WASHINGTON STATE
DEPARTMENT OF
ECOLOGY

Concentrations of Chemical Contaminants and Bioassay Response to Sediments in Salmon Bay, Seattle

Results of Phase III Sampling

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Concentrations of Chemical Contaminants and Bioassay Response to Sediments in Salmon Bay, Seattle

Results of Phase III Sampling

by
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Abstract

Ecology's Environmental Assessment Program has conducted a multi-phase study of Salmon Bay sediments to facilitate cleanup efforts by Ecology's Toxics Cleanup Program. Phase I and Phase II examined physical characteristics and toxic contaminants of Salmon Bay sediments on a broad geographical scale. Objectives of this Phase III study were to assess toxicity of sediments, delineate boundaries of highly contaminated areas, and confirm sediment contamination found during the Phase II study.

Bottom sediments were collected from 27 locations throughout Salmon Bay and two reference locations in Lake Washington. Samples were analyzed for conventional parameters, metals, semivolatile organics, and butyltins. Polychlorinated biphenyls (PCBs) were sampled in areas of known contamination. Toxicity was assessed through *Hyalella azteca* survival, *Chironomus tentans* growth and survival, and Microtox®. Potential toxicity of the sediments was assessed by comparing chemistry to Freshwater Sediment Quality Values (FSQVs) and the Puget Sound Dredge Disposal Analysis screening level (SL) for tributyltin (TBT).

Results confirmed widespread chemical contamination in Salmon Bay found during the Phase II study. TBT, mercury, bis(2-ethylhexyl)phthalate, indeno(1,2,3-cd)pyrene, and carbazole appear to be the most pervasive problem chemicals based on comparisons to the SL and FSQVs. Zinc, copper, arsenic, lead, chromium, and polycyclic aromatic hydrocarbons also exceeded FSQVs. At least one chemical was detected above FSQVs in 23 of the 27 samples. TBT concentrations were above the SL in 26 of the 27 Salmon Bay sediments.

Ninety percent of the Salmon Bay samples were toxic to at least one bioassay organism. The *Chironomus* growth test was the most sensitive bioassay, followed by Microtox®, *Hyalella* survival, and *Chironomus* survival. Results suggest that the number of organic chemicals exceeding FSQVs was more closely related to toxicity than to the degree of metals contamination.

The distribution of contaminants in Salmon Bay could be characterized by "hot-spots" generally occurring near shore, with cleaner sediments toward the channel center. In most cases, hot-spots detected during Phase II were verified by this survey. However, the sample coverage was too thin to delineate hot-spot boundaries. Therefore, it is recommended that future sampling be designed to delineate hot-spots by focusing on the most contaminated Phase III stations individually.

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Introduction

Background

Salmon Bay and the Lake Washington Ship Canal comprise a narrow body of water in Seattle, Washington, connecting Lake Union to the east with Puget Sound to the west through the Hiram Chittenden Locks (Figure 1). Salmon Bay was originally a saltwater bay, but was inundated with freshwater in 1914 when the locks were constructed to the west of Salmon Bay and connected the bay to Lake Union through the Lake Union Ship Canal. The Ship Canal is a narrow channel with some shallow embayments on the southern shoreline near the west end of the canal.

Numerous industries have been located along the shores of Salmon Bay and the Ship Canal, including shipyards, marinas, bulk fuel plants, fish processing, wood treating, lumber mills and plywood plants, bulk materials handling facilities, a large steel manufacturing plant, and an asphalt plant. In addition, stormwater from urban areas, the Ballard and Fremont bridges, and combined sewer overflows (CSOs) discharge into the Ship Canal and Salmon Bay. These various sources have contributed to sediment contamination in Salmon Bay and the west end of the Ship Canal, but the nature, extent, and sources of contamination are not well defined. This lack of information has hampered attempts at source control and sediment cleanup in this area.

Recently, contamination of Salmon Bay sediments has been addressed in a three-phase study conducted by Ecology's Environmental Assessment Program (formerly Environmental Investigations and Laboratory Services Program).

1. Phase I reconnaissance sampling was completed during 1995 and consisted of visual examination of sediments from 81 stations evenly distributed throughout Salmon Bay and the Ship Canal (Michelsen, 1995). Samples were inspected for grain size (e.g., sand, silt, clay), evidence of contamination (oil, wood debris, paint chips), and biological organisms. Results were used to differentiate areas with probable contamination and those unlikely to contain high levels of contaminants.

2. Phase II, also conducted during 1995, included chemical analyses from 29 stations distributed throughout Salmon Bay based on Phase I results (Serdar and Cubbage, 1996). Chemicals analyzed included metals, semivolatile organics, PCBs, and butyltins. Most of the 29 stations sampled during the Phase II study had at least one chemical above criteria recommended for the protection of aquatic life, with several stations exceeding criteria for multiple chemicals. Problem chemicals included copper, mercury, lead, arsenic, zinc, chromium, benzyl alcohol, 4-methylphenol, bis(2-ethylhexyl)phthalate, PAHs, and PCB-1260. Tributyltin (TBT) was judged to be a significant concern at many stations due to its exceedence of the Puget Sound Dredge Disposal Analysis screening level.

   Although a number of stations showed significant sediment contamination during the Phase II study, cleanup decisions remain difficult because Ecology has not yet formally

adopted chemical standards for freshwater sediment. In the absence of chemical standards, biological toxicity testing may be used to determine the need for cleanup and/or source control.

3. Phase III study of Salmon Bay was conducted to assess the toxicity of sediments and delineate potential contaminated areas using sediment bioassays and chemical analyses in order to facilitate cleanup and source control efforts. Results of the Phase III study are the focus of this report.

Objectives of the Phase III Study

The primary objectives of the present study are as follows:

- Confirm and delineate areas of clean and contaminated sediment in Salmon Bay and nearshore areas of the Ship Canal found during the Phase II study.
- Evaluate the toxicity of these problem areas with sediment bioassays and assess the potential for sediments to be toxic, by comparison to chemical criteria recommended to protect aquatic life.
- To the extent possible, identify the contaminants contributing to sediment toxicity in the problem areas, including an evaluation of butyltins to determine whether this class of contaminants should be included in routine (e.g., National Pollutant Discharge Elimination System, NPDES) sediment analyses for Lake Union and the Ship Canal.
- To the extent possible, identify likely historical and current sources of contaminants to these problem areas.

The Salmon Bay study benefits cleanup and source control programs by:

- Identifying areas that require remediation, with recommendations and some indication of their relative priority. In addition, the data may provide adequate evidence to allow cleanup of some offshore areas within existing Model Toxics Control Act (MTCA) and Resource Conservation and Recovery Act (RCRA) actions at related upland facilities.
- Streamlining dredging, construction, and NPDES permit processing for areas that are identified as “clean”. The results may also provide justification for discharge and baseline sediment monitoring as part of the NPDES permitting program for areas that are identified as contaminated.
- Beginning to identify areas that require additional stormwater or CSO control to prevent recontamination of areas targeted for dredging or cleanup.
- Contributing synoptic chemistry and bioassay data to help evaluate the toxicity of butyltin compounds, with the eventual goal of establishing apparent effects thresholds (AETs) for these compounds.

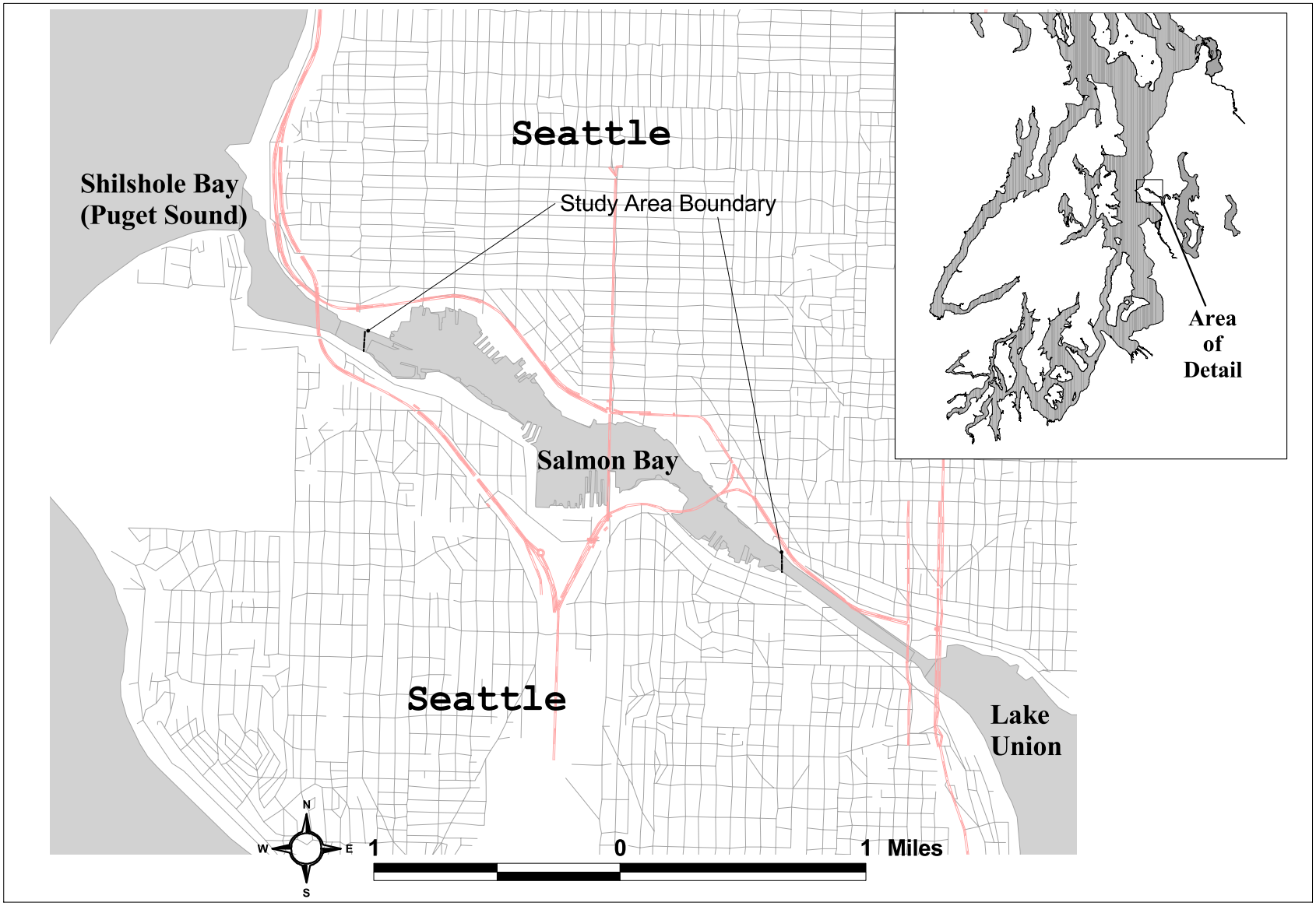

Figure 1. Salmon Bay and Vicinity.

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Methods

Sampling Strategy

Chemical analyses was performed on bottom sediments from 27 locations throughout Salmon Bay and two reference locations in Lake Washington; bioassays were performed on a subset of 20 Salmon Bay sediments and the reference samples. The study area extends from the locks (on the west) to the western end of the Ship Canal (on the east).

Results of the reconnaissance (Phase I) study indicated that most sediments in the vicinity of the eastern Ship Canal are coarse-grained which suggests little deposition of fine material. Little visible oil or other evidence of contamination was seen in this area as well. Based on these observations, this area was excluded from further investigation during Phases II and III.

Phase II revealed several highly contaminated areas in Salmon Bay. Because the Sediment Management Standards (SMS; Ecology, 1991) require at least three stations for any regulatory decisions, three or more stations were grouped in each major area of concern or natural geographical feature for Phase III (Figure 2). These zones were chosen to represent groups of industries and CSOs or areas that may have similar contaminant levels (e.g., the central channel). A description of each sampling station is in Appendix A.

Sampling Methods

Sampling methods were consistent with the Puget Sound Estuary Program (PSEP) protocols (EPA, 1986a) as modified by the SMS and sampling methods used during Phase II and previous Lake Union and Lake Washington studies conducted by Ecology. However, to support evaluation of historical contamination and the cleanup program, the top 10 cm of sediment was sampled. This layer includes most of the biologically active zone in freshwater.

Samples were collected from Ecology's 20-foot skiff equipped with a 0.1 m^2 stainless steel Van Veen grab sampler. Stations were recorded using a Magellan® GPS (Global Positioning System) receiver with differential correction as well as from sightings on nearby landmarks. Datasheets were used at grab stations to log samples (number of grabs, observations, samples collected) and at the helm to log position with reference to landmarks. A grab was considered adequate if it was filled with sediment and both the grab and access doors on top of the grab were closed tightly (see PSEP protocols for full description). For each grab, the overlying water was siphoned off and the top 10 cm of sediment not touching the walls of the grab was scooped out of the top doors and placed in a stainless steel beaker.

To prevent contamination from boat engine exhaust, the boat was maneuvered so the stern was downwind of sampling gear. To prevent sample cross-contamination, sites were sampled in a gradient from lowest suspected concentration of contaminants to highest.

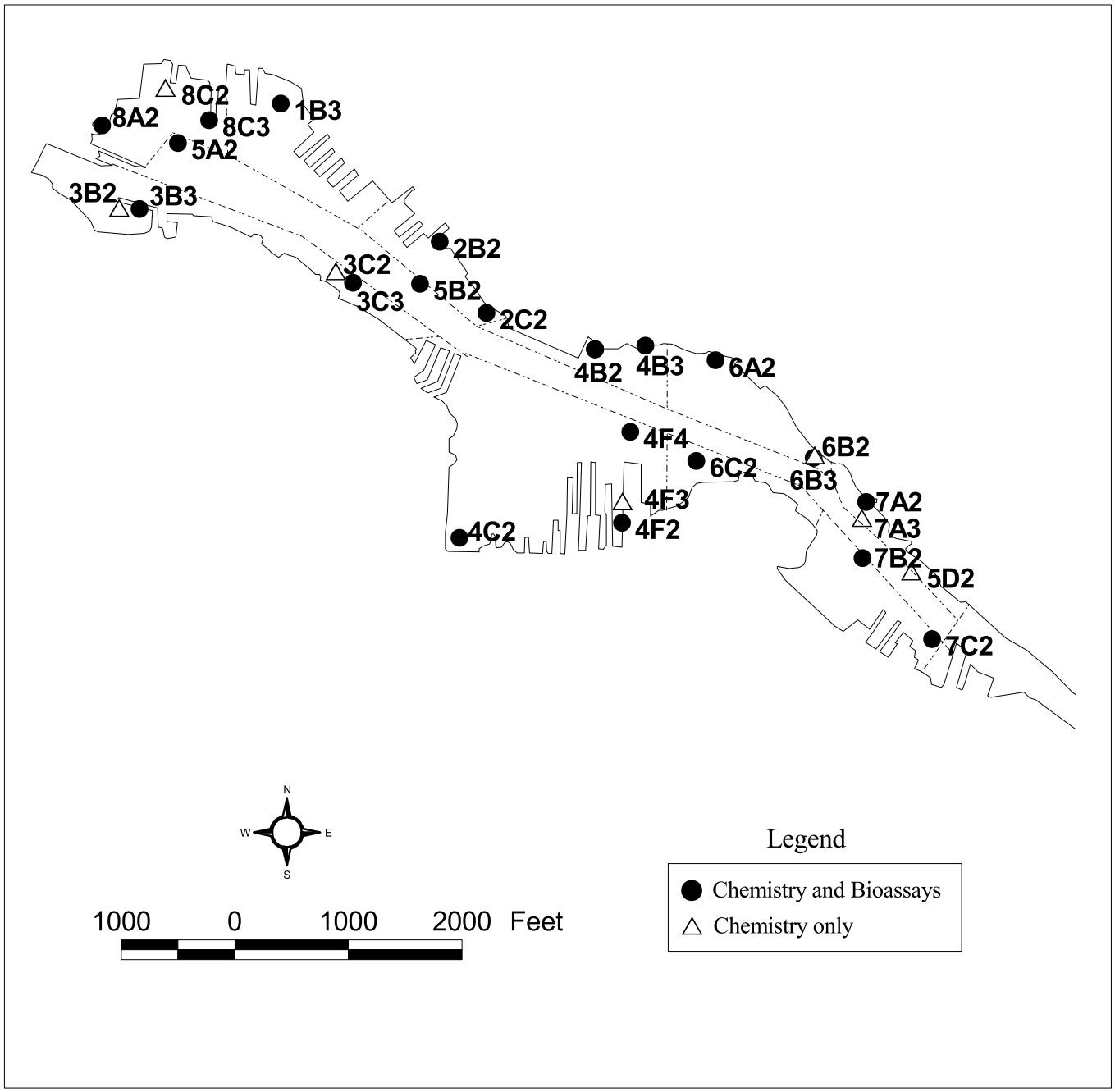

Figure 2. Station Locations and Sample Zones for Salmon Bay Phase III Sampling. Zone 5 Occupies the Channel Center and Zones 4,6, and 7 are on Both Sides of the Channel.

Prior to sampling, all stainless steel tools (grab, beakers, spoons) were decontaminated with the following procedure:

- wash in hot water and Liquinox® detergent
- rinse in tap water
- rinse in 10% nitric acid
- rinse with deionized water
- rinse with pesticide analysis grade acetone
- air dry
- wrap in aluminum foil

The beaker contents were homogenized, and subsamples for metals and organics analysis were dispensed into separate 8-oz priority pollutant-clean jars capped with teflon lid liners. Samples for organic carbon analysis were placed in 4-oz jars. Grain size samples were placed in Whirl-Pak® bags. If oil was visible in the sample, the sampler was washed with detergent and the sample was disposed into a drum onboard. Between samples, the grab sampler was thoroughly brushed and rinsed with on-site water. Samples for bioassays were placed into 1-gal jars.

Quality assurance samples collected in the field included homogenized sediments from two stations sent to the lab under different labels to represent blind field splits. Split samples are primarily used to measure laboratory precision, but results may also be influenced by homogenization and packaging in the field. Sampling was also replicated at one station to measure overall (environmental + sampling + laboratory) precision.

Chemical Analysis and Data Quality

All samples were analyzed for the chemical parameters in Table 1, except PCBs which were analyzed at six sites only. Grain size analysis was done by Rosa Environmental & Geotechnical Laboratory, Seattle, WA. All other analyses were performed at the Ecology/EPA Manchester Environmental Laboratory in Manchester, WA.

Data quality was assessed through analysis of field splits, field replicates, laboratory replicates, matrix spikes, laboratory control samples (metals only), and surrogate spikes (organics only). Holding times and adherence to EPA CLP quality control limits was assessed. Procedural blanks were analyzed to assess laboratory contamination. Quality assurance results are in Appendix B.

Quality of the conventional sediment data (solids, grain size, TOC) was excellent at all levels. Results of field splits, field replicates, and laboratory replicate suggest that environmental or sampling variability accounted for roughly equal loss of precision compared to the laboratory analyses. Some of the percent solids analyses were performed one day past holding times and are flagged (H).

Table 1. Methods for Analysis of Sediments.

Analysis	Method	Reference	Target Detection Limit
Total organic carbon (TOC)	PSEP Method	EPA, 1986a	0.1%, dw
Grain size	PSEP Method	EPA, 1986a	--
% Solids	Gravimetric - EPA Method 160.3	EPA, 1986b	0.1%
Arsenic	ICP - EPA Method 200.7 or ICP/MS - EPA Method 200.8	EPA, 1986b	1 ug/g, dw
Cadmium	ICP - EPA Method 200.7	EPA, 1986b	1 ug/g, dw
Chromium	ICP - EPA Method 200.7	EPA, 1986b	1 ug/g, dw
Copper	ICP - EPA Method 200.7	EPA, 1986b	1 ug/g, dw
Mercury	CVAA - EPA Method 245.5	EPA, 1986b	0.1 ug/g, dw
Lead	ICP - EPA Method 200.7	EPA, 1986b	1 ug/g, dw
Nickel	ICP - EPA Method 200.7	EPA, 1986b	1 ug/g, dw
Zinc	ICP - EPA Method 200.7	EPA, 1986b	1 ug/g, dw
Semivolatile organics	GC/MS - modified EPA Method 8270	EPA, 1986b	100 ug/Kg, dw
PCBs	GC/ECD - EPA Method 8080	EPA, 1986b	50 ug/Kg, dw
Butyltins	SIM mode GC/MS - PSEP/NOAA Methods	EPA, 1986a Krone et al., 1989	20 ug/Kg, dw

Precision and accuracy of the metals data were good. Arsenic analysis was hampered by high iron, >50,000 ug/g in some samples, requiring qualification (J). Samples with lower arsenic concentrations (<100 ug/g) were analyzed using ICP/MS EPA Method 200.8 due to the iron interference. The only other qualification (J) for the metals data was the cadmium result for the sample from 6B2 due to a relatively high standard deviation of results.

Quality of the semivolatile organics analysis was mixed. Practical quantitation limits were generally much higher than anticipated due in part to the high water content of the samples. In many cases, however, analytes were detected at concentrations much lower than the quantitation limits and are qualified as estimates (J). Matrix spike and surrogate recoveries were low for most analytes, possibly indicating the data were systematically biased low. Poor precision of the matrix spike duplicates suggests that laboratory analysis accounted for much of the data variability. Analysis of a certified reference material (National Research Council of Canada HS-6 - PAHs in Nova Scotia marine harbor sediments) yielded 75% of results within certified values, no evident systematic bias, and high precision. These results support the conclusion that data quality problems with the semivolatile analyses were due primarily to matrix effects.

Overall quality of the butyltin data was poor, also probably due in large part to matrix effects. Environmental variability of samples also appeared to result in poor precision, thought to be due to the presence of hull paint particles which contain highly concentrated tributyltin (see Case Narrative in Appendix B). Similar problems were encountered in the Salmon Bay Phase II study (Serdar and Cubbage, 1996). Accuracy of the data was difficult to assess due to degradation of

the PACS-1 reference material (National Research Council of Canada PACS-1 – British Columbia marine harbor sediments). Analysis of a newer reference material, PACS-2, produced better data but results remained outside certified ranges.

The PCB data should be used with caution due to a number of factors making their accuracy questionable. Calibration curves for Aroclors 1242 and 1260 were outside control limits. In some cases surrogate recoveries were poor, although matrix spike recoveries were generally good and results from matrix spike duplicates were precise. Analysis of the reference material HS-2 (National Research Council of Canada HS-2 – PCBs in Nova Scotia marine harbor sediments) yielded results slightly below certified values for Aroclor 1254.

Bioassay Procedures

Bioassay tests included 10-day *Hyalella azteca* survival, 10-day *Chironomus tentans* growth and survival, and 15-minute *Vibrio fischeri* luminescence (i.e., Microtox®). *Hyalella* and *Chironomus* tests were performed by EVS Environment Consultants (North Vancouver, B.C.) through SAIC (Poulsbo, WA). Microtox testing was done by CH2M Hill in Corvallis, OR. A discussion of the highlights and data for each test replicate are in Appendix D.

There were few problems associated with testing the bioassay organisms. Negative control survival rates for *Hyalella* and *Chironomus* were 96% and 100%, respectively.

Data Analysis

Chemical data were compared to Ecology recommended freshwater sediment quality values (FSQVs; Table 2) (Cubbage et al., 1997). FSQVs were derived by analyzing freshwater bioassay and chemistry data sets collected in Washington, and by reviewing freshwater and marine sediment criteria developed in Canada and the U.S., including Washington standards for marine waters. The authors concluded that, when applied to freshwater, the existing Sediment Management Standards (SMS; Ch. 173-204 WAC) for marine waters provided the best mix of sensitivity and efficiency in predicting effects to the bioassay organism *Hyalella azteca* and miscellaneous effects related to metals. Numerical criteria promulgated in the SMS are essentially minimum chemical concentrations expected to cause adverse effects on biological resources. For organics, FSQVs are based on Microtox® probable apparent effects thresholds derived from a variety of bioassay and chemistry data sets from freshwater sediments in Washington. Like FSQVs for metals, the FSQVs for organics are not codified standards. However, creators of the FSQVs conclude they predict biological effects better than other sets of values, including sediment quality criteria and guidelines developed by other regulatory agencies.

Table 2. Freshwater Sediment Quality Values (FSQVs)*
for Metals and Organics in Washington State.

Chemical	FSQV
Metals (ug/g, dw)	
Arsenic	57
Cadmium	5.1
Chromium	260
Copper	390
Nickel	na
Lead	450
Zinc	410
Mercury	0.41
PAHs(ug/kg, dw)	
Naphthalene	37,000
Acenaphthylene	1,900
Acenaphthene	3,500
Fluorene	3,600
Phenanthrene	5,700
Anthracene	2,100
LPAH[a]	27,000
Fluoranthene	11,000
Pyrene	9,600
Benzo(a)anthracene	5,000
Chrysene	7,400
Total Benzofluoranthenes	11,000
Benzo(a)pyrene	7,000
Indeno(1,2,3-cd)pyrene	730
Dibenzo(a,h)anthracene	230
Benzo(ghi)perylene	1,200
HPAH[b]	36,000
Total PAH[c]	60,000
Other Semivolatile Organics(ug/kg, dw)	
Bis(2-Ethylhexyl)phthalate	640
Carbazole	140
Chlorinated Organics(ug/kg, dw)	
PCB-1248	21
PCB-1254	7.3
Total PCB	21

* FSQVs derived by Cubbage et al. (1997).

[a] Represents the sum of Anthracene, Acenaphylene, Acenaphthene, Phenanthrene, Fluorene, and Naphthalene. The LPAH criterion is not the sum of the criterion values for individual LPAH as listed above.

[b] Represents the sum of Pyrene, Benzo(g,h,i)perylene, Indeno(1,2,3-c,d)pyrene, Benzofluoranthene(s), Fluoranthene, Chrysene, Benzo(a)pyrene, Dibenzo(a,h)anthracene, and Benzo(a)anthracene. The HPAH criterion is not the sum of the criterion values for individual HPAH as listed above.

[c] Total PAH = LPAH + HPAH

na= not available

Results

Field Observations

Sediments were observed for characteristics of color, odor, grain composition, oil sheen, and content. Complete results of field observations are in Appendix A.

Most of the sediments were brown or dark brown in color and appeared in the field to be composed mainly of silt or sand, with some "muck" or clay. Approximately two-thirds of the sediments had an oil sheen, with the heaviest sheen in sediment from Station 6B2. Sediments from some stations had a petroleum odor, although this did not always correspond to an observable oil sheen (e.g., Stations 3B2 and 8A2). Only one station (5B2) appeared to have noticeably anoxic sediments based on its rotten egg odor.

Contents of the sediments varied from station to station. Samples from Stations 1B3, 2B2, 3B3, 4B3, 6A2, 7A2, and 7A3 contained partially decomposed organic debris. Paint particles were observed in sediments from Stations 4F2, 5D2, 6A2, 7A2, 7A3, and 8C3. Clams from the Lake Washington reference stations (10A2 and 10B2) were the only recorded observations of macroinvertebrates in sediments.

Conventional Characteristics of Sediments

Conventional parameters measured in Salmon Bay sediments (solids, grain size, TOC) are presented in Table 3. TOC70 is determined at 70°C whereas TOC104 is determined at 104°C. On average, TOC104 results were 4% higher than TOC70. TOC, which has been known to correlate well with non-polar organic compounds, ranged from 0.8% at Station 7C2 to 21.3% at 7B2. Sediment from Station 7B2 was described by the grain size analyst as fibrous and mostly peat (see Case Narrative in Appendix B).

Grain size analysis showed that sediments from all stations were made up of mostly sand or silt, generally followed by clay and gravel. Sediments from 5D2, 7C2, and 4C2 had sand and gravel making up 70% or more of the sample dry weight, as did sediment from reference station 10B2. The characterization of sediment from 7B2 as mostly sand and gravel is not entirely accurate since, as mentioned previously, this sample was mostly peat.

Samples from Stations 3C3, 3C2, 6C2, 4B2, and 8C3 were composed of 80% or more fine material (i.e., ≤ 62 um) by weight, mostly silt for all sediments except 7A3 which contained 41% clay. Contaminant concentrations in sediments are often positively correlated with percent fines since more surface area is available for binding.

Table 3. Organic Carbon, Solids, and Grain Size Composition of Salmon Bay Phase III Sediments and Lake Washington Reference Sediments.

				Grain Size Composition (%)			
Station	**TOC70 (%)**	**TOC104 (%)**	**Solids (%)**	**Gravel (>2,000 um)**	**Sand (62-2,000 um)**	**Silt (3.9-62 um)**	**Clay (<3.9 um)**
1B3	6.5	6.8	26.1	0	34	54	12
2B2	11.5	12.2	23.2	4	51	37	8
2C2	7.7	7.9	25.9	6	37	44	13
3B2	5.1	5.1	28.5	0	24	56	20
3B3	4.5	4.6	34.2	0	45	39	16
3C2	5.9	6.1	24.3	0	16	76	8
3C3	6.0	6.3	24.4	0	15	77	8
4B2	6.2	6.4	26.9	0	18	68	14
4B3	10.5	10.6	26.0	1	38	54	7
4C2	4.7	5.0	38.2 H	1	69	22	8
4F2	14.9	15.8	16.3 H	13	48	32	7
4F3	7.4	7.8	26.4 H	0	25	56	19
4F4	11.7	12.1	27.3	3	45	43	9
5A2	4.8	5.2	25.3	0	26	57	17
5B2	5.0	4.9	26.3	0	27	55	18
5D2	3.2	3.0	55.9 H	14	66	13	7
6A2	9.2	9.7	33.4	2	43	44	11
6B2	2.4	2.5	42.7	0	51	44	5
6B3	3.3	3.4	36.3	0	26	64	10
6C2	5.4	5.7	45.8	2	15	51	32
7A2	2.6	2.8	42.8	2	62	28	8
7A3	1.6	1.6	54.1 H	2	26	31	41
7B2	18.7	21.3	15.3 H	14	56	18	12
7C2	0.78	0.82	66.1 H	0	73	21	6
8A2	2.8	3.0	48.9	2	63	29	6
8C2	4.3	4.5	43.4	0	60	32	9
8C3	5.5	5.6	38.8	2	17	56	24
10A2 (ref.)	3.4	3.6	38.2 H	0	26	62	11
10B2 (ref.)	1.2	1.2	58.9 H	1	75	20	4

TOC70= Total organic carbon determination at 70°C

TOC104= Total organic carbon determination at 104°C

H= Exceeds sample holding time

*Results may be biased due to the fibrous nature of this sample. See Case Narrative in Appendix B for more detail.

Chemical Concentrations in Sediments

Metals

Concentrations of metals in sediments are shown in Table 4. Extremely high levels were found at some stations. The range of dry weight concentrations (ug/g, parts per million) for individual metals were as follows: arsenic 5 - 210, mercury 0.1 - 43, cadmium 0.3 - 5, chromium 24 - 620, copper 48 - 10,800, lead 12 - 1,300, nickel 30 - 640, and zinc 84 - 4,200. Station 4F2 had the highest concentrations of mercury, cadmium, copper, lead, and zinc. Arsenic was found at the highest concentration at 1B3. Chromium and nickel concentrations were highest in sediments from 6B2. Metals in reference sediments were at concentrations near the low end of the Salmon Bay range.

Higher metals concentrations were positively correlated with sites that had higher proportions of fine sediments (Appendix C). Conversely, sites with more sand tended to have lower metals concentrations. All metals were positively correlated except nickel-arsenic and nickel-lead. The strongest links were cadmium-chromium, cadmium-copper, chromium-copper, chromium-nickel, and mercury-zinc.

Table 5 ranks the stations according to concentrations of each metal. Stations 1B3, 4F2, and 3B3 had the highest overall rank. The Lake Washington reference stations (10A2 and 10B2) and Salmon Bay stations 7C2, 6C2, and 7B2 tended to have the least metals, the latter showing little or no metals enrichment above reference conditions.

Concentrations of all metals except cadmium exceed freshwater sediment quality values (FSQVs) at two or more stations. Fully three-quarters of the stations exceed the FSQV for mercury, including one of the Lake Washington reference stations (10B2). Nearly half the stations exceed FSQVs for copper or zinc, five exceed the arsenic FSQV, and two stations each exceed chromium and lead FSQVs. The cadmium FSQV was not exceeded by any samples. No FSQV has been derived for nickel.

Stations 1B3 and 4F2 each exceed FSQVs for five metals; 3B3 and 7A2 each exceed FSQVs for four metals. Only six stations – 5D2, 6C2, 10A2, 7A3, 7B2, and 7C2 – did not surpass the FSQVs for any of the metals analyzed.

Table 4. Concentrations of Metals in Salmon Bay Phase III Sediments and Lake Washington Reference Sediments (ug/g, dw).

Station	Arsenic	Mercury	Cadmium	Chromium	Copper	Lead	Nickel	Zinc
1B3	209 *	3.7	3.6	102	2,010	525	62	2,010
2B2	16	0.66	2.7	62	651	431	44	754
2C2	17	0.84	1.4	100	508	177	77	407
3B2	25	2.1	1.8	66	314	311	53	497
3B3	175 *	2.7	3.0	81	651	436	48	1,770
3C2	28	1.0	1.3	64	856	199	48	490
3C3	31	0.99	1.4	67	627	194	49	567
4B2	13	1.0	2.0	121	536	187	102	453
4B3	13	0.66	1.3	77	327	150	64	368
4C2	20	0.44	1.1	45	142	99	39	391
4F2	152 J*	43	5.0	96	10,800	1,310	58	4,150
4F3	23	1.6	1.7	77	632	305	61	614
4F4	13	0.62	1.0	56	210	114	54	269
5A2	31	2.0	1.6	80	571	249	62	550
5B2	22	0.80	1.2	57	363	152	45	377
5D2	25	0.36	0.61	44	145	408	34	246
6A2	13	0.75	1.6	81	315	150	71	354
6B2	17 J	0.27	3.5 J	621	2,220	74	644	259
6B3	20 J	0.56	2.9	348	1,460	133	355	406
6C2	6	0.16	(0.3) U	54	48	12	60	86
7A2	123 *	3.0	1.3	63	829	230	49	1,080
7A3	16	0.10	0.65	53	73	321	54	165
7B2	31	0.10	(0.3) U	24	50	27	46	84
7C2	5	0.10	0.31	25	74	27	30	98
8A2	14	1.2	1.0	45	158	258	38	423
8C2	12	1.2	1.3	45	206	194	39	419
8C3	111 *	2.2	2.0	68	371	299	53	675
10A2 (ref.)	7	0.14	0.45	43	28	59	39	90
10B2 (ref.)	4	0.54	0.69	27	24	90	26	131

*Analyzed using EPA 200.7. All other Arsenic results using EPA 200.8.

J= Estimated concentration

U= Undetected at concentration in parentheses

Table 5. Salmon Bay Phase III and Lake Washington Reference Stations Ranked According to Metals Concentrations (lower rank = higher concentration).

Rank	Arsenic	Mercury	Cadmium	Chromium	Copper	Lead	Nickel	Zinc	Overall Rank
1	1B3	4F2	4F2	6B2	4F2	4F2	6B2	4F2	1B3
2	3B3	1B3	1B3	6B3	6B2	1B3	6B3	1B3	4F2
3	4F2	7A2	6B2	4B2	1B3	3B3	4B2	3B3	3B3
4	7A2	3B3	3B3	1B3	6B3	2B2	2C2	7A2	8C3
5	8C3	8C3	6B3	2C2	3C2	5D2	6A2	2B2	4F3
6	7B2	3B2	2B2	4F2	7A2	7A3	4B3	8C3	5A2
7	3C3	5A2	4B2	3B3	2B2	3B2	1B3	4F3	7A2
8	5A2	4F3	8C3	6A2	3B3	4F3	5A2	3C3	6B3
9	3C2	8A2	3B2	5A2	4F3	8C3	4F3	5A2	4B2
10	5D2	8C2	4F3	4F3	3C3	8A2	6C2	3B2	3B2
11	3B2	3C2	5A2	4B3	5A2	5A2	4F2	3C2	3C3
12	4F3	3C3	6A2	8C3	4B2	7A2	7A3	4B2	6B2
13	5B2	4B2	2C2	3C3	2C2	3C2	4F4	8A2	2C2
14	4C2	2C2	3C3	3B2	8C3	3C3	3B2	8C2	2B2
15	6B3	5B2	3C2	3C2	5B2	8C2	8C3	2C2	3C2
16	2C2	6A2	4B3	7A2	4B3	4B2	3C3	6B3	6A2
17	6B2	4B3	7A2	2B2	6A2	2C2	7A2	4C2	4B3
18	2B2	2B2	8C2	5B2	3B2	5B2	3B3	5B2	5B2
19	7A3	4F4	5B2	4F4	4F4	4B3	3C2	4B3	8A2
20	8A2	6B3	4C2	6C2	8C2	6A2	7B2	6A2	8C2
21	4B2	10B2	4F4	7A3	8A2	6B3	5B2	4F4	7A3
22	6A2	4C2	8A2	8A2	5D2	4F4	2B2	6B2	4F4
23	4B3	5D2	10B2	4C2	4C2	4C2	4C2	5D2	5D2
24	4F4	6B2	7A3	8C2	7C2	10B2	10A2	7A3	4C2
25	8C2	6C2	5D2	5D2	7A3	6B2	8C2	10B2	7B2
26	10A2	10A2	10A2	10A2	7B2	10A2	8A2	7C2	6C2
27	6C2	7A3	7C2	10B2	6C2	7C2	5D2	10A2	10B2
28	7C2	7B2	6C2	7C2	10A2	7B2	7C2	6C2	10A2
29	10B2	7C2	7B2	7B2	10B2	6C2	10B2	7B2	7C2

Exceeds Freshwater Sediment Quality Values (Cubbage et al., 1997). No FSQV has been derived for Nickel.

Semivolatile Organics

Table 6 summarizes the median and concentration range of each semivolatile organic compound detected in sediments. Complete results of semivolatile organic analyses are in Appendix C.

Slightly more than half (39 of 75) of the semivolatiles analyzed were detected, with "priority pollutant" PAHs the most frequently detected group (Figure 3). Total PAH concentrations ranged from 1,100 ug/kg at Station 7B2 to over 300,000 ug/kg at 4F2, which translates to 0.03% of the dry sample weight. High levels of total PAHs were also found at 2C2 (96,000 ug/kg), 8A2 (79,000 ug/kg), and 2B2 (64,000 ug/kg). Concentrations at most stations were between 10,000 and 50,000 ug/kg, with a median of 18,000 ug/kg. Total PAHs at Stations 10A2 and 10B2 were low: 700 ug/kg and 3,000 ug/kg, respectively.

Eighteen of the 27 Salmon Bay sediment samples had one or more PAH at concentrations above FSQVs. Station 4F2 had 13 individual PAHs as well as total PAH concentrations above FSQVs. Stations 2B2, 2C2, and 8A2 also had total PAHs as well as several individual PAHs above FSQVs.

Phenol and alkyl-substituted phenols were detected in more than half the samples, with the highest concentration in sediment from Station 4B3. Pentachlorophenol was detected at several sites at concentrations from 300 - 700 ug/kg, but was highest at 7A2 (1,240 ug/kg). Other semivolatile organics, when detected, were generally in the 100 - 1,000 ug/kg range, and like phenols have no associated FSQV. Bis(2-ethylhexyl)phthalate was an exception with concentrations both high and in exceedence of the FSQV in about three-quarters of the samples. Carbazole was above the FSQV in more than half the samples, although concentrations were not particularly high.

Total PAH showed a moderately strong positive correlation with TOC (Appendix C). Other semivolatile compounds such as bis(2-ethylhexyl)phthalate, 4-methylphenol, and carbazole were even more strongly correlated with TOC. There appears to be no relationship between stations with visible oil or petroleum odor in samples and high levels of PAH. For instance, an oil sheen was visible in sediment from 4F2 but was not observed at 2C2 where total PAH was 100,000 ug/kg. Conversely, some sites with oily sediments had relatively low PAH (e.g., 6B2, 6C2, 7A3, 1B3).

Table 6. Median, Minimum, and Maximum Detected Concentrations of Semivolatile Organic Compounds in Salmon Bay Phase III Sediments (ug/kg, dw).

Chemical	Median	Min.	Station	Max.	Station
Priority Pollutant PAHS					
Naphthalene	640	37	7C2	5,600	4F2
Acenaphthylene	260	12	7C2	1,300	4B3
Acenaphthene	350	33	7C2	7,400	4F2
Fluorene	480	39	7C2	7,000	4F2
Phenanthrene	2,000	71	7B2	41,000	4F2
Anthracene	590	67	7C2	16,000	4F2
Total LPAH	4,400	71	7B2	78,000	4F2
Fluoranthene	3,400	120	7B2	46,000	4F2
Pyrene	3,500	120	7B2	56,000	4F2
Benzo(a)anthracene	1,200	150	6C2	26,000	4F2
Chrysene	1,500	59	7B2	28,000	4F2
Benzo(b+k)fluoranthenes	2,300	67	7B2	42,000	4F2
Benzo(a)pyrene	1,400	180	7B2	24,000	4F2
Indeno(1,2,3-cd)pyrene	990	91	7A3	14,000	4F2
Dibenzo(a,h)anthracene	250	34	7C2	3,100	4F2
Benzo(ghi)perylene	1,000	87	7B2	12,000	4F2
Total HPAH	15,000	1,000	7B2	250,000	4F2
Total PAH	18,000	1,100	7B2	329,000	4F2
Phenols and non-Priority Pollutant PAHs					
Phenol	120	36	5D2	770	4B3
2-Methylphenol	90	72	8C2	300	4B3
4-Methylphenol	510	52	5D2	6,300	4B3
2,4-Dimethylphenol	140	140	4B3	140	4B3
Pentachlorophenol	470	290	4C2	1,200	7A2
Retene	1,100	94	7C2	76,000	4F4
2-Methylnaphthalene	220	28	7C2	3,500	4F2
1-Methylnaphthalene	110	14	7C2	1,800	4F2
Phthalates					
Dimethylphthalate	150	15	7C2	580	6A2
Diethylphthalate	90	32	4F3	180	3C3
Di-N-Butylphthalate	420	69	4F3	1,700	3C3
Butylbenzylphthalate	190	28	7C2	1,500	2B2
Bis(2-Ethylhexyl)phthalate	2,800	280	6C2	23,000	4F3
Di-N-Octyl Phthalate	300	200	4C2	400	4B3
Miscellaneous Semivolatiles					
1,4-Dichlorobenzene	50	27	4B2	94	8C2
1,2-Dichlorobenzene	110	73	4F2	120	2B2
Benzyl Alcohol	80	14	7C2	330	2B2
Isophorone	51	51	4B3	51	4B3
Benzoic Acid	2,500	1,000	6B2	4,200	4B3
Dibenzofuran	240	24	7C2	3,800	4F2
Caffeine	34	34	6C2	34	6C2
Carbazole	180	24	7C2	2,900	4F2
3β-Coprostanol	2,100	1,400	4C2	32,000	4B2

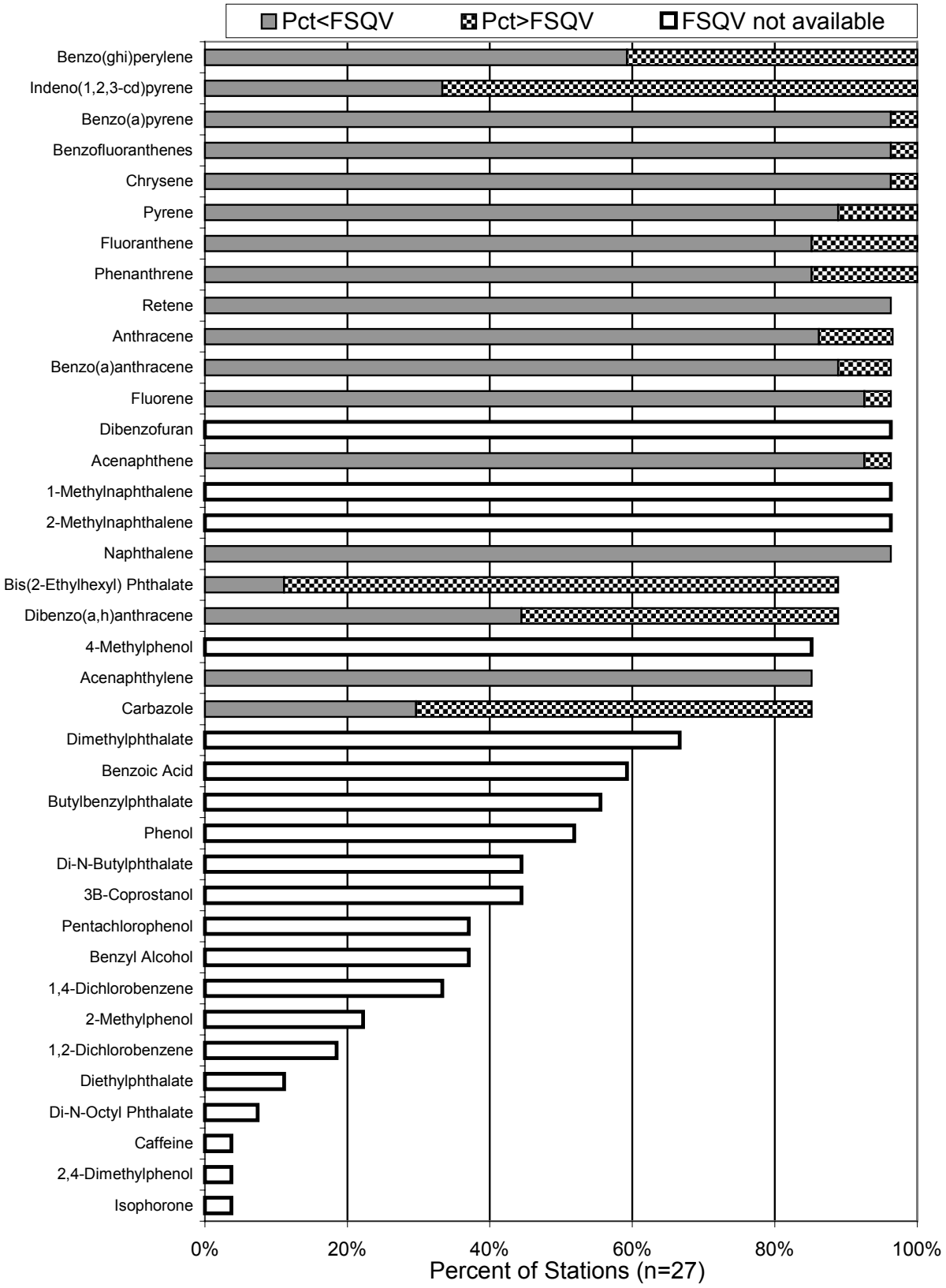

Figure 3. Frequency of Detection and Exceedence of Freshwater Sediment Quality Values (FSQVs) for Semivolatile Organics in Salmon Bay Phase III Sediments.

Butyltins

Butyltin concentrations are shown in Table 7. Tributyl-chlorotin (TBTCl) was detected in all samples, with concentrations ranging from 45 to 72,000 ug/kg. Ion-equivalent tributyltin (TBT^+) concentrations ranged from 40 ug/kg to 64,000 ug/kg. Monobutyl-chlorotin (MBTCl), dibutyl chlorotin (DBTCl), and tetrabutyltin (TeBT) were detected in most samples.

TBT is an organometallic compound with biocidal properties. Its presence in the aquatic environment is mainly due to its use in anti-fouling paint for vessel hulls, although in 1988 its use in the U.S. was severely restricted for most applications. MBT and DBT are metabolites formed during the progressive debutylation of TBT. Substituted-MBTs and -DBTs are also used as PVC stabilizers, and as catalysts in the manufacture of polyurethane foam and silicone elastomers (EPA, 1996). TeBT may be an impurity produced during TBT manufacturing or possibly formed photolytically or microbially from lesser butylated congeners.

On average, TBTCl made up 70% of the butyltin concentrations in the Phase III samples. Concentrations of all butyltins were extremely high in the sample from 4F2, with total butyltin concentrations making up 0.01% of the dry sample weight. It should be noted that the accuracy of these data is suspect due to the poor precision encountered during analysis, probably as a result of matrix effects such as the presence of paint particles.

Red paint chips were observed in the sample from 4F2 which most likely contributed to the high level of TBT, and probably copper as well as zinc, in this sample. However, visual observations are probably a poor indicator of contaminant levels among sites since most samples with high TBT, copper, and zinc concentrations had no observable paint chips. Of the four additional stations where paint chips were observed (5D2, 6A2, 7A2, 8C3), only 7A2 had concentrations of TBT^+, copper, and zinc above median values. Nevertheless, there is evidence that hull paint is associated with high copper and zinc concentrations in sediments. Rank order data for copper and zinc is highly correlated to TBT (Spearman correlation coefficients of 0.76 and 0.72, respectively; Appendix C), signifying that sites with high TBT tend to have high copper and zinc. Conversely, sites with low TBT concentrations tended toward lower copper and zinc concentrations.

The presence of paint particles adds to the complexity of determining the bioavailability and toxicity of TBT in sediment. Other factors include organic carbon, pH, salinity, clay content, and the presence of inorganic constituents such as iron oxides (EPA, 1996). Due to its complex behavior in the aquatic environment, no sediment quality criteria have been adopted for TBT in marine sediments. In 1988, the PSDDA agencies developed an interim screening level (73 ug TBT^+/kg) for use in marine areas, based on best available knowledge of the chemical and its properties. There is currently much uncertainty surrounding the use of a bulk sediment screening level for TBT due to unresolved questions about environmental partitioning, bioavailability, and methods to determine toxicity (Michelsen et al., 1996). Although site-specific screening levels for TBT have been recommended at Superfund Sites in Puget Sound (EPA, 1996), numerical criteria have not been established to replace the 1988 PSDDA screening level concentrations for bulk sediments. There are also no available sediment quality criteria for TBT in freshwater.

Table 7. Concentrations of Butyltins in Salmon Bay Phase III Sediments and Lake Washington Reference Sediments (ug/kg, dw).

Station	Monobutyl-trichlorotin	Dibutyl-dichlorotin	Tributyl-chlorotin	Tetrabutyltin	TBT^+ (ion equiv.)
1B3	4,110 J	2,515 J	17,600	451	15,664
2B2	736	182	1,920	35 J	1,709
2C2	636	202	2,470	30 J	2,198
3B2	307	262	973	60	866
3B3	267	139	782	70	696
3C2	840	393	4,030	59 J	3,587
3C3	608	663	7,460	68	6,639
4B2	534 J	260	1,214	20 J	1,080
4B3	428	171	1,050	(36) U	935
4C2	340	376	811	7 J	722
4F2	7,785 J	22,150 J	72,450	771	64,481
4F3	537	1,980	3,180	96 J	2,830
4F4	95	91	671	(28) U	597
5A2	737	862	2,840	51 J	2,528
5B2	610 J	642 J	1,580	45 J	1,406
5D2	60	24	142	(18) U	126
6A2	355 J	69 J	909	24 J	809
6B2	186 J	246	1,360	51	1,210
6B3	312 J	419	1,360	(23) U	1,210
6C2	38 J	(24) U	70	(24) U	62
7A2	248 J	346	2,490	36	2,216
7A3	32 J	37	150	(15) U	134
7B2	61 J	(62) U	127	(61) U	113
7C2	87	100	222	(14) U	198
8A2	500	304	2,800	112 J	2,492
8C2	389 J	288	1,155	16 J	1,028
8C3	65 J	(30) U	925	148	823
10A2 (ref.)	41 J	22 J	87	(28) U	77
10B2 (ref.)	36 J	16 J	45	(17) U	40

U= Undetected at associated concentration
J= Estimated concentration
Exceeds PSDDA Screening Level

Concentrations of TBT in Phase III sediment samples generally exceeded the PSDDA screening level (SL) by an order of magnitude. Samples from 1B3 and 3C3 had TBT levels two orders of magnitude above the SL, and TBT was 900 times the SL in sediment from Station 4F2. Several stations had TBT near or below the SL, including the reference stations.

PCBs

PCBs were analyzed at six stations in the vicinities of stations where substantial concentrations (~1,000 ug/kg or greater) were detected during Phase II sampling. Five of the six stations analyzed had detectable PCB concentrations (Table 8). Total PCBs were highest at 4F2 (2,100 ug/kg) and 1B3 (1,500 ug/kg). The lowest concentrations were at 7A2 (140 ug/kg) and at 7A3 which had no detectable PCBs at quantitation limits of 66 ug/kg.

Table 8. PCB Concentrations in Selected Salmon Bay Phase III Sediments (ug/kg, dw).

Station	PCB - 1016	PCB - 1221	PCB - 1232	PCB - 1242	PCB - 1248	PCB - 1254	PCB - 1260	Total PCBs
1B3	140 HUJ	140 HUJ	140 HUJ	140 HUJ	140 HUJ	**960** H	**500** H	**1,460** H
4C2	79 UJ	79 UJ	79 UJ	79 UJ	79 UJ	**230** J	**74** J	**304** J
4F2	180 HUJ	180 HUJ	180 HUJ	**570** H	180 HUJ	**1,060** H	**460** H	**2,090** H
4F3	130 HUJ	130 HUJ	130 HUJ	130 HUJ	130 HUJ	**570** H	**210** H	**780** H
7A2	82 U	82 U	82 U	82 U	82 U	**140**	82 U	**140**
7A3	66 U	66 U	66 U	66 U	66 U	66 U	66 U	66 U

Detected compounds in **bold**
U= Undetected at associated concentration
UJ= Undetected at associated estimated concentration
J= Estimated concentration
H= Exceeded holding time

In general, it appeared that concentrations were similar to those detected in nearby sites from Phase II. The exceptions were at Stations 7A2 and 7A3 whose "root" station (7A from Phase II) had the highest total PCB concentrations in sediments (7,600 ug/kg).

Sediment Bioassays

Bioassay results for *Hyalella* survival, *Chironomus* growth and survival, and Microtox® response are summarized in Table 9. Complete test results are in Appendix D.

Each station was compared to one reference site using a one-sided upper tail student's T-test. Alpha was set at 0.05 except for the *Chironomus* growth bioassay where alpha was 0.10 as recommended by SMS/PSDDA, since larval bioassays tend to have large variance (Michelsen and Shaw, 1996).

Reference station 10A2 was used for all comparisons except *Chironomus* survival, since grain size and TOC content of reference station 10A2 were closer to those of test stations than reference station 10B2. Average survival in the *Chironomus* survival bioassay was 50% in reference sediment 10A2. This is below the SMS performance standard of greater than 70% survival for reference sediments (WAC 173-204-315); as a result, station 10B2 was used for *Chironomus* survival comparisons.

Table 9. Summary of Bioassay Test Results on Selected Salmon Bay Phase III Sediments.

	***Hyalella* Survival** (%)		***Chironomus* Survival** (%)		***Chironomus* Growth** (mg, dw)		**Microtox** (% light red. from control)	
Station	mean	*p*	mean	*p*	mean	*p*	mean	*p*
1B3	90	0.055	66	0.24	1.40	**<0.00025**	12	**<0.00025**
2B2	90	0.16	54	**0.013**	2.08	**<0.00025**	8.7	**0.0005**
2C2	82	**0.002**	80	1.0	1.68	**<0.00025**	48	**<0.00025**
3B3	78	**0.001**	74	0.15	1.50	**<0.00025**	11	**<0.00025**
3C3	98	0.19	88	0.005*	2.91	**0.014**	-1.5	#
4B2	92	0.19	96	0.001*	2.56	**0.008**	44	**<0.00025**
4B3	70	**0.002**	68	**0.006**	3.08	**0.011**	57	**<0.00025**
4C2	98	0.19	76	0.24	2.71	**0.0005**	59	**<0.00025**
4F2	86	**0.049**	60	**0.011**	1.40	**<0.00025**	37	**<0.00025**
4F4	62	**0.0005**	82	0.40	3.22	**0.040**	19	**<0.00025**
5A2	88	0.17	86	0.15	2.32	**0.0005**	18	**<0.00025**
5B2	84	0.13	78	0.31	2.93	**0.0005**	-6.1	#
6A2	80	**0.028**	82	0.35	3.09	**0.021**	45	**<0.00025**
6B3	92	0.19	72	**0.05**	1.51	**<0.00025**	7.8	0.099
6C2	94	0.23	82	0.37	3.22	0.21	-13	#
7A2	70	0.093	82	0.40	3.54	0.43	-8.9	#
7B2	64	**0.007**	72	0.17	2.93	**0.010**	1.6	0.004**
7C2	80	**0.039**	64	**0.098**	3.09	**0.014**	19	**<0.00025**
8A2	68	**0.008**	54	**0.083**	1.31	**0.0005**	19	**<0.00025**
8C3	78	**0.004**	28	**<.00025**	0.40	**<0.00025**	8.4	**<0.00025**
10A2 (ref.)	98	--	50	--	3.60	--	4.2	--
10B2 (ref.)	96	--	80	--	3.46	--	17	--

P values of a one tailed T-test of sample (n = 4-5 replicates) against one reference site (n=5). Station 10A2 used as reference site for *Hyalella* survival, *Chironomus* growth, and Microtox. Station 10B2 used as reference site for *Chironomus* survival.

All percentile results were arcsin-square root transformed prior to data analysis (*Hyalella*, *Chironomus* survival, and Microtox).

"Hits" are in **bold**. A hit is p<0.05 for all but *Chironomus* survival (p<0.1, per SMS/PSDDA guidance).

*Survival in sample was significantly *higher* than in reference

**Light reduction in sample was significantly *lower* than in reference

= no difference: there was no reduction in the light emission compared to the laboratory controls. As a result, these replicate samples had a negative decreased illumination. The arcsin transformation will not work on negative values.

All stations except 6C2 and 7A2 had significant bioassay responses for one or more tests. Stations 4B3, 4F2, 7C2, 8A2, and 8C3 showed hits in all four bioassays; five other stations had hits in three tests (2B2, 2C2, 3B3, 4F4, and 6A2). *Chironomus* growth was the most sensitive (i.e., significant difference from reference site) of the bioassay tests, followed by the Microtox test. In contrast, only seven stations had hits for *Chironomus* survival due mainly to low survival rates at the reference station 10A2. Results of the *Chironomus* growth bioassays were correlated with *Chironomus* survival ($r = 0.328$, $p = 0.020$), and Microtox ($r = 0.301$, $p = 0.045$).

Discussion

Confirmation of Phase II Results

The distribution of contaminants in Salmon Bay could be characterized by "hot-spots" interspersed among a field of sediments with more moderate concentrations. These areas of high contamination tend to be closer to shore, with decreasing concentrations toward the channel center. This is consistent with findings of the Phase II study, and generally indicates shoreside point sources of contamination, although these sources may extend outward from shore in the case of piers and moored vessels. A more detailed discussion of contaminants related to possible sources in Salmon Bay is discussed in the Phase II report (Serdar and Cubbage, 1996). Shoreside businesses or activities located near each station are included in the table of station descriptions (Appendix A)

One of the objectives of the Phase III study was to confirm and delineate areas of clean and contaminated sediment found during Phase II. For the most part, this survey was successful in confirming areas of highly contaminated sediments. Table 10 lists instances where chemical concentrations at Phase III stations agreed well with either high or low degrees of contamination at their associated Phase II stations. Figure 4 shows locations of both Phase II and Phase III stations.

Table 10. Instances Where Phase III Samples Confirmed Phase II Results*.

Phase II Station	Associated Phase III Station	Similarities Between Phase II and Phase III
1B	1B3	High As, Hg, Pb, Cd, Cu, Zn, PCB, and TBT Low HPAH
3B	3B2, 3B3	High Hg
3C	3C2, 3C3	High TBT
4B	4B2	High TBT
4F	4F2, 4F3	High Pb, Cd, Cu, Zn, HPAH, LPAH, PCB, and TBT
6A	6A2	High Cd
6B	6B2, 6B3	High Ni, Cd, Cr, and Cu Low Hg
7A	7A2	High Cu and Zn
7C	7C2	Low As, Hg, Pb, Cd, Cu, Zn, HPAH, LPAH, and TBT
8A	8A2	High TBT
8B	8C2	High Hg Low HPAH
8C	8C3	High Hg, Pb, and Cd Low HPAH

*Serdar and Cubbage, 1996

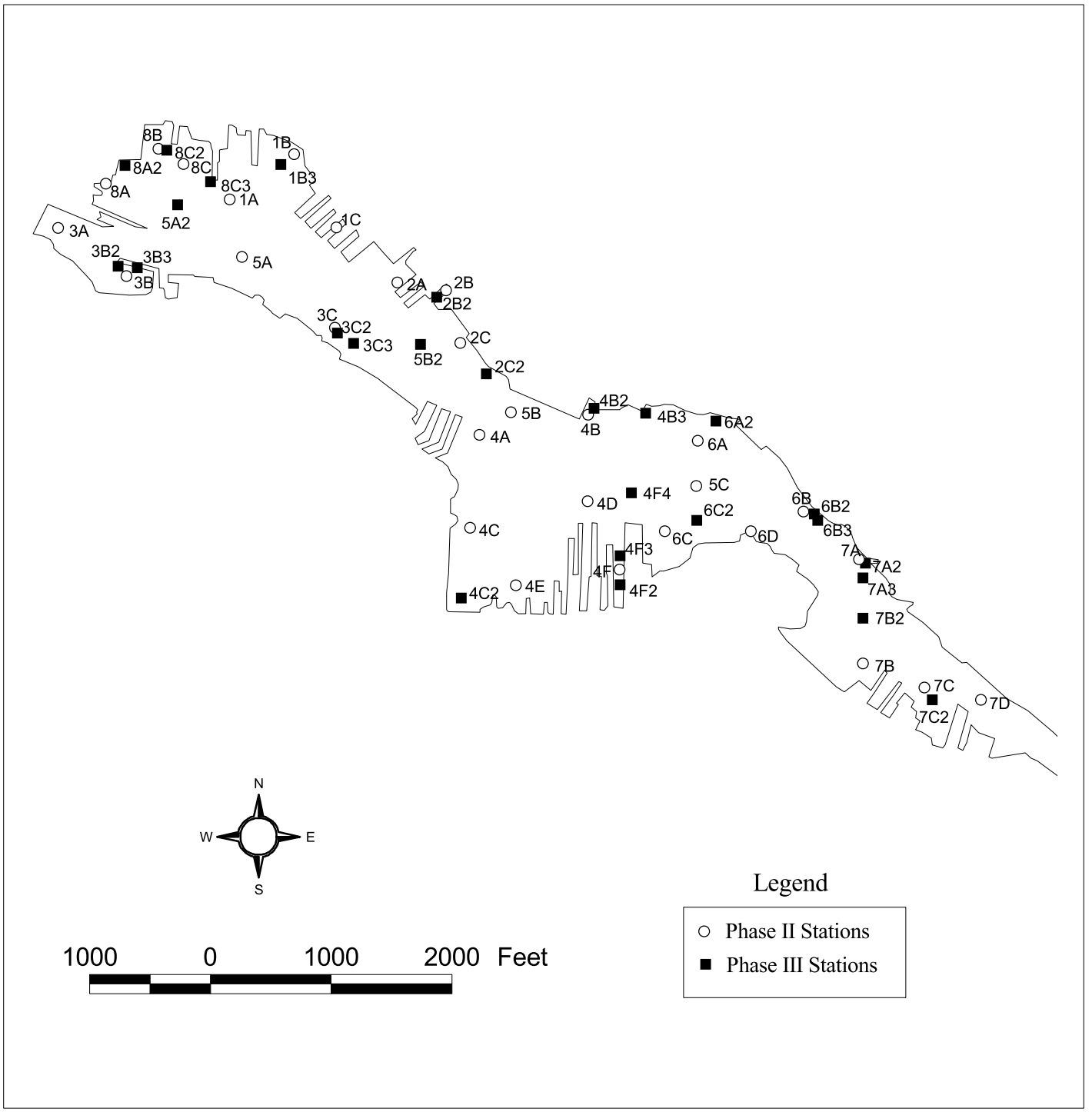

Figure 4. Salmon Bay Station Locations for Phase II and Phase III.

Moderate contaminant levels were generally confirmed during Phase III sampling, although these comparisons are subject to the extreme range of concentrations for many chemicals. There were few confirmations of "clean" areas, due mainly to the lack of Phase III samples designed for this purpose. For instance, further sampling of the relatively clean and sandy central channel region was not considered warranted for Phase III.

Due to the variability of sample results, the sampling coverage used for this project was unable to delineate hot-spots. Delineation and resolution of hot-spots will require more intensive sampling in a small area together with extremely accurate determinations of sampling locations. However, in some cases Phase III samples failed to confirm high contaminant levels found at associated Phase II stations, thereby yielding clues about the directional boundaries of these hot-spots. For instance, Station 7A2 had concentrations of copper and zinc almost identical to Phase II Station 7A, yet copper and zinc concentrations decreased by an order of magnitude 150 feet offshore at Station 7A3. The 7A/7A2 hot-spot southern boundary therefore extends no farther than Station 7A3. It is noteworthy that PCB concentrations at these stations did not follow the same pattern as copper and zinc. Total PCBs were high at 7A2 (7,600 ug/kg), one-fiftieth of that concentration at 7A2, and undetectable at Station 7A3.

The southeast portion of the Fisherman's Terminal embayment represents another hot-spot area. The extreme southeast corner appears to have the most overall contaminated sediments from both phases of sampling (Stations 4F and 4F2). Other samples in Fisherman's Terminal southwest corner (4C2) and to the north (4F3 and 4F4) indicate that: 1) contaminant concentrations are inversely related to distance from 4F2, and 2) the western and northern portions of Fisherman's Terminal have low-to-moderate contamination.

Phase III sampling may have revealed a new hot-spot in the case of Station 2B2. This station was sampled to confirm clean sediments 170 feet from Phase II Station 2B. However, Station 2B2 had much higher contaminant levels than 2B, especially copper and TBT. Although differences between Stations 2B and 2B2 are probably related to sediment grain size (90% sand vs. 51% sand, respectively), this example suggests that other hot-spots may have been missed with the existing sample coverage.

Toxicity of Sediments

Samples analyzed during Phase III represent some of the most contaminated freshwater sediments Ecology has found in Washington. For instance, the highest copper concentration found during the present survey (11,000 mg/kg) surpassed all 332 detectable results listed in the SEDQUAL database. Maximum Phase III concentrations of mercury and nickel also exceeded all SEDQUAL results for these metals (265 and 234 results, respectively). Given the number of highly concentrated chemicals in many samples, a high degree of toxicity seems likely. Of the 80 bioassay tests performed on 20 samples, 49 showed significant toxicity compared to controls. However, none of the samples appeared to be extremely toxic to test organisms. Median survival for *Hyalella* and *Chironomus* were 83% and 75%, respectively (compared to an average *Chironomus* survival of 65% in reference sediments). Only one sample (8C3) had survival less than 50%. *Chironomus* growth was the most sensitive test in terms of response relative to reference sediments.

The number of chemicals in sediments, the limited sampling coverage for bioassays, and the varying degrees of contamination and bioassay response make it difficult to assess the toxic effects of individual chemicals. Likewise, the predictive and protective powers of the FSQVs are impossible to determine without more rigorous analysis of the results and are beyond the scope of this report. More general observations about sediment toxicity related to chemical concentrations suggest that sediments having the most chemicals above FSQVs also demonstrated the most toxicity to test organisms (Table 11). Sixty-one percent of the bioassay hits occurred at the ten most contaminated stations. About one-half of the bioassay hits and one-half of the total FSQV exceedences occurred at the seven most contaminated stations. Therefore, it appears there is a positive correlation between the number of contaminants above FSQVs and toxicity in a sample. Exceptions to this are samples from Stations 7A2, with seven chemicals above FSQVs and no toxic response, and 7C2 where only TBT exceeded (the PSDDA SL), yet there was significant toxicity in all four bioassays. Station 6C2 did not have chemicals above FSQVs or bioassay hits. Like the "hot-spots" of chemical concentrations in Salmon Bay, toxicity appeared to be distributed irregularly throughout Salmon Bay. Figure 5 summarizes bioassay hits for the four tests performed on the 20 Salmon Bay sediments.

Most chemicals exceeding FSQVs are organic compounds. When stations were sorted according to the number of organics above FSQVs, the pattern of bioassay hits remains the same (61% of hits occurred at the ten most contaminated stations). The ten sediments most contaminated with PAH (LPAH, HPAH, or total PAH) had 65% of the bioassay hits, the most of any chemical or group of chemicals analyzed. Carbazole appeared to be the second most toxic constituent, followed by chromium and bis(2-ethylhexyl)phthalate.

Stations sorted according to their overall metals concentrations (as in Table 5) had only 47% of the bioassay hits in the ten highest ranked samples. The least toxic metals among the ten most contaminated stations appeared to be arsenic (47% of hits), followed by nickel and lead (51% each). Even fewer hits (45%) were associated with samples having the top ten TBT concentrations. Using this approach, TBT appears to have relatively low toxicity.

Table 11. Summary of Chemicals Exceeding Freshwater Sediment Quality Values and Bioassay Hits in Salmon Bay Phase III Sediments.

	Stations																												
	4F2	8A2	2C2	2B2	4B2	4B3	8C3	3B3	5A2	3C3	3B2	6A2	3C2	7A2	1B3	4F3	6B3	4F4	8C2	5B2	6B2	4C2	5D2	7C2	7B2	7A3	10A2	10B2	6C2
CHEMICALS																													
Tributyltin*	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
Mercury	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X		X	X					X	
Bis(2-ethylhexyl)phthalate	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X							
Indeno(1,2,3-cd)pyrene	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X	X		X			X						
Carbazole	X	X	X	X	X	X	X		X	X	X	X		X		X		X	X										
Zinc	X	X		X	X		X	X	X	X	X		X	X	X	X			X										
Copper	X		X	X	X			X	X	X			X	X	X	X	X				X								
Dibenzo(a,h)anthracene	X	X	X	X	X	X	X		X	X	X	X	X																
Benzo(ghi)perylene	X	X	X	X	X	X	X	X	X		X	X																	
Arsenic	X						X	X						X	X														
Phenanthrene	X	X	X			X																							
Fluoranthene	X	X	X	X																									
HPAH	X	X	X	X																									
TotPAH	X	X	X	X																									
Anthracene	X	X	X																										
Pyrene	X	X	X																										
Lead	X														X														
LPAH	X		X																										
Chromium																	X				X								
Benzo(a)anthracene	X	X																											
Chrysene	X																												
Benzo(b+k)fluoranthenes	X																												
Benzo(a)pyrene	X																												
Acenaphthene	X																												
Fluorene	X																												
Number > FSQVs	24	15	15	12	9	8	8	8	8	8	8	7	7	7	7	7	6	5	5	4	3	3	3	1	1	1	1	1	0
BIOASSAYS																													
Chironomus Growth	X	X	X	X	X	X	X	X	X	X	na	X	na		X	na	X	X	na	X	na	X	na	X	X	na	--	--	
MICROTOX	X	X	X	X	X	X	X	X	X		na	X	na		X	na		X	na		na	X	na	X		na	--	--	
Hyalella Survival	X	X	X			X	X	X			na	X	na			na		X	na		na		na	X	X	na	--	--	
Chironomus Survival	X	X		X		X	X				na		na			na	X		na		na		na	X		na	--	--	
Number of Hits	4	4	3	3	2	4	4	3	2	1	--	3	--	0	2	--	2	3	--	1	--	2	--	4	2	--	--	--	0

*PSDDA Screening Level (No FSQV developed for tributyltin)
na=not analyzed

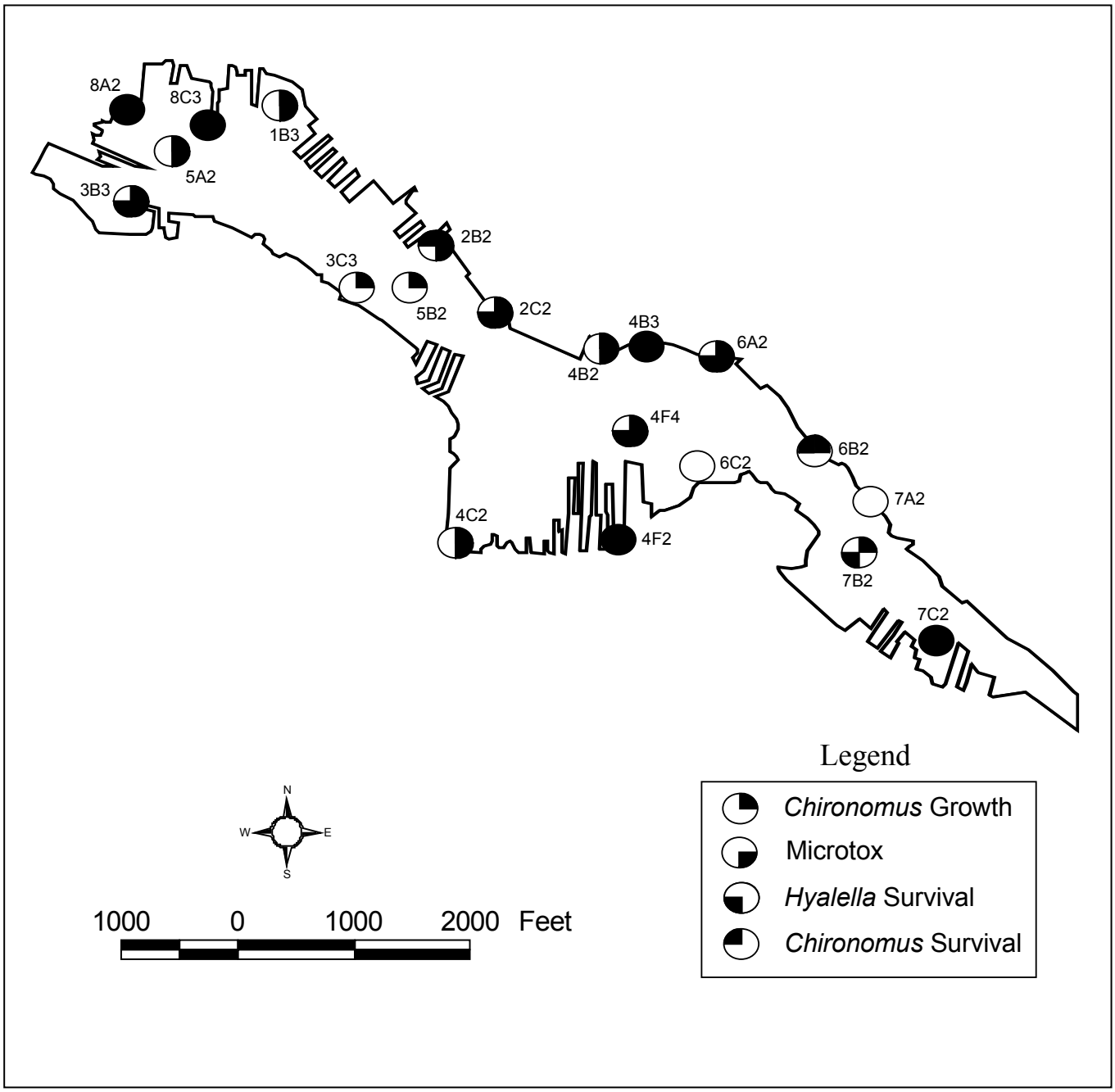

Figure 5. Summary of Bioassay Hits in Salmon Bay Phase III Sediments.

Summary and Conclusions

There is widespread chemical contamination in Salmon Bay, based on results of 27 Phase III sediment samples analyzed for metals and organics. Table 12 summarizes concentrations of the major chemical contaminants in Salmon Bay sediments. Tributyltin, mercury, bis(2-ethylhexyl)-phthalate, indeno(1,2,3-cd)pyrene, and carbazole were found at elevated concentrations in most stations. These appear to be the most pervasive problem chemicals, based on comparisons to FSQVs and the PSDDA SL.

Table 12. Summary of Major Contaminant Concentrations in Salmon Bay Phase III Sediments.

Chemical	Maximum	Minimum	Median
Metals (ug/g, dw)			
Arsenic	210	5	20
Mercury	43	0.1	0.8
Cadmium	5	<0.3	1.4
Chromium	620	24	66
Copper	11,000	48	370
Lead	1,300	12	190
Nickel	640	30	53
Zinc	4,200	84	420
Organics (ug/kg, dw)			
Low Molecular Weight PAHs (LPAH)	78,000	70	4,400
High Molecular Weight PAHs (HPAH)	250,000	1,200	15,000
Total PAH	330,000	1,300	18,000
Bis(2-ethylhexyl)phthalate	23,000	<140	2,500
Carbazole	2,900	24	170
Tributyltin (ion equivalent)	64,000	62	1,100

In some cases, chemicals were found at extremely high concentrations. The tributyltin (TBT) concentration at Station 4F2, located in the furthest southeast corner of Fisherman's Terminal, was 64,000 ug/kg TBT. This station also had extremely high concentrations of mercury (43 ug/g), copper (11,000 ug/g), lead (1,300 ug/g), zinc (4,200 ug/g), PAHs (total = 330,000 ug/kg), bis(2-ethylhexyl)phthalate (23,000 ug/kg), and carbazole (2,900 ug/kg). Other chemicals in 4F2 sediment were also found in high concentrations, making it by far the most contaminated of any station examined.

The distribution of contaminants in Salmon Bay could be characterized by "hot-spots" interspersed among a field of more moderate concentrations. These hot-spots generally occur near shore; cleaner sediments tend to be found toward the channel center. In most cases, hot-spots detected during Phase II sampling were verified by the Phase III survey. Some areas of cleaner sediments were also verified. Although Phase III sampling generally succeeded in

verifying hot-spots, sample coverage was too thin to delineate the hot-spot boundaries. The thin coverage, along with the failure to verify all of the “clean” Phase II stations, suggests that additional hot-spots may have gone undetected by the two rounds of sampling conducted to date.

Most of the sediments analyzed in Phase III probably have an adverse effect on benthic organisms. This conclusion is based on: 1) comparisons to Freshwater Sediment Quality Values (FSQVs) which attempt to strike a balance between protecting aquatic organisms and predicting minimum adverse biological effects, and 2) four bioassay toxicity tests conducted on 20 of the 27 Salmon Bay sediment samples.

At least one chemical was detected above FSQVs in 23 of the 27 samples. Tributyltin concentrations were above the SL in 26 of the 27 Salmon Bay sediments. One of the reference samples (10B2) had mercury above the FSQV, and the other reference sample (10A2) had TBT above the SL. Most samples had multiple chemicals above FSQVs/SL, with seven as the median number of exceedences at each station. Only one station (6C2, located east of Fisherman's Terminal) had no chemicals above FSQVs or the SL.

Eighteen of the 20 Salmon Bay sediments were toxic to at least one bioassay organism. One-half of the samples showed a toxic response in three or more toxicity tests. The *Chironomus* growth test was the most sensitive bioassay, followed by Microtox, *Hyalella* survival, and *Chironomus* survival. Toxicity of sediments appeared to be positively correlated to the number of chemicals above FSQVs/SL, although this pattern is somewhat inconsistent. It appears that the number of organic chemicals exceeding FSQVs is more closely related to toxicity than to the degree of metals contamination in samples. A coarse analysis of the relationship between individual chemicals or chemical groups suggests that PAHs (LPAH, HPAH, or total PAH) are the most toxic, followed by carbazole, chromium, and bis(2-ethylhexyl)phthalate. Arsenic appeared to have the least toxicity among metals. TBT appeared to be the least toxic chemical analyzed in terms of relationships between relative concentration and toxic response. Like the "hot-spots" of chemical concentrations, toxicity exhibited an irregular distribution in Salmon Bay.

Recommendations

Focus sampling around highly contaminated areas (hot-spots) to better resolve and define the boundaries of contamination. Sampling should be designed to:

1. Determine concentration gradients with confidence.

2. Delineate a boundary with statistically significant differences in chemical concentration across the boundary.

The best candidates for focused sampling appear to be the areas around Stations 4F2, 8A2, and 2C2.

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Appendices

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Appendix A

Station Descriptions

Field Observations

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Table A-1. Salmon Bay Phase III Station Descriptions.

Station	Sample No.	Date and Time	Depth (ft)	Lat (deg)	Lat (min)	Lat (sec)	Long (deg)	Long (min)	Long (sec)	Location Description
1B3	8281	5/21/97 12:30	15	47	40	00.06	122	23	15.30	Off Pacific Fishermen, Inc.
2B2	8282	5/20/97 16:12	30	47	39	49.38	122	22	54.48	Off 20th Ave NW
2C2	8283	5/20/97 13:23	20	47	39	42.30	122	22	48.24	Off Ballard Mill Properties
3B2	8284	5/20/97 19:23	18	47	39	50.64	122	22	35.76	Off Time Oil inside pier near end
3B3	8285	5/20/97 18:50	17	47	39	50.82	122	23	32.94	Off Time Oil inside pier east of 3B2
3C2	8286	5/20/97 17:10	36	47	39	45.60	122	23	07.74	Off float on west side of Marco Shipyard
3C3	8287	5/20/97 16:46	36	47	39	44.64	122	23	05.46	Off NW corner of Marco Shipyard drydock
4B2	(8288/8308)/8312	5/20/97 12:25	15	47	39	39.36	122	22	34.14	Off Lake Union Boat Center
4B3	8289	5/20/97 12:00	5	47	39	39.78	122	22	27.72	Off Seattle Maritime Education
4C2	8290	5/19/97 18:41	11	47	39	22.68	122	22	51.00	West End of Fishermen's Terminal
4F2	8291	5/19/97 19:55	7	47	39	24.36	122	22	30.18	East End of Fishermen's Terminal
4F3	8292	5/19/97 19:30	19	47	39	25.80	122	22	28.86	Under 15th Ave. bridge
4F4	8293	5/20/97 9:05	15	47	39	32.28	122	22	29.40	Off Bakketun & Thomas Boat Refitters
5A2	8294	5/21/97 8:44	27	47	39	56.40	122	23	28.44	North of breakwater for locks
5B2	8295	5/20/97 15:49	37	47	39	44.70	122	22	56.88	Mid-channel off 20th Ave. NW
5D2	8296	5/19/97 15:19	35	47	39	20.70	122	21	52.86	Mid-channel off Foss dock
6A2	8297	5/20/97 8:41	16	47	39	38.64	122	22	18.66	Off Commercial Marine Center by 14th Ave.
6B2	8298	5/20/97 15:06	12	47	39	30.60	122	22	05.64	Off Seattle Steel
6B3	8299	5/20/97 15:29	17	47	39	30.36	122	22	05.70	Off small cove by Seattle Steel
6C2	8300	5/20/97 9:41	16	47	39	29.88	122	22	20.82	Off unknown property
7A2	8301	5/20/97 17:42	13	47	39	26.64	122	21	58.86	By docks at Union Bay Shipbuilding
7A3	8302	5/19/97 16:59	22	47	39	25.26	122	21	59.34	Off Union Bay Shipbuilding
7B2	8303	5/19/97 16:25	21	47	39	21.78	122	21	59.16	Off west side of Foss
7C2	8304	5/19/97 15:51	18	47	39	14.88	122	21	49.98	Off Always Ready Bldg.
8A2	8305	5/21/97 9:17	15	47	39	59.04	122	23	38.70	By Army Corps Bldg. At locks
8C2	8306/8309	5/21/97 10:13	8	47	40	01.14	122	23	30.18	Off Seaborn Marine Terminal
8C3	8307	5/21/97 10:42	21	47	39	59.46	122	23	24.48	Off end of pier at Seattle Shop Bldg.
10A2	8310	5/19/97 11:30	22	47	44	49.26	122	16	25.86	Reference - Sheridan Beach in Lake Washington
10B2a	8311	5/19/97 13:30	26	47	39	48.60	122	15	50.46	Reference - Wolf Beach in Lake Washington
10B2b	8311	5/19/97 13:55	26	47	39	48.48	122	15	49.68	Reference - Wolf Beach in Lake Washington
10B2c	8311	5/19/97 14:15	26	47	39	49.68	122	15	51.06	Reference - Wolf Beach in Lake Washington

Table A-2. Field Observations Made During Phase III Sampling.

Station	Color	Odor	Oil Sheen?	Composition	Comments
1B3	dark brown	slight petroleum	slight	silt	Had terrible time obtaining sample. Moved station after 10-12 attempts. Much large debris. This is the station where they had run the boat prop with boat against dock?
2B2	dark brown	oil	yes	silty, mucky	Leaves & twigs
2C2	dark brown	none	no	silty	Chunks of organic debris
3B2	medium brown	slight petroleum	no	silty and fine	
3B3	brown	petroleum	yes	sand & silt	Chunks of debris and clay
3C2	dark brown	muddy	spots	silty muck	
3C3	dark brown	muddy	spots	muck	Tarps over dry dock opening doing poor job of containment.
4B2	very dark brown	slight muddy	slight	silty	
4B3	dark brown	sedimenty	slight	silt	A little organic debris
4C2	black/brown	none	yes	fine mucky silt	Composite of 2 grabs
4F2	brownish black		yes		Red paint chips
4F3	brownish		yes	silty sand	
4F4	greyish brown	oily, muddy	slight	silty	Large organic debris
5A2	medium brown	none	no	silt	
5B2	dark brown	rotten eggs	no	very silty, mucky	
5D2	grey		slight	sandy	2 grabs, broken glass, rusty metal, paint chips
6A2	dark brown	none	slight	silty	A few red paint chips, a little organic debris
6B2	dark brownish grey	oily, muddy	yes	silty, mucky	Large oil sheen came up with sample
6B3	dark brown	none	slight	mucky, silty	
6C2	grey		light	clay	Moved from original site which had a lot of wood debris.
7A2	medium brown		yes	silty, clay clumps	Composite of 2 grabs, large chunks of organic debris, red paint chips
7A3	grey		spots	silt & sand, chunks of clay	Wood debris, one blue paint chip
7B2	brown	none	no	sand & chunks	
7C2	grey/brown			silt & sand, chunks of clay	
8A2	brown	mild oil		silt	Composite of 3 grabs
8C2	dark brown	none	spots	lumpy silt with sand	
8C3	dark brown	none	no	silt/clay	Composite of 2 grabs. Boats were anchored at planned station. Bits of rusted metal debris, some red paint chips
10A2	chocolate	none	no	fines & silt	Big clam in grab
10B2					
10B2a	grey	none	no	silts sand	First of 3 grabs, clams.
10B2b	grey	none	no	silts sand	Second of 3 grabs, clams.
10B2c	grey	none	no	silts sand	Third of 3 grabs, clams.

Appendix B

Quality Assurance Data

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State of Washington Department of Ecology
Manchester Environmental Laboratory
7411 Beach Dr. East Port Orchard WA. 98366

July 15; 1997

Project: Salmon Bay Sediments

Samples: 21-8281-8312

Laboratory: Rosa Environmental

By: Pam Covey

Case Summary

These samples required thirty-two (32) Grain Size analyses on sediment using Puget Sound EstuaryProtocol (PSEP) method.

The samples were received at the Manchester Environmental Laboratory on May 22, 1997 and transported to Rosa Entironmental on May 29, 1997 for Grain Size analyses.

The analyses were reviewed for qualitative and quantitative accuracy, validity and usefulness.

The results are acceptable for use as reported.

ROSA ENVIRONMENTAL & GEOTECHNICAL LABORATORY, LLC.

Washington State Department of Ecology
Manchester Laboratory
Salmon Bay Project
Narrative

The following notes were taken during the analyses.

1. The samples were analyzed for grain size distribution following the Puget Sound Estuary Protocol. The samples were not treated for organics, and are thus reported as "apparent" grain size distributions. There were not any significant deviations from the procedure, nor were there any significant anomalies in the sediment samples, except as noted below.

2. Sample 21-8291 did not contain enough fines to get the required 5 grams for the pipette portion of the analysis. This small sample size may have biased the data.

3. Sample 21-8296 had a large rock, which was excluded from the analysis (it was approximately 1.5" x 1").

4. Samples 21-8298 and 21-8299 had an oily sheen during the washing and pipetteing portions of the analysis.

5. Sample 21-8303 was mostly peat, with some coarse sand. After washing the minus #230 material, the sample was oven dried at 90° C. During the oven drying, the peat formed a thick mass that resisted breaking up for the sieve portion of the analysis. Every effort was made to separate the fibers without compromising the grain size, but the chunks of peat would not break up into individual particles. The sieve data reported indicates a sample that is much more coarse that it actually was, and the data should be evaluated carefully. Also, because the sample was mostly organic and water (472% water on a dry weight basis), there was not enough fines (3.68 g.) to meet the required 5 gram minimum.

6. The triplicate run on sample 21-8307 needs to be evaluated carefully. The second sample in the triplicate had a large piece of rusted iron retained on both the #4 and #10 sieves. There were no pieces of iron visible in the other samples of the set. The presence of metal fragments may have skewed the entire analysis, if the finer fractions also contained significant amounts of metal, as the specific gravity of the sediment in the pipette portion of the analysis would be higher than accounted for by the procedure.

7. Sample 21-8309 had what appeared to be a green sequin retained on the #10 sieve.

8. Sample 21-8312 had an oily sheen on it during washing and pipetteing.

Washington State Department of Ecology
Manchester Laboratory

July 11, 1997

TO: Jim Cubbage

FROM: Aileen Richmond, Technician

THROUGH: Becky Bogaczyk, Chemist

SUBJECT: General Chemistry Quality Assurance memo: Salmon Bay, week 21.

SUMMARY

The data generated by the analysis of these samples is acceptable for use. Some samples have a holding time issue.

SAMPLE INFORMATION

These samples were received by Manchester Laboratory on 5/22/97 in good condition.

HOLDING TIMES

The samples were analyzed within the EPA holding times for total organic carbon and total solids with the exception of those samples collected on 5/19/97. Total solids (percent solids) samples # 97-218290, 91, 92, 96, and 97-218302, 3, 4, 10, and 11 were analyzed one day past the holding due to several things. The memorial day weekend, transit time, and the visit of Dan Silver to the lab were the main interferences with timely analysis.

ANALYSIS PERFORMANCE

Instrument Calibration

Where applicable, instrument calibration was performed before each analytical run and checked by initial calibration verification standards and blanks. All initial and continuing calibration verification standards were within the relevant USEPA (CLP) control limit. A correlation coefficient of 0.995 or greater was met as stated in CLP calibration requirements. The turbidimeter is standardized quarterly and calibrated with known check standards before each analytical run. All balances are calibrated yearly with calibration verification occurring monthly. Oven temperatures are recorded before and after analyses to ensure control.

Laboratory Control Sample

The laboratory controls were within acceptance windows.

Precision Data

Results from duplicate analysis were used to evaluate precision. All were within the acceptance window of ± 20 % Relative Percent Difference(RPD).

Procedural Blanks

Procedural blanks associated with these samples showed no analytically significant levels of analytes.

Other Quality Assurance Measures and Issues

The percent solid results for samples # 97-218290, 91, 92, 96, and 97-218302, 3, 4, 10, and 11 are qualified as estimates because they were analyzed one day past the holding time.

Total organic carbon samples # 97-218292, 95, and 97-218308 do not have replicate results for the 104°C analysis because the analyst running the 104°C determination did not duplicate the same samples as the analyst running the total organic carbon and 70°C percent solids determination.

Please call Aileen Richmond at 360-871-8823, or Becky Bogaczyk if you have any questions.

cc: Bill Kammin
Project file

Table B-1. Precision of Field Sampling and Laboratory Analysis for Grain Size Composition.

Sample No.	Station	QA type		<4750 um	2000-4750 um	1000-2000 um	500-1000 um	200-500 um	125-200 um	62-125 um	31-62 um	15.6-31 um	7.8-15.6 um	3.9-7.8 um	2-3.9 um	1-2 um	<1 um
97218288	4B2	split	%	0	0	0	1	3	7	10	15	20	17	10	7	5	5
97218308	9A2	split	%	0	0	1	0	2	5	10	15	21	18	12	7	8	1
			mean=	0	0	1	1	2	6	10	15	20	18	11	7	6	3
			RPD=			200%	200%	50%	33%	0%	0%	5%	6%	18%	0%	50%	133%
97218288/97218308	4B2/9A2	fld rep	%	0	0	1	1	2	6	10	15	20	18	11	7	6	3
97218312	9C2	fld rep	%	0	0	0	1	1	3	12	20	16	18	18	8	0	3
			mean=	0	0	0	1	2	4	11	18	18	18	14	8	3	3
			RPD=			200%	67%	57%	75%	18%	29%	22%	3%	50%	13%	185%	0%
97218306	8C2	split	%	0	0	1	3	13	31	15	10	9	6	5	2	3	2
97218309	9B2	split	%	0	0	1	3	11	28	14	10	8	8	8	5	4	0
			mean=	0	0	1	3	12	30	14	10	8	7	6	4	4	1
			RPD=			0%	0%	17%	10%	7%	0%	13%	29%	50%	75%	25%	200%
97218307	8C3	lab rep	%	0	1	4	4	3	3	4	6	17	19	14	8	9	8
97218307	8C3	lab rep	%	3	2	2	4	4	3	4	5	17	19	14	9	7	7
97218307	8C3	lab rep	%	0	0	4	4	3	3	4	8	16	20	14	10	7	7
			mean=	1	1	3	4	3	3	4	6	17	19	14	9	8	7
			RSD=	173%	100%	38%	0%	19%	0%	0%	25%	3%	3%	0%	11%	14%	8%
97218310	10A2	lab rep	%	0	0	0	0	1	8	19	12	22	14	13	7	3	1
97218310	10A2	lab rep	%	0	0	0	0	1	7	17	13	21	15	14	9	2	1
97218310	10A2	lab rep	%	0	0	0	0	2	7	17	15	18	17	13	8	2	1
			mean=	0	0	0	0	1	7	18	13	20	15	13	8	2	1
			RSD=					58%	8%	6%	12%	10%	10%	4%	13%	29%	0%

Table B-2. Precision of Field Sampling and Laboratory Analysis for Organic Carbon and Solids Composition.

Sample No.	Station	QA type		TOC70	TOC104	Solids	
97218288	4B2	split	%	6.5	6.4	26.6	
97218308	9A2	split	%	6.0	6.2	26.5	
			mean=	6.2	6.3	26.6	
			RPD=	8.1%	3.2%	0.4%	
97218288/9721	4B2/9A2	fld rep	%	6.2	6.3	26.6	
97218312	9C2	fld rep	%	5.9	6.5	27.2	
			mean=	6.2	6.4	26.9	
			RPD=	4.8%	3.1%	2.4%	
97218306	8C2	split	%	4.2	4.4	44.2	
97218309	9B2	split	%	4.4	4.6	42.7	
			mean=	4.3	4.5	43.4	
			RPD=	4.7%	4.4%	3.5%	
97218292	4F3	lab rep	%	7.6			
97218292	4F3	lab rep	%	7.4			
97218292	4F3	lab rep	%	7.1			
			mean =	7.4			
			RSD=	3.4%			
97218295	5B2	lab rep	%	4.9			
97218295	5B2	lab rep	%	5.2			
			mean =	5.0			
			RPD=	6.0%			
97218308	9A2	lab rep	%	6.0			
97218308	9A2	lab rep	%	5.9			
97218308	9A2	lab rep	%	6.1			
			mean =	6.0			
			RSD=	1.7%			
97218290	4C2	lab rep	%			38.1	H
97218290	4C2	lab rep	%			38.2	H
			mean=			38.2	
			RPD=			0.3%	
97218300	6C2	lab rep	%			45.6	
97218300	6C2	lab rep	%			45.9	
			mean =			45.8	
			RPD=			0.7%	
97218310	10A2	lab rep	%			38.2	H
97218310	10A2	lab rep	%			38.3	H
			mean =			38.2	
			RPD=			0.3%	
97218312	9C2	lab rep	%			27.0	
97218312	9C2	lab rep	%			27.4	
			mean =			27.2	
			RPD=			1.5%	

H=Exceeds recommended holding time

July 3, 1997

To: Jim Cubbage RBK

From: Randy Knox, Metals Chemist

Subject: Salmon Bay Project Sediment

QUALITY ASSURANCE SUMMARY

Data quality for this project is generally good. High iron levels in some samples interfered with arsenic. Samples 97218298 and 97218299 had extremely high iron levels. Cadmium on 97218298 showed poor replicate precision. No other significant quality assurance issues are noted with the data.

SAMPLE INFORMATION

The samples from the Salmon Bay Project were received by the Manchester Laboratory on 5/22/97 in good condition.

HOLDING TIMES

All analyses were performed within the USEPA Contract Laboratory Program (CLP) holding times for metals analysis (28 days for mercury, 180 days for all other metals).

INSTRUMENT CALIBRATION

Instrument calibration was performed before each analytical run and checked by initial calibration verification standards and blanks. Continuing calibration standards and blanks were analyzed at a frequency of 10% during the run and again at the end of the analytical run. All initial and continuing calibration verification standards were within the relevant USEPA (CLP) control limits. AA calibration gave a correlation coefficient (r) of 0.995 or greater, also meeting CLP calibration requirements. Internal standard used for ICP-MS analysis of arsenic was outside allowed limits for the high iron sample, 97218298 and 97218299. Arsenic data for these samples is qualified J, as estimated.

PROCEDURAL BLANKS

The procedural blanks associated with these samples show no analytically significant levels of analyte.

SPIKED SAMPLES ANALYSIS

Spiked and duplicate spiked sample analysis were performed on this data set. All spike recoveries are within the CLP acceptance limits of +/- 25%.

PRECISION DATA

The results of the spiked and duplicate spiked samples are used to evaluate precision on this sample set. The relative percent difference (RPD) for all analytes is within the 20% CLP acceptance window for duplicate analysis. One spiked sample pair in the mercury analysis showed a relative percent difference of 21. Since we also ran a duplicate of this sample with the RPD within the allowed 20%, data was not qualified based on this result. ICP data showed a high relative standard deviation of results for cadmium on sample 97218298. Cadmium data, for this sample only, is qualified J as estimated.

SERIAL DILUTION

A five times serially diluted portion of several samples was analyzed by ICP and the analytical results, corrected for dilution were compared to the original sample analyses as a test for interference. The RPD (relative % difference) for all analytes at levels greater than 50 times the detection level was within the allowed 10%. Arsenic levels less than 200 mg/Kg , determined by ICP, on samples with iron greater than 50000 mg/Kg are qualified J. Interference was noted to be significant for lower level arsenic samples for this iron level.

LABORATORY CONTROL SAMPLE (LCS) ANALYSIS

LCS analyses are within the windows established for each parameter.

Please call Randy Knox at SCAN 360-871-8811 or Jim Ross at SCAN 360-871-8808 to further discuss this project.

RLK:rlk

STATE OF WASHINGTON
DEPARTMENT OF ECOLOGY
MANCHESTER ENVIRONMENTAL LABORATORY
7411 Beach Drive East • Port Orchard, Washington 98366-8204 • (360) 871-8860 • FAX (360) 871-8850

August 14, 1997

TO: Jim Cubbage
EILS

THROUGH: Bill Kammin
Laboratory Director

FROM: Susan Davis
Mercury Analyst

SUBJECT: Replacement of Mercury Analysis Report

Please replace your current Mercury Analysis Report for Salmon Bay with this version. This new report has been corrected to an actual Dry Weight unit value. It was the policy of the Manchester Laboratory, prior to August 1 of this year, to report Mercury in sediment on a wet-weight, or as-received, basis. At the request of our clients we will discontinue this practice. All future sediments analyzed for Mercury will reflect a Dry Weight value.

Thank you for your patience with this cross-over, and please let us know if you have other suggestions or questions where we might be of help to you.

SD

Attachment

Table B-3. Precision and Accuracy of Metals Data.

Sample No.	QA Type	Field ID	As EPA 200.8	As EPA 200.7	Hg	Cd	Cr	Cu	Pb	Ni	Zn
8288	Field Splits (ug/g, dry)	4B2	14.3	na	0.8	2.1	133	619	204	113	527
8308		9A2	13.5	na	0.972	1.8	107	484	177	94.7	418
		mean=	13.9		0.9	2.0	120	552	191	104	473
		RPD=	6%		19%	15%	22%	24%	14%	18%	23%
8306	Field Splits (ug/g, dry)	8C2	12.1	na	1.1	1.2	44.7	207	196	40.4	416
8309		9B2	11.6	na	1.3	1.4	44.9	204	192	37	422
		mean=	11.9		1.2	1.3	44.8	205.5	194	39	419
		RPD=	4%		17%	15%	0.4%	1%	2%	9%	1%
8288/8308	Field Replicates (ug/g, dry)	4B2/9A2	13.9	na	0.9	2.0	120	552	191	104	473
8312		9C2	13	na	1.03	1.5 U	122	520	184	101	433
		mean=	13		1.0		121	536	187	102	453
		RPD=	7%		15%		2%	6%	3%	3%	9%
8285	Lab Duplicates (ug/g, dry)	3B3	na	na	2.48	na	na	na	na	na	na
8285		3B3	na	na	3	na	na	na	na	na	na
		mean=			2.7						
		RPD=			19%						
8303	Lab Duplicates (ug/g, dry)	7B2	na	na	0.075	na	na	na	na	na	na
8303		7B2	na	na	0.119	na	na	na	na	na	na
		mean=			0.097						
		RPD=			45%						
8281	Matrix Spikes (% recov.)	1B3	100	95	na	90	88	NC	82	84	NC
8281		1B3	100	89	na	94	82	NC	82	85	NC
		mean=	100	92		92	85		82	85	
		RPD=	0%	7%		4%	7%		0%	1%	
8312	Matrix Spikes (% recov.)	9C2	86	91	na	104	80	NC	112	84	104
8312		9C2	79	89	na	108	103	NC	106	95	103
		mean=	83	90		106	92		109	90	104
		RPD=	8%	2%		4%	25%		6%	12%	1%
8303	Matrix Spikes (% recov.)	7B2	na	na	107	na	na	na	na	na	na
8303		7B2	na	na	107	na	na	na	na	na	na
		mean=			107						
		RPD=			0%						
LCS71269	Lab Control Samples (% recov.)	M7155SL1	94	94	na	98	96	98	107	100	94
LCS71270		M7155SL2	90	88	na	93	90	91	102	93	88
		mean=	92	91		96	93	95	105	97	91
		RPD=	4%	7%		5%	6%	7%	5%	7%	7%
27071264	Lab Control Samples (% recov.)	M7154SG	na	na	99	na	na	na	na	na	na
BLN71267	Lab Blanks (ug/g, dry)	M7155SB1	3 U	0.3 U	na	0.3 U	0.5 U	1 U	2 U	1 U	2 U
BLN71268		M7155SB2	3 U	0.3 U	na	0.3 U	0.5 U	1 U	2 U	1 U	2 U
BLN71263		M7154SH	na	na	0.005 U	na	na	na	na	na	na

U=Undetected at concentration shown

na=not analyzed

NC=Not Calculated

MANCHESTER ENVIRONMENTAL LABORATORY

7411 Beach Drive E , Port Orchard Washington 98366

CASE NARRATIVE

September 19, 1997

Subject: Salmon Bay

Samples: 97218281 to 97218312

Case No. 1259-97

Officer: Jim Cubbage

By: Dickey D. Huntamer
Organics Analysis Unit

SEMIVOLATILE ORGANICS

ANALYTICAL METHODS:

The semivolatile soil samples were extracted with acetone following the Manchester modification of the EPA CLP and SW 846 8270 procedure with capillary GC/MS analysis of the sample extracts. Normal QA/QC procedures were performed with the analyses. Most of the samples had a high water content and low percent, solids. Consequently a solvent back extraction of the water layer remaining after the Soxhlet extraction was used in addition to sodium sulfate to dry the extracts.

HOLDING TIMES:

All sample and extraction holding times were within the recommended limits.

BLANKS:

Low levels of some target compounds were detected in the laboratory blanks. The EPA five times rule was applied to all target compounds which were found in the blank. Compounds that were found in the sample and in the blank were considered real and not the result of contamination if the levels in the sample are greater than or equal to five times the amount of compounds in the associated method blank.

SURROGATES:

The normal Manchester Laboratory surrogates were added to the sample prior to extraction. Generally surrogate recoveries were within acceptable limits except for sample 97218281 which had 4% to 13% recoveries of all analytes. The data, for 97218281 was "J" qualified. A few other samples 97-218299, 97218298, 972182886, 972182887, 972182895 and 97218309 had one surrogate below the recommended guidelines but all other surrogates were acceptable and no qualifiers were added to the data.

Sample 97218289 had six of eight surrogates which were higher than the guidelines which was probably due to the low internal standard areas. Those compound results in sample 97218289 affected by the internal standard areas were "J" qualified.

MATRIX SPIKE AND MATRIX SPIKE DUPLICATE:'

Matrix spike recoveries were low (<40%) for pyridine, aniline, 2,2'oxybis(1-chloropropane), hexchloroethane, nitrobenzene, hexachlorocylcopentadiene, 3 and 4-nitroanilines, and 4-chloroaniline. High native concentrations caused low calculated recoveries for pyrene, chrysene, bis-(2-ethylhexyl)phthalate and benzo(b)fluoranthene. The "J" qualifier was added to the results for these compounds in the matrix source sample 97218294. Hexachlorocyclopentadiene was not recovered and the data in the source sample was flagged as rejected "REJ".

ANALYTICAL COMMENTS:

No special analytical problems were encountered in the semivolatile analyses other one sample with low surrogates and another with low internal standard area counts. One other analytical problem was the high water content which in some samples exceeded 70%. This resulted in higher quantitation limits for some samples.

Quantitation limits were reported not detection limits. Detection limits were generally three or four times lower than the quantitation limits. An example is sample 97218311 where the quantitation limit for naphthalene and the methylnaphthalenes is 63U but the analytes were detected at 18J, 16J and 8J respectively. The data is acceptable for use as qualified.

DATA QUALIFIER CODES:

U	-	The analyte was not detected at or above the reported value.
J	-	The analyte was positively identified. The associated numerical value is an <u>estimate</u>.
UJ	-	The analyte was not detected at or above the reported estimated result.
REJ	-	The data are <u>unusable</u> for all purposes.
EXP	-	The result is equal to the number before EXP times 10 to the power of the number after EXP. As an example 3EXP6 equals 3×10^6.
NAF	-	Not analyzed for.
N	-	For organic analytes there is evidence the analyte is present in this sample.
NJ	-	There is evidence that the analyte is present. The associated numerical result is an estimate.
E	-	This qualifier is used when the concentration of the associated value exceeds the known calibration range.
bold	-	The analyte was present in the sample. (Visual Aid to locate detected compound on report sheet.)

CN_SBBNA.DOC

Table B-4. Precision and Accuracy of Semivolatile Organics Data.

Sample No.	Station	QA type	Units	N-Nitrosodimethylamine	Pyridine	Aniline	Phenol	Bis(2-Chloroethyl)Ether	2-Chlorophenol	1,3-Dichlorobenzene	1,4-Dichlorobenzene	1,2-Dichlorobenzene	Benzyl Alcohol	2-Methylphenol
97218294	5A2	LMX1	%	47	NAF	3	66	49	64	46	47	50	75	67
97218294	5A2	LMX2	%	40	NAF	4	52	40	51	42	45	46	58	51
		RPD=		16%		29%	24%	20%	23%	9%	4%	8%	26%	27%
97218288	4B2	split	ug/Kg	659 U	659 UJ	659 U	172	132 U	132 U	132 U	264 U	264 U	130 J	93 J
97218308	9A2	split	ug/Kg	616 U	616 UJ	616 U	171	123 U	123 U	123 U	246 U	246 U	211	246 U
		mean	ug/Kg	616 U	616 UJ	616 U	172	123 U	123 U	123 U	246 U	246 U	170 J	93 JFSU
		RPD=					1%						48%	
97218288/97218308	4B2/9A2	fld rep	ug/Kg	616 U	616 UJ	616 U	172	123 U	123 U	123 U	246 U	246 U	170 J	93 JFSU
97218312	9C2	fld rep	ug/Kg	635 U	254 UJ	635 U	181	127 U	127 U	127 U	27 J	254 U	127 U	96 J
		mean	ug/Kg	616 U	254 UJ	616 U	176	123 U	123 U	123 U	27 JFRU	246 U	170 JFRU	93 J
		RPD=					5%							3%
97218306	8C2	split	ug/Kg	360 U	360 UJ	360 U	63 J	72 U	72 U	72 U	111 J	144 U	72 U	144 U
97218309	9B2	split	ug/Kg	441 U	441 UJ	441 U	102	88 U	88 U	88 U	76 J	176 U	31 J	72 J
		mean	ug/Kg	360 U	360 UJ	360 U	82 J	72 U	72 U	72 U	94 J	144 U	31 JFSU	72 JFSU
		RPD=					48%				37%			
BLN72138	OBS7148B1	BLNK	ug/Kg	267 U	267 U	267 U	133 U	267 U	267 U	267 U	267 U	267 U	267 U	133 U
BLN72139	OBS7148B2	BLNK	ug/Kg	267 U	267 U	267 U	133 U	267 U	267 U	267 U	267 U	267 U	267 U	133 U
BLN72140	OBS7153A	BLNK	ug/Kg	267 U	**1850**	267 U	133 U	267 U	267 U	267 U	267 U	267 U	267 U	133 U

U= Undetected at concentration shown
J= Estimated concentration
NAF= Not analyzed for
FSU= Field split undetected
FRU= Field rep undetected

Table B-4. Precision and Accuracy of Semivolatile Organics Data.

Sample No.	Station	QA type	Units	2,2'-Oxybis[1-chloropropane]	N-Nitroso-Di-N-Propylamine	4-Methylphenol	Hexachloroethane	Nitrobenzene	Isophorone	2-Nitrophenol	2,4-Dimethylphenol	Bis(2-Chloroethoxy)Methane	Benzoic Acid	2,4-Dichlorophenol	1,2,4-Trichlorobenzene
97218294	5A2	LMX1	%	NAF	58	71	6	52	66	56	67	73	124	86	68
97218294	5A2	LMX2	%	NAF	46	50	5	36	51	41	52	56	100	66	56
		RPD=			23%	35%	18%	36%	26%	31%	25%	26%	21%	26%	19%
97218288	4B2	split	ug/Kg	264 U	264 U	476	264 U	659 U	132 U	659 U	132 U	132 U	2910 J	132 U	132 U
97218308	9A2	split	ug/Kg	246 U	246 U	497	246 U	616 U	526 U	616 U	123 U	123 U	2950 J	123 U	123 U
		mean	ug/Kg	246 U	246 U	486	246 U	616 U	526 U	616 U	123 U	123 U	2930 J	123 U	123 U
		RPD=				4%							1%		
97218288/97218308	4B2/9A2	fld rep	ug/Kg	246 U	246 U	486	246 U	616 U	526 U	616 U	123 U	123 U	2930 J	123 U	123 U
97218312	9C2	fld rep	ug/Kg	254 U	254 U	538	254 U	635 U	127 U	635 U	127 U	127 U	2540 UJ	127 U	127 U
		mean	ug/Kg	246 U	246 U	512	246 U	616 U	127 U	616 U	123 U	123 U	2930 JFRU	123 U	123 U
		RPD=				10%									
97218306	8C2	split	ug/Kg	144 U	144 U	591	144 U	360 U	72 U	360 U	72 U	72 U	1650 J	72 U	72 U
97218309	9B2	split	ug/Kg	176 U	176 U	631	176 U	441 U	88 U	441 U	88 U	88 U	1830 J	88 U	88 U
		mean	ug/Kg	144 U	144 U	611	144 U	360 U	72 U	360 U	72 U	72 U	1740 J	72 U	72 U
		RPD=				7%							10%		
BLN72138	OBS7148B1	BLNK	ug/Kg	133 U	267 U	133 U	267 U	133 U	133 U	267 U	133 U	133 U	2670 UJ	133 U	133 U
BLN72139	OBS7148B2	BLNK	ug/Kg	133 U	267 U	133 U	267 U	133 U	133 U	267 U	133 U	133 U	2670 UJ	133 U	133 U
BLN72140	OBS7153A	BLNK	ug/Kg	133 U	267 U	133 U	267 U	133 U	133 U	267 U	133 U	133 U	2670 UJ	133 U	133 U

U= Undetected at concentration shown
J= Estimated concentration
NAF= Not analyzed for
FSU= Field split undetected
FRU= Field rep undetected

Table B-4. Precision and Accuracy of Semivolatile Organics Data.

Sample No.	Station	QA type	Units	Naphthalene	4-Chloroaniline	Hexachlorobutadiene	4-Chloro-3-Methylphenol	2-Methylnaphthalene	1-Methylnaphthalene	Hexachlorocyclopentadiene	2,4,6-Trichlorophenol	2,4,5-Trichlorophenol	2-Chloronaphthalene	2-Nitroaniline	Dimethylphthalate
97218294	5A2	LMX1	%	65	2	61	76	79	NAF	REJ	86	89	74	75	75
97218294	5A2	LMX2	%	46	3	54	55	61	NAF	REJ	67	65	56	53	55
		RPD=		34%	40%	12%	32%	26%			25%	31%	28%	34%	31%
97218288	4B2	split	ug/Kg	3220	659 U	132 U	264 U	555	192	659 UJ	264 U	264 U	132 U	659 U	311
97218308	9A2	split	ug/Kg	1420	616 U	123 U	246 U	598	303	616 UJ	246 U	246 U	123 U	616 U	302
		mean	ug/Kg	2320	616 UJ	246 U	246 U	576	248	616 UJ	246 U	246 U	123 U	616 U	306
		RPD=		78%				7%	45%						3%
97218288/97218308	4B2/9A2	fld rep	ug/Kg	2320	616 UJ	246 U	246 U	576	248	616 UJ	246 U	246 U	123 U	616 U	306
97218312	9C2	fld rep	ug/Kg	1080	635 U	127 U	254 U	471	240	635 UJ	254 U	254 U	127 U	635 U	253
		mean	ug/Kg	1700	616 UJ	127 U	246 U	471	244	616 UJ	246 U	246 U	123 U	616 U	280
		RPD=		73%				22%	3%						19%
97218306	8C2	split	ug/Kg	472	360 U	72 U	144 U	227	102	360 UJ	144 U	144 U	72 U	360 U	52 J
97218309	9B2	split	ug/Kg	421	441 U	88 U	176 U	213	99	441 UJ	176 U	176 U	88 U	441 U	43 J
		mean	ug/Kg	446	360 U	72 U	144 U	220	100	360 UJ	144 U	144 U	72 U	360 U	48 J
		RPD=		11%				6%	3%						19%
BLN72138	OBS7148B1	BLNK	ug/Kg	133 U	133 U	133 U	133 U	133 U	133 U	1330 UJ	267 U	267 U	133 U	667 U	267 U
BLN72139	OBS7148B2	BLNK	ug/Kg	133 U	133 U	133 U	133 U	133 U	133 U	1330 UJ	267 U	267 U	133 U	667 U	267 U
BLN72140	OBS7153A	BLNK	ug/Kg	133 U	133 U	133 U	133 U	**5.5** J	**3.3** J	1330 UJ	267 U	267 U	133 U	667 U	267 U

U= Undetected at concentration shown
J= Estimated concentration
NAF= Not analyzed for
FSU= Field split undetected
FRU= Field rep undetected

Table B-4. Precision and Accuracy of Semivolatile Organics Data.

Sample No.	Station	QA type	Units	2,6-Dinitrotoluene	Acenaphthylene	3-Nitroaniline	Acenaphthene	2,4-Dinitrophenol	4-Nitrophenol	Dibenzofuran	2,4-Dinitrotoluene	Diethylphthalate	Fluorene	4-Chlorophenyl-Phenylether
97218294	5A2	LMX1	%	62	71	14	68	73	67	73	62	75	70	77
97218294	5A2	LMX2	%	45	53	12	51	60	48	59	47	56	54	58
		RPD=		32%	29%	15%	29%	20%	33%	21%	28%	29%	26%	28%
97218288	4B2	split	ug/Kg	659 U	314	659 U	316	1320 UJ	659 U	443	1320 U	132 U	507	132 U
97218308	9A2	split	ug/Kg	616 U	394	616 U	407	1230 UJ	616 U	384	1230 U	123 UJ	609	123 U
		mean	ug/Kg	616 U	354	616 U	362	1230 UJ	616 U	414	1230 U	123 UJ	558	123 U
		RPD=			23%		25%			14%			18%	
97218288/97218308	4B2/9A2	fld rep	ug/Kg	616 U	354	616 U	362	1230 UJ	616 U	414	1230 U	123 UJ	558	123 U
97218312	9C2	fld rep	ug/Kg	635 U	331	635 U	378	1270 UJ	635 U	359	1270 U	127 U	557	127 U
		mean	ug/Kg	616 U	342	616 U	370	1230 UJ	616 U	386	1230 U	123 UJ	558	123 U
		RPD=			7%		4%			14%			0%	
97218306	8C2	split	ug/Kg	360 U	112	360 U	216	720 U	360 U	205	720 U	72 U	328	72 U
97218309	9B2	split	ug/Kg	441 U	112	441 U	272	883 UJ	441 U	228	883 U	88 J	322	88 U
		mean	ug/Kg	360 U	112	360 U	244	720 U	360 U	216	720 U	88 JFSU	325	72 U
		RPD=			0%		23%			11%			2%	
BLN72138	OBS7148B1	BLNK	ug/Kg	267 U	133 U	267 U	133 U	2670 UJ	667 U	133 U	667 U	**26** J	133 U	133 U
BLN72139	OBS7148B2	BLNK	ug/Kg	267 U	**6.7** J	267 U	133 U	2670 UJ	667 U	133 U	667 U	**22** J	133 U	133 U
BLN72140	OBS7153A	BLNK	ug/Kg	267 U	**6.6** J	267 U	**16** J	2670 UJ	667 U	**8.1** J	667 U	**16** J	**13** J	133 U

U= Undetected at concentration shown
J= Estimated concentration
NAF= Not analyzed for
FSU= Field split undetected
FRU= Field rep undetected

Table B-4. Precision and Accuracy of Semivolatile Organics Data.

Sample No.	Station	QA type	Units	4-Nitroaniline	4,6-Dinitro-2-Methylphenol	N-Nitrosodiphenylamine	1,2-Diphenylhydrazine	4-Bromophenyl-Phenylether	Hexachlorobenzene	Pentachlorophenol	Phenanthrene	Anthracene	Caffeine	Carbazole
97218294	5A2	LMX1	%	32	62	55	60	84	81	61	60	73	NAF	NAF
97218294	5A2	LMX2	%	15	47	44	45	64	61	46	47	55	NAF	NAF
		RPD=		72%	28%	22%	29%	27%	28%	28%	24%	28%		
97218288	4B2	split	ug/Kg	264 U	1320 U	132 U	132 U	132 U	132 U	706	2080	660	132 U	124 J
97218308	9A2	split	ug/Kg	246 U	1230 U	123 U	123 U	123 U	123 U	836	2670	880	123 U	236
		mean	ug/Kg	246 U	1230 U	123 U	123 U	123 U	123 U	771	2375	770	123 U	180 J
		RPD=								17%	25%	29%		62%
97218288/97218308	4B2/9A2	fld rep	ug/Kg	246 U	1230 U	123 U	123 U	123 U	123 U	771	2375	770	123 U	180 J
97218312	9C2	fld rep	ug/Kg	254 U	1270 U	127 U	127 U	127 U	127 U	652	2370	744	127 U	178
		mean	ug/Kg	246 U	1230 U	123 U	123 U	123 U	123 U	712	2372	757	123 U	179 J
		RPD=								17%	0%	3%		1%
97218306	8C2	split	ug/Kg	144 U	720 U	72 U	72 U	72 U	72 U	269 J	1600	358	72 U	139
97218309	9B2	split	ug/Kg	176 U	883 U	88 U	88 U	88 U	88 U	329 J	1830	360	88 U	182
		mean	ug/Kg	144 U	720 U	72 U	72 U	72 U	72 U	299 J	1715	359	72 U	160
		RPD=								20%	13%	1%		27%
BLN72138	OBS7148B1	BLNK	ug/Kg	1330 U	1330 U	133 U	133 U	133 U	133 U	1330 U	133 U	133 U	133 U	133 U
BLN72139	OBS7148B2	BLNK	ug/Kg	1330 U	1330 U	133 U	133 U	133 U	133 U	1330 U	133 U	133 U	133 U	133 U
BLN72140	OBS7153A	BLNK	ug/Kg	1330 U	1330 U	133 U	133 U	133 U	133 U	1330 U	**76** J	**22** J	133 U	**12** J

U= Undetected at concentration shown
J= Estimated concentration
NAF= Not analyzed for
FSU= Field split undetected
FRU= Field rep undetected

Table B-4. Precision and Accuracy of Semivolatile Organics Data.

Sample No.	Station	QA type	Units	Di-N-Butylphthalate	Fluoranthene	Benzidine	Pyrene	Retene	Butylbenzylphthalate	Benzo(a)anthracene	3,3'-Dichlorobenzidine	Chrysene	Bis(2-Ethylhexyl) Phthalate
97218294	5A2	LMX1	%	73	71	NAF	44	NAF	74	68	NAF	65	36
97218294	5A2	LMX2	%	59	56	NAF	22	NAF	56	48	NAF	39	36
		RPD=		21%	24%		67%		28%	34%		50%	0%
97218288	4B2	split	ug/Kg	805	3370	264 U	3540	5400	274	1180	264 U	1710	4330
97218308	9A2	split	ug/Kg	597	4050	246 U	3600	3290	246 U	1550	246 U	2110	4170
		mean	ug/Kg	701	3710	246 U	3570	4345	274 FSU	1365	246 U	1910	4250
		RPD=		30%	18%		2%	49%		27%		21%	4%
97218288/97218308	4B2/9A2	fld rep	ug/Kg	701	3710	246 U	3570	4345	274 FSU	1365	246 U	1910	4250
97218312	9C2	fld rep	ug/Kg	261	3720	254 U	3760	3160	286	1390	254 U	1970	4240
		mean	ug/Kg	481	3715	246 U	3665	3752	280	1378	246 U	1940	4245
		RPD=		91%	0%		5%	32%	4%	2%		3%	0%
97218306	8C2	split	ug/Kg	132 J	2530	144 U	2070	1080	223	722	144 U	973	3090
97218309	9B2	split	ug/Kg	175 J	2800	176 U	2300	1030	159 J	881	176 U	1180	2780
		mean	ug/Kg	154 J	2665	144 U	2185	1055	191 J	802	144 U	1076	2935
		RPD=		28%	10%		11%	5%	34%	20%		19%	11%
BLN72138	OBS7148B1	BLNK	ug/Kg	**48** J	133 U	267 U	133 U	133 U	133 U	133 U	2670 U	133 U	**34** J
BLN72139	OBS7148B2	BLNK	ug/Kg	**123** J	133 U	267 U	133 U	133 U	133 U	133 U	2670 U	133 U	**36** J
BLN72140	OBS7153A	BLNK	ug/Kg	**47** J	**49** J	267 U	**52** J	133 U	133 U	133 U	2670 U	**20** J	**26** J

U= Undetected at concentration shown
J= Estimated concentration
NAF= Not analyzed for
FSU= Field split undetected
FRU= Field rep undetected

Table B-4. Precision and Accuracy of Semivolatile Organics Data.

Sample No.	Station	QA type	Units	Di-N-Octyl Phthalate	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Benzo(a)pyrene	3B-Coprostanol	Indeno(1,2,3-cd)pyrene	Dibenzo(a,h)anthracene	Benzo(ghi)perylene
97218294	5A2	LMX1	%	60	59	75	67	NAF	76	79	72
97218294	5A2	LMX2	%	49	36	57	44	NAF	53	57	46
		RPD=		20%	48%	27%	41%		36%	32%	44%
97218288	4B2	split	ug/Kg	659 U	2080	751	1620	2820	1350	294	1520
97218308	9A2	split	ug/Kg	616 U	2540	880	1870	2770	1510	329	1620
		mean	ug/Kg	616 U	2310	816	1745	2795	1430	312	1570
		RPD=			20%	16%	14%	2%	11%	11%	6%
97218288/97218308	4B2/9A2	fld rep	ug/Kg	616 U	2310	816	1745	2795	1430	312	1570
97218312	9C2	fld rep	ug/Kg	635 U	2510	806	1800	3590	1460	332	1620
		mean	ug/Kg	616 U	2410	811	1772	31922	1445	322	1595
		RPD=			8%	1%	3%	2%	2%	6%	3%
97218306	8C2	split	ug/Kg	360 U	1130	406	689	4780	586	159	544
97218309	9B2	split	ug/Kg	441 U	1280	492	822	3890	657	184	592
		mean	ug/Kg	360 U	1205	449	756	4335	622	172	568
		RPD=			12%	19%	18%	21%	11%	15%	8%
BLN72138	OBS7148B1	BLNK	ug/Kg	1330 U	133 U	133 U	133 U	1330 U	267 U	133 U	133 U
BLN72139	OBS7148B2	BLNK	ug/Kg	1330 U	133 U	133 U	133 U	1330 U	267 U	133 U	133 U
BLN72140	OBS7153A	BLNK	ug/Kg	1330 U	**10** J	**5.9** J	**8.9** J	1330 U	267 U	133 U	133 U

U= Undetected at concentration shown
J= Estimated concentration
NAF= Not analyzed for
FSU= Field split undetected
FRU= Field rep undetected

Table B-5. Results of PAH Standard Reference Material Analysis (NRCC HS-6; µg/Kg, dry).

	HS672141	HS672142	RPD	NRCC HS-6 Certified Values
Anthracene	965	956	1%	1100 ± 400
Pyrene	2470	2610	6%	3000 ± 600
Benzo(ghi)perylene	1570	1630	4%	1780 ± 720
Indeno(1,2,3-cd)pyrene	1910	1970	3%	1950 ± 580
Benzo(b)fluoranthene	3370	3710	10%	2800 ± 600
Fluoranthene	3400	3500	3%	3540 ± 650
Benzo(k)fluoranthene	1450	1440	1%	1430 ± 150
Acenaphthylene	450	470	4%	190 ± 50
Chrysene	2110	2180	3%	2000 ± 300
Benzo(a)pyrene	1640	1600	2%	2200 ± 400
Dibenzo(a,h)anthracene	503	503	0%	490 ± 160
Benzo(a)anthracene	1390	1520	9%	1800 ± 300
Acenaphthene	162 J	148 J	9%	230 ± 70
Phenanthrene	3000	3050	2%	3000 ± 600
Fluorene	402	413	3%	470 ± 120
Naphthalene	3790	3540	7%	4100 ± 1100

J = estimated concentration

= outside range of certified values

MANCHESTER ENVIRONMENTAL LABORATORY

7411 Beach Drive E , Port Orchard Washington 98366

CASE NARRATIVE

September 19, 1997

Subject: Salmon Bay

Samples: 97218281 to 97218312

Case No. 1259-97

Officer: Jim Cubbage

By: Dickey D. Huntamer
Organics Analysis Unit

TRIBUTYL TINS

ANALYTICAL METHODS:

The samples were extracted following the methods given in Puget Sound Estuary Program (PSEP) "Recommended Guidelines for Measuring Organic Compounds in Puget Sound Sediment and Tissue Samples" Recommended Methods for Organotin Compounds. The samples were extracted by tumbling with sodium sulfate and methylene chloride/10% methanol and 0.1% by weight tropolone. After extraction the samples were solvent exchanged to hexane. The organotin compounds were hexylated using the Grignard reaction given in Krone et al (1989) including the silica gel/alumina cleanup. Analysis was done by capillary Gas Chromatography using Single Ion Monitoring (SIM) mode GC/MS. All samples are reported on a dry weight basis.

HOLDING TIMES:

The samples were stored frozen following PSEP Guidelines until extraction. After extraction all samples were analyzed within the recommended 40 day extract time.

BLANKS:

No target analytes were detected in the laboratory blanks.

SURROGATES:

Recovery of the surrogate spike, Tripropyltin, ranged from 6% to 115%. Recoveries of the tripentyl tin ranged from 18% to 141%. No surrogate recovery QC limits have been established for this method. Although several samples had one surrogate with less than 20% recovery none of the samples had <20% recovery for both surrogates. Consequently no data qualifiers were added to the results based on surrogate recoveries.

MATRIX SPIKE AND MATRIX SPIKE DUPLICATE:

No spike recovery or RPD QC limits have been established for organotins at this time. Two and one-half pairs of matrix spikes were analyzed with the samples. Source samples were 91218297 and -218302 and 97218310. Sample 97218297 had significant levels of organotin compounds native to the sample. These may have affected the recoveries which ranged from 2% to 204%. Tetrabutyltin which was not detected in the sample had 63% and 64% recovery. Matrix spike recoveries for 97218302 which was a high clay content sample ranged from 50% to 85%. Recoveries for 97218310 ranged from 10% to 73%.

The relative percent differences ranged from 1.4% to 193% for 97218297 and from 0.7% to 63% for 97218310.

ANALYTICAL COMMENTS:

Two additional samples were analyzed with the sediment samples. These were Sequim Bay Reference Sediments which presumably was spiked with 100 ng/gm (100 ug/Kg) wet weight of tributyltin. No value for tributyltin has been established for the Sequim Bay Reference Sediment so the accuracy of the analysis cannot be determined. These samples are identified as -SBR72041 (SRMl) and SBR72042 (SRM2).

SRMl	70.6	ug/Kg (wet weight)	Tributyltin
SRM2	75.6	ug/Kg (wet weight)	Tributyltin

Note that the data sheets report these values as dry weight. The percent solids is 56% for these samples.

Two reference materials, PACS-1 (PAC72043 and PAC72044) and PACS-2 (PAC72045) was also analyzed with the samples. PACS-2 is a new material and has not been certified as to it's value for organotins. PACS-1 provided anomalous results with lower concentrations of the tributyltin and higher concentrations relative to tributyltin for the dibutyl- and monobutyltins. Results for tributyltin were roughly one-third the certified value. Since the concentrations of the less substituted tin species increased it may be that the sample is deteriorating over time. A phone conversation with Eric Crecilius at Battelle Sequim laboratory confirmed that PACS-1 was not stable and the concentrations had been changing over time. Consequently data reported for PACS-1 should not be used and previous data reported for PACS-1 may be compromised.

Table B-6. Precision and Accuracy of Butyltin Data.

Sample No.	Field ID	QA Type	Monobutyltin Chloride	Dibutyltin Chloride	Tributyltin Chloride	Tetrabutyltin Chloride
8297	6A2	Matrix Spikes	29	2	144	63
8297	6A2	(% recov.)	64	86	205	64
	mean=		47	44	175	64
	RPD=		75%	191%	35%	2%
8302	7A3	Matrix Spikes (% recov.)	57	30	85	62
8310	10A2	Matrix Spikes	14	73	10	43
8310	10A2	(% recov.)	14	38	12	30
	mean=		14	56	11	37
	RPD=		0%	63%	18%	36%
8288	4B2	Field splits	816	434	2090	32 J
8308	9A2	(ug/kg, dry)	906	355	1830	25 J
	mean=		861	395	1960	28 J
	RPD=		10%	20%	13%	23%
8288/8308	4B2/9A2	Field reps.	861	395	1960	28 J
8312	9C2	(ug/kg, dry)	206 J	126	468	11 J
	mean=		534 J	260	1214	20 J
	RPD=		123%	103%	123%	88%
97218306	8C2	Field splits	386 J	209	1190	17 J
97218309	9B2	(ug/kg, dry)	391	368	1120	14 J
	mean=		389 J	288	1155	16 J
	RPD=		1%	55%	6%	19%
BLN72033	OBS7153A3	Lab Blanks	33 J	21 U	44	20 U
BLN72034	OBS7153A4	(ug/kg, dry)	24 J	21 U	36 J	20 U
BLN72035	OBS7154A2		12 J	23 U	31 J	22 U
BLN72040	OBS7154A3		22 J	23 U	20 J	22 U
PAC72043	OCS7154A3	Certified	1120 J	188 J	380 J	500 U
PAC72044	OCS7154A4	Reference	920 J	100 J	292 J	440 U
	mean=	Material NRCC	1020 J	144 J	336 J	
	RPD=	PACS-1, ug/kg	20%	61%	26%	
		as Sn, dry)				
PACS-1certified values			280 +/-170	1160 +/-180	1270+/-220	
PAC72045	OCS7154A5		640 J	400 J	820 J	620 U
PACS-2 certified values			450+/-50	1090 +/-150	980+/ -130	

U=Undetected at concentration shown
J=estimated concentration
[ ] = outside certified range of values

State of Washington Department of Ecology
Manchester Environmental Laboratory
7411 Beach Dr. East Port Orchard WA. 98366

PCB Data Review
September 19, 1997

Project: **Salmon Bay**

Samples: 218281 218291 218292 218301 218302

By: Stuart Magoon

Case Summary for Polychlorinated Biphenyl's (PCB)

Data from these analyses were reviewed for qualitative and quantitative accuracy, validity, and usefulness. These samples were prepared and analyzed according to EPA method SW-846 8080.

The results are reported in micrograms per kilogram (ug/Kg); parts per billion dry weight.

PCB Analysis

Holding times:

Sample no.	Collect date	Extraction date	Analysis date
218281	5/21/97	6/2/97	7/1/97
218281 re-extract	5/21/97	7/21/97	7/30/97
218291	5/19/97	5/28/97	7/1/97
218292	5/19/97	5/28/97	7/1/97
218301	5/20/97	6/2/97	7/1/97
218302	5/19/97	5/28/97	7/1/97

* data from this sample has been rejected, and was not included in the final report.

All samples were extracted within fourteen (14) days of collection, with one exception. The re-extract of sample 218281 occurred sixty one (61) days after the sample was collected. It is unlikely given the environmentally persistent nature of PCB's that

exceeding the recommended holding time by 47 days has had a measurable effect on the results. However, positive results 1254 and 1260 for sample 218281 have been qualified as estimates ("J"), and all the non-detects have been qualified with "UJ".

All sample extracts were analyzed within forty (40) days of extraction.

Method Blank:

No target analytes were detected in any of the method blanks.

Calibration:

The calibration standards were within 20% relative standard deviations (RSD) for all the PCB aroclors except 1242 and 1260 on July 1, 1997. As a consequence aroclors 1242 and 1260 detected in samples 218291 and 218292 have been reported as estimated values ("J" qualified).

Surrogate Recoveries:

Sample 218281 was re-extracted due to poor surrogate recoveries. Surrogate recoveries for the re-extraction of 218281 and the other samples, blanks, and reference material demonstrate the extraction and analysis are within control. The surrogate recoveries for one of the blanks (BLN71686) were extremely poor. This blank was evaporated to dryness during the final concentration procedure; the results have been rejected (“REJ”) due to the poor surrogate recoveries. Since the second blank (BLN71687) extracted and analyzed along with this data set displayed acceptable recoveries, no qualification of the sample data was warranted.

Certified Reference Material HS2:

The certified sediment reference material (SRM) from NRCC, HS2, was analyzed in duplicate along with this sample set. HS2 is certified for aroclor 1254 at 111.8 ug/Kg +/-2.5. There is also some 1260 aroclor present in this SRM sample, but the values are not certified. Aroclor 1254 was reported at 98 and 106 ug/Kg which corresponds to 87.7% and 94.8% of the certified value with an RPD of 7.8%.

Matrix Spikes:

Sample 218290 was used for the matrix spikes. PCB analysis was not requested for sample 218290, however, due to a mistake during the extraction process (BNA's were extracted along with the PCB's) this sample was chosen. There were no pesticide surrogates added to the unspiked aliquot of sample 218290, however the extract was also analyzed for BNA compounds and the surrogate recoveries for the BNA analysis were well within control limits. Sample 218290 was re-extracted with PCB surrogates added. Results from the re-extraction were quite different from the original:

	218290	218290 re-ext
Aroclor 1254	230 ug/Kg	2500 ug/kg
Aroclor 1260	74 ug/Kg	460 ug/Kg

Since there were no PCB surrogate recoveries on the original extract, but the BNA recoveries were within control, it is not clear why there is such are large discrepancy for the two analyses. Some of the analyte may have been lost during the florisil treatment, or the sample may not have been homogenous.
Inconsistent native determinations for sample 218290 combined with the poor calibration curve for aroclors 1242 and 1260 render the matrix spike data unreliable. Matrix spike recoveries for aroclor 1260 have been rejected ("REJ") and aroclor 1242 recoveries should be considered estimates. This matrix spike data should not be used to assess overall recovery, precision or accuracy for this project.

Summary:

The original analysis of sample 218281 has not been included because surrogate recoveries for all three surrogates were less than 15%, and the PCB results were rejected. The results from the re-extraction of this sample have been reportd. I recommend that samples 218291 and 218292 be re-extracted and re-analyzed in order to quantitate the PCB aroclors 1242 and 1260 with a valid calibration curve.

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Manchester Environmental Laboratory

7411 Beach Dr E
Port Orchard Washington 98366
December 10, 1997

Project: **Salmon Bay**

Parameter: PCB re-extracts

Samples: 97218281, 97218291, 97218292

By: Karin Feddersen KF

These samples were analyzed by EPA Method 8080 for PCB's, employing the dual column confirmation technique.

Holding Times:

These samples were extracted and analyzed after the method-specified holding times. PCB's are normally very persistent in the environment. Exceeding the holding time probably has had little significant effect on the results. However, the results for these samples have been qualified as estimates; positive results with "J", and non-detects with "UJ".

Method Blanks:

No analytes of interest were detected in the method blanks.

Surrogates:

All recoveries were within the recommended range of between 50% and 150%.

Matrix Spikes

Sample 97218281 was chosen for matrix spike/spike duplicate analysis. These samples can be used to assess accuracy and precision. Instead of spiking the sample with one of the PCB aroclors, it was spiked with 18 different PCB congeners. PCB aroclors are a complex mixture of the 209 PCB congeners. PCB aroclors are identified by pattern recognition and quantitated on 4-8 distinct peaks which represent one or more congeners. The percent recovery of an aroclor is actually the average percent recovery of the peaks used for quantitation. The average recovery of the 18 congeners for each of the spikes are 79% and 83%, and the relative percent difference (RPD) is 4%.

Sample Results:

This data is acceptable for use with the qualifications mentioned.

Table B-7. Precision and Accuracy of PCB Data.

Sample No.	Field ID	QA Type	Decachlorobiphenyl	PCB congener 8	PCB congener 18	PCB congener 28	PCB congener 44	PCB congener 52	PCB congener 66	PCB congener 101	PCB congener 105	PCB congener 118	PCB congener 128	PCB congener 138
8281	1B3	Matrix Spikes	102	106	98	99	88	74	75	48	66	49	83	44
8281	1B3	(% recov.)	103	117	101	102	93	77	79	53	68	56	80	49
	mean=		103	112	100	101	91	76	77	51	67	53	82	47
	RPD=		1%	10%	3%	3%	6%	4%	5%	10%	3%	13%	4%	11%

			PCB congener 153	PCB congener 170	PCB congener 180	PCB congener 187	PCB congener 195	PCB congener 206
8281	1B3	Matrix Spikes	58	86	77	80	98	99
8281	1B3	(% recov.)	63	87	77	88	96	96
	mean=		61	87	77	84	97	98
	RPD=		8%	1%	0%	10%	2%	3%

			PCB - 1260	PCB - 1254	PCB - 1221	PCB - 1232	PCB - 1248	PCB - 1016	PCB - 1242
8290	4C2	Matrix Spikes	REJ	NAF	NAF	NAF	NAF	NAF	110
8290	4C2	(% recov.)	REJ	NAF	NAF	NAF	NAF	NAF	86
	mean=								98
	RPD=								24%

			PCB - 1260	PCB - 1254	PCB - 1221	PCB - 1232	PCB - 1248	PCB - 1016	PCB - 1242
BLN71686	OBS7148B1		REJ	REJ	REJ	REJ	REJ	REJ	REJ
BLN71687	OBS7148B2	Lab Blanks	20 U	20 U	20 U	20 U	20 U	20 U	20 U
BLN71704	OBS7153A1	(ug/kg, dry)	20 U	20 U	20 U	20 U	20 U	20 U	20 U
BLN71705	OBS7153A2		20 U	20 U	20 U	20 U	20 U	20 U	20 U
BLN73455	OBS7302A1		130 U	130 U	130 U	130 U	130 U	130 U	130 U
BLN73456	OBS7302A2		130 U	130 U	130 U	130 U	130 U	130 U	130 U

			PCB - 1260	PCB - 1254	PCB - 1221	PCB - 1232	PCB - 1248	PCB - 1016	PCB - 1242
HS272467	OCS7148A1	Reference	50	98	20 U	20 U	20 U	20 U	20 U
HS272468	OCS7148A2	Material NRCC	76	106	20 U	20 U	20 U	20 U	20 U
	mean=	HS-2, ug/kg,	63	102					
	RPD=	dry)	41%	8%					

U=Undetected at Concentration Shown

REJ=Sample result rejected, data are unusable

NAF=Not Analyzed For

[ ] = Outside of certified range of values. HS-2 is certified for PCB-1254 at 111.8 +/- 2.5 ug/kg, dry. It is not certified for other PCBs.

Appendix C

Complete Results of Semivolatile Organics Analyses

Spearman Correlation Matrix for Chemistry Data

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Table C-1. Priority Pollutant Low Molecular Weight PAHs (LPAH) Detected in Salmon Bay Phase III Sediments (µg/kg, dw).

Station	Naphthalene	Acenaphthylene	Acenaphthene	Fluorene	Phenanthrene	Anthracene	Total LPAH
1B3	110 J	(276) UJ	162 J	167 J	1,130 J	233 J	1,800
2B2	650	265	523	666	5,470	1,230	8,800
2C2	4,890	642	2,460	3.400	14,200	2,920	28,500
3B2	751	294	434	539	2,130	799	4,900
3B3	627	209	177	274	1,070	406	2,800
3C2	427	174	172	230	1,100	465	2,600
3C3	424	171	252	270	1,480	552	3,100
4B2	1,700	342	370	558	2,372	757	6,100
4B3	4,870 J	1,260 J	1,250 J	1,720 J	6,190 J	1,580 J	16,900
4C2	471	136	310	465	1,200	465	3,000
4F2	5,630	1,020	7,420	6.970	41,100	16,200	78,300
4F3	3,060	323	938	1.020	4,020	1,070	10,400
4F4	4,970	697	1,320	1.540	4,440	1,110	14,100
5A2	913	279	332	498	1,990	717	4,700
5B2	501	148	156	185	778	320	2,100
5D2	304	95	1,680	542	2,640	528	5,800
6A2	2,280	594	792	932	3,620	915	9,100
6B2	366	(77) U	196	262	1,040 J	294 J	2,200
6B3	466	110	203	251	1,300	373	2,700
6C2	1,030	265	130	126	569	124	2,200
7A2	291	42 J	360	400	2,660	630	4,400
7A3	73 J	(132) UJ	74 J	95 J	384	95 J	720
7B2	(201) U	(201) U	(201) U	(201) U	71 J	(201) U	70
7C2	37 J	12 J	33 J	39 J	234	67	420
8A2	1,360	362	2,460	3,240	8,420	2,860	18,700
8C2	446	112	244	325	1,715	359	3,200
8C3	1,310	640	1,060	1,070	3,990	1,130	9,200
10A2	(100) U	(100) U	(100) U	(100) U	39 J	14 J	50
10B2	18 J	(63) UJ	18 J	25 J	244	53 J	360

U=Undetected at concentration in parentheses
UJ=Undetected at estimated concentration in parentheses
J=Estimated concentration

Exceeds Freshwater Sediment Quality Values (Cubbage *et al*,1997).

Table C-2. Priority Pollutant High Molecular Weight PAHs (HPAH) Detected in Salmon Bay Phase III Sediments (µg/kg, dw).

Station	Fluoranthene	Pyrene	Benzo(a)anthracene	Chrysene	Benzo(b+k)fluoranthenes	Benzo(a)pyrene	Indeno(1,2,3-cd)pyrene	Dibenzo(a,h)anthracene	Benzo(ghi)perylene	Total HPAH
1B3	1,690 J	1,630 J	600 J	816 J	1,151 J	615 J	363 J	82 J	424	7,400
2B2	11,100	8,790	4,260	5,940	10,990	4,810	4,120	839	4,020	54,900
2C2	29,200	15,900	3,750	5,880	6,590	2,750	1,750	437	1,720	68,000
3B2	5,350	6,880	2,430	2,780	4,560	3,000	1,880	412	2,140	29,400
3B3	2,340	2,530	958	1,300	2,315	1,530	1,180	217	1,330	13,700
3C2	2,690	2,250	1,030	1,340	2,095	1,180	993	287	944	12,800
3C3	3,140	2,710	1,220	1,540	2,451	1,420	1,160	292	1,150	15,100
4B2	3,715	3,665	1,378	1,940	3,221	1,772	1,445	322	1,595	19,100
4B3	7,730 J	7,540	2,380	3,430	4,440	2,220	1,450	327	1,660	31,200
4C2	3,450	2,960	1,060	1,440	2,022	890	643	214	613	13,300
4F2	46,100	55,600	25,600	28,100	41,800	24,300	13,900	3,070	12,100	250,000
4F3	3,480	4,610	1,240	1,780	2,444	1,430	917	212	1,020	17,100
4F4	4,700	4,700	1,100	1,130	2,002	1,070	740	200 J	827	16,500
5A2	3,210	4,410 J	1,580	2,170 J	3,620	1,890	1,340	332	1,410	20,000
5B2	1,640	1,590	523	755	1,376	783	773	216 J	791	8,400
5D2	3,800	5,190	1,430	1,890	3,139	1,850	1,170	205	1,180	19,900
6A2	4,780	5,120	1,720	2,210	3,396	1,840	1,220	342	1,350	22,000
6B2	1,380 J	2,000 J	631 J	893 J	1,234 J	715 J	431 J	(77) UJ	438 J	7,700
6B3	1,780	2,340	917	1,260	1,955	1,080	763	116	821	11,000
6C2	646	679	148	193	283 J	206	180	157 U	187	2,500
7A2	3,360	3,460	1,270	1,560	1,778	915	518	132 J	497	13,500
7A3	478	536	192	240	307 J	176	91 J	(130) U	110 J	2,100
7B2	123 J	118 J	(201) U	59 J	67 J	176 J	198 J	176 J	87 J	1,200
7C2	359	488	181	263	421	226	133	34 J	146	2,300
8A2	21,100	14,500	5,430	5,730	7,110	2,960	1,500	424	1,350	60,100
8C2	2,665	2,185	802	1,076	1,654	756	622	172	568	10,500
8C3	7,710	7,150	2,620	3,700	5,530	3,340	2,340	490	2,510	35,400
10A2	97 J	150	(100) U	91 J	127 J	37 J	59 J	(100) U	68 J	630
10B2	428	523	199	320	496	248	199	(63) U	216	2,600

U=Undetected at concentration in parentheses
UJ=Undetected at estimated concentration in parentheses
J=Estimated concentration

Exceeds Freshwater Sediment Quality Values (Cubbage *et al*,1997).

Table C-3. Total Priority Pollutant PAHs Detected in Salmon Bay Phase III Sediments (µg/kg, dw).

Station	Total LPAH	Total HPAH	Total PAH
1B3	1,800	7,400	9,200
2B2	8,800	54,900	63,700
2C2	28,500	68,000	96,500
3B2	4,900	29,400	34,300
3B3	2,800	13,700	16,500
3C2	2,600	12,800	15,400
3C3	3,100	15,100	18,200
4B2	6,100	19,100	25,200
4B3	16,900	31,200	48,100
4C2	3,000	13,300	16,300
4F2	78,300	250,000	328,300
4F3	10,400	17,100	27,500
4F4	14,100	16,500	30,600
5A2	4,700	20,000	24,700
5B2	2,100	8,400	10,500
5D2	5,800	19,900	25,700
6A2	9,100	22,000	31,100
6B2	2,200	7,700	9,900
6B3	2,700	11,000	13,700
6C2	2,200	2,500	4,700
7A2	4,400	13,500	17,900
7A3	720	2,100	2,820
7B2	70	1,200	1,270
7C2	420	2,300	2,720
8A2	18,700	60,100	78,800
8C2	3,200	10,500	13,700
8C3	9,200	35,400	44,600
10A2	50	630	680
10B2	360	2,600	2,960

Exceeds Freshwater Sediment Quality Values (Cubbage *et al*,1997).

Table C-4. Phenols and Non-Priority Pollutant PAHs Detected in Salmon Bay Phase III Sediments (µg/kg, dw).

Station	Phenol	2-Methylphenol	4-Methylphenol	2,4-Dimethylphenol	Pentachlorophenol	Retene	2-Methylnaphthalene	1-Methylnaphthalene
1B3	276 UJ	276 UJ	276 UJ	276 UJ	2,760 UJ	**352**	**62** J	**58** J
2B2	**247**	238 U	**1,210**	119 U	**524** J	**2,170**	**469**	**232**
2C2	**187**	257 U	**699**	129 U	**472** J	**4,230**	**2,310**	**1,220**
3B2	112 U	112 U	**192**	112 U	1,120 U	**542**	**239**	**124**
3B3	**58** J	187 U	**215**	94 U	468 U	**202**	**188**	**94** J
3C2	**66** J	**83** J	**189** J	134 U	**457** J	**726**	**172**	**81** J
3C3	**121** J	**93** J	**239** J	138 U	692 U	**782**	**170**	**96** J
4B2	**176**	**93** J	**512**	123 U	**712**	**3,752**	**471**	**244**
4B3	**767** J	**295** J	**6,310** J	**140** J	1,230 UJ	**19,200**	**1,770** J	**1,050** J
4C2	79 U	158 U	**159**	79 U	**288** J	**289**	**214**	**102**
4F2	371 U	371 U	**2,360**	371 U	3,710 U	**54,500**	**3,470**	**1,810**
4F3	119 U	119 U	**581**	119 U	1,190 U	**35,600**	**1,060**	**523**
4F4	115 U	230 U	**2,030**	115 U	576 U	**73,600**	**1,720**	**922**
5A2	135 U	135 U	**512**	135 U	1,350 U	**1,170**	**353**	**171**
5B2	**50** J	**88** J	**188** J	142 U	**626** J	**564**	**180**	**93** J
5D2	**36** J	70 U	**52** J	70 U	704 U	**291**	**90**	**65** J
6A2	**193**	191 U	**1,730**	96 U	**459** J	**11,200**	**982**	**629**
6B2	77 U	77 U	**195**	77 U	773 UJ	**908**	**162**	**101**
6B3	86 U	86 U	**150**	86 U	863 U	**1,470**	**180**	**93**
6C2	**52** J	157 U	**551**	79 U	393 U	**6,020**	**160**	**109**
7A2	**212**	164 U	**77** J	164 U	**1,240** J	**553**	**141** J	**103** J
7A3	132 U	132 U	132 U	132 U	1,320 U	**132**	**53** J	**35** J
7B2	201 U	401 U	401 U	201 U	1,000 U	401	201 U	201 U
7C2	50 U	50 U	50 U	50 U	500 U	**94**	**28** J	**14** J
8A2	**72** J	150 U	**382**	75 U	375 U	**1,050**	**877**	**438**
8C2	**82** J	**72** JFSU	**611**	72 U	**299** J	**1,055**	**220**	**100**
8C3	**235**	200 U	**1,560**	100 U	500 U	**1,900**	**443**	**265**
10A2	100 U	100 U	100 U	100 U	1,000 U	**201**	100 U	100 U
10B2	63 U	63 U	**16** J	63 U	**484** J	**75**	**16** J	**8** J

detected compounds in **bold**
U=Undetected at associated concentration
UJ=Undetected at associated estimated concentration
J=Estimated concentration
FSU=field split undetected

Exceeds Freshwater Sediment Quality Values (Cubbage *et al*,1997).

Table C-5. Phthalates Detected in Salmon Bay Phase III Sediments (µg/kg, dw).

Station	Dimethylphthalate	Diethylphthalate	Di-N-Butylphthalate	Butylbenzylphthalate	Bis(2-Ethylhexyl) Phthalate	Di-N-Octyl Phthalate
1B3	**54** J	276 UJ	276 UJ	**131** J	**3,010** J	2,760 UJ
2B2	**436**	119 U	**690**	**1,520**	**2,800**	594 U
2C2	**362**	129 U	257 U	**198** J	**2,800**	644 U
3B2	225 U	112 U	225 U	112 U	**2,500**	1,120 U
3B3	94 U	94 U	187 U	187 U	**727**	468 U
3C2	**105** J	134 U	269 UJ	**193** J	**1,970**	672 U
3C3	**172**	**179**	**1,740**	**222** J	**2,520**	692 U
4B2	**280**	123 UJ	**481**	**280**	**4,245**	616 U
4B3	**270** J	123 UJ	**350** J	**366**	**6,360**	**399** J
4C2	**158**	79 U	158 U	158 U	**6,380**	**201** J
4F2	**314** J	371 UJ	742 U	371 U	**10,500**	3,710 U
4F3	**82** J	**32** J	**69** J	119 U	**22,600**	1,190 U
4F4	115 U	115 UJ	**254**	230 U	**5,120**	576 U
5A2	**147** J	135 U	270 U	**165**	**4,970** J	1,350 U
5B2	**108** J	142 U	**306**	**182** J	**1,970**	711 U
5D2	141 U	70 U	141 UJ	70 U	141 UJ	704 U
6A2	**576**	96 U	**893**	**258**	**3,970**	478 U
6B2	**131** J	77 U	77 UJ	77 UJ	**2,220** J	773 UJ
6B3	**156** J	86 U	**1,180**	**53** J	**2,140**	863 U
6C2	79 U	79 UJ	**158**	**163**	**275**	393 U
7A2	**31** J	164 UJ	164 UJ	164 U	**1,090**	1,640 U
7A3	263 U	132 UJ	263 UJ	130 U	658 UJ	1,320 U
7B2	201 U	201 U	201 UJ	401 U	401 UJ	1,000 U
7C2	**15** J	50 UJ	**481**	**28** J	**520**	500 U
8A2	75 U	75 U	150 U	150 U	**3,420**	375 U
8C2	**48** J	**88** JFSU	**154** J	**191** J	**2,935**	360 U
8C3	100 U	100 U	200 U	200 U	**501**	500 U
10A2	200 U	100 UJ	100 UJ	100 U	500 UJ	1,000 U
10B2	126 U	63 UJ	**841**	**48** J	**444**	629 U

detected compounds in **bold**
U=Undetected at associated concentration
UJ=Undetected at associated estimated concentration
J=Estimated concentration
FSU=field split undetected

Exceeds Freshwater Sediment Quality Values (Cubbage *et al*,1997).

Table C-6. Miscellaneous Semivolatile Organics Detected in Salmon Bay Phase III Sediments (µg/kg, dw).

Station	1,4-Dichlorobenzene	1,2-Dichlorobenzene	Benzyl Alcohol	Isophorone	Benzoic Acid	Dibenzofuran	Caffeine	Carbazole	3β-Coprostanol
1B3	552 UJ	552 UJ	552 UJ	276 UJ	5,520 UJ	**116** J	276 UJ	276 UJ	**2,010** J
2B2	**94** J	**119** J	**329**	119 U	**3,790** J	**384**	119 U	**923**	**6,730**
2C2	**91** J	129 U	129 U	129 U	**2,840** J	**2,260**	129 U	**825**	1,290 U
3B2	**31** J	225 U	225 U	112 U	2,250 U	**282**	112 U	**176**	1,120 U
3B3	**34** J	**106** J	94 U	94 U	**2,020** J	**166**	94 U	**85** J	935 U
3C2	269 U	269 U	**70** J	134 U	**2,790** J	**168**	134 U	**128** J	**1,640**
3C3	277 U	277 U	**86** J	138 U	2,770 UJ	**180**	138 U	**172**	**2,310**
4B2	**27** JFRU	246 U	**170** JFRU	127 U	**2,930** JFRU	**386**	123 U	**179** J	**31,922**
4B3	**53** J	**116** J	**184** J	**51** J	**4,200** J	**928** J	123 UJ	**389** J	**3,890**
4C2	79 U	158 U	79 U	79 U	**1,650** J	**244**	79 U	**117**	**1,450**
4F2	742 U	**73** J	742 U	371 U	7,420 U	**3,810**	371 U	**2,920**	3,710 U
4F3	239 U	239 U	239 U	119 U	2,390 UJ	**743**	119 U	**196**	1,190 U
4F4	**36** J	230 U	115 U	115 U	**2,640** J	**1,010**	115 U	**238**	**1,930**
5A2	270 U	270 U	270 U	135 U	2,700 UJ	**372**	135 U	**194**	**2,180**
5B2	284 U	284 U	**53** J	142 U	**2,830** J	**138** J	142 U	**71** J	**1,680**
5D2	141 U	141 U	141 U	70 U	1,410 UJ	**119**	70 U	**91**	704 U
6A2	**57** J	**106** J	**95** J	96 U	**2,170**	**460**	96 U	**274**	**2,100**
6B2	155 U	155 U	155 U	77 U	**1,020** J	**167**	77 UJ	**116** J	773 UJ
6B3	173 U	173 U	173 U	86 U	1,730 UJ	**168**	86 U	**94**	863 U
6C2	157 U	157 U	79 U	79 U	1,570 UJ	**90**	**34** J	79 UJ	786 U
7A2	329 U	329 U	**53** J	164 U	**2,070** J	**234**	164 U	**229**	1,640 U
7A3	263 U	263 U	263 U	132 U	2,630 UJ	**51** J	132 U	132 U	1,320 U
7B2	401 U	401 U	201 U	201 U	**4,110** J	201 U	201 U	201 U	2,010 U
7C2	100 U	100 U	**14** J	50 U	1,000 UJ	**24** J	50 U	**24** J	500 U
8A2	**48** J	75 U	75 U	75 U	**1,540** J	**1,750**	75 U	**437**	750 U
8C2	**94** J	144 U	**31** JFSU	72 U	**1,740** J	**216**	72 U	**160**	**4,335**
8C3	100 UJ	200 U	100 U	100 U	**2,430** J	**399**	100 U	**234**	1,000 U
10A2	200 U	200 U	200 U	100 U	2,000 UJ	100 U	100 U	100 U	1,000 U
10B2	126 U	126 U	126 U	63 U	**813** J	**14** J	63 U	63 U	629 U

detected compounds in **bold**
U=Undetected at associated concentration
UJ=Undetected at associated estimated concentration
J=Estimated concentration
FSU=field split undetected
FRU=field rep undetected

Exceeds Freshwater Sediment Quality Values (Cubbage *et al*,1997).

Table C-7. Semivolatile Organic Compounds Below Detectable Concentrations in Salmon Bay Phase III Sediments (Practical Quantitation Limits in ug/kg, dw).

Station	N-Nitrosodimethylamine	Pyridine	Aniline	Bis(2-Chloroethyl)Ether	2-Chlorophenol	1,3-Dichlorobenzene	2,2'-Oxybis[1-chloropropane]	N-Nitroso-Di-N-Propylamine	Hexachloroethane	Nitrobenzene	2-Nitrophenol	Bis(2-Chloroethoxy)Methane	2,4-Dichlorophenol	1,2,4-Trichlorobenzene	4-Chloroaniline	Hexachlorobutadiene	4-Chloro-3-Methylphenol	Hexachlorocyclopentadiene	2,4,6-Trichlorophenol	2,4,5-Trichlorophenol	2-Chloronaphthalene	2-Nitroaniline	2,6-Dinitrotoluene	3-Nitroaniline	2,4-Dinitrophenol	4-Nitrophenol	2,4-Dinitrotoluene	4-Chlorophenyl-Phenylether	4-Nitroaniline	4,6-Dinitro-2-Methylphenol	N-Nitrosodiphenylamine	1,2-Diphenylhydrazine	4-Bromophenyl-Phenylether	Hexachlorobenzene	Benzidine	3,3'-Dichlorobenzidine
1B3	552	552	552	552	552	552	276	552	552	276	552	276	276	276	276	276	276	2760	552	552	276	1380	552	552	5520	1380	1380	276	2760	2760	276	276	276	276	552	5520
2B2	594	594	594	119	119	119	238	238	238	594	594	119	119	119	594	119	238	594	238	238	119	594	594	594	1190	594	1190	119	238	1190	119	119	119	119	238	238
2C2	644	644	644	129	129	129	257	257	257	644	644	129	129	129	644	129	257	644	257	257	129	644	644	644	1290	644	1290	129	257	1290	129	129	129	129	257	257
3B2	225	262	225	225	225	225	112	225	225	112	225	112	112	112	112	112	112	1120	225	225	112	562	225	225	2250	562	562	112	1120	1120	112	112	112	112	225	2250
3B3	468	468	468	94	94	94	187	187	187	468	468	94	94	94	468	94	187	468	187	187	94	468	468	468	935	468	935	94	187	935	94	94	94	94	187	187
3C2	672	672	672	134	134	134	269	269	269	672	672	134	134	134	672	134	269	672	269	269	134	672	672	672	1340	672	1340	134	269	1340	134	134	134	134	269	269
3C3	692	692	692	138	138	138	277	277	277	692	692	138	138	138	692	138	277	692	277	277	138	692	692	692	1380	692	1380	138	277	1380	138	138	138	138	277	277
4B2	616	254	616	123	123	123	246	246	246	616	616	123	123	123	616	127	246	616	246	246	123	616	616	616	1230	616	1230	123	246	1230	123	123	123	123	246	246
4B3	616	616	616	123	123	123	246	246	246	616	616	123	123	123	616	123	246	616	246	246	123	616	616	616	1230	616	1230	123	246	1230	123	123	123	123	246	246
4C2	395	395	395	79	79	79	158	158	158	395	395	79	79	79	395	79	158	395	158	158	79	395	395	395	790	395	790	79	158	790	79	79	79	79	158	158
4F2	742	742	742	742	742	742	371	742	742	371	742	371	371	371	371	371	371	3710	742	742	371	1850	742	742	7420	1850	1850	371	3710	3710	371	371	371	371	742	7420
4F3	239	239	239	239	239	239	119	239	239	119	239	119	119	119	119	119	119	1190	239	239	119	597	239	239	2390	597	597	119	1190	1190	119	119	119	119	239	2390
4F4	576	576	576	115	115	115	230	230	230	576	576	115	115	115	576	115	230	576	230	230	115	576	576	576	1150	576	1150	115	230	1150	115	115	115	115	230	230
5A2	270	270	270	270	270	270	135	270	270	135	270	135	135	135	135	135	135		270	270	135	676	270	270	2700	676	676	135	1350	1350	135	135	135	135	270	2700
5B2	711	711	711	142	142	142	284	284	284	711	711	142	142	142	711	142	284	711	284	284	142	711	711	711	1420	711	1420	142	284	1420	142	142	142	142	284	284
5D2	141	141	141	141	141	141	70	141	141	70	141	70	70	70	70	70	70	704	141	141	70	352	141	141	1410	352	352	70	704	704	70	70	70	70	141	1410
6A2	478	478	478	96	96	96	191	191	191	478	478	96	96	96	478	96	191	478	191	191	96	478	478	478	956	478	956	96	191	956	96	96	96	96	191	191
6B2	155	155	155	155	155	155	77	155	155	77	155	77	77	77	77	77	77	773	155	155	77	386	155	155	1550	386	386	77	773	773	77	77	77	77	155	1550
6B3	173	173	173	173	173	173	86	173	173	86	173	86	86	86	86	86	86	863	173	173	86	432	173	173	1730	432	432	86	863	863	86	86	86	86	173	1730
6C2	393	393	393	79	79	79	157	157	157	393	393	79	79	79	393	79	157	393	157	157	79	393	393	393	786	393	786	79	157	786	79	79	79	79	157	157
7A2	329	329	329	329	329	329	164	329	329	164	329	164	164	164	164	164	164	1640	329	329	164	823	329	329	3290	823	823	164	1640	1640	164	164	164	164	329	3290
7A3	263	263	263	263	263	263	132	263	263	132	263	132	132	132	132	132	132	1320	263	263	132	658	263	263	2630	658	658	132	1320	1320	132	132	132	132	263	2630
7B2	1000	1000	1000	201	201	201	401	401	401	1000	1000	201	201	201	1000	201	401	1000	401	401	201	1000	1000	1000	2010	1000	2010	201	401	2010	201	201	201	201	401	401
7C2	100	100	100	100	100	100	50	100	100	50	100	50	50	50	50	50	50	500	100	100	50	250	100	100	1000	250	250	50	500	500	50	50	50	50	100	1000
8A2	375	379	375	75	75	75	150	150	150	375	375	75	75	75	375	75	150	375	150	150	75	375	375	375	750	375	750	75	150	750	75	75	75	75	150	150
8C2	360	360	360	72	72	72	144	144	144	360	360	72	72	72	360	72	144	360	144	144	72	360	360	360	720	360	720	72	144	720	72	72	72	72	144	144
8C3	500	200	500	100	100	100	200	200	200	500	500	100	100	100	500	100	200	500	200	200	100	500	500	500	1000	500	1000	100	200	1000	100	100	100	100	200	200
10A2	200	200	200	200	200	200	100	200	200	100	200	100	100	100	100	100	100	1000	200	200	100	501	200	200	2000	501	501	100	1000	1000	100	100	100	100	200	2000
10B2	126	126	126	126	126	126	63	126	126	63	126	63	63	63	63	63	63	629	126	126	63	314	126	126	1260	314	314	63	629	629	63	63	63	63	126	1260

Table C-8. Spearman Rank-Order Correlation Coefficients for Salmon Bay Phase III Conventional, Metals, and Selected Organics Data.

	TOC																			
Gravel	0.36	Gravel																		
Sand	-0.24	0.35	Sand																	
Silt	0.23	-0.59	-0.87	Silt																
Clay	0.11	-0.13	-0.64	0.38	Clay															
Fines	0.18	-0.48	-0.98	0.92	0.60	Fines														
Arsenic	0.11	-0.01	-0.13	0.12	0.13	0.08	Arsenic													
Mercury	0.16	-0.22	-0.22	0.33	0.15	0.24	0.60	Mercury												
Cadmium	0.20	-0.33	-0.24	0.46	0.04	0.28	0.43	0.60	Cadmium											
Chromium	0.22	-0.33	-0.43	0.62	0.11	0.45	0.27	0.43	0.85	Chromium										
Copper	0.15	-0.32	-0.21	0.46	-0.18	0.25	0.53	0.58	0.85	0.78	Copper									
Lead	0.02	0.04	-0.08	0.03	0.13	0.06	0.56	0.67	0.48	0.19	0.41	Lead								
Nickel	0.28	-0.16	-0.50	0.55	0.27	0.49	-0.02	0.10	0.52	0.84	0.44	-0.12	Nickel							
Zinc	0.20	-0.22	-0.20	0.33	0.06	0.23	0.63	0.90	0.72	0.47	0.72	0.73	0.06	Zinc						
LPAH	0.42	0.37	0.02	0.09	-0.15	-0.03	-0.07	0.42	0.26	0.26	0.16	0.30	0.18	0.36	LPAH					
HPAH	0.39	0.32	-0.03	0.15	-0.14	0.02	0.09	0.48	0.37	0.30	0.24	0.43	0.12	0.47	0.93	HPAH				
Total PAH	0.43	0.36	-0.02	0.12	-0.15	0.01	0.05	0.46	0.34	0.28	0.23	0.40	0.12	0.45	0.96	0.99	TotalPAH			
Bis(2-EH)Phthal.	0.45	-0.14	0.02	0.23	-0.18	0.03	-0.13	0.36	0.37	0.37	0.29	0.09	0.32	0.36	0.60	0.49	0.52	Bis(2-EH)Phthal.		
4-MePhenol	0.70	0.28	-0.20	0.23	0.06	0.17	-0.21	0.24	0.25	0.27	0.10	0.00	0.32	0.19	0.72	0.62	0.66	0.54	4-MePhenol	
Carbazole	0.58	0.36	0.03	0.11	-0.20	-0.04	0.05	0.49	0.37	0.32	0.33	0.30	0.23	0.49	0.87	0.84	0.88	0.65	0.73	Carbazole
TBT	0.20	-0.30	-0.22	0.46	-0.20	0.27	0.42	0.66	0.56	0.51	0.76	0.42	0.22	0.72	0.30	0.36	0.34	0.51	0.14	0.50

Appendix D

Bioassay Results

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Our File #: 9/771-01
Work Order #: 9700432, 9700433

June 13, 1997

Dave Goodwin
SAIC
18960 State Highway 305 NE
Suite 200
Poulsbo, WA 98370-7400

Dear Mr. Goodwin:

Re: Results of Sediment Toxicity Testing using *Hyalella azteca, Chironomus tentans and Vibrio fischeri*

EVS Environment Consultants performed toxicity testing on 22 freshwater sediment samples using *Hyalella azteca, Chironomus tentans* and V*ibrio fischeri.* Testing of *H. azteca* and *C. tentans* involved exposures for 10 days and followed procedures outlined in ASTM (1994). Testing of *V. fischeri* involved the Saline Extract Microtox test method as outlined by Microbics Corporation, EPA (1991). Microtox testing was performed by the CH2M Hill Laboratory in Corvallis, OR. All tests were performed following procedures described in PESP (1995) as applicable.

Copies of all raw bench sheets and calculations of means (± SD) are attached. Below are some points that we have highlighted for your convenience.

General Notes:
- Chain-of-Custody (C-O-C) forms were not received with the samples, they were faxed later. Please refer to the EVS C-O-C for sample receipt and integrity information.

10-d *H. azteca* Survival Test:
- Low dissolved oxygen levels were reported in some of the vessels designated for water quality measurements due to a stoppage in aeration overnight, aeration was reinitiated. Aeration was checked in additional replicates and confirmed to within appropriate levels. This appeared not to affected the results.

- Due to a buildup of food on the sediment surface on Day 6, tetramin slurry was not fed on this day (only algae was fed). The feeding schedule was resumed after this.

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200 West Mercer Street
Suite 403
Seattle, WA 98119
Tel: (206) 217-9337
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evswa@halcyon.com

- Negative control survival (96%) met the required criterion (80%).

- Sample 7A2 (EVS 4805) had one replicate (D) which may have been missed in seeding, when compared to the other replicate results. Mean (± SD) survival calculations have been provided including this replicate (5 replicates total), removing it as an outlier would result in a mean (± SD) of 87.5 ± 12.6% (4 replicates).

- Reference toxicant value is within the established range.

10-d *C tentans* Survival and Growth Test:
- Low dissolved oxygen levels were reported in some of the vessels designated for water quality measurements due to a stoppage in aeration overnight, aeration was reinitiated. Aeration was checked in additional replicates and confirmed to within appropriate levels. This appeared not to affected the results.

- Sample 1B3 (EVS 4840) had one replicate (C) which may have been missed in seeding; when compared to the other replicate results. Mean (± SD) survival calculations have been provided including this replicate (5 replicates total), removing it as an outlier would result in a mean (± SD) of 82.5 ± 17.1% (4 replicates).

- Sample 8A2 (EVS 4829) had one replicate (E) which may have been missed in seeding, when compared to the other replicate results. Mean (± SD) survival calculations have been provided including this replicate (5 replicates total), removing it as an outlier would result in a mean (± SD) of 67.5 ±18.9% (4 replicates).

- Negative control survival (100%) met the required criterion (70%).

- Reference toxicant value is within the established range.

Saline Extract Microtox Test:
- Data enclosed is a faxed version, when the official final report has been received we will forward it to you.

- The highest dilution tested was 54 - 56%, approximately 58%

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If you have any questions or need further information, please do not hesitate to call me at (604) 986-4331.

Yours truly,

EVS ENVIRONMENT CONSULTANTS

Jennifer Stewart

Jennifer V. Stewart, B.Sc.
Supervisor, Toxicology Testing

JVS/js

Table D-1. Test Results for Each Bioassay Replicate.

Sample No.	Station	Rep	*Hyalella* Survival	*Chironomus* Survival	*Chironomus* Growth (mg)	Microtox Light Reduction
8310	10A2	1	10	3	4.40	5.00
8310	10A2	2	9	5	3.16	6.00
8310	10A2	3	10	6	4.17	3.60
8310	10A2	4	10	4	3.05	3.90
8310	10A2	5	10	7	3.20	2.50
8311	10B2	1	10	9	2.48	16.70
8311	10B2	2	10	8	3.14	15.60
8311	10B2	3	9	7	3.16	19.40
8311	10B2	4	10	9	4.92	16.10
8311	10B2	5	9	7	3.59	18.40
8281	1B3	1	8	10	1.32	13.40
8281	1B3	2	10	6	1.33	12.70
8281	1B3	3	9	0	.	11.30
8281	1B3	4	9	8	1.59	10.60
8281	1B3	5	9	9	1.38	11.90
8282	2B2	1	9	5	1.98	9.20
8282	2B2	2	8	7	1.84	8.70
8282	2B2	3	8	7	2.29	7.50
8282	2B2	4	10	5	1.84	7.50
8282	2B2	5	10	3	2.47	10.40
8283	2C2	1	8	4	1.18	46.80
8283	2C2	2	9	9	2.08	48.70
8283	2C2	3	7	9	1.84	48.00
8283	2C2	4	8	9	1.60	48.60
8283	2C2	5	9	9	1.72	47.40
8285	3B3	1	7	8	1.69	9.50
8285	3B3	2	8	6	1.30	11.20
8285	3B3	3	9	7	1.90	9.50
8285	3B3	4	8	7	1.06	11.80
8285	3B3	5	7	9	1.54	10.40
8287	3C3	1	9	8	3.35	-1.90
8287	3C3	2	10	10	2.64	-0.60
8287	3C3	3	10	9	2.31	-0.90
8287	3C3	4	10	8	3.38	-0.90
8287	3C3	5	10	9	2.86	-3.10
8288	4B2	1	9	9	2.57	41.90
8288	4B2	2	8	10	1.98	46.00
8288	4B2	3	10	10	3.50	42.70
8288	4B2	4	10	9	2.22	43.80
8288	4B2	5	9	10	2.54	44.20

Table D-1. Test Results for Each Bioassay Replicate.

Sample No.	Station	Rep	*Hyalella* Survival	*Chironomus* Survival	*Chironomus* Growth (mg)	Microtox Light Reduction
8289	4B3	1	8	5	3.48	57.40
8289	4B3	2	6	6	3.08	53.40
8289	4B3	3	6	7	3.27	57.90
8289	4B3	4	9	8	2.65	57.10
8289	4B3	5	6	8	2.93	58.40
8290	4C2	1	10	7	2.41	59.90
8290	4C2	2	9	6	2.65	57.80
8290	4C2	3	10	8	2.59	61.00
8290	4C2	4	10	8	2.88	55.90
8290	4C2	5	10	9	3.04	58.40
8291	4F2	1	9	4	0.93	37.50
8291	4F2	2	8	6	1.48	36.20
8291	4F2	3	10	7	1.61	35.90
8291	4F2	4	9	6	1.65	38.50
8291	4F2	5	7	7	1.33	37.20
8293	4F4	1	7	9	3.07	17.60
8293	4F4	2	5	7	3.37	18.60
8293	4F4	3	5	6	3.75	20.40
8293	4F4	4	6	9	2.79	19.50
8293	4F4	5	8	10	3.14	17.10
8294	5A2	1	10	7	2.40	18.00
8294	5A2	2	9	9	2.00	17.60
8294	5A2	3	6	8	1.91	17.90
8294	5A2	4	9	9	2.74	18.00
8294	5A2	5	10	10	2.54	20.70
8295	5B2	1	6	7	3.06	-5.40
8295	5B2	2	9	8	2.66	-5.30
8295	5B2	3	10	8	2.84	-7.80
8295	5B2	4	7	9	3.06	-6.70
8295	5B2	5	10	7	3.04	-5.40
8297	6A2	1	8	8	2.51	46.60
8297	6A2	2	10	8	3.56	43.10
8297	6A2	3	8	8	3.00	45.20
8297	6A2	4	7	7	3.26	44.50
8297	6A2	5	7	10	3.12	45.10
8299	6B3	1	10	7	1.01	10.30
8299	6B3	2	9	7	1.23	8.50
8299	6B3	3	9	8	1.36	0.98
8299	6B3	4	8	8	2.03	9.10
8299	6B3	5	10	6	1.93	10.20

Table D-1. Test Results for Each Bioassay Replicate.

Sample No.	Station	Rep	*Hyalella* Survival	*Chironomus* Survival	*Chironomus* Growth (mg)	Microtox Light Reduction
8300	6C2	1	9	9	4.41	-9.00
8300	6C2	2	9	9	1.80	-12.80
8300	6C2	3	10	9	2.98	-15.10
8300	6C2	4	10	8	3.50	-12.60
8300	6C2	5	9	6	3.42	-13.00
8301	7A2	1	7	10	3.34	-9.00
8301	7A2	2	9	7	3.54	-7.80
8301	7A2	3	10	9	2.68	-9.00
8301	7A2	4	0	9	3.52	-10.40
8301	7A2	5	9	6	4.63	-8.40
8303	7B2	1	7	8	3.13	3.10
8303	7B2	2	2	5	3.50	1.90
8303	7B2	3	8	6	2.47	0.90
8303	7B2	4	8	8	2.86	0.80
8303	7B2	5	7	9	2.71	1.30
8304	7C2	1	8	8	2.36	21.10
8304	7C2	2	10	4	4.40	19.50
8304	7C2	3	7	9	2.22	18.70
8304	7C2	4	9	7	3.57	19.90
8304	7C2	5	6	4	2.88	16.40
8305	8A2	1	8	8	1.68	19.50
8305	8A2	2	3	8	1.24	17.00
8305	8A2	3	9	4	1.38	18.60
8305	8A2	4	7	7	0.97	20.30
8305	8A2	5	7	0	.	18.60
8307	8C3	1	9	3	0.33	7.60
8307	8C3	2	8	4	1.03	9.00
8307	8C3	3	9	3	0.13	8.20
8307	8C3	4	6	1	0.30	8.50
8307	8C3	5	7	3	0.20	8.50
1111	Control	1	10	10	3.48	
1111	Control	2	10	10	2.18	
1111	Control	3	10	10	2.11	
1111	Control	4	10	10	2.47	
1111	Control	5	8	10	2.27	