ES-WB-comp3	10.1
LDW-07-T1-M-ES-WB-comp5	5.74
LDW-07-T2-A-ES-WB-comp2	15.0
LDW-07-T2-A-ES-WB-comp4	14.5
LDW-07-T3-M-ES-WB-comp4	25.0 J
LDW-07-T3-M-ES-WB-comp6	7.00
Shiner surfperch – whole body	
LDW-07-T1-B-SS-WB-comp1	12.1
LDW-07-T1-C-SS-WB-comp1	7.29
LDW-07-T2-B-SS-WB-comp1	5.54 J
LDW-07-T2-E-SS-WB-comp1	8.00
LDW-07-T3-E-SS-WB-comp1	7.87
LDW-07-T3-F-SS-WB-comp1	12.2
Dungeness crab – Edible meat	
LDW-07-T1-M-DC-EM-comp1	0.553

SAMPLE ID	MAMMALIAN PCB TEQ[a] (ng/kg ww)
LDW-07-T3-M-DC-EM-comp3	0.761
Dungeness crab – Hepatopancreas	
LDW-07-T1-M-DC-HP-comp1	8.80
Slender crab – edible meat	
LDW-07-T1-M-SC-EM-comp2	1.40
LDW-07-T2-M-SC-EM-comp1	1.17

[a] The method for calculating PCB TEQs is presented in Appendix D.

ID - identification

PCB – polychlorinated biphenyl

TEQ – toxic equivalent

ww – wet weight

4.1.3 Arsenic

Total arsenic and inorganic arsenic were detected in all clam tissue samples in which they were analyzed (Table 4-6). Mean concentrations of total arsenic in depurated and non-depurated clam samples were 6.803 and 5.279 mg/kg ww, respectively. Mean concentrations of inorganic arsenic in depurated and non-depurated clams were 3.37 and 3.50 mg/kg ww, respectively. Concentrations of total arsenic in co-located sediment samples ranged from 3.569 to 172.180 mg/kg dw, with a mean concentration of 27.40 mg/kg dw.

Table 4-6. Summary of arsenic concentrations in clam tissue and co-located sediment samples

CHEMICAL	UNIT	DETECTION FREQUENCY	DETECTED CONCENTRATION		
			MINIMUM	MAXIMUM	MEAN
Depurated clams					
Total arsenic	mg/kg ww	15/15	2.350	19.700	6.803
Inorganic arsenic	mg/kg ww	15/15	0.720	9.300	3.37
Non-depurated clams					
Total arsenic	mg/kg ww	15/15	2.230	15.200	5.279
Inorganic arsenic	mg/kg ww	15/15	0.690	11.300	3.50
Co-located sediment					
Total arsenic	mg/kg dw	15/15	3.569	172.180	27.40

dw – dry weight

ww – wet weight

The highest total arsenic concentrations in depurated and non-depurated clam tissues were detected in samples collected from location C12 (19.7 and 15.2 mg/kg ww,

respectively) and location C4 (12.4 and 9.29 mg/kg ww, respectively) (Table 4-7). The highest total arsenic concentrations in co-located sediment were also at these two locations: 172.180 mg/kg dw at location C4 and 67.630 mg/kg dw at location C12. The inorganic arsenic concentrations in individual clam samples ranged from 17 to 99% of the respective total arsenic concentrations in those samples (Table 4-7).

Table 4-7. Arsenic concentrations in composite clam tissue samples and co-located sediment samples

Location	Depurated Clams					Non-depurated Clams					Co-located Sediment		
	Sample ID	Total Arsenic (mg/kg ww)	Inorganic Arsenic (mg/kg ww)	Inorganic Arsenic Percent of Total Arsenic	Total Solids (%)	Sample ID	Total Arsenic (mg/kg ww)	Inorganic Arsenic (mg/kg ww)	Inorganic Arsenic Percent of Total Arsenic	Total Solids (%)	Sample ID	Total Arsenic (mg/kg dw)	Total Solids (%)
C1	LDW-07-C1-comp-dep	2.350	0.720	31	21.765	LDW-07-C1-comp	2.230	0.690	31	17.820	LDW-07-C1-S	4.884 J	78.675
C2-1	LDW-07-C2-1-comp-dep	3.580	1.130	32	22.800	LDW-07-C2-1-comp	4.970	2.750	55	19.590	LDW-07-C2-1-S	4.530 J	72.850
C2-2	LDW-07-C2-2-comp-dep	2.480	0.920	37	18.000	LDW-07-C2-2-comp	4.020	1.730	43	19.550	LDW-07-C2-2-S	3.569 J	72.850
C3-1	LDW-07-C3-1-comp-dep	4.880	1.700	35	19.650	LDW-07-C3-1-comp	3.910	2.220	57	17.190	LDW-07-C3-1-S	5.303 J	77.310
C3-2	LDW-07-C3-2-comp-dep	5.400	2.340	43	19.400	LDW-07-C3-2-comp	3.240	1.580	49	16.930	LDW-07-C3-2-S	5.274 J	75.840
C4	LDW-07-C4-comp-dep	12.400	7.600	61	21.230	LDW-07-C4-comp	9.290	6.650 J	72	16.225	LDW-07-C4-S	172.180	73.760
C5	LDW-07-C5-comp-dep	4.240	2.170	51	21.100	LDW-07-C5-comp	3.440	1.820	53	17.890	LDW-07-C5-S	14.073	71.060
C6	LDW-07-C6-comp-dep	7.050	5.720	81	23.930	LDW-07-C6-comp	4.680	4.410	94	19.160	LDW-07-C6-S	22.404	70.970
C7	LDW-07-C7-comp-dep	11.505	9.300	81	20.270	LDW-07-C7-comp	6.480	6.400	99	17.780	LDW-07-C7-S	10.092	80.260
C8	LDW-07-C8-comp-dep	8.270	6.250	76	23.18	LDW-07-C8-comp	5.500	4.100	75	18.74	LDW-07-C8-S	27.715	64.030
C9	LDW-07-C9-comp-dep	6.760	2.470	37	22.22	LDW-07-C9-comp	4.870	2.780	57	19.900	LDW-07-C9-S	5.622	74.710
C10-1	LDW-07-C10-1-comp-dep	4.670	2.610	56	21.26	LDW-07-C10-1-comp	5.130	2.680	52	18.520	LDW-07-C10-1-S	37.473	68.850
C10-2	LDW-07-C10-2-comp-dep	6.270	3.260	52	22.300	LDW-07-C10-2-comp	3.560	2.080	58	15.370	LDW-07-C10-2-S	8.101	72.830
											LDW-07-C10-2-S-FDa	7.219	70.650
C11	LDW-07-C11-comp-dep	2.490	1.010	41	24.270	LDW-07-C11-comp	2.660	1.370	52	18.280	LDW-07-C11-S	22.308	75.310
C12	LDW-07-C12-comp-dep	19.700	3.280	17	22.330	LDW-07-C12-comp	15.200	11.300	74	18.510	LDW-07-C12-S	67.630	60.920

[a] This sample is a field duplicate of the co-located sediment sample collected at location C10-2.

dw – dry weight

ID - identification

ww – wet weight

4.2 DATA VALIDATION RESULTS

Independent data validation of all results was conducted by LDC according to current EPA guidance for data validation (EPA 1995, 1999, 2004). The complete data validation reports are provided in Appendix F. The following sections summarize the results of the validation but do not list every sample affected by a qualification. Detailed information regarding every qualified sample is included in Appendix C.

4.2.1 Overall data quality

The tissue samples were analyzed by Brooks Rand in one SDG, by ARI in eight SDGs, and by Axys in two SDGs.[6] LDC conducted full-level data validation on 20% of the results in the Brooks Rand SDG, greater than 20% of the results in two of the ARI SDGs, all of the results in one ARI SDG, and all of the results in both of the Axys SDGs. All sample results that were not selected for full validation underwent a summary validation. The percent of samples submitted for full validation for each analysis is consistent with the QAPP requirements. Table 4-8 provides a summary of the number of samples in each SDG and the level of data validation.

Table 4-8. Data validation performed for each SDG

LABORATORY	SDG	VALIDATION LEVEL	NUMBER OF SAMPLES	ANALYSES
Brooks Rand	07BR1246	full/summary[a]	30 tissue, 16 sediment	total and inorganic arsenic, total solids
ARI	LO74	full/summary[a]	12 tissue	PCB Aroclors, lipids
ARI	LO75	full/summary[a]	18 tissue	lipids
ARI	LT29	full	20 tissue	PCB Aroclors, lipids, total solids
ARI	LT30	summary	9 tissue	PCB Aroclors, lipids, total solids
ARI	LT31	summary	12 tissue	PCB Aroclors, lipids, total solids
ARI	LT32	summary	11 tissue	PCB Aroclors, lipids, total solids
ARI	LT33	summary	18 tissue	PCB Aroclors, lipids, total solids
ARI	LT34	summary	4 tissue	PCB Aroclors, lipids, total solids
Axys	WG24520	full	10 tissue	PCB congeners
Axys	WG25504	full	7 tissue	PCB congeners

[a] Twenty percent or more of the results in this SDG underwent full-level data validation; the remainder underwent summary validation.

ARI – Analytical Resources, Inc.

Axys – Axys Analytical Services, Ltd.

PCB – polychlorinated biphenyl

SDG – sample delivery group

[6] Individual samples in each SDG are presented in Appendix C.

The majority of the data were either not qualified or were J-qualified as estimated. No results were rejected during data validation. Based on the information reviewed, the overall data quality was considered acceptable for all uses in the RI, as qualified. The results of the data validation are summarized below by analyte group.

4.2.2 Sample transport and holding times

All analyses of the tissue and co-located sediment samples were conducted within the maximum holding times. The sample receipt documents were reviewed for documentation of cooler temperatures. All cooler temperatures were within validation criteria.

4.2.3 Arsenic and inorganic arsenic

4.2.3.1 Calibration

Initial calibration and continuing calibration verifications (CCVs) were conducted at the required frequencies. The percent relative standard deviations (RSDs) of the calibrations were within QC limits. The percent differences calculated for the CCVs were within QC limits of 75 – 125% for all analyses with one exception. One CCV analyzed for total arsenic had a percent recovery of 133%, resulting in the J-qualification of the associated total arsenic results in five sediment samples.

4.2.3.2 Blanks

Arsenic was not detected in any laboratory blank samples. Rinsate blanks of the equipment used during the clam tissue homogenization and compositing procedures were analyzed to ensure that there was no cross-contamination between samples. Arsenic was not detected in any of the homogenization blank samples.

4.2.3.3 Matrix spike

Matrix spike (MS) and matrix spike duplicate (MSD) analyses were analyzed at the required frequencies. The MS/MSD percent recoveries and relative percent differences (RPDs) were within QC limits with one exception. The MS percent recovery for inorganic arsenic in sample LDW-07-C4-comp was 63%, below the QC limits of 65 to 135%; consequently, the associated result was J-qualified as estimated.

4.2.3.4 Laboratory control samples

Laboratory control samples (LCSs) were analyzed at the required frequencies. All of the LCS results were within QC limits.

4.2.4 PCBs as Aroclors

4.2.4.1 Calibration

Initial calibrations and CCVs were conducted at the required frequencies. The percent RSDs of the initial calibrations were less than or equal to 20% for all Aroclors. The percent differences calculated for the CCVs were within QC limits of less than 15% for all analyses. The retention times of all compounds were also within QC limits. The Aroclor 1260 percent differences in two second source initial calibration standards were outside of QC limits, resulting in the J-qualification of 25 detected results for Aroclor 1254, J-qualification of 22 detected results for Aroclor 1260, and UJ-qualification of 21 non-detected results for both Aroclor 1242 and Aroclor 1248.

4.2.4.2 Blanks

PCBs were not detected in the method blanks. Rinsate blanks of the equipment used during the fish and crab tissue homogenization and compositing procedures were analyzed to ensure that there was no cross-contamination between samples. PCBs were not detected in any of these blanks.

4.2.4.3 Surrogate recovery

Surrogates were added to all samples and blanks as required by Method EPA 8082. All surrogate recoveries were within QC limits; however, surrogate recoveries were generally lower than the surrogate recoveries of fish and crab composite samples collected in 2004 and 2005.

4.2.4.4 Matrix spike

MS/MSD analyses were analyzed in all SDGs. The MS/MSD percent recoveries and RPDs were within QC limits with the following exceptions. The Aroclor 1260 percent recoveries in samples LDW-07-T3-M-DC-EM-comp3, LDW-07-T2-A-ES-WB-comp2, and LDW-07-T4-B-SS-WB-comp1 were below the QC limits of 38-150% at 16% 13%, and 35%, respectively. The associated results in these three sample were J- or UJ-qualified for Aroclors 1242, 1248, 1254, and 1260. The Aroclor 1260 percent recovery in sample LDW-07-T3-M-ES-WB-comp5 was above QC limits at 350%. The associated results for detected concentrations of Aroclor 1254 and Aroclor 1260 were J-qualified in this sample.

4.2.4.5 Laboratory control samples

LCSs were analyzed at the required frequency. All of the LCS results were within QC limits.

4.2.4.6 Compound identification and quantification

Identification parameters of all PCB compounds were within validation criteria. Analyst experience in pattern recognition of the individual Aroclors was used in

interpreting the PCB results. When samples had more than one detected Aroclor, a higher level of analyst expertise and review was necessary to ensure the correct identification and quantification. The results were quantified based on the Aroclors that provided the best possible match to the observed PCB congener pattern.

Quantification parameters of all PCB compounds were within validation criteria. When detected concentrations exceeded the calibration range of the instrument, extracts were diluted and re-analyzed to obtain results within the calibrated range. The results from the two analytical columns exceeded the RPD QC limit of 40% for Aroclor 1248 and Aroclor 1254 in one sample each, at 44% and 46%, respectively. These results were J-qualified as estimated. The higher of the two results reported for the two analytical columns was selected as the final result.

4.2.4.7 Internal standards

The laboratory used internal standards for PCB Aroclor quantification. All internal standard recoveries were within QC limits.

4.2.5 PCB congeners

4.2.5.1 Calibration and instrument performance

Initial calibrations, CCVs, and instrument performance checks were conducted at the required frequencies. The percent RSDs of the calibrations were less than or equal to 20% for all compounds. The percent differences calculated for the CCVs were within QC limits of less than 30% for all unlabeled compounds, or less than 50% for all labeled compounds. All other calibration and instrument performance parameters were within validation criteria.

4.2.5.2 Blanks

Select PCB congeners were detected in the method blanks. Sample concentrations were compared to the concentrations detected in the associated method blank samples. Detected sample concentrations that were less than five times the associated method blank sample were qualified as non-detect at the reported concentrations. Five results for PCB-11 were qualified as non-detect at concentrations ranging from 3.42 ng/kg ww to 24.5 ng/kg ww because of method blank contamination.

4.2.5.3 Surrogate and internal standard recoveries

Results for individual PCB congeners in 10 samples were J- or UJ- qualified as estimated because internal standard recoveries were below QC limits of 25 to 150% (306 results).

4.2.5.4 Laboratory control samples

LCSs were analyzed at the required frequency. All of the LCS results were within QC limits.

4.2.5.5 Compound identification and quantification

The result for PCB-24 in sample LDW-07-T3-M-ES-WB-comp6 was J-qualified as estimated because of high RPD between the results of the sample and its laboratory replicate sample.

Results for 105 individual PCB congeners did not meet method ion abundance criteria and were K-qualified by Axys to indicate that these results were estimated maximum possible concentrations. These K-qualified results were considered potential false positive results, and were qualified as not detected (U-qualified) at the reported concentration.

4.2.6 Total solids and lipids

4.2.6.1 Calibration

All calibration criteria were met.

4.2.6.2 Blanks

Four method blanks contained trace lipid concentrations (0.0040 to 0.0080% ww). All sample results were significantly greater than five times the blank levels, so no data qualification was applied.

4.2.6.3 Laboratory replicates

Laboratory replicate analyses were conducted at the required frequencies. All RPDs were within QC criteria.

5.0 References

ASTM. 2001. Standard guide for conducting in-situ field bioassays with marine, estuarine, and freshwater bivalves. E2122-01. American Society for Testing and Materials, West Conshohocken, PA.

EPA. 1995. EPA Region 10 SOP For the validation of Method 1668 toxic, dioxin-like, PCB data. Revision 1.0. Environmental Services Division, US Environmental Protection Agency, Region 10, Seattle, WA.

EPA. 1999. USEPA contract laboratory program national functional guidelines for organic data review. EPA-540/R-99/008. Office of Emergency and Remedial Response, US Environmental Protection Agency, Washington, DC.

EPA. 2000. Guidance for assessing chemical contaminant data for use in fish advisories. Volume 2: Risk assessment and fish consumption limits. Third ed. EPA 823-B-00-008. US Environmental Protection Agency, Washington, DC.

EPA. 2002. USEPA contract laboratory program national functional guidelines for inorganic data review. EPA 540-R-01-008. Office of Emergency and Remedial Response, US Environmental Protection Agency, Washington, DC.

EPA. 2004. USEPA contract laboratory program national functional guidelines for inorganic data review. EPA 540-R-04-004. Office of Emergency and Remedial Response, US Environmental Protection Agency, Washington, DC.

NOAA. 1993. Tissue lipid determination method. In: Sampling and analytical methods of the National Status and Trends Program national benthic surveillance and mussel watch projects, 1984-1992. Vol 2: Comprehensive descriptions of complementary measurements. NOAA technical memorandum NOS ORCA 71. National Status and Trends Program, National Oceanic and Atmospheric Administration, Silver Spring, MD.

PSEP. 1986. Recommended protocols for measuring conventional sediment variables in Puget Sound. Prepared for the Puget Sound Estuary Program. US Environmental Protection Agency, Region 10, Seattle, WA.

PSEP. 1997a. Recommended guidelines for measuring organic compounds in Puget Sound water, sediment and tissue samples. Prepared for Puget Sound Estuary Program, US Environmental Protection Agency Region 10. Puget Sound Water Quality Action Team, Olympia, WA.

PSEP. 1997b. Recommended guidelines for sampling marine sediment, water column, and tissue in Puget Sound. Final report. Prepared for the US Environmental Protection Agency, Seattle, WA. Puget Sound Water Quality Action Team, Olympia, WA.

Van den Berg M, Birnbaum LS, Denison M, De Vito M, Farland W, Feeley M, Fiedler H, Hakansson H, Hanberg A, Haws L, Rose M, Safe S, Schrenk D, Tohyama C, Tritscher A, Tuomisto J, Tysklind M, Walker N, Peterson RE. 2006. The 2005 World Health Organization reevaluation of human and mammalian toxic equivalency factors for dioxins and dioxin-like compounds. Tox Sci 93(2):223-241.

Windward. 2004a. Lower Duwamish Waterway remedial investigation. Intertidal clam survey data report. Prepared for Lower Duwamish Waterway Group. Windward Environmental LLC, Seattle, WA.

Windward. 2004b. Lower Duwamish Waterway remedial investigation. Quality assurance project plan: Benthic invertebrate sampling of the Lower Duwamish Waterway. Prepared for Lower Duwamish Waterway Group. Windward Environmental LLC, Seattle, WA.

Windward. 2004c. Lower Duwamish Waterway remedial investigation. Quality assurance project plan: Fish and crab tissue collection and chemical analyses.

Prepared for Lower Duwamish Waterway Group. Windward Environmental LLC, Seattle, WA.

Windward. 2005. Lower Duwamish Waterway remedial investigation. Data report: Chemical analyses of benthic invertebrate and clam tissue samples and co-located sediment samples. Prepared for Lower Duwamish Waterway Group. Windward Environmental LLC, Seattle, WA.

Windward. 2007a. Lower Duwamish Waterway remedial investigation. Baseline ecological risk assessment. Prepared for Lower Duwamish Waterway Group. Windward Environmental LLC, Seattle, WA.

Windward. 2007b. Lower Duwamish Waterway remedial investigation. Baseline human health risk assessment. Prepared for Lower Duwamish Waterway Group. Windward Environmental LLC, Seattle, WA.

Windward. 2007c. Lower Duwamish Waterway remedial investigation. Quality assurance progress plan: fish crab, and clam tissue collection and chemical analyses. Addendum for additional fish, crab, and clam sampling in the Lower Duwamish Waterway in 2007. Final. Prepared for Lower Duwamish Waterway Group. Windward Environmental LLC, Seattle, WA.

Oversize Maps