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Chemical Characterization of Stormwater Runoff from Three Puget Sound Boatyards

by
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Olympia, Washington 98504-7710

December 2006

Waterbody Numbers:
WA-13-0030 - Budd Inlet (Inner)
WA-08-9340 - Lake Washington Ship Canal
WA-PS-0220 - Admiralty Inlet (Inner)

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Abstract

Stormwater runoff and stormwater outfall sediments at three Puget Sound boatyards were analyzed during 2006 for a range of chemical contaminants including petroleum, copper and other metals, organotins, semivolatile organic compounds, and polychlorinated biphenyls (PCBs). The boatyards studied were Swantown Boatworks in Olympia, Port Townsend Boatyard/Shipyard, and Seaview East Boatyard in Seattle. These three represent a small sample of the 90 yards in Washington State under the Boatyard General Permit.

The results are compared to Washington State water and sediment quality standards. Boatyard-related chemicals that appear to have the greatest potential for adverse effects in the receiving waters are copper, zinc, lead, tributyltin, polyaromatic hydrocarbons, and phthalates. Recommendations are made for addressing these contaminants.

Acknowledgements

The authors of this report appreciate the help and cooperation extended by the boatyards that were the subject of this study.

This project benefited from advice and information provided by Gary Bailey, Lydia Wagner, Cynthia Callahan, Donna Ortiz de Anaya of the Ecology Water Quality Program.

Project samples were analyzed by the Ecology Manchester Environmental Laboratory. Their good work is appreciated.

The report was improved by review comments from Gary Bailey and Lydia Wagner, as well as from Dale Norton and Brandi Lubliner of the Ecology Environmental Assessment (EA) Program. The final report was formatted by EA's Joan LeTourneau.

Introduction

In November 2005, the Washington State Department of Ecology (Ecology) issued the third Boatyard General Permit under the National Pollutant Discharge Elimination System (NPDES). The permit expires in November 2010.

A boatyard, as defined in the permit, is a commercial business engaged in the construction, repair, and maintenance of small vessels, 85% of which are 65 feet or less in length or revenues from which constitute more than 85% of gross receipts. Services typically provided include, but are not limited to, pressure washing hulls, painting and coating, engine and propulsion system repair and replacement, hull repair, joinery, bilge cleaning, fuel and lubrication system repair and replacement, welding and grinding of hull, buffing and waxing, marine sanitation device repair and replacement, and other activities necessary to maintain a vessel.

The NPDES permit for boatyards contains stormwater self-monitoring requirements that include copper, oil & grease, total suspended solids (TSS), and visual monitoring (www.ecy.wa.gov/programs/wq/permits/boatyard/index.html). Stormwater samples are to be collected during the first flush of the storm event, at a minimum frequency of once each during January, April, May, October, and November.

While stormwater from these facilities has already been well characterized for copper, other toxic pollutants have not been analyzed. Therefore, the Ecology Water Quality Program (WQ) requested a study to analyze boatyard stormwater runoff for a wider range of potentially toxic chemicals. WQ wanted to determine if other chemicals are a potential concern for the receiving environment. If so, then these chemicals would be considered for future actions and requirements of the Boatyard General Permit.

In response to WQ's request, Ecology's Environmental Assessment (EA) Program sampled stormwater runoff from three Puget Sound boatyards during April and May 2006. From one to three storm events were sampled at each yard; six sets of samples were obtained in all. One composite sediment sample was also collected in the receiving waters adjacent to each stormwater outfall during February 2006. Chemicals analyzed included total petroleum hydrocarbons (TPH), priority pollutant metals, organotins, semivolatile organic compounds, and polychlorinated biphenyls (PCBs), in additional to general water and sediment quality parameters.

Results from this study of three boatyards represent a small sample of the 90 yards in Washington State under the Boatyard General Permit.

Sampling Design

Boatyard Selection

The following three boatyards – two marine and one freshwater – were selected for stormwater sampling, in consultation with Ecology's NPDES permit managers (Figure 1). These facilities were selected to provide stormwater data that reflect a range of boatyard sizes and services. Each yard employs varying degrees of best management practices (BMPs) for stormwater and monitors their discharge during winter and spring.

1. Swantown Boatworks – Permit #WAG03-1043
   Port of Olympia
   650 Marine Drive NE
   Olympia, WA 98501-6964
   Bruce Marshall, Harbor Director
   (360) 528-8049

2. Port Townsend Boatyard/Shipyard – Permit #WAG03-1006
   2601 Washington Street
   Port Townsend, WA 98368
   Ken Radon, Operations Manager
   (360) 385-2355

3. Seaview East Boatyard – Permit #WAG03-0042
   4701 Shilshole Avenue N.W.
   Seattle, WA 98107
   John Papajani, Business Manager
   (206) 789-3030

Swantown Boatworks in Olympia on Budd Inlet was opened in 1999 and is Puget Sound's newest boatyard. It operates a 77-ton Travelift for vessels up to 22 feet wide. The 2.9-acre paved yard has capacity for 45 recreational and commercial vessels. In addition to the boatyard and boat storage, 20,000 square feet of marine oriented repair, retail, and office space has been constructed. Swantown's stormwater is discharged to a retention pond wetland at the south end of the facility and then routed to an outfall in the intertidal zone adjacent to the haul-out structure.

Construction of the Port Townsend Boatyard/Shipyard was completed in 1997. It is capable of lifting large vessels up to 150 feet long. The shipyard is home to a number of marine trade businesses with expertise in maintenance and restoration, as well as a 10-acre dryland storage area. The yard has a capacity of up to 200 vessels ashore at any given time. Stormwater is discharged to Port Townsend (Admiralty Inlet) via two outfalls to the Port Townsend Boat Haven.

Seaview East Boatyard is located in Ballard on the Lake Washington Ship Canal. It was opened in 1985 at the former Seattle Cedar Mill site. The yard has a 28,000-square-foot repair building and 88-ton Travelift. Services include paint work, fiberglass repairs, woodwork, rigging, mechanical installations, general maintenance, as well as do-it-yourself and storage facilities. Vessels are predominantly 20–60 feet in length. Stormwater runoff is discharged to the ship canal through a single submerged drain.

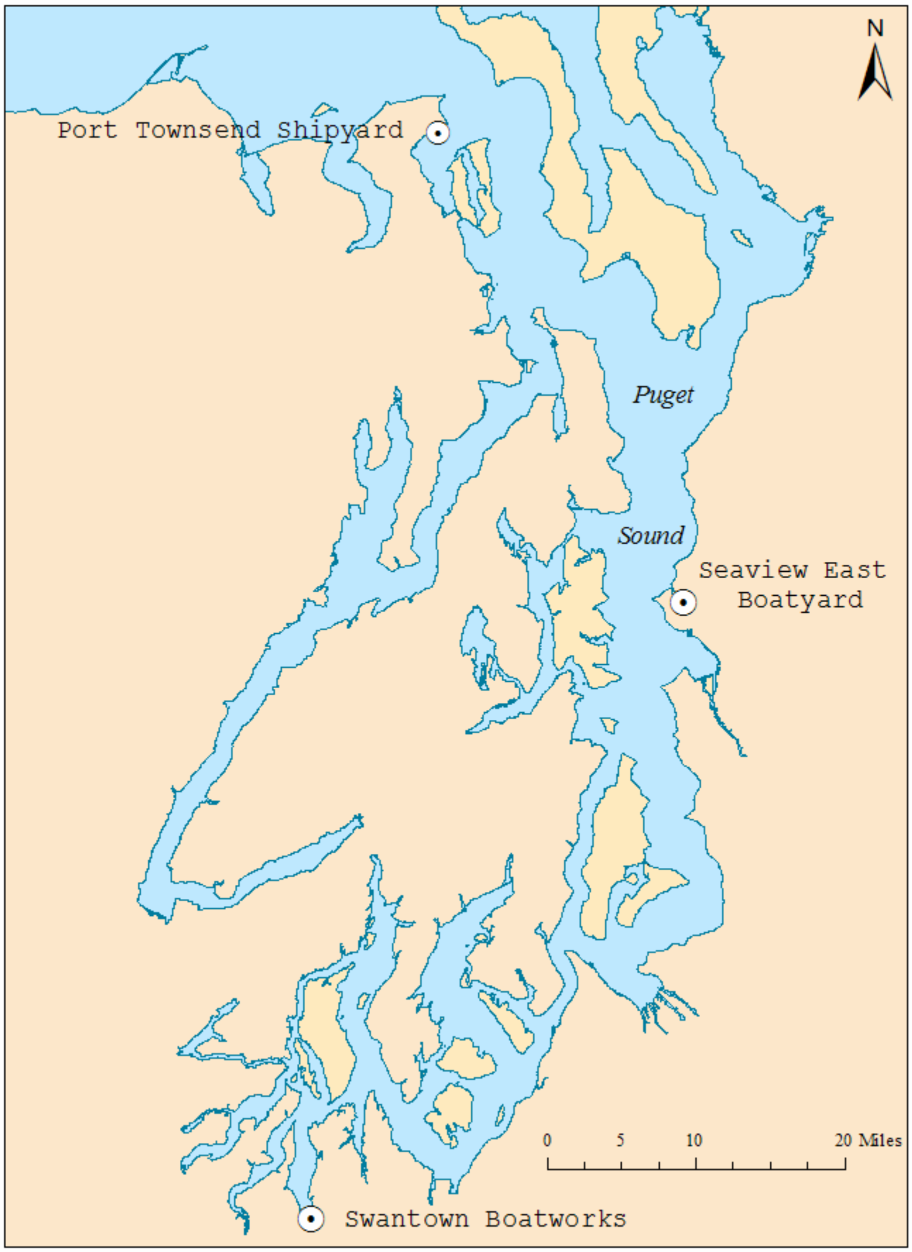

Figure 1. Location of Boatyards Selected for Stormwater Sampling in 2006.

Sampling and Analysis

The stormwater runoff samples were collected during April and May 2006. Monitoring data collected through the Boatyard General Permit has shown that copper levels in boatyard runoff are usually higher in the spring than during fall or winter.

Sampling procedures generally followed guidance in the Boatyard General Permit and the Ecology (2002) guide for sampling stormwater from industrial facilities. A storm event was considered appropriate for sampling if it was preceded by at least 24 hours of no greater than trace precipitation. The dates, times, and pertinent rainfall data for each of the six storm events sampled are shown in Table 1.

Table 1. Storm Events Where Boatyard Runoff was Sampled by Ecology During 2006

Boat Yard	Sample Collection		Local Precipitation for Day of Sample Collection (in.)	Date of Last Rainfall	Precipitation Amount for Last Rainfall (in.)
	Date	Time			
Swantown	8-Apr	0940-1000	0.26 (Olympia airport)	3-Apr	0.06
"	13-Apr	1250-1310	0.36 (Olympia airport)	8-Apr	0.01
"	31-May	2000 - 2030	0.10 (Olympia airport)	27-May	0.15
Port Townsend	23-May	0930 - 0940	0.06 (Clinton, Whidbey Is.)	22-May	0.32
Seaview	8-Apr	1330-1400	0.38 (SeaTac airport)	3-Apr	0.02
"	23-May	1030-1100	0.17 (SeaTac airport)	22-May	0.24

The wetland employed to treat stormwater runoff from the Swantown facility is unique among Puget Sound boatyards. In order to obtain data that are applicable to boatyards in general, samples for the present study were collected at the mouth of the drain pipe that delivers runoff to the wetland. Swantown collects their NPDES sample downstream of the wetland at the outfall in the intertidal zone.

Port Townsend takes their NPDES stormwater samples from two sites: a northeast storm drain that primarily serves vehicle parking areas (outfall 001A) and a southwest drain that serves the greater part of the outside working area (outfall 002B). Samples for the present study were taken through a manhole just upstream of outfall 002B.

The stormwater system at the Port Townsend yard collects surface runoff into four baffled wet vaults located in different areas of the facility. The vaults remove settleable solids before being gravity discharged to a larger (12,500 gallon) stormwater vault located upstream of the manhole where the stormwater samples were collected. A high volume pump, activated by float switch, drains the vault. The outfall, located in the innermost corner of the marina, is a submerged four-foot concrete pipe. Two tide gates prevent saltwater from inundating the stormwater system. Because the period during which the stormwater vault discharges is short (<15 minutes) and hard to predict, it was difficult to time sample collection. Only one discharge episode was captured for the present study.

The Seaview East samples were collected approximately 50 feet upstream of the junction box where the yard collects their NPDES sample. This box has a heavy wooden cover that could only be moved with mechanical assistance, which the yard was unable to provide on short notice during storm events. Ecology's stormwater samples incorporated runoff from the west side of the yard (via a small eastward flowing culvert that routes runoff under the Travelift ramp) and the east side (overland flow to a catch basin west of the ramp). Half of the total sample volume came from each source. The samples were judged to represent most of the yard's runoff.

First-flush samples were collected for the study. The samples were taken as simple grabs during the first 15-30 minutes of discharge. The April 8 sample at Swantown was an exception. A vehicle breakdown delayed sampling for about two hours after runoff first began.

All samples were analyzed for conductivity, turbidity, TSS, TPH, priority pollutant metals, and organotins. The semivolatiles analysis was limited to one or two samples from each yard. A detailed list of the chemicals analyzed is in Appendix A.

Sediment samples were collected in the immediate vicinity of each stormwater outfall. Each sample consisted of the top 2 cm surface layer composited from three separate grabs. Analyzing the top 2 cm is recommended in cases where conditions in the vicinity of a permitted discharge are being monitored (Ecology, 2003). The composites were split into separate samples for priority metals, organotins, semivolatiles, PCBs, total organic carbon (TOC), grain size, and percent solids. PCB analysis for the study was limited to sediments because of the cost of analyzing low-levels of these compounds in water. The sediment samples were collected in February 2006.

Figures 2-4 show the locations of Ecology's stormwater runoff and sediment sampling sites. The latitude and longitude of each site is in Appendix B.

This study was conducted according to a Quality Assurance Project Plan (Johnson, 2005).

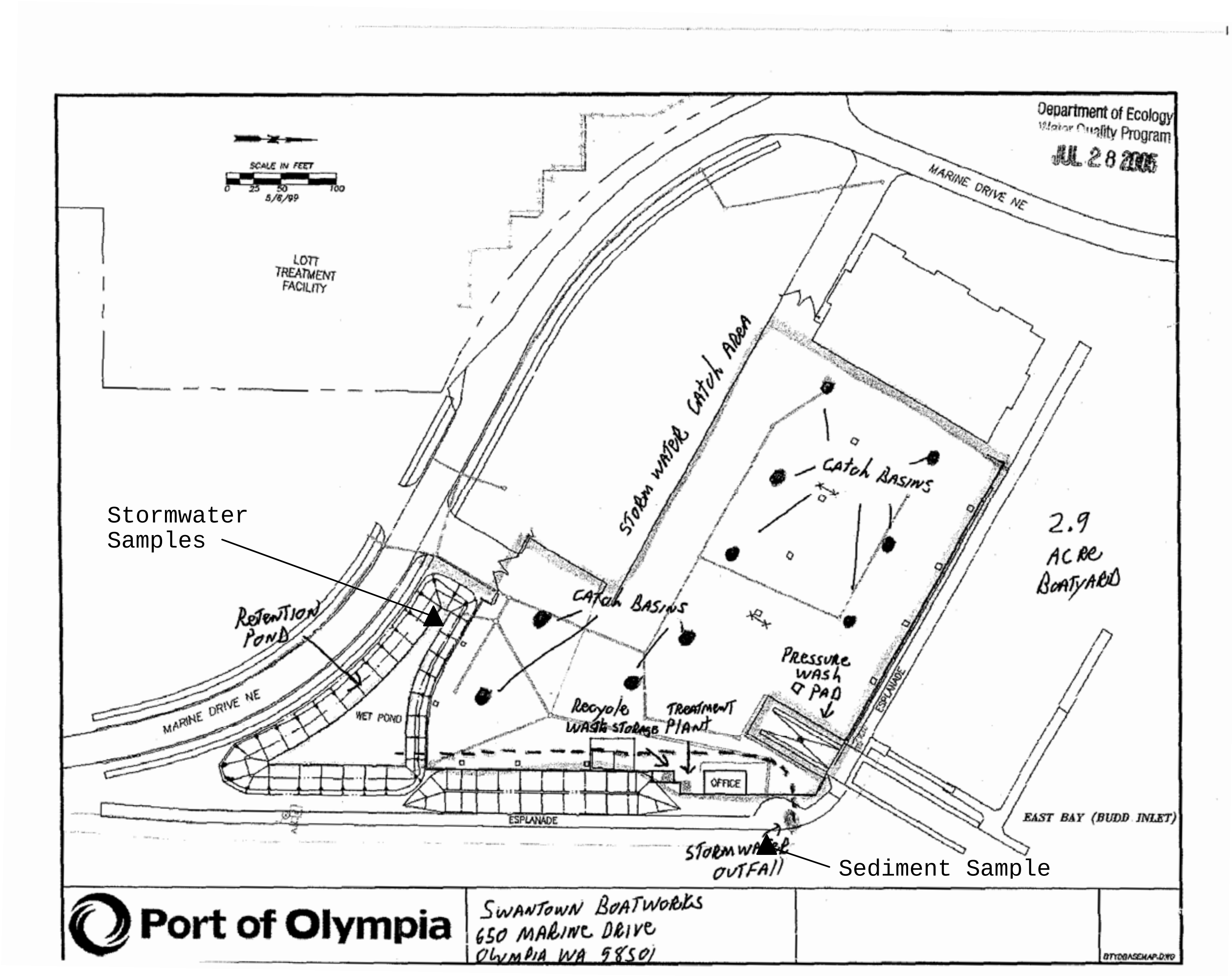

Figure 2. Swantown Boatworks Showing Location of Ecology's 2006 Stormwater Runoff and Sediment Samples.

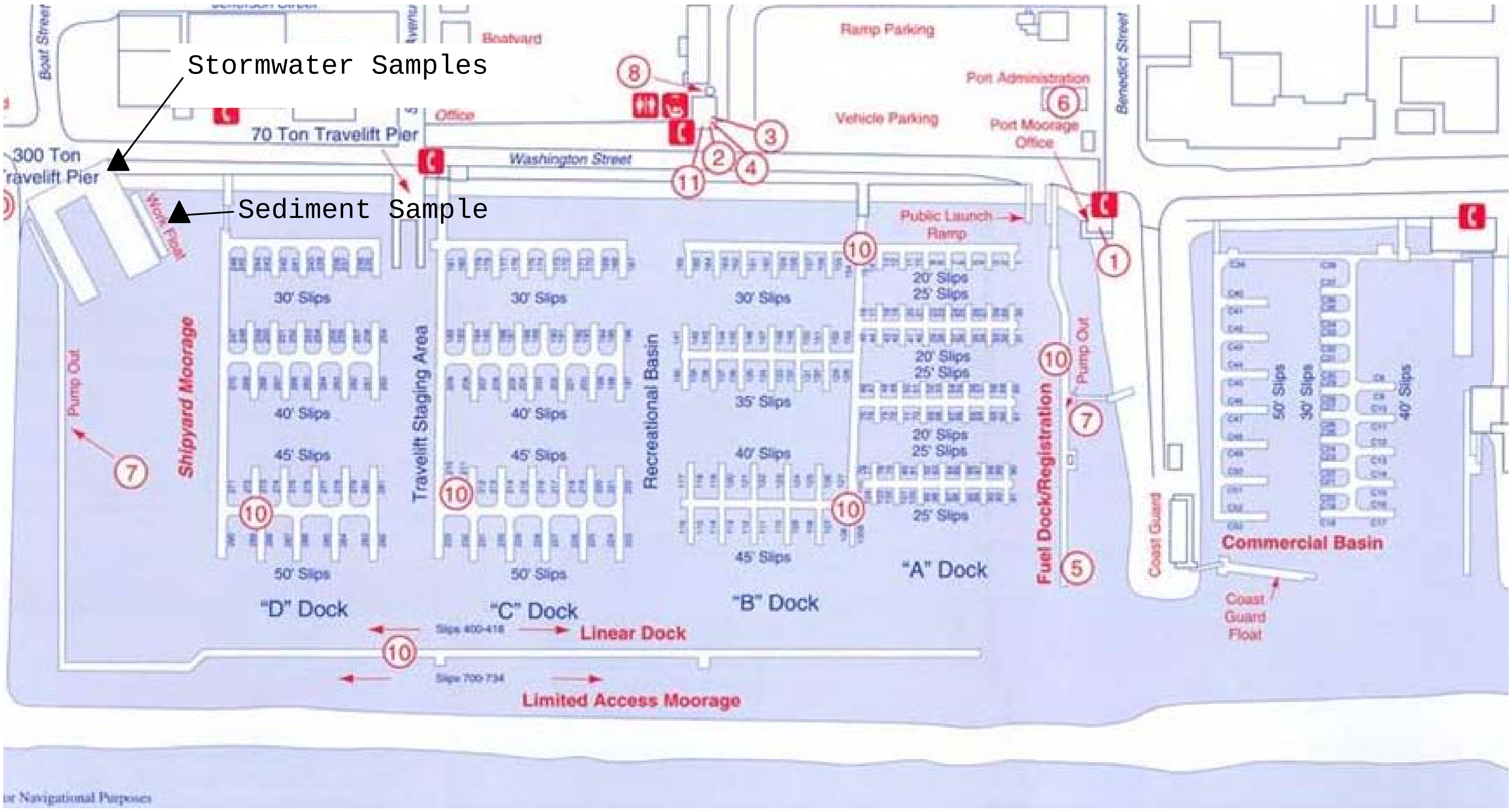

Figure 3. Port Townsend Boatyard/Shipyard Showing Location of Ecology's 2006 Stormwater Runoff and Sediment Samples.

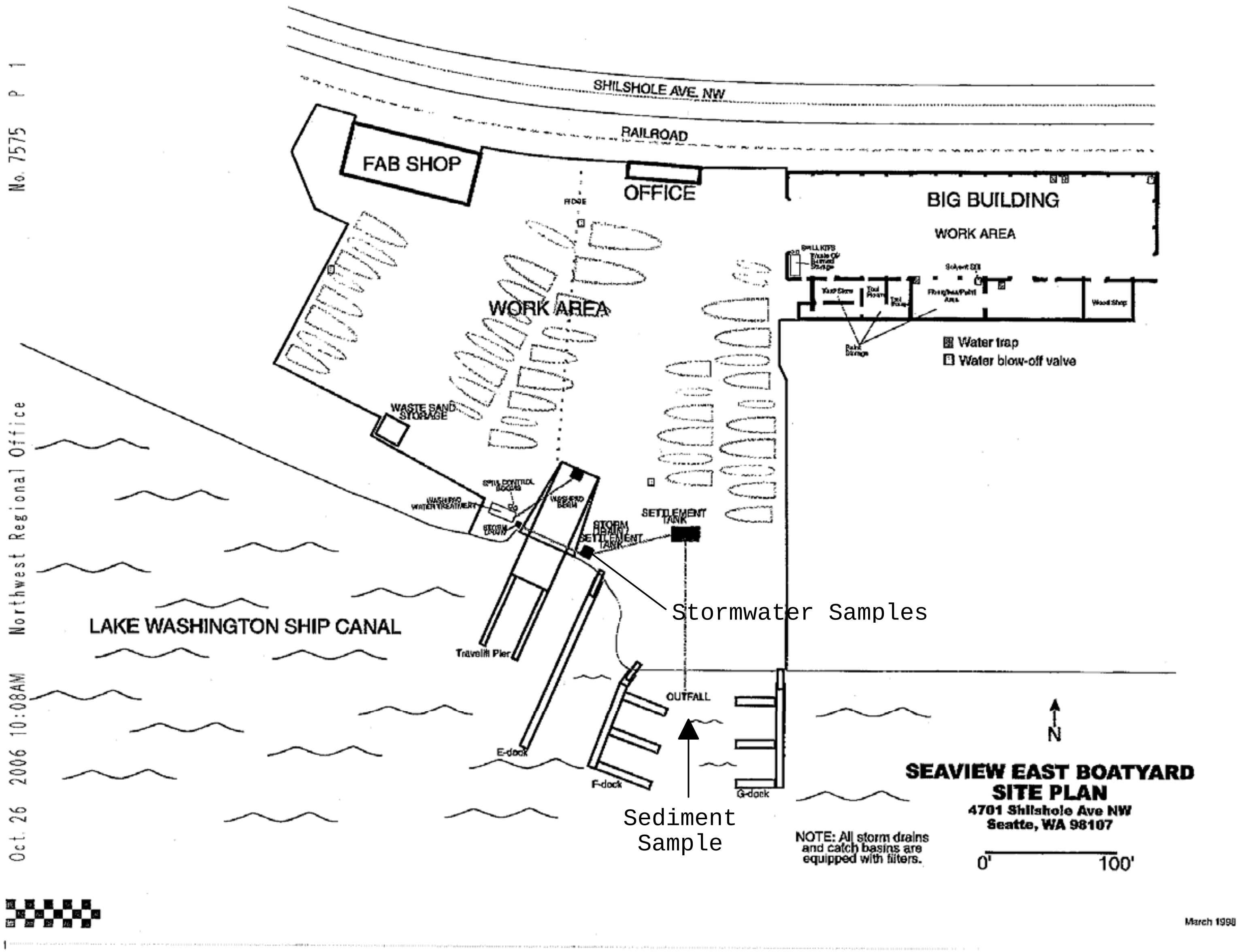

Figure 4. Seaview East Boatyard Showing Location of Ecology's 2006 Stormwater Runoff and Sediment Samples.

Methods

Sampling Procedures

Sample volumes, containers, preservation, and holding times for the stormwater and sediment samples are shown in Table 2.

Table 2. Sample Containers, Preservation, and Holding Times for Boatyard Stormwater Samples

Parameter	Container	Preservation	Holding Time
Water Samples			
Conductivity	500 mL poly bottle	Cool to 4°C	28 days
Turbidity	500 mL poly bottle	Cool to 4°C	48 hours
TSS	1,000 mL poly bottle	Cool to 4°C	7 days
TPH diesel	1 L glass jar*	HCl to pH<2 Cool to 4°C	7/14 days
TPH gas	(3) 40 mL vials w/ septum*	HCl to pH<2 Cool to 4°C	7/14 days
Metals	1 L HDPE bottle	HNO_3 to pH<2	6 months (28 days mercury)
Organotins	1 L glass jar*	HCl to pH<2, 4°C	7/14 days
Semivolatiles	1 gal. glass jar*	HCl to pH<2, 4°C	7/14 days
Sediment Samples			
TOC	2 oz. glass jar	Cool to 4°C	28 days
Grain Size	2 oz. glass jar	Cool to 4°C	6 months
Metals	8 oz. glass jar*	Cool to 4°C	6 months (28 days mercury)
Organotins	8 oz. glass jar*	Cool to 4°C	1 year
Semivolatiles	8 oz. glass jar*	Cool to 4°C	1 year
PCBs	8 oz. glass jar*	Cool to 4°C	1 year

*Organic-free with Teflon-lined lids

The runoff samples were collected in appropriate sample containers, labeled with a unique sample identifier, and put on ice in a cooler. The samples were returned to Ecology Headquarters on the day of collection, and held in a secure cooler for transport with chain-of-custody record to the Ecology Manchester Environmental Laboratory the following day.
*
Sediment sampling methods were consistent with Puget Sound Estuary Program (PSEP, 1996) protocols and requirements of the Sediment Management Standards (Ecology, 2003). The samples were collected from an Ecology vessel using a 0.05 m^2 stainless steel Ponar grab. Sampling sites were located and positions recorded using GPS and landmarks. A grab was

considered acceptable if not over-filled with sediment, overlying water was present and not excessively turbid, the sediment surface was relatively flat, and the desired depth penetration was achieved.

All samples were composites of the top 2 cm layer. After siphoning off overlying water, the top 2 cm of sediment from three grabs per sampling site was removed with a stainless steel scoop, placed in a stainless steel bowl, and homogenized by stirring. Material touching the side walls of the grab was not taken.

Subsamples of the homogenized sediment were put into appropriate sample containers (Table 2), labeled, and placed on ice. The samples were returned to Ecology HQ and held in a secure cooler for transport with chain-of-custody record to Manchester Laboratory the following day.

Stainless steel implements used to collect and manipulate the sediments were cleaned by washing with Liquinox detergent, followed by sequential rinses with tap water, dilute nitric acid, deionized water, and pesticide-grade acetone. The equipment was then air dried and wrapped in aluminum foil. Between-sample cleaning of the Ponar grab consisted of thorough brushing in the receiving waters.

Laboratory Analysis

Project samples were analyzed by Manchester Laboratory, except for organotins in water and grain size in sediment which were analyzed by Pacific Rim Laboratories, Surrey B.C. and Analytical Resources, Tukwila WA, respectively. Analytical methods are shown in Table 3.

Table 3. Analytical Methods for Boatyard Stormwater Samples

Parameter	Analytical Method
Water Samples	
Conductivity	SM 2510B
Turbidity	SM 2130
TSS	SM 2540D
NWTPH-Dx	GC/FID NWTPH-Dx
NWTPH-Gx	GC/FID NWTPH-Gx
Metals	ICP/MS EPA 200.8
Mercury	CVAA EPA 245.1
Organotins	GC/HRMS Ikonomou et al. (2002)
Semivolatiles	GC/MS EPA SW 846 8270
Sediment Samples	
Grain Size	Plum (1981)
TOC	Puget Sound Estuary Program-TOCM
Percent Solids	SM 2540B
Metals	ICP/MS EPA 200.8
Mercury	CVAA EPA 245.5
Organotins	GC/MS-SIM Krone et al. (1989)
Tributyltin	SW 8270
Semivolatiles	GC/MS EPA SW 846 8270
PCBs	GC-ECD EPA SW 846 8082

Data Quality

Manchester Laboratory prepared written case narratives assessing the quality of the data collected for this project. The reviews include a description of analytical methods and an assessment of holding times, tuning, initial and continuing calibration verification and degradation checks, method blanks, matrix spike/matrix spike duplicate recoveries, laboratory control samples, surrogate recoveries, laboratory duplicates, and standard reference materials. No significant problems were encountered in the analysis of these samples, and the data are usable as qualified. The reviews and complete Manchester Laboratory data reports are available on request.

Transfer blanks were analyzed for metals and organic compounds to detect contamination arising from sample containers and/or sample handling. The blanks were prepared during storm events using sample bottles filled with blank water by the analyzing laboratory. The bottle was opened in the field and its contents transferred to a new bottle, in essence mimicking the grab sampling procedure. Traces of benzoic acid (0.32 ug/L) and di-N-butylphthalate (0.03 ug/L) were detected in the transfer blank for semivolatiles (Appendix C). These concentrations are insignificant compared to runoff samples. No metals or organotins were detectable in the blanks.

A field duplicate stormwater sample was analyzed to provide estimates of sampling and analytical variability. The duplicates consisted of two sample bottles filled from the same grabs. Results for metals, tributyltin, most conventional parameters, and most semivolatile compounds agreed within 25% or better (Appendix D).

Substantial variability (140%) was encountered for turbidity in the field duplicate. This appears to be an isolated incident not indicative of the overall precision of the turbidity data. Conductivity and TSS measurements on the duplicates agreed within 2%, showing the samples were homogeneous. Manchester Laboratory analyzed split samples for turbidity as part of their routine quality control procedures for this project, and results agreed within 10%.

A pair of duplicate samples was also analyzed for the sediment survey (Appendix E). Results for metals and organotin agreed within 20%, except for lead, arsenic, and antimony (33%, 45%, and 81%, respectively). Considerable variability was encountered for certain semivolatile compounds. Results for six compounds – 1,2-dichlorobenzene, 1,3-dichlorobenzene, butylbenzyl phthalate, di-N-butylphthalate, di-N-octylphthalate, and carbazole – varied by more than 50%. This uncertainty was taken into account when assessing compliance with sediment management standards.

The average results from the stormwater and sediment duplicate samples were used in the remainder of this report.

Except as noted above, the analytical data met the data quality objectives identified in the Quality Assurance Project Plan for this project (Johnson, 2005).

Results and Discussion

Runoff Analyses

Conventional Parameters and Petroleum

Results from analyzing boatyard stormwater runoff for conventional water quality parameters and petroleum are shown in Table 4.

Table 4. Results of Analyzing Conventional Water Quality Parameters and Petroleum in Boatyard Stormwater Runoff Collected during April - May 2006

Boatyard	Sample Number	Date	Conductivity (umhos/cm)	TSS (mg/L)	Turbidity (NTU)	Lube Oil (mg/L)	Gasoline (mg/L)
Swantown	6144010/11	4/8	65	12	42	0.56*	0.14 U
"	6154012	4/13	337	6	8.2	0.49 U	0.40
"	6224000	5/31	1230	7	8.2	0.41 U	0.04 J
Port Townsend	6214000	5/23	33	106	85	4.3	0.14 U
Seaview	6144012	4/8	160	45	14	2.4	0.14 U
"	6214001	5/23	- -	27	90	3.8	0.14 U

*Not detected in duplicate sample
U = Not detected at or above the reported value
J = Estimated concentration

TSS and turbidity ranged widely, with TSS concentrations of 6–106 mg/L (parts per million) and turbidities of 8–90 NTU[1]. Swantown had much lower TSS and turbidity levels than either Port Townsend or Seaview.

Lube oil was detected in runoff from Port Townsend and Seaview at 2.4–4.3 mg/L, but was near or below detection limits at Swantown. In this analysis, lube oil is a collective term for petroleum products such as motor oil, hydraulic fluid, transmission fluid, and cutting oils that primarily consist of an unresolved envelope of compounds. Gasoline was not detected, except for trace amounts of 0.04–0.40 mg/L in two of the three Swantown samples.

Metals

Table 5 has metals data on boatyard runoff. The dominant metals in terms of concentration were copper, zinc, and lead, in that order. Concentration ranges were 319–12,300 ug/L for copper, 345–2,600 ug/L for zinc, and 22–317 ug/L for lead (parts per billion). Seaview had higher concentrations than the other yards. Sources of these metals at boatyards include, but are not limited to, copper and zinc in bottom and topside paints; sacrificial zincs to protect props, shafts, and other metal parts; and lead ballast keels.

[1] nephelometric turbidity units

Table 5. Results of Analyzing Metals in Boatyard Stormwater Runoff Collected during April-May 2006 (ug/L; parts per billion; total recoverable metals)

Boatyard	Sample Number	Date	Copper	Zinc	Lead	Chromium	Arsenic
Swantown	6144010/11	4/8	1002	345	22	1.2	0.74
"	6154012	4/13	2650	550	320	2.9	1.7
"	6224000	5/31	1620	1200	33	2.5 U	3.4 J
Port Townsend	6214000	5/23	319	610	23	25 UJ	30 J
Seaview	6144012	4/8	4690	1700	142	9.7 J	6.0
"	6214001	5/23	12300	2600	317	39	13

Boatyard	Sample Number	Date	Nickel	Antimony	Cadmium	Mercury	Silver
Swantown	6144010/11	4/8	2.0	1.6	0.52	0.05 U	0.10 U
"	6154012	4/13	3.0	1.8	0.74	0.072	0.10 U
"	6224000	5/31	9.9	2.5	2.7	0.05 U	1.0 U
Port Townsend	6214000	5/23	19 J	10 U	5.0 U	0.10	5.0 U
Seaview	6144012	4/8	13	5.0	2.4	0.14	0.23
"	6214001	5/23	25	6.9	3.3	1.1	1.2

Boatyard	Sample Number	Date	Selenium	Thallium	Beryllium
Swantown	6144010/11	4/8	0.50 U	0.10 U	0.10 U
"	6154012	4/13	0.50 U	0.10 U	0.10 U
"	6224000	5/31	5.0 U	1.0 U	1.0 U
Port Townsend	6214000	5/23	120	5.0 U	5 U
Seaview	6144012	4/8	0.50 U	0.10 U	0.10 U
"	6214001	5/23	5.0 U	1.0 U	1.0 U

U = Not detected at or above the reported value
J = Estimated concentration
UJ = Not detected at or above the reported estimated value

Relatively low concentrations of chromium, arsenic, nickel, antimony, and cadmium were detected in stormwater. Most concentrations were in the vicinity of 1–10 ug/L. One sample each at Seaview and Port Townsend had an elevated level of chromium (39 ug/l) and arsenic (30 ug/L), respectively.

Trace amounts of mercury (0.072–1.1 ug/L) and silver (0.23–1.2 ug/L) were detected in a few samples, primarily those from Seaview. Selenium, thallium, and beryllium were not detected at any of the yards, except for a single high selenium result of 120 ug/L at Port Townsend.

Organotins

The organotin data are summarized in Table 6. The antifouling agent tributyltin and degradation products dibutyl- and monobutyltin were detected in all runoff samples. Tributyltin concentrations were 0.010–0.35 ug/L, except 5.9 ug/L in one of the two Seaview samples.

Table 6. Results of Analyzing Organotins in Boatyard Stormwater Runoff Collected during April-May 2006 (ug/L; parts per billion)

Boatyard	Sample Number	Date	Tributyltin	Dibutyltin	Monobutyltin
Swantown	6144010/11	4/8	0.22	0.041 J	0.001 UJ
"	6154012	4/13	0.13	0.002 UJ	0.001 UJ
"	6224000	5/31	0.010 J	0.033 J	0.012 J
Port Townsend	6214000	5/23	0.18 J	0.010	0.006 J
Seaview	6144012	4/8	6.0	0.064 J	0.001 UJ
"	6214001	5/23	0.36	0.10	0.014

J = Estimated concentration
UJ = Not detected at or above the reported estimated value

The harmful effects of tributyltin on marine organisms became recognized in the 1980s. Currently, paints containing tributyltin are prohibited from use on any vessel less than 25 meters in length except as applied by a licensed applicator for painting aluminum hulls less than 25 meters in length, and for painting outboard motors and outdrives of vessels less than 25 meters in length. The extent to which the boatyards in the present study do or do not use tributyltin paints was not determined. A complete prohibition on the use of tributyltin is to take effect nationwide on January 1, 2008.

Semivolatiles

Thirty-seven semivolatile compounds were detected in stormwater runoff (Table 7). The majority of these (30 compounds) were either polyaromatic hydrocarbons (PAHs), phthalates, or phenols. Concentrations of these and other semivolatiles were 5 ug/L or less, except 13– 5 ug/L for bis(2-ethylhexyl)phthalate, dimethylphthalate, and caffeine at the Seaview yard and 8.4 ug/L of 4-chloro-3-methylphenol at Port Townsend. High molecular weight PAH, phthalates, phenol, methylphenols, and caffeine were detected at all three yards.

PAHs are found in petroleum and other fossil fuels and are formed during their combustion. They are commonly grouped into low molecular weight (LPAH) and high molecular weight (HPAH) compounds. LPAH are 2–3 ring compounds, and HPAH are 4–6 ring compounds. Elevated concentrations of LPAH are generally considered to be indicative of petroleum, while high concentrations of HPAH are generally attributed to combustion of fossil fuels. Potential phthalate sources at boatyards include their use as plasticizers in PVC (e.g., pipe, fittings, sheeting, wire coatings) and in adhesives. Phenol and methylphenols are formed in gasoline exhaust, but have a variety of other sources. Caffeine is a common contaminant in urban runoff.

Table 7. Semivolatile Compounds Detected in Boatyard Stormwater Runoff Collected during April - May 2006 (ug/L; parts per billion)

Boatyard:	Swantown				Port Townsend		Seaview	
Sample Number:	6144010/11		6154012		6214000		6144012	
Date:	4/8		4/13		5/23		4/8	
Low Molecular Weight Polyaromatic Hydrocarbons (LPAH)								
Naphthalene	0.06	U	2.6		0.06	U	0.32	
1-Methylnaphthalene	0.06	U	2.9		0.06	U	0.19	
2-Methylnaphthalene	0.06	U	3.3		0.06	U	0.27	
Acenaphthylene	0.06	U	3.9		0.06	U	0.42	
Acenaphthene	0.06	U	0.11		0.06	U	0.22	
Fluorene	0.06	U	0.29		0.06	U	0.33	
Phenanthrene	0.13		0.12		0.15		2.1	
Anthracene	0.06	U	0.07		0.06	U	0.58	
High Molecular Weight Polyaromatic Hydrocarbons (HPAH)								
Fluoranthene	0.12		0.35		0.42		2.4	
Pyrene	0.10		0.63		0.38	J	1.3	
Benzo(a)anthracene	0.06	U	0.05	J	0.14		0.24	
Chrysene	0.07	J	0.08		0.26		0.82	
Benzo(b)fluoranthene	0.06	U	0.05	J	0.2		0.39	
Benzo(k)fluoranthene	0.06	U	0.07		0.15		0.4	
Benzo(a)pyrene	0.06	U	0.06	U	0.04	J	0.26	
Indeno(1,2,3-cd)pyrene	0.06	U	0.06	U	0.05	J	0.12	
Benzo(ghi)perylene	0.06	U	0.08		0.06	J	0.16	
Phthalates								
Bis(2-Ethylhexyl) Phthalate	2.8		1.3	UJ	2.1		15	
Di-N-Butylphthalate	2.6		0.54		0.16	J	4.3	
Dimethylphthalate	1.0		0.22		0.68		13	E
Diethylphthalate	0.28	J	0.05	J	0.09	J	1.2	
Butylbenzylphthalate	0.39		0.14		0.03	J	2.1	
Phenols								
Phenol	0.84		0.55		0.29		4.6	
2-Methylphenol	0.19		0.54		0.07		1.0	
4-Methylphenol	0.85		0.06	U	1.2		3.1	
2,4-Dimethylphenol	0.16		3.0		0.06	U	1.1	
4-Chloro-3-Methylphenol	0.12	U	0.13	U	8.4		0.13	U
2-Nitrophenol	0.25	J	0.25	U	0.26	U	0.26	U
4,6-Dinitro-2-Methylphenol	0.59	J	0.63	U	0.64	U	0.64	U
Pentachlorophenol	REJ		0.13	U	0.13	U	2.2	J

Boatyard:	Swantown				Port Townsend		Seaview	
Sample Number:	6144010/11		6154012		6214000		6144012	
Date:	4/8		4/13		5/23		4/8	
Miscellaneous Compounds								
Benzyl Alcohol	0.64		0.13	U	0.13	UJ	4.5	
Dibenzofuran	0.06	U	0.08		0.06	U	0.29	
Retene	0.08		0.06	U	0.06	U	0.58	
Caffeine	2.7		0.61		0.46		15	
Benzoic Acid	5.8		1.3	U	0.74	J	1.3	U
Isophorone	0.06	U	0.06	U	0.06	U	0.35	
Carbazole	0.06	UJ	0.06	UJ	0.06	UJ	1.2	J

U = Not detected at or above the reported value
J = Estimated concentration
UJ = Not detected at or above the reported estimated value
E = Exceeds calibration range
REJ = Data rejected

Sediment Analyses

General Physical/Chemical Characteristics

Grain size, total organic carbon (TOC), and percent solids determinations on the bottom sediment samples collected off the stormwater outfalls are in Table 8. Seaview sediments had more fine material than those at Port Townsend or Swantown. The Seaview sample was also noteworthy in having a higher organic content than the other yards (8.2% vs. 2.2-3.0% TOC). Fine sediments with high TOC content tend to have higher levels of metals and organic compounds, other factors being equal. An oily sheen was noted in the sediments off Seaview.

Table 8. Physical/Chemical Characteristics of Bottom Sediments Collected off Boatyard Storm Drains in February 2006 (percent)

Boatyard:	Swantown	Port Townsend	Seaview
Sample No.:	6080412	6980410	6080413
Gravel	14	3.0	1.0
Sand	38	55	46
Fines (silt + clay)	47	42	53
TOC	3.0	2.2	8.2
Solids	48	44	19

Metals

The three metals that occurred in the highest concentrations in stormwater runoff – zinc, copper, and lead – were also the predominant metals in the outfall sediments (Table 9). Concentrations ranged from 75–600 mg/Kg for zinc, 25–737 mg/Kg for copper, and 18–145 mg/Kg for lead (parts per million). These results are consistent with the runoff samples. As with stormwater, the highest metals concentrations were found in the sediments off Seaview.

Table 9. Metals Concentrations in Bottom Sediments Collected off Boatyard Storm Drains in February 2006 (mg/Kg, dry weight; parts per million)

Boatyard:	Swantown		Port Townsend		Seaview	
Sample No.:	6080412		6080410/11		6080413	
Zinc	75		353		600	
Copper	35		240		737	
Lead	18		48		145	
Nickel	24		49		48	
Chromium	27		45		71	
Arsenic	6.3		33		20	
Antimony	0.20	UJ	3.4		1.1	
Cadmium	1.3		1.5		1.4	
Selenium	0.66		0.99		0.62	
Thallium	0.21		0.36		0.10	U
Silver	0.42		0.16		0.59	
Mercury	0.17		0.19	J	0.64	
Beryllium	0.22		1.0	U	0.22	

U = Not detected at or above reported result
J = Estimated concentration
UJ = Not detected at or above the reported estimated result

With the exception of mercury, sediment concentrations of other metals were generally similar among the yards. Mercury concentrations were approximately 3–4 times higher at Seaview than Swantown or Port Townsend (0.64 mg/Kg vs 0.17–0.19 mg/Kg). The highest mercury concentrations were also found in Seaview stormwater.

Organotins

Tri-, di-, and monobutyltin were detected in the sediments off the Seaview and Port Townsend outfalls (Table 10.). None of these compounds were detected off Swantown (4.0 ug/Kg detection limit; parts per billion). The highest concentrations were again at Seaview: 1,200 ug/Kg tributyltin, 720 ug/Kg dibutyltin, and 280 ug/Kg monobutyltin. Organotin concentrations at Port Townsend were in the 47–200 ug/Kg range. These results are generally in line with the organotin levels measured in runoff from the three yards.

Table 10. Organotin Concentrations in Bottom Sediment Samples Collected off Boatyard Storm Drains in February 2006 (ug/Kg, parts per billion)

Boatyard:	Swantown		Port Townsend		Seaview	
Sample No.:	6080412		6080410/11		6080413	
Tributyltin Chloride	4.0	U	200		1,200	
Dibutyltin Dichloride	4.0	U	100		720	
Monobutyltin Trichloride	4.0	UJ	47	J	280	J
Tetrabutyltin	4.0	U	4.3	U	48	U

U = Not detected at or above reported result
J = Estimated concentration
UJ = Not detected at or above the reported estimated result

Semivolatiles

Most of the semivolatile compounds detected in the sediment samples were either PAHs or phthalates (Table 11). The Seaview outfall sediments had the highest concentrations, in most cases by an order of magnitude or more.

Relatively high concentrations (i.e., > 1,000 ug/Kg) of dibenzofuran, retene, coprostanol, and benzoic acid were also detected at Seaview. Lower concentrations of these four compounds were found in the sediments at one or both of the other yards.

Sources of dibenzofuran are not well known, but its distribution in Puget Sound correlates with PAH, suggesting similar origins. Retene is associated with wood waste. The elevated levels at Seaview could be related to the old Seattle Cedar Mill that once occupied this site. Coprostanol is an environmentally persistent steroid formed in the digestive tract of mammals. Its presence indicates inputs of human and/or animal fecal matter. Benzoic acid is widely used in chemical manufacturing but also has natural plant and animal sources.

Traces of 1,4-dichlorobenzene, primarily used as a deodorant for toilets and waste holding tanks, were detected off all three yards. The wood preservative pentachlorophenol was detected off the Port Townsend outfall.

Except for 1,4-dichlorobenzene and coprostanol, all of the above compounds were detected in the stormwater runoff. The boatyards are therefore sources of sediment contamination. It should be acknowledged that there are other urban/industrial sources in the vicinity of these yards that could also be contributing factors.

Table 11. Semivolatile Compounds Detected in Bottom Sediments Collected off Boatyard Storm Drains in February 2006 (ug/Kg, dry weight, parts per billion)

Boatyard:	Swantown		Port Townsend		Seaview	
Sampling Date:	2/24/2006		2/23/2006		2/24/2006	
Sample Number:	6080412		6080410/11		6080413	
Low Molecular Weight Polyaromatic Hydrocarbons (LPAH)						
Naphthalene	452		88		3,600	
1-Methylnaphthalene	61		33		996	
2-Methylnaphthalene	101		50		1,690	
Acenaphthylene	78		136		803	
Acenaphthene	71		51		2,510	
Fluorene	78		81		2,300	
Phenanthrene	357		380		9,790	
Anthracene	166		329		1,950	
Total LPAH	1,364		1,146		23,639	
High Molecular Weight Polyaromatic Hydrocarbons (HPAH)						
Fluoranthene	557		1,100		16,800	
Pyrene	686		1,100		12,600	
Benzo(a)anthracene	282		368		2,980	
Chrysene	378		798		3,080	
Benzo(b)fluoranthene	273		904		2,340	
Benzo(k)fluoranthene	264		570		2,940	
Benzo(a)pyrene	218		414		1,950	
Indeno(1,2,3-cd)pyrene	107		260		1,130	
Dibenzo(a,h)anthracene	54		133		440	
Benzo(ghi)perylene	114		243		1,400	
Total HPAH	2,933		5,887		45,660	
Phthalates						
Bis(2-Ethylhexyl) Phthalate	358	UJ	533		8,000	
Di-N-Butylphthalate	36		289	*	1,380	
Dimethylphthalate	10	U	268		804	
Diethylphthalate	17	J	3.2	J	290	
Butylbenzylphthalate	20	U	59		51	U
Miscellaneous Compounds						
Dibenzofuran	70		60		1,780	
Retene	2,120		65		4,910	
3B-Coprostanol	333	J	717	J	2,100	J
Benzoic Acid	483	J	224	UJ	1,030	J
1,4-Dichlorobenzene	8.9	J	20		60	
Pentachlorophenol	20	U	73		51	U

Boatyard:	Swantown		Port Townsend		Seaview	
Sampling Date:	2/24/2006		2/23/2006		2/24/2006	
Sample Number:	6080412		6080410/11		6080413	
4-Methylphenol	530		11	U	25	U
Isophorone	10	U	140		25	U

U = Not detected at or above reported result
J = Estimated concentration
UJ = Not detected at or above the reported estimated result
*Not detected in duplicate sample

PCBs

Polychlorinated biphenyls (PCBs) were detected in the sediments off all three yards (Table 12). The PCB mixtures detected most closely resembled -1254 and -1260. The highest concentrations were at Seaview, followed by Port Townsend and Swantown: 107, 30, and 24 ug/Kg total PCBs, respectively. As noted previously, PCBs were not analyzed in stormwater runoff because of cost.

Table 12. Results of Analyzing PCBs in Bottom Sediments Collected off Boatyard Storm Drains in February 2006 (ug/Kg, dry weight, parts per billion)

Boatyard:	Swantown		Port Townsend		Seaview	
Sampling Date:	2/24/2006		2/23/2006		2/24/2006	
Sample Number:	6080412		6080410/11		6080413	
PCB - 1260	7	J	10	J	37	J
PCB - 1254	17	J	20	J	70	
PCB - 1268	4.9	U	5.5	U	12	U
PCB - 1262	4.9	U	5.5	U	12	U
PCB - 1248	9.9	UJ	17	UJ	37	UJ
PCB - 1232	4.9	U	5.5	U	25	UJ
PCB - 1221	4.9	U	5.5	U	25	UJ
PCB - 1016	4.9	U	5.5	U	25	UJ
PCB - 1242	4.9	U	11	UJ	25	UJ
Total PCBs	24	J	30	J	107	J

U = Not detected at or above reported result
J = Estimated concentration
UJ = Not detected at or above the reported estimated result

PCBs were once widely used in hydraulic fluids and transformers, as plasticizers, and in a variety of other applications. They were manufactured as complex mixtures designated by a numbering system based on chlorine content. The last two digits are the average chlorine content by weight (e.g., PCB-1254 averages 54% chlorine) while the first two refer to the number of carbon atoms in biphenyl. The U.S. Environmental Protection Agency (EPA) banned the manufacture and use of PCBs in the 1970s and 1980s. Due to their persistence and widespread use, PCBs are routinely detectable in environmental samples. There is currently no information that would link their presence in the sediments to the boatyards.

Comparison with the NPDES Permit

The Boatyard General Permit has limits and benchmarks for stormwater discharges. Benchmarks differ from limits in being indicator values. The NPDES permit states that Ecology considers values at or below benchmark as unlikely to cause a water quality violation.

Table 13 compares the stormwater discharge limits and benchmarks in the 2005 permit to results of the 2006 runoff study. The limits and benchmarks for copper vary depending on the type of waterbody receiving the discharge. There are no permit limits or benchmarks for other metals.

Table 13. Stormwater Discharge Limits and Benchmarks in the 2005 Boatyard General Permit Compared to Present Study Results

Parameter	Type of Waterbody Receiving Discharge	Limit	Bench-mark	Present Study Median (Range)
Oil & Grease (mg/L)	All waterbodies	NA	6.0	not analyzed
TSS (mg/L)	All waterbodies	NA	21	20 (6 - 106)
Copper (ug/L, T.R.)	Lakes not 303(d) listed* for copper or zinc	NA	77	2,140 (319 - 12,300)
"	Marine waters not 303(d) listed for copper or zinc	NA	229	"
"	Rivers not 303(d) listed for copper or zinc	NA	384	"
"	Waterbodies 303(d) listed for copper or zinc	16	- -	"
"	Infiltration basin at least 200' from waters edge	1,000	NA	"

TSS = total suspended solids
T.R. = total recoverable
NA = not applicable
* the federal Clean Water Act section 303(d) list

The median TSS concentration in the stormwater runoff samples was 20 mg/L which is at the 21 mg/L benchmark that applies to all facilities. The median concentration of total recoverable copper was 2,140 ug/L, one to two orders of magnitude above the benchmarks in the permit. Only one of the six stormwater samples analyzed was within the highest of the copper benchmarks: 384 ug/L for non-303(d) listed rivers vs. a sample result of 319 ug/L. All other samples substantially exceeded the copper benchmarks.

Comparison with Aquatic Life Criteria

Washington State Criteria

Among the chemicals analyzed in boatyard stormwater runoff, Washington's aquatic life criteria are limited to metals and pentachlorophenol (Chapter 173-210A WAC). The water quality criteria are not stormwater standards and are used here only to assess the likelihood that water quality standards will be exceeded. The actual violation of water quality standards depends on flow, water hardness, and other factors not measured in the present study.

Table 14 compares the acute metals criteria to the concentrations measured in runoff. The acute criteria are one-hour average concentrations not to be exceeded more than once every three years on the average. Except for mercury, these criteria are for the dissolved fraction whereas total recoverable metals were analyzed in runoff. For these metals, Table 14 should be viewed as a screening level comparison.

Table 14. Metals Concentrations in Boatyard Stormwater Runoff from 2006 Study Compared to Washington State Acute Criteria for Protection of Aquatic Life (ug/L, parts per billion) [see caveat in text above]

Metal	Acute Marine Criteria	Acute Freshwater Criteria*	Present Study Total Recoverable Metals Median (Range)
Copper (dissolved)	4.8	4.6	2,130 (319 - 12,300)
Zinc (dissolved)	90	35	900 (345 - 2,600)
Lead (dissolved)	210	14	88 (22 - 320)
Chromium (dissolved, hexavalent)	1,100	15	6.3 (1.2 - 39)
Chromium (dissolved trivalent)	- -	176	6.3 (1.2 - 39)
Arsenic (dissolved)	69	360	4.7 (0.74 - 30)
Nickel (dissolved)	74	438	11 (2.0 - 25)
Cadmium (dissolved)	42	0.82	2.5 (0.52 - 3.3)
Mercury (total recoverable)	1.8	2.1	0.09 (<0.05 -1.1)
Silver (dissolved)	1.9	0.32	0.62 (<0.1 - 1.2)
Selenium (total recoverable)	290	20	2.8 (<0.50 - 120)

*Freshwater criteria assume a hardness of 25 mg/L (from Boatyard General Permit)

All of the total recoverable copper and zinc concentrations and most of the lead concentrations in boatyard stormwater runoff substantially exceeded both the marine and freshwater dissolved criteria. Moderate exceedances of the freshwater criteria for chromium, cadmium, and silver also occurred.

In setting the copper benchmark for the Boatyard General Permit, it was assumed that 30% was dissolved, based on data on shipyard runoff reported by Hart Crowser (1997). Similar data were not available for boatyards.

Copper, zinc, and lead were analyzed in the Hart Crowser study; the averaged dissolved percentages were 30%, 47%, and 24%, respectively. These percentages were applied to the boatyard total recoverable data, and the adjusted values were compared to the dissolved criteria in Figure 5. This figure plots the estimated dissolved concentration divided by the acute criterion; values >1 exceed the criterion. Although both sets of criteria are compared to runoff from all yards, only the marine criteria strictly apply to Swantown and Port Townsend, and only the freshwater criteria strictly apply to Seaview.

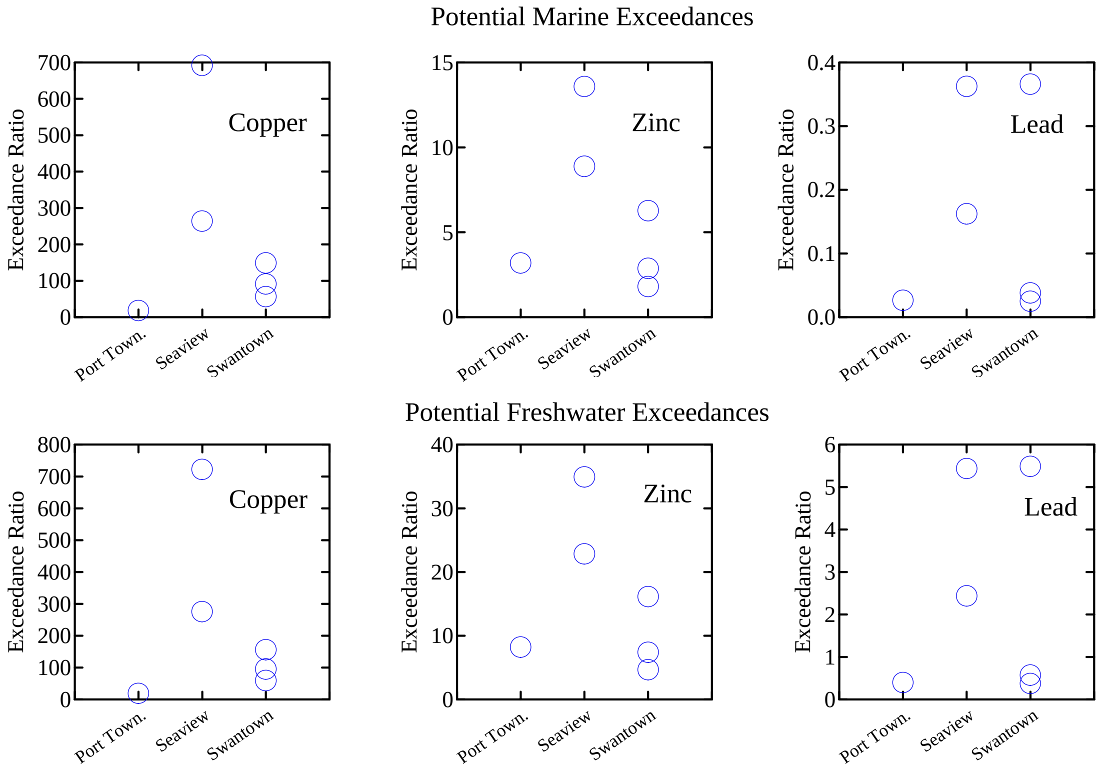

Figure 5. Estimated Dissolved Copper, Zinc, and Lead Concentrations in Boatyard Stormwater Runoff Compared to Acute Criteria for Protection of Aquatic Life [Ratios > 1 exceed criteria]

As shown in the figures, the dissolved concentrations of copper and zinc that potentially occurred in the stormwater samples are far above both the marine and freshwater acute criteria. The copper exceedances are on the order of 20-700 times the criterion. The dissolved estimates for zinc are approximately 2-15 times above the marine criterion and 5-30 times the freshwater criterion. Half of the stormwater samples had dissolved lead estimates higher than the freshwater acute criterion by factors of 2-5. The lead criterion for marine water is much less restrictive than for freshwater, and there does not appear to be much potential for the criterion to be exceeded in these samples.

Washington's acute aquatic life criterion for pentachlorophenol is 13 ug/L for marine waters. The freshwater criteria vary with pH. Surface water pH values in Western Washington are typically in the 7.0-8.0 range. The corresponding acute criteria for pentachlorophenol are 9.0– 25 ug/L and were not exceeded in stormwater runoff. The highest pentachlorophenol concentration measured in stormwater runoff was 2.2 ug/L at Seaview.

Other Aquatic Life Criteria

EPA recently developed aquatic life criteria for tributyltin (EPA, 2003). EPA concluded that marine aquatic organisms and their uses should not be affected unacceptably if the one-hour average concentration does not exceed 0.42 ug/L. For freshwater organisms, the EPA acute criterion is 0.46 ug/L.

Tributyltin concentrations in the two stormwater samples collected at Seaview (0.35 and 5.9 ug/L) approached or exceeded the acute criterion (see Table 6). Runoff from the two other yards did not exceed the criterion. EPA's tributyltin criteria have not been adopted as Washington state standards.

Alaska has marine and freshwater criteria for aromatic hydrocarbons (Department of Environmental Conservation 18 AAC 70 Water Quality Standards, www.dec.state.ak.us/water/wqsar/wqs/wqs.htm). Total aromatic hydrocarbons (TAH) may not exceed 10 ug/L for aquaculture, growth and propagation of fish/shellfish, other aquatic life, and wildlife. In Alaska's standards, TAH includes both mono (e.g., benzene) and polyaromatic compounds (PAH); only the latter were analyzed in the present study. Two samples – one at Seaview and one at Swantown – had total PAH concentrations of 10 and 28 ug/L, which are at or above the Alaska criterion (see Table 7).

Aquatic life criteria of comparable standing to those discussed above were not located for other organic compounds detected in boatyard stormwater.

Comparison with Sediment Standards and Criteria

Marine Standards

Table 15 compares results on the Swantown and Port Townsend sediment samples to the marine sediment quality standards (SQS) and cleanup screening level (CSL) chemical criteria established in the Washington Sediment Management Standards (WAC 173-204-420).

Chemicals meeting SQS criteria are not expected to cause adverse effects on biological resources. Chemicals exceeding CSLs may require further investigation and remediation. For comparison to the standards, concentrations of nonionizable organic compounds (e.g., PAH, phthalates, and PCBs) are normalized to the organic carbon content of the sample in question (dry weight concentration divided by the decimal fraction representing percent TOC). These chemicals bind to organic carbon, which reduces their toxicity. As directed in the WAC, only detected concentrations were used to calculate total LPAH and total HPAH, and methylnaphthalenes were not included. For individual undetected compounds, the detection limit is used in normalizing.

Thirty-seven of the 47 marine sediment standard chemicals were detected at Swantown and/or Port Townsend. None of them exceeded standards.

Table 15. Swantown and Port Townsend Sediment Samples Compared to Marine Sediment Quality Standards (WAC 173-204)

Chemical Parameter	Sediment Quality Standard	Swantown Sediment Concentration	Port Townsend Sediment Concentration	SQS Exceedance?
Metals (mg/Kg, dry weight; ppm)				
Arsenic	57	6.3	33	No
Cadmium	5.1	1.3	1.5	No
Chromium	260	27	45	No
Copper	390	35	240	No
Lead	450	18	48	No
Mercury	0.41	0.17	0.19 J	No
Silver	6.1	0.42	0.16	No
Zinc	410	75	353	No
Nonionizable Organic Compounds (mg/Kg TOC; ppm)				
Polyaromatic Hydrocarbons				
Naphthalene	99	15	4.0	No
Acenaphthylene	66	2.6	6.2	No
Acenaphthene	16	2.4	2.3	No
Fluorene	23	2.6	3.7	No
Phenanthrene	100	12	17	No
Anthracene	220	5.5	15	No
2-Methylnaphthalene	38	3.4	2.3	No
Total LPAH[a]	370	40	48	No
Fluoranthene	160	19	50	No
Pyrene	1,000	23	50	No
Benzo[a]anthracene	110	9.4	17	No
Chrysene	110	13	36	No
Total Benzofluoranthenes	230	18	67	No
Benzo[a]pyrene	99	7.3	19	No
Indeno[1,2,3-c,d]pyrene	34	3.6	12	No
Dibenzo[a,h]anthracene	12	1.8	6.0	No
Benzo[g,h,i]perylene	31	3.8	11	No
Total HPAH[b]	960	98	268	No
Chlorinated Benzenes				
1,2-Dichlorobenzene	2.3	0.33 U	0.50 U	No
1,4-Dichlorobenzene	3.1	0.30 J	0.89	No
1,2,4-Trichlorobenzene	0.81	0.33 U	0.50 U	No
Hexachlorobenzene	0.38	0.33 U	0.50 U	No
Phthalate Esters				
Dimethyl phthalate	53	0.33 U	12	No

Chemical Parameter	Sediment Quality Standard	Swantown Sediment Concentration		Port Townsend Sediment Concentration		SQS Exceedance?
Diethyl phthalate	61	0.57	J	0.15	J	No
Di-N-butyl phthalate	220	0.67	U	2.7		No
Butylbenzyl phthalate	4.9	1.2		13	*	No
Bis(2-ethylhexyl)phthalate	47	12	UJ	24		No
Di-N-octyl phthalate	58	0.67	U	1.0	U	No
PCBs						
Total PCBs	12	0.80	J	1.4	J	No
Miscellaneous						
Dibenzofuran	15	2.3		2.7		No
Hexachlorobutadiene	3.9	0.33	U	0.50	U	No
N-Nitrosodiphenylamine	11	0.67	U	1.0	U	No
Ionizable Organic Compounds (ug/Kg, dry weight; ppb)						
Phenol	420	81	UJ	139	UJ	No
2-Methylphenol	63	10	U	11	U	No
4-Methylphenol	670	530		11	U	No
2,4-Dimethylphenol	29	10	U	11	U	No
Pentachlorophenol	360	20	U	73		No
Benzyl alcohol	57	20	U	22	U	No
Benzoic acid	650	483	J	224	UJ	No

[a] naphthalene+acenaphthylene+acenaphthene+fluorene+phenanthrene+anthracene
[b] fluoranthene+pyrene+benzo[a]anthracene+chrysene+total benzofluoranthenes+benzo[a]pyrene indeno[1,2,3-c,d]pyrene+dibenzo[a,h]anthracene+benzo[g,h,i]perylene
U = Not detected at or above reported value
J = Estimated concentration
UJ = Not detected at or above the reported estimated result
*Not detected in duplicate sample

Currently, there are no sediment standards for tributyltin. The Puget Sound Dredge Disposal Analysis program (PSDDA) formerly had a screening level of 73 ug/Kg. The tributyltin concentration of 200 ug/Kg measured in the Port Townsend sediment sample exceeds that screening level (see Table 10). However, interagency sediment programs are no longer using bulk sediment chemistry for tributyltin because of an inconsistent relationship to toxicity (Michelsen, 1996). The PSDDA value has now been replaced by an interstitial[2] water concentration.

[2] The spaces between sediment particles.

Freshwater Criteria

Standards have not been established for freshwater sediments in Washington. WAC 173-204-340, Freshwater Sediment Standards, states that Ecology "will determine on a case-by-case basis the criteria, methods, and procedures necessary to meet the intent of this chapter."

Avocet Consulting (2003) proposed a set of sediment quality standards (SQS) and cleanup screening levels (CSL) as part of Ecology's effort to develop freshwater sediment criteria for Washington. These values were provided to Ecology for discussion purposes only; final values remain to be selected and could differ from Avocet's.

Table 16 compares results on the Seaview sediment sample to the freshwater SQS and CSL values proposed by Avocet, showing which chemicals exceed criteria. Of the 35 chemicals or chemical categories for which criteria were proposed, 21 exceeded the SQS and 15 exceeded the CSL.

Table 16. Seaview Sediment Sample Compared to Freshwater Sediment Criteria Proposed in Avocet Consulting (2003)

Chemical Parameter	Proposed Sediment Quality Standard	Proposed Cleanup Screening Level	Seaview Sediment Concentration	Exceeds Proposed SQS?	Exceeds Proposed CSL?
Metals (mg/Kg, dry weight; ppm)					
Antimony	0.40	0.60	1.1	**Yes**	**Yes**
Arsenic	20	51	20	No	No
Cadmium	0.6	1.0	1.4	**Yes**	**Yes**
Chromium	95	100	71	No	No
Copper	80	830	737	**Yes**	No
Lead	335	430	145	No	No
Mercury	0.50	0.75	0.64	**Yes**	No
Nickel	60	70	48	No	No
Silver	2.0	2.5	0.59	No	No
Zinc	140	160	600	**Yes**	**Yes**
Organotins (ug/Kg, dry weight; ppb)					
Tributyltin	75	75	1,160	**Yes**	**Yes**
Organic Compounds (ug/Kg; dry weight; ppb)					
Polyaromatic Hydrocarbons					
Naphthalene	500	1,310	3,600	**Yes**	**Yes**
Acenaphthylene	470	640	803	**Yes**	**Yes**
Acenaphthene	1,060	1,320	2,510	**Yes**	**Yes**
Fluorene	1,000	3,000	2,300	**Yes**	**Yes**
Phenanthrene	6,100	7,600	9,790	**Yes**	**Yes**
Anthracene	1,200	1,580	1,950	**Yes**	**Yes**

Chemical Parameter	Proposed Sediment Quality Standard	Proposed Cleanup Screening Level	Seaview Sediment Concentration		Exceeds Proposed SQS?	Exceeds Proposed CSL?
2-Methylnaphthalene	470	560	1,690		**Yes**	**Yes**
Total LPAH[a]	6,600	9,200	23,639		**Yes**	**Yes**
Fluoranthene	11,000	15,000	16,800		**Yes**	**Yes**
Pyrene	8,800	16,000	12,600		**Yes**	No
Benzo[a]anthracene	4,260	5,800	2,980		No	No
Chrysene	5,940	6,400	3,080		No	No
Total Benzofluoranthenes	11,000	14,000	5,280		No	No
Benzo[a]pyrene	3,300	4,810	1,950		No	No
Indeno[1,2,3-c,d]pyrene	4,120	5,300	1,130		No	No
Dibenzo[a,h]anthracene	800	840	440		No	No
Benzo[g,h,i]perylene	4,020	5200	1,400		No	No
Total HPAH[b]	31,000	54,800	45,660		**Yes**	No
Phthalate Esters						
Bis(2-ethylhexyl)phthalate	230	320	8,000		**Yes**	**Yes**
Butylbenzyl phthalate	260	370	51	U	No	No
Dimethyl phthalate	46	440	804		**Yes**	**Yes**
Di-N-octyl phthalate	26	45	22	U	No	No
PCBs						
Total PCBs	60	120	107	J	**Yes**	No
Miscellaneous						
Dibenzofuran	400	440	1,780		**Yes**	**Yes**

[a] naphthalene+acenaphthylene+acenaphthene+fluorene+phenanthrene+anthracene
[b] fluoranthene+pyrene+benzo[a]anthracene+chrysene+total benzofluoranthenes+benzo[a]pyrene indeno[1,2,3-c,d]pyrene+dibenzo[a,h]anthracene+benzo[g,h,i]perylene
U = Not detected at or above reported value
J = Estimated concentration
*Not detected in duplicate sample

The extent of these exceedances can be more easily gaged in Figures 6 and 7, which plot the ratio of the chemical concentration divided by the SQS or CSL. Again, values > 1 exceed the criteria.

Bis(2-ethylhexyl)phthalate, dimethylphthalate, tributyltin, copper, and naphthalene exceeded SQS by factors of 5 or more. Chemicals that exceeded by a factor of at least 2 included dibenzofuran, zinc, antimony, cadmium, several LPAH, and total PCBs.

Many of these chemicals also exceeded the proposed CSL; exceptions were copper, PCBs, HPAH, and mercury. Bis(2-ethylhexyl)phthalate and tributyltin exceeded the CSL by factors of 15–25.

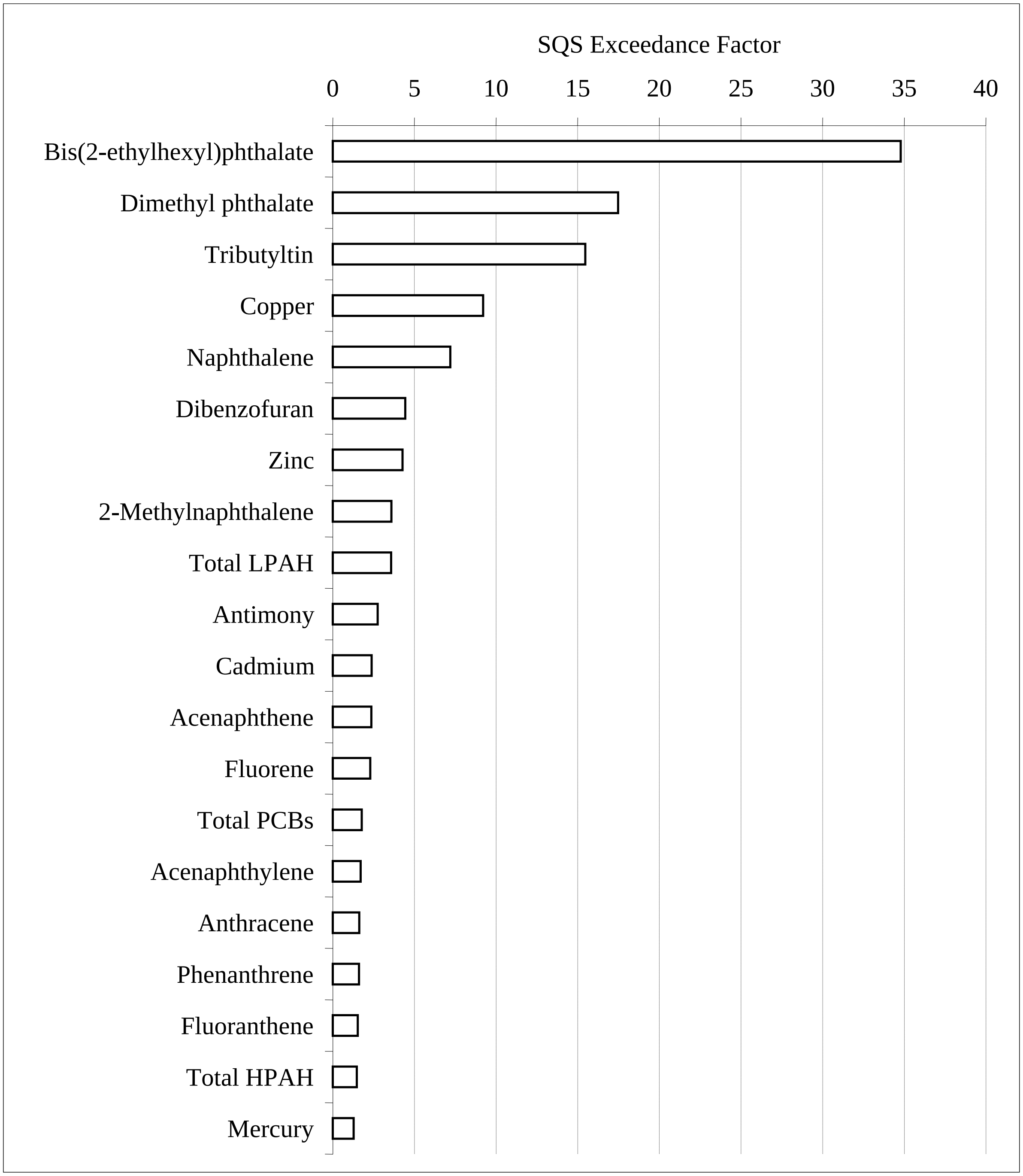

Figure 6. Chemical Concentrations in the Seaview Sediment Sample Compared to Freshwater Sediment Quality Standards Proposed in Avocet (2003).
[Exceedance factor = concentration / SQS; values > 1 exceed criterion]

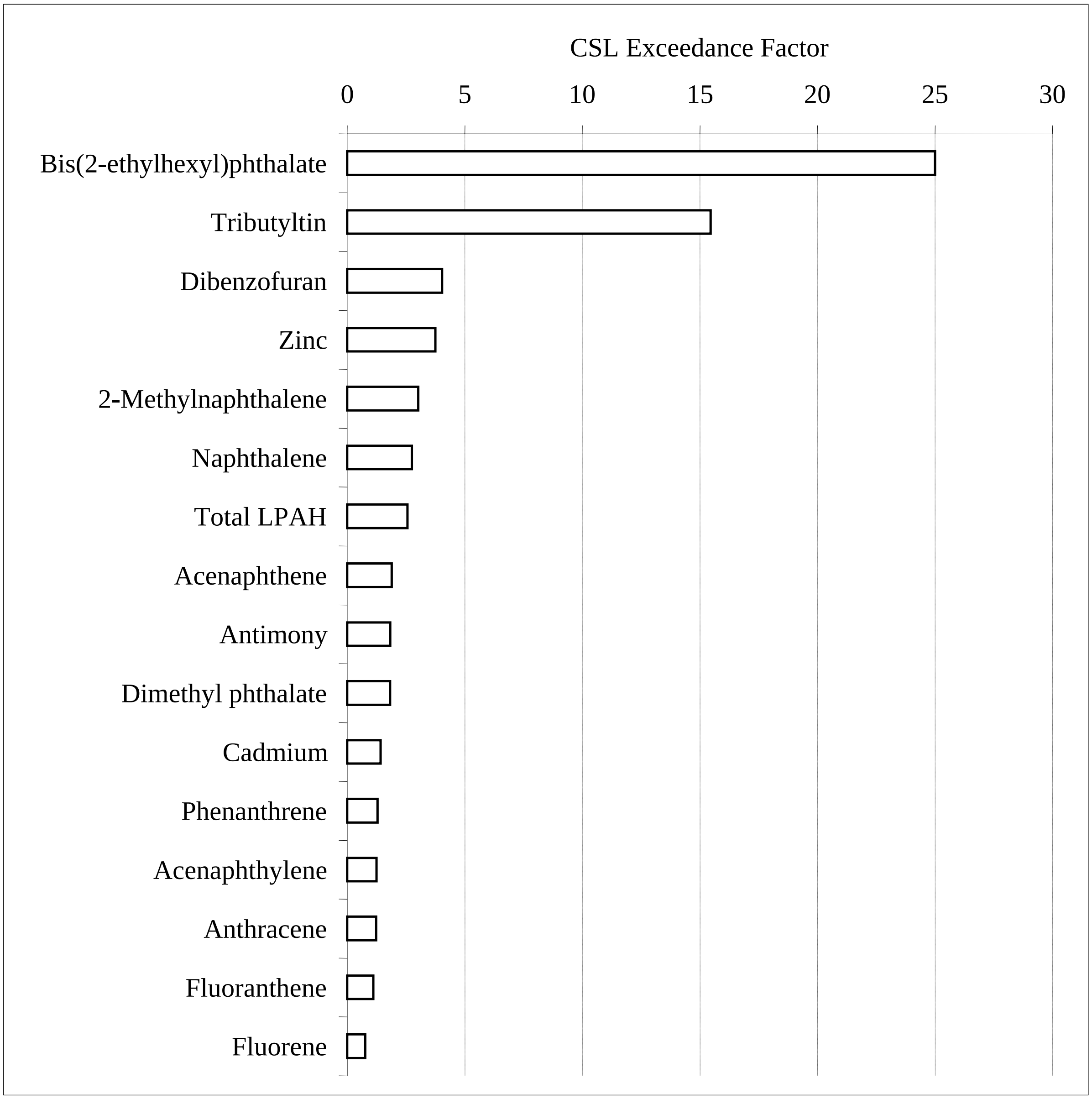

Figure 7. Chemical Concentrations in the Seaview Sediment Sample Compared to Freshwater Cleanup Screening Levels Proposed in Avocet (2003).
[Exceedance factor = concentration / CSL; values > 1 exceed criterion]

Conclusions

Results of this 2006 stormwater study show that boatyard–related chemicals with the greatest potential for adverse effects in the receiving waters are copper, zinc, lead, tributyltin, polyaromatic hydrocarbons (PAHs), and phthalate plasticizers. These contaminants were detected in both stormwater runoff and stormwater outfall sediments at all three of the yards in the study: Swantown Boatworks in Olympia, Port Townsend Boatyard/Shipyard in Port Townsend, and Seaview East Boatyard in Seattle.

Based on estimates of the dissolved fraction, copper, zinc, and lead concentrations in the stormwater were likely to exceed Washington State acute water quality criteria for protection of aquatic life, substantially so for copper and zinc. Lead potentially exceeded the freshwater acute criteria, but not the less restrictive marine acute criteria.

Detected concentrations of the antifouling agent tributyltin exceeded EPA acute water quality criteria in stormwater runoff from one boatyard, Seaview East.

The sediment sample collected off the stormwater outfall at Seaview had levels of copper, zinc, tributyltin, PAHs, and phthalates that could be toxic to sediment-dwelling organisms. The outfall sediments at a second yard, Port Townsend, exceeded a Puget Sound Dredge Disposal Analysis program screening level for tributyltin. Otherwise, the Port Townsend sediment sample was in compliance with Washington State marine sediment quality standards.

Swantown generally had the lowest levels of chemical contaminants in their stormwater and in the sediments off their stormwater outfall, followed by Port Townsend. Seaview was the most contaminated of the three yards. Swantown has a stormwater treatment pond between the location where the runoff samples were collected and the receiving waters.

This study represents a small sample of the 90 yards under the Boatyard General Permit.

Recommendations

Following are recommendations made as a result of this study.

1. Data should be obtained on the dissolved fraction of copper, zinc, and lead in boatyard stormwater runoff, either through the Boatyard General Permit or a dedicated study. The permit currently relies on dissolved metals data from shipyards.

2. Continued sampling for tributyltin could be used as an indicator of residual contamination of boatyard soils and ground surfaces.

3. Monitoring requirements for polyaromatic hydrocarbons (PAHs) or phthalates are not recommended at this time because of the high cost of these analyses. The extent to which PAHs and phthalates are significant contaminants in stormwater runoff from Puget Sound boatyards in general could be more effectively determined through sediment sampling.

4. There appeared to be a qualitative correlation between contaminants detected in boatyard stormwater runoff and in bottom sediments near the stormwater outfalls. Due to the logistical difficulties, data variability, and high cost inherent in monitoring chemical contaminants in stormwater, consideration should be given to conducting a screening-level survey of sediment quality at stormwater outfalls from other Puget Sound boatyards. The results would show how well findings of the present 2006 study apply to other yards, help determine the effectiveness of pollution control measures currently in place, and could lead to identification and cleanup of contaminated sites.

5. In view of the substantial exceedances of water and sediment quality criteria at Seaview East Boatyard in Seattle, a survey should be conducted to assess the extent and significance of sediment contamination in the vicinity of this boatyard.

6. Ecology should review the stormwater best management practices (BMPs) with Seaview East personnel to ensure the BMPs are being implemented.

References

Avocet, 2003. Development of Freshwater Sediment Quality Values for Use in Washington State. Phase II Report: Development and Recommendations of SQVs for Freshwater Sediments in Washington State. Prepared for Washington State Department of Ecology, Toxics Cleanup Program, Olympia, WA. Avocet Consulting, Kenmore, WA.

Ecology, 2002. How to Do Stormwater Sampling: A Guide for Industrial Facilities. Washington State Department of Ecology, Olympia, WA. Publication No. 02-10-071. www.ecy.wa.gov/biblio/0210071.html.

Ecology, 2003. Sediment Sampling and Analysis Plan Appendix: Guidance on the Development of Sediment Sampling and Analysis Plans Meeting the Requirements of the Sediment Management Standards (Chapter 173-204 WAC). Washington State Department of Ecology, Olympia, WA. Publication No. 03-09-043. www.ecy.wa.gov/biblio/0309043.html.

EPA, 2003. Ambient Aquatic Life Water Quality Criteria for Tributyltin (TBT) – Final. U.S. Environmental Protection Agency. EPA-822-R-03-031.

Hart Crowser, 1997. Final Report: Shipyard AKART Analysis for Treatment of Stormwater. Prep. for Maritime Environmental Coalition, Seattle, WA. Report J-4699.

Ikonomou, M.G., M. Fernandez, T. He., and D. Cullon, 2002. A Gas Chromatography – High Resolution Mass Spectrometry (GC-HRMS) Based Method for the Simultaneous Determination of Nine Organotin Compounds in Water, Sediment, and Tissue. J. Chrom. A. 975(2):319-333.

Johnson, A. 2005. Quality Assurance Project Plan: Toxics in Stormwater Runoff from Puget Sound Boatyards. Washington State Department of Ecology, Olympia, WA. Publication No. 05-03-118. www.ecy.wa.gov/biblio/0503118.html

Krone, C.A., D.W. Brown, D.G. Burrows, S-L Chan, and U. Varanasi, 1989. Butyltins in Sediments from Marinas and Waterways in Puget Sound, Washington State, USA. Mar. Pollut. Bull. 20(10):528-531.

Michelsen, T., 1996. PSDDA Issue Paper: Testing, Reporting, and Evaluation of Tributyltin data in PSDDA and SMS Programs. Washington State Department of Ecology and U.S. Army Corps of Engineers.

Plum, R.H., 1981. Procedures for Handling and Chemical Analysis of Sediment and Water Samples. EPA/COE Technical Committee on Criteria for Dredged and Fill Material. U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MS.

PSEP (Puget Sound Estuary Program), 1996. Recommended Protocols and Guidelines for Measuring Selected Environmental Variables in Puget Sound. Prepared by Tetra Tech. Inc. for EPA Region 10, Seattle, WA (w/1996 updates by METRO, Seattle, WA).

Appendices

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Appendix A. Chemicals Analyzed for the 2006 Boatyard Stormwater Characterization Study

Total Petroleum Hydrocarbons
NWTPH-Dx (kerosene, diesel, lube oils, heavy fuel oils, other semivolatile petroleum products)
NWTPH-Gx (gasoline range petroleum hydrocarbons)

Metals
Antimony
Arsenic
Beryllium
Cadmium
Chromium
Copper
Lead
Mercury
Nickel
Selenium
Silver
Thallium
Zinc

Organotins
Monobutyltin
Dibutyltin
Tributyltin
Tetrabutyltin

Semivolatiles
Acenaphthene
Acenaphthylene
Aniline
Anthracene
Benzidine
Benzo (a) anthracene
Benzo (a) pyrene
Benzo (b) fluoranthene
Benzo (k) fluoranthene
Benzo (g,h,i) perylene
Benzo (a,l) pyrene
Benzoic Acid
Benzyl Alcohol
Butylbenzylphthalate
4-Bromophenyl-Phenylether
Di-N-Butylphthalate
Caffeine
Carbazole
Cholesterol
4-Chloro-3-Methylphenol
4-Chloroaniline
Bis(2-Chloroethoxy) Methane
Bis(2-Chloroethyl) Ether
Bis(2-Chloroisopropyl) Ether
2-Chloronaphthalene
2-Chlorophenol
4-Chlorophenyl-Phenylether
Chrysene
3B-Coprostanol
Dibenzo (a,h) anthracene
Dibenzofuran
Dibenzo (a,j) acridine
Dibenzo (a,e) pyrene
Dibenzo (a,i) pyrene
Dibenzo (a,h) pyrene
3,3'-Dichlorobenzidine
1,2-Dichlorobenzene
1,3-Dichlorobenzene
1,4-Dichlorobenzene
2,4-Dichlorophenol
2,4-Dimethylphenol
2,4-Dinitrophenol
2,4-Dinitrotoluene
2,6-Dinitrotoluene
1,2-Diphenylhydrazine
Fluoranthene
Fluorene
2-Fluorophenol
Hexachlorobenzene
Hexachlorobutadiene
Hexachlorocyclopentadiene
Hexachloroethane
Indeno (1,2,3-cd) pyrene
Isophorone
p-Isopropyltoluene
4,6-Dinitro-2-Methylphenol
1-Methylnaphthalene
2-Methylnaphthalene
2-Methylphenol
4-Methylphenol
Naphthalene
2-Nitroaniline
3-Nitroaniline
4-Nitroaniline
Nitrobenzene
2-Nitrophenol
4-Nitrophenol
N-Nitroso-Di-N-Propylamine
N-Nitrosodiphenylamine
4-Nonyl Phenol
2,2'-Oxybis[1-chloropropane]
Pentachlorophenol
Bis (2-Ethylhexyl) Phthalate
Diethylphthalate
Dimethylphthalate
Di-N-Octyl Phthalate
Phenanthrene
Phenol
Pyridine
Pyrene
Retene
B-Sitosterol
1,2,4-Trichlorobenzene
2,4,5-Trichlorophenol
2,4,6-Trichlorophenol

PCBs
PCB-l0l6
PCB-l22l
PCB-l232
PCB-l242
PCB-l248
PCB-l254
PCB-l260

Appendix B. Coordinates of Sampling Sites for Ecology's 2006 Boatyard Runoff Samples

Table B-1. Coordinates of Sampling Sites for Ecology's 2006 Boatyard Runoff Samples (NAD 83)

Boatyard	Latitude	Longitude
Stormwater Runoff Samples		
Swantown	47.050	122.896
Port Townsend	48.107	122.777
Seaview	47.662	122.381
Stormwater Outfall Sediment Samples		
Swantown	47.051	122.895
Port Townsend	48.106	122.778
Seaview	47.662	122.381

Appendix C. Results on Field Blanks for the Boatyard Stormwater Study

Table C-1. Results on Field Blanks for the Boatyard Stormwater Study (ug/L)
[data are for transfer blanks at Swantown, except 4/8 bottle blank for mercury was at Seaview]

Sample No.	Date	Analyte	Result	
6144013	4/8/2006	Mercury	0.002	U
6224001	5/31/2006	Silver	0.1	U
6224001	5/31/2006	Arsenic	0.1	UJ
6224001	5/31/2006	Beryllium	0.1	U
6224001	5/31/2006	Cadmium	0.1	U
6224001	5/31/2006	Chromium	0.25	U
6224001	5/31/2006	Copper	0.1	U
6224001	5/31/2006	Mercury	0.05	U
6224001	5/31/2006	Nickel	0.25	U
6224001	5/31/2006	Lead	0.1	U
6224001	5/31/2006	Antimony	0.2	U
6224001	5/31/2006	Selenium	0.5	U
6224001	5/31/2006	Thallium	0.1	U
6224001	5/31/2006	Zinc	5	U
6224001	5/31/2006	Tributyltin	0.001	UJ
6224001	5/31/2006	Dibutyltin	0.002	UJ
6224001	5/31/2006	Monobutyltin	0.002	UJ
6154013	4/13/2006	4-Nitroaniline	0.77	UJ
6154013	4/13/2006	4-Nitrophenol	0.77	U
6154013	4/13/2006	Benzyl Alcohol	0.15	U
6154013	4/13/2006	4-Bromophenyl-Phenylether	0.08	U
6154013	4/13/2006	2,4-Dimethylphenol	0.08	U
6154013	4/13/2006	4-Methylphenol	0.08	U
6154013	4/13/2006	1,4-Dichlorobenzene	0.08	U
6154013	4/13/2006	4-Chloroaniline	REJ	
6154013	4/13/2006	2,2'-Oxybis[1-chloropropane]	0.08	U
6154013	4/13/2006	Phenol	0.07	J
6154013	4/13/2006	Bis(2-Chloroethyl) Ether	0.15	U
6154013	4/13/2006	Bis(2-Chloroethoxy) Methane	0.08	U
6154013	4/13/2006	Bis(2-Ethylhexyl) Phthalate	0.15	U
6154013	4/13/2006	Di-N-Octyl Phthalate	0.15	U
6154013	4/13/2006	Hexachlorobenzene	0.08	U
6154013	4/13/2006	Anthracene	0.08	U
6154013	4/13/2006	1,2,4-Trichlorobenzene	0.08	U
6154013	4/13/2006	2,4-Dichlorophenol	0.15	U

Sample No.	Date	Analyte	Result	
6154013	4/13/2006	2,4-Dinitrotoluene	0.77	U
6154013	4/13/2006	1,2-Diphenylhydrazine	0.08	U
6154013	4/13/2006	Pyrene	0.08	U
6154013	4/13/2006	Dimethylphthalate	0.08	U
6154013	4/13/2006	Dibenzofuran	0.08	U
6154013	4/13/2006	Benzo(ghi)perylene	0.08	U
6154013	4/13/2006	Indeno(1,2,3-cd)pyrene	0.08	U
6154013	4/13/2006	Benzo(b)fluoranthene	0.08	U
6154013	4/13/2006	Fluoranthene	0.08	U
6154013	4/13/2006	Benzo(k)fluoranthene	0.08	U
6154013	4/13/2006	Acenaphthylene	0.08	U
6154013	4/13/2006	Chrysene	0.08	U
6154013	4/13/2006	3B-Coprostanol	0.77	U
6154013	4/13/2006	Retene	0.08	U
6154013	4/13/2006	Benzo(a)pyrene	0.08	U
6154013	4/13/2006	2,4-Dinitrophenol	REJ	
6154013	4/13/2006	4,6-Dinitro-2-Methylphenol	0.77	U
6154013	4/13/2006	Dibenzo(a,h)anthracene	0.08	U
6154013	4/13/2006	1,3-Dichlorobenzene	0.08	U
6154013	4/13/2006	Benzo(a)anthracene	0.08	U
6154013	4/13/2006	Caffeine	0.08	U
6154013	4/13/2006	4-Chloro-3-Methylphenol	0.15	U
6154013	4/13/2006	2,6-Dinitrotoluene	0.08	U
6154013	4/13/2006	N-Nitroso-Di-N-Propylamine	0.08	U
6154013	4/13/2006	Aniline	REJ	
6154013	4/13/2006	N-Nitrosodimethylamine	0.15	U
6154013	4/13/2006	Benzoic Acid	0.32	J
6154013	4/13/2006	Hexachloroethane	0.08	U
6154013	4/13/2006	4-Chlorophenyl-Phenylether	0.08	U
6154013	4/13/2006	Hexachlorocyclopentadiene	0.15	U
6154013	4/13/2006	Isophorone	0.08	U
6154013	4/13/2006	Acenaphthene	0.08	U
6154013	4/13/2006	Diethylphthalate	0.31	U
6154013	4/13/2006	Di-N-Butylphthalate	0.03	J
6154013	4/13/2006	Phenanthrene	0.08	U
6154013	4/13/2006	Butylbenzylphthalate	0.15	U
6154013	4/13/2006	N-Nitrosodiphenylamine	0.15	U
6154013	4/13/2006	Fluorene	0.08	U
6154013	4/13/2006	Carbazole	0.08	UJ
6154013	4/13/2006	Hexachlorobutadiene	0.08	U
6154013	4/13/2006	Pentachlorophenol	0.15	U

Sample No.	Date	Analyte	Result	
6154013	4/13/2006	2,4,6-Trichlorophenol	0.15	U
6154013	4/13/2006	2-Nitroaniline	0.15	UJ
6154013	4/13/2006	2-Nitrophenol	0.31	U
6154013	4/13/2006	1-Methylnaphthalene	0.08	U
6154013	4/13/2006	Naphthalene	0.08	U
6154013	4/13/2006	2-Methylnaphthalene	0.08	U
6154013	4/13/2006	2-Chloronaphthalene	0.08	U
6154013	4/13/2006	3,3'-Dichlorobenzidine	0.15	UJ
6154013	4/13/2006	2-Methylphenol	0.08	U
6154013	4/13/2006	1,2-Dichlorobenzene	0.08	U
6154013	4/13/2006	2-Chlorophenol	0.08	U
6154013	4/13/2006	2,4,5-Trichlorophenol	0.15	U
6154013	4/13/2006	Nitrobenzene	0.08	U
6154013	4/13/2006	3-Nitroaniline	7.7	UJ

U = Not detected at or above the reported value.
UJ = Not detected at or above the reported estimated value.
J = Estimated concentration
REJ = Data rejected

Appendix D. Precision Data for Duplicate Runoff Samples Prepared at Swantown Boatworks

Table D-1. Precision Data for Conventional Parameters and Petroleum Hydrocarbons (duplicate field samples) Prepared at Swantown Boatworks

Sample Number:	6144010		6144011 (duplicate)		Relative Percent Difference
Date:	4/8/2006		4/8/2006		
Time:	0940		0940		
Conductivity (umhos/cm)	65.4		65.3		0.2%
Total Suspended Solids (mg/L)	12		12		0%
Turbidity (NTU)	13		70		140%
Lube Oil (mg/L)	0.50	U	0.62		>21%
Gasoline (mg/L)	0.14	U	0.14	U	ND

U = Not detected at or above the reported value.
ND = Not detected

Table D-2. Precision Data for Metals and Organotins Prepared at Swantown Boatworks (ug/L; duplicate field samples)

Sample Number:	6144010		6144011 (duplicate)		Relative Percent Difference
Date:	4/8/2006		4/8/2006		
Time:	0940		0940		
Silver	0.1	U	0.1	U	ND
Arsenic	0.74		0.75		1%
Beryllium	0.1	U	0.1	U	ND
Cadmium	0.52		0.51		2%
Chromium	1.2		1.2		0%
Copper	953		1050		10%
Mercury	0.05	U	0.05	U	ND
Nickel	2.07		2.01		3%
Lead	19.8		23.8		18%
Antimony	1.6		1.5		6%
Selenium	0.5	U	0.5	U	ND
Thallium	0.1	U	0.1	U	ND
Zinc	340		350		3%
Tributyltin	0.22		0.27		17%
Dibutyltin	0.006	J	0.10	J	180%
Monobutyltin	0.002	UJ	0.002	UJ	0%

U = Not detected at or above the reported value.
UJ = Not detected at or above the reported estimated value.
J = Estimated concentration
ND = Not detected

Table D-3. Precision Data for Semivolatile Compounds (duplicate field samples) Prepared at Swantown Boatworks (ug/L)

Sample Number:	6144010		6144011 (duplicate)		Relative Percent Difference
Date:	8-Apr-06		8-Apr-06		
Time:	0940		0940		
4-Nitroaniline	0.64	UJ	0.62	UJ	ND
4-Nitrophenol	0.64	U	0.62	U	ND
Benzyl Alcohol	0.64		0.65		2%
4-Bromophenyl-Phenylether	0.06	U	0.06	U	ND
2,4-Dimethylphenol	0.06	U	0.25		<120%
4-Methylphenol	0.77		0.92		18%
1,4-Dichlorobenzene	0.06	U	0.06	U	ND
4-Chloroaniline	REJ		REJ		REJ
2,2'-Oxybis[1-chloropropane]	0.06	U	0.06	U	ND
Phenol	0.73		0.94		25%
Bis(2-Chloroethyl)Ether	0.13	U	0.12	U	ND
Bis(2-Chloroethoxy)Methane	0.06	U	0.06	U	ND
Bis(2-Ethylhexyl) Phthalate	2.4		3.2		29%
Di-N-Octyl Phthalate	0.13	U	0.12	U	ND
Hexachlorobenzene	0.06	U	0.06	U	ND
Anthracene	0.06	U	0.06	U	ND
1,2,4-Trichlorobenzene	0.06	U	0.06	U	ND
2,4-Dichlorophenol	0.13	U	0.12	U	ND
2,4-Dinitrotoluene	0.64	U	0.62	U	ND
1,2-Diphenylhydrazine	0.06	U	0.06	U	ND
Pyrene	0.07		0.13		60%
Dimethylphthalate	0.91		1.1		19%
Dibenzofuran	0.06	U	0.06	U	ND
Benzo(ghi)perylene	0.06	U	0.06	U	ND
Indeno(1,2,3-cd)pyrene	0.06	U	0.06	U	ND
Benzo(b)fluoranthene	0.06	U	0.06	U	ND
Fluoranthene	0.08		0.16		67%
Benzo(k)fluoranthene	0.06	U	0.06	U	ND
Acenaphthylene	0.06	U	0.06	U	ND
Chrysene	0.05	J	0.09		57%
3B-Coprostanol	0.64	U	0.62	U	ND
Retene	0.07		0.09		25%
Benzo(a)pyrene	0.06	U	0.06	U	ND
2,4-Dinitrophenol	REJ		REJ		REJ
4,6-Dinitro-2-Methylphenol	0.55	J	0.62	U	>12%
Dibenzo(a,h)anthracene	0.06	U	0.06	U	ND
1,3-Dichlorobenzene	0.06	U	0.06	U	ND

Sample Number:	6144010		6144011 (duplicate)		Relative Percent Difference
Date:	8-Apr-06		8-Apr-06		
Time:	0940		0940		
Benzo(a)anthracene	0.06	U	0.06	U	ND
Caffeine	2.5		2.9		15%
4-Chloro-3-Methylphenol	0.13	U	0.12	U	ND
2,6-Dinitrotoluene	0.06	U	0.06	U	ND
N-Nitroso-Di-N-Propylamine	0.06	U	0.06	U	ND
Aniline	REJ		REJ		REJ
N-Nitrosodimethylamine	0.13	U	0.12	U	ND
Benzoic Acid	5.1		6.5		24%
Hexachloroethane	0.06	U	0.06	U	ND
4-Chlorophenyl-Phenylether	0.06	U	0.06	U	ND
Hexachlorocyclopentadiene	1.3	U	1.2	U	ND
Isophorone	0.06	U	0.06	U	ND
Acenaphthene	0.06	U	0.06	U	ND
Diethylphthalate	0.25	J	0.31		21%
Di-N-Butylphthalate	2.3		2.8		20%
Phenanthrene	0.09		0.16		56%
Butylbenzylphthalate	0.31		0.46		39%
N-Nitrosodiphenylamine	0.13	U	0.12	U	ND
Fluorene	0.06	U	0.06	U	ND
Carbazole	0.06	UJ	0.06	UJ	ND
Hexachlorobutadiene	0.06	U	0.06	U	ND
Pentachlorophenol	REJ		REJ		REJ
2,4,6-Trichlorophenol	0.13	U	0.12	U	ND
2-Nitroaniline	0.13	U	0.12	U	ND
2-Nitrophenol	0.26	U	0.24	J	>8%
1-Methylnaphthalene	0.06	U	0.06	U	ND
Naphthalene	0.06	U	0.06	J	>0%
2-Methylnaphthalene	0.06	U	0.06	U	ND
2-Chloronaphthalene	0.06	U	0.06	U	ND
3,3'-Dichlorobenzidine	0.13	UJ	0.12	UJ	ND
2-Methylphenol	0.17		0.20		16%
1,2-Dichlorobenzene	0.06	U	0.06	U	ND
2-Chlorophenol	0.06	U	0.06	U	ND
2,4,5-Trichlorophenol	0.13	U	0.12	U	ND
Nitrobenzene	0.06	U	0.06	U	ND
3-Nitroaniline	6.4	U	6.2	U	ND

U = Not detected at or above the reported value.
UJ = Not detected at or above the reported estimated value.
J = Estimated concentration REJ = Data rejected ND = Not detected

Appendix E. Precision Data for Duplicate Sediment Samples Prepared at Port Townsend Marina

Table E-1. Precision Data for Duplicate Sediment Samples Prepared at Port Townsend Marina (detected chemicals only)

Sample Number:	6080410	6080411 (duplicate)	Relative Percent Difference
Date:	2/23/2006	2/23/2006	
Metals (mg/Kg, dry weight)			
Copper	234	246	5%
Zinc	318	388	20%
Chromium	46	44	4%
Nickel	48	50	5%
Arsenic	26	41	45%
Selenium	0.98	1.0	2%
Silver	0.16	0.16	0%
Cadmium	1.5	1.4	8%
Antimony	2.0	4.7	81%
Thallium	0.35	0.36	3%
Lead	40	56	33%
Mercury	0.17 J	0.21	23%
Organotins (ug/Kg, dry weight)			
Monobutyltin Trichloride	83 J	94 J	12%
Dibutyltin Dichloride	140	120	15%
Tributyltin Chloride	220	220	0%
Semivolatiles (ug/Kg, dry weight)			
4-Bromophenyl-Phenylether	11 J	11 U	>0%
1,4-Dichlorobenzene	26	13	67%
Bis(2-Ethylhexyl) Phthalate	532	534	0%
Di-N-Octyl Phthalate	138	22 U	>140%
Anthracene	322	335	4%
1,2,4-Trichlorobenzene	8.4 J	11 U	>27%
Pyrene	1150	1050	9%
Dimethylphthalate	238	297	22%
Dibenzofuran	65	54	18%
Benzo(ghi)perylene	276	209	28%
Indeno(1,2,3-cd)pyrene	298	221	30%
Benzo(b)fluoranthene	1010	798	23%
Fluoranthene	1230	978	23%
Benzo(k)fluoranthene	595	544	9%
Acenaphthylene	146	125	15%

Sample Number:	6080410		6080411 (duplicate)		Relative Percent Difference
Date:	2/23/2006		2/23/2006		
Chrysene	811		785		3%
3B-Coprostanol	714	J	720	J	1%
Retene	81		49		49%
Benzo(a)pyrene	450		377		18%
Dibenzo(a,h)anthracene	164		101		48%
1,3-Dichlorobenzene	6.6	J	11	U	>50%
Benzo(a)anthracene	400		335		18%
Aniline	111	J	112	UJ	>1%
Hexachlorocyclopentadiene		REJ	22		- -
Isophorone	160		119		29%
Acenaphthene	55		47		16%
Diethylphthalate	4	J	2.4	J	50%
Di-N-Butylphthalate	477		101	UJ	>130%
Phenanthrene	445		314		35%
Butylbenzylphthalate	86		31		94%
Fluorene	87		74		16%
Carbazole	148	J	11	UJ	<170%
Pentachlorophenol	75		70		7%
2,4,6-Trichlorophenol	29			REJ	- -
1-Methylnaphthalene	38		28		30%
Naphthalene	94		82		14%
2-Methylnaphthalene	54		46		16%
2,4,5-Trichlorophenol	24		22	U	>9%
PCBs (ug/Kg, dry weight)					
PCB - 1260	8	J	11	J	32%
PCB - 1254	20	J	19	J	5%
Physical/chemical Parameters (%)					
Gravel	3.04		0.6		134%
Sand	54.68		55.4		1%
Silt	25.67		27.6		7%
Clay	16.6		16.3		2%
TOC	2.3		2.1		7%
Solids	45		44		2%

U = Not detected at or above reported result
J = Estimated concentration
UJ = Not detected at or above the reported estimated result
REJ = Data rejected