



Contaminants Associated with Settling Particulate Matter and Bottom Sediments at Two Marinas in Thea Foss Waterway

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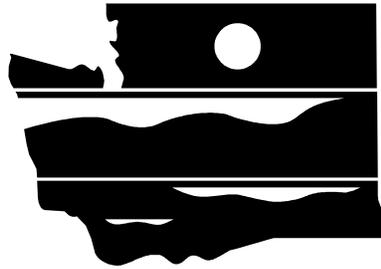
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Contaminants Associated with Settling Particulate Matter and Bottom Sediments at Two Marinas in Thea Foss Waterway

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Olympia, Washington 98504-7710

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Abstract

Settling particulate matter (SPM) and bottom sediments were collected at two marinas in Thea Foss Waterway, Commencement Bay, Tacoma, Washington, between September 1999 and February 2000. The samples were analyzed for metals (copper, lead, mercury, zinc), semivolatile organics, and butyltins. These data were needed to refine contaminant flux estimates for marinas in order to model the potential for sediment recontamination in the waterway. This information was also needed to evaluate the need for further source control activities related to marinas.

In general, concentrations of most contaminants were higher at the head of the waterway near City Marina compared to the mouth near Totem Marina. In bottom sediments, 22 individual chemicals (primarily mercury, LPAHs, HPAHs, bis(2 ethyl hexyl)phthalate, and benzoic acid) were measured at concentrations above the Commencement Bay Sediment Quality Objectives (CMBSQO). A similar chemical suite (19) also exceeded the CMBSQO in SPM. Based on comparison with bulk sediment chemistry levels, tributyltin concentrations in all SPM and bottom sediment samples have the potential to exceed the Puget Sound Dredge Disposal Analysis recommended screening level of 0.15 ugTBT/L for interstitial water.

Based on data collected in this study, there does not appear to be clear evidence that would isolate marinas as unique sources of these contaminants within Thea Foss Waterway. Consequently, the data most likely represent the combined flux of contaminants from all sources within the areas sampled.

Acknowledgements

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Introduction

Contamination of sediments in Thea Foss Waterway with a variety of compounds (metals and organics) has been documented in previous investigations (Tetra Tech, 1985; Norton, 1996). Over the last 10 years, controls have been implemented on a number of land-based sources to reduce contaminant loadings to the waterway. Recently a series of Water Quality Analysis Simulation Program (WASP) modeling runs have been performed to evaluate the potential for recontamination of bottom sediments in the waterway following remediation (Hart Crowser, 1998). This work identified several contaminants – primarily polynuclear aromatic hydrocarbons (PAHs) and bis(2 ethyl hexyl)phthalate (BEHP) – that have the potential to recontaminate sediments in the waterway.

Marinas have been shown to be sources of PAHs, tributyltin, and selected metals during a study conducted in 1989 by Battelle at two marinas, located in Port Townsend and Anacortes, Washington (Crecelius et al, 1989). Due to the lack of site specific information, data from this earlier study were used in modeling contaminant loads from marinas in Thea Foss Waterway. Both of the marinas in the Battelle study are enclosed by breakwaters with only one outlet. In contrast, marinas in Thea Foss Waterway are not enclosed, so water and particulates can flow freely into and out of the marina. Given the age of the data and the differences in physical configuration, it was decided that actual data from Thea Foss Waterway on contaminant levels associated with marinas were needed to refine source-loading terms for the model. The model results, in conjunction with other available information, would be used to determine the potential for sediment recontamination and the need for further source control activities related to marinas.

Project Description

To address these data gaps, the Washington State Department of Ecology (Ecology) collected a series of samples of settling particulate matter (SPM) and bottom sediments from two marinas in Thea Foss Waterway. SPM was collected with the use of moored sediment traps. These traps have been used in other monitoring programs between 1989 and 1997 to determine contaminant levels associated with particulates in several Commencement Bay waterways (Norton, 1996). At each marina sediment traps were deployed at four locations, three inside the marina (two bottom and one surface) and one outside (bottom). Analysis of the material collected by the traps focused on contaminants which have been identified as having the greatest potential to recontaminate bottom sediments in the waterway (PAHs and BEHP), or are known to be associated with marinas (copper, lead, zinc, mercury, and tributyltin). A hydrocarbon identification analysis was also conducted in an attempt to differentiate hydrocarbon sources, such as fuel/oil spills and exhaust emissions. Gross sedimentation rates were also determined. Bottom sediments were collected at each of the sediment trap stations to facilitate comparison with bottom conditions.

The primary objectives of this Thea Foss Marinas Study were as follows:

- Determine contaminant concentrations associated with SPM at two marinas in Thea Foss Waterway. These data are needed to refine source loading terms for remediation modeling.
- Evaluate spatial patterns of contaminants associated with SPM and bottom sediments inside and outside two marinas. This evaluation will help determine if marinas are a uncontrolled source of contaminants to sediments.
- Compare the data collected to the Commencement Bay Sediment Quality Objectives (EPA, 1989) and other applicable sediment quality guidelines.

The data generated from this study will be used to refine source-loading terms for remediation modeling. In addition, the information will be useful in determining the need for further source control activities related to marinas throughout the waterway.

Methods

Site Selection

To evaluate a range of conditions in Thea Foss Waterway, two marinas were selected for sampling. One marina was located near the head (City Marina) and the other was located in the outer portion (Totem Marina) of the waterway. The marinas selected for sampling are shown in Figure 1.

At both marinas, three stations (two bottom and one surface) were located inside the marina (within slips). One additional station (bottom) was located outside the perimeter of each marina. This station configuration was designed to allow comparison of both the vertical and horizontal patterns of contaminant levels associated with particulates to be evaluated. Detailed station information for SPM and bottom sediments is presented in Appendix A, Table A1 (SPM) and Table A2 (sediments).

Sampling Procedures

Settling Particulate Matter

SPM samples were collected with the use of moored sediment traps. The traps used are straight-sided glass cylinders with a collection area of 78.5 cm^2 and a height-to-width ratio of 5. A schematic of the construction details of the traps and their mooring configuration is shown in Figure 2. The bottom traps were positioned one meter above the bottom, while the surface traps were set one meter below the surface (suspended from docks). The surface traps were intended to collect recent SPM primarily associated with the surface freshwater layer. The bottom traps collect a combination of recently deposited particulates and resuspended bottom sediments.

The sediment traps were deployed between September 1999 and February 2000 at the marinas shown in Figure 1. Material collected by the traps was retrieved approximately every two months during the deployment period.

Prior to deployment, the collection cylinders were cleaned with sequential washes of hot water/Liquinox detergent, 10% nitric acid, distilled/deionized water, and pesticide-grade acetone. They were then air-dried and wrapped in aluminum foil until used in the field. At the time of deployment, the traps were filled with two liters of high salinity water (4% NaCl), which contains sodium azide (2% Na_3N) as a preservative to reduce microbial degradation of the samples.

Upon retrieval of the traps, overlying water in the collection cylinders was removed with a peristaltic pump. The remaining contents were then transferred to half-gallon priority pollutant-cleaned glass jars with teflon-lined lids and stored at 4°C for transport to the Manchester Environmental Laboratory.

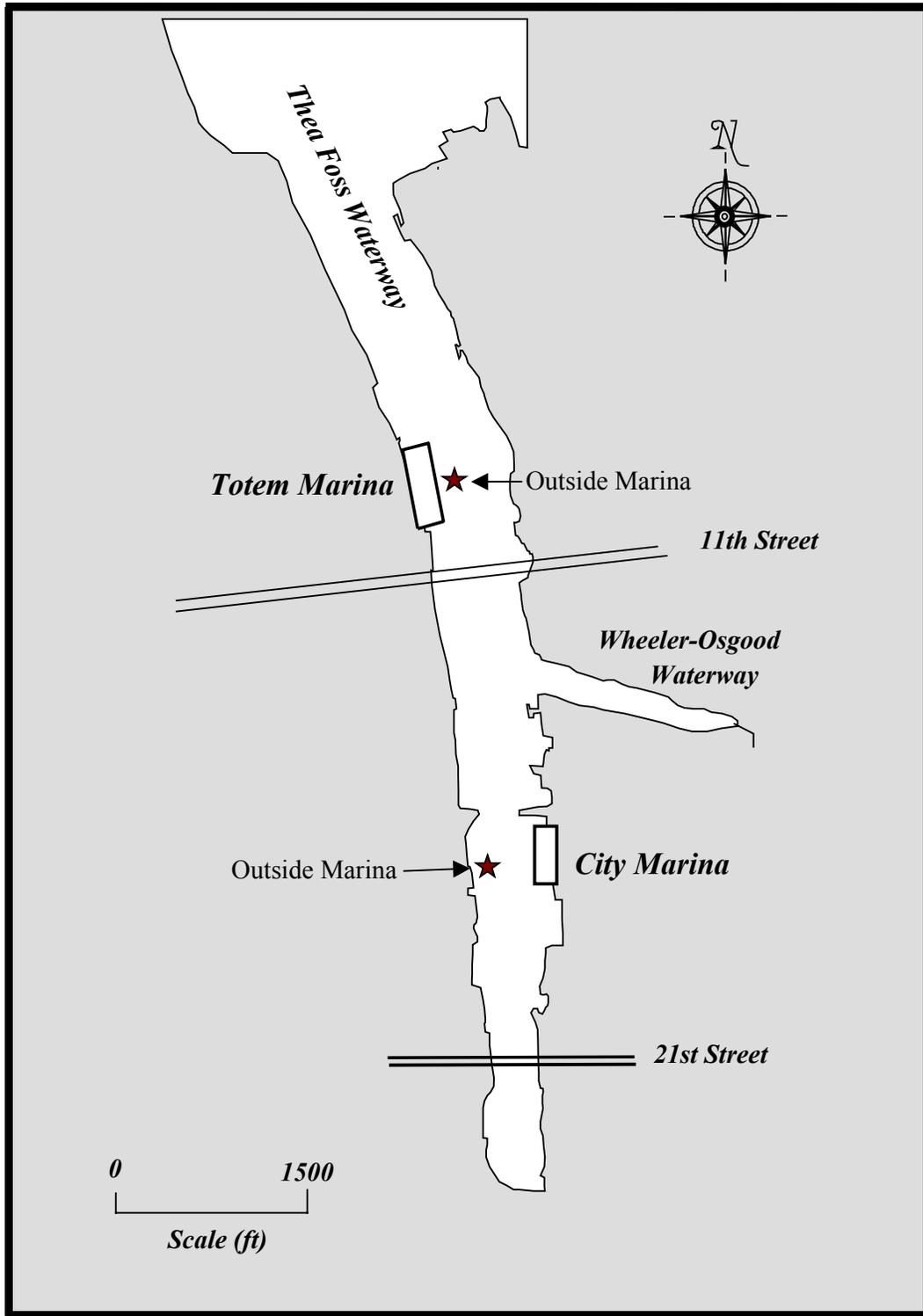


Figure 1. Locations of Marinas Sampled.

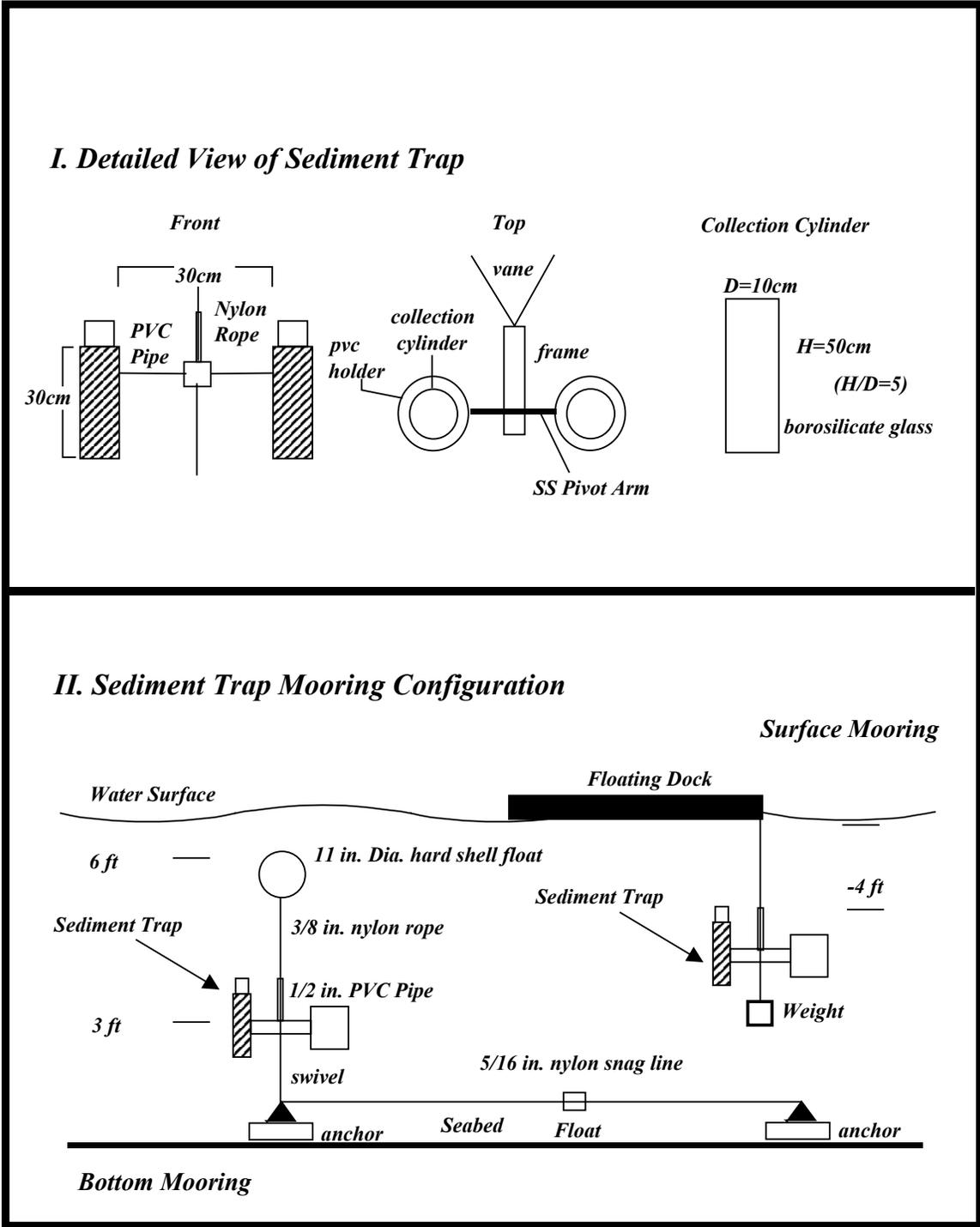


Figure 2. Schematic of Sediment Trap and Mooring Configurations.

At the laboratory, samples from the first collection (December 1999) were frozen within 12 hours of collection pending processing at the end of the sampling period (February 2000). Samples from the final retrieval were processed unfrozen within two days of collection.

Thawed samples were centrifuged for approximately 10 minutes @ 1000 rpm in pre-weighed jars to isolate the particulate fraction. All nekton >2 cm in size was removed from the samples prior to determining sample weights and conducting physical/chemical analyses. To obtain sufficient volume for all the planned analyses, samples from the first and second collections at each location were composited for all analyses, except percent solids. Sedimentation rates (using percent solids) were determined for each two-month collection period. Manipulation of all SPM samples in the laboratory was accomplished with stainless steel spoons, cleaned as previously described for the collection cylinders.

Positions of each sediment trap station were recorded using a differentially corrected Northstar Global Positioning System interfaced with a laptop computer using Nobeltec Visual Navigation Suite (Version 4.1.311) software, in conjunction with depth measurements.

Bottom Sediment

Sampling procedures for bottom sediment followed Puget Sound Protocols where applicable (PSEP, 1996). At each of the sediment trap stations, three individual grabs of surface sediments (top 2 cm) were collected using a 0.1 m² stainless steel van Veen grab and composited. The top 2-cm layer was retained for analysis to allow comparisons with historical data sets. All sediment samples were collected at the end of the sediment trap deployment period. Ecology's 20' skiff was used as a sampling platform for all fieldwork.

After retrieving the grab, the top 2-cm layer not in contact with the sidewalls of the sampler was transferred to a stainless steel beaker and homogenized by stirring with a stainless steel spoon. Aliquots for individual analyses were taken from this homogenate and placed in priority-pollutant cleaned glass jars with teflon-lined lids, wrapped in polyethylene bags, and stored at 4°C for transport to Manchester Laboratory. All sample containers were cleaned to EPA QA/QC specifications (EPA, 1990).

Laboratory Procedures

Analytical methods and laboratories used for analysis of samples are shown in Table 1. All samples were processed at Ecology's headquarters laboratory facilities prior to being shipped to the Manchester Laboratory for analysis. Samples submitted for analysis are listed in Appendix A, Table A3 (SPM) and A4 (sediments).

Quality Assurance

Laboratory quality control samples (primarily for metals and organics) included analysis of surrogate spikes, internal standards, method blanks, duplicate matrix spikes and a laboratory

Table 1. Analytical Methods and Laboratories Used.

Analyte	Method	Reference	Laboratory
Percent Solids	Gravimetric (160.3)	PSEP, 1996	MEL
Total Organic Carbon	Combustion/CO ₂ Measurement @ 70°C	PSEP, 1996	MEL
Grain Size	Sieve and Pipet	PSEP, 1996	
Copper, Lead, Zinc	ICP (6010B)	EPA, 1998	MEL
Mercury	CVAA (245.5)	PSEP, 1996	MEL
Semivolatiles	GC/MS (8270)	PSEP, 1996	MEL
Hydrocarbon ID	WTPH-HCID	Ecology, 2000	MEL
Butyltins	GC/MS-SIM	PSEP, 1996	MEL

MEL – Manchester Environmental Laboratory

control sample (metals only). One blind field duplicate was collected for the bottom sediments. The blind field duplicate was a single sample that was homogenized and split in the field into two separate aliquots for analysis. A field duplicate for the SPM was not prepared, due to an insufficient amount of material.

In general, data quality was good for the project, especially for conventionals and metals. Mean relative percent difference (RPD) between sediment duplicates was 20% for grain size and 5% for metals (copper = 5%, lead = 0%, zinc = 0.6%, mercury = 16%). The results of blind field duplicate analyses are included in Appendix B, Table B1.

Several problems were noted in the semivolatile analysis. This included peak broadening, which affected identification and quantitation of certain closely eluting PAH pairs. As a result benzo(a)anthracene and chrysene, as well as benzo(b)fluoranthene and benzo(k)fluoranthene, did not fully resolve in some samples. Where approximate integration was performed, the results were flagged as estimates. More importantly, a change in the cleanup procedure at the laboratory for the semivolatile analysis was insufficiently documented. This resulted in a small amount of sample loss not being taken into account when the concentration calculations were originally performed. As a result, the data initially reported by the laboratory underestimated actual levels by about 10%. The data reported in this document have been recalculated to reflect this earlier error. Mean RPD calculated from detected PAHs and phthalates were as follows: LPAH= 122%, HPAH= 77%, and phthalates= 59%.

Finally, low matrix spike recoveries were obtained for tributyltin (36% and 37%). This is probably due to the low spiking levels relative to the native sample concentrations. The values reported for tributyltin should be viewed as minimum concentrations. RPD for tributyltin in sediment duplicates was 27%.

Copies of the case narratives for laboratory analysis are included in Appendix B. Unless otherwise specified, all data in this document is reported on a *dry weight* basis.

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Results

Settling Particulate Matter

Analytical results for analysis conducted on SPM from Thea Foss Waterway are listed in Appendix C, Tables C1 to C3.

Gross sedimentation rates data are summarized below in Table 2 and displayed in Figure 3. The calculation used to generate these rates is shown at the bottom of Table C1, in Appendix C.

Table 2. Summary of Gross Sediment Accumulation Rates ($\text{g}/\text{cm}^2/\text{yr}$).

Location	Quarter 1	Quarter 2	Mean
City Marina		Inside	
Surface	2.5	1.8	2.2
Bottom*	1.5	0.8	1.1
		Outside	
Bottom	1.2	0.8	1.0
Totem Marina		Inside	
Surface	2.4	0.8	1.6
Bottom*	1.6	1.1	1.4
		Outside	
Bottom	1.2	0.9	1.1

*= Values shown represent means of both inside stations

Sedimentation rates measured ranged from 0.8 to 2.5 $\text{g}/\text{cm}^2/\text{yr}$. In general, sedimentation rates were consistently higher in all traps during Quarter 1 (September 28 – December 1, 1999) compared to Quarter 2 (December 1, 1999 – February 4, 2000). The highest rates (up to 2.5 $\text{g}/\text{cm}^2/\text{yr}$) were typically measured in the surface traps. Surface rates were approximately 1 $\text{g}/\text{cm}^2/\text{yr}$ higher than those measured in bottom traps during the same period. An exception to this pattern was noted at Totem Marina where surface and bottom rates were similar in Quarter 2.

Comparison of bottom rates inside and outside the marinas indicates that slightly higher rates were measured inside the marinas during Quarter 1. During Quarter 2 rates were essentially the same inside and outside the marinas. Factors such as water depth, the amount of vessel activity, and the quantity of freshwater entering the waterway were probably influencing the sedimentation patterns observed.

Total organic carbon (TOC) levels ranged from 3.3 to 7.6%, with a mean of 5.3%. The highest levels at each marina were measured in surface particulates. Very little difference was noted between TOC levels in bottom particulates collected inside and outside the marinas.

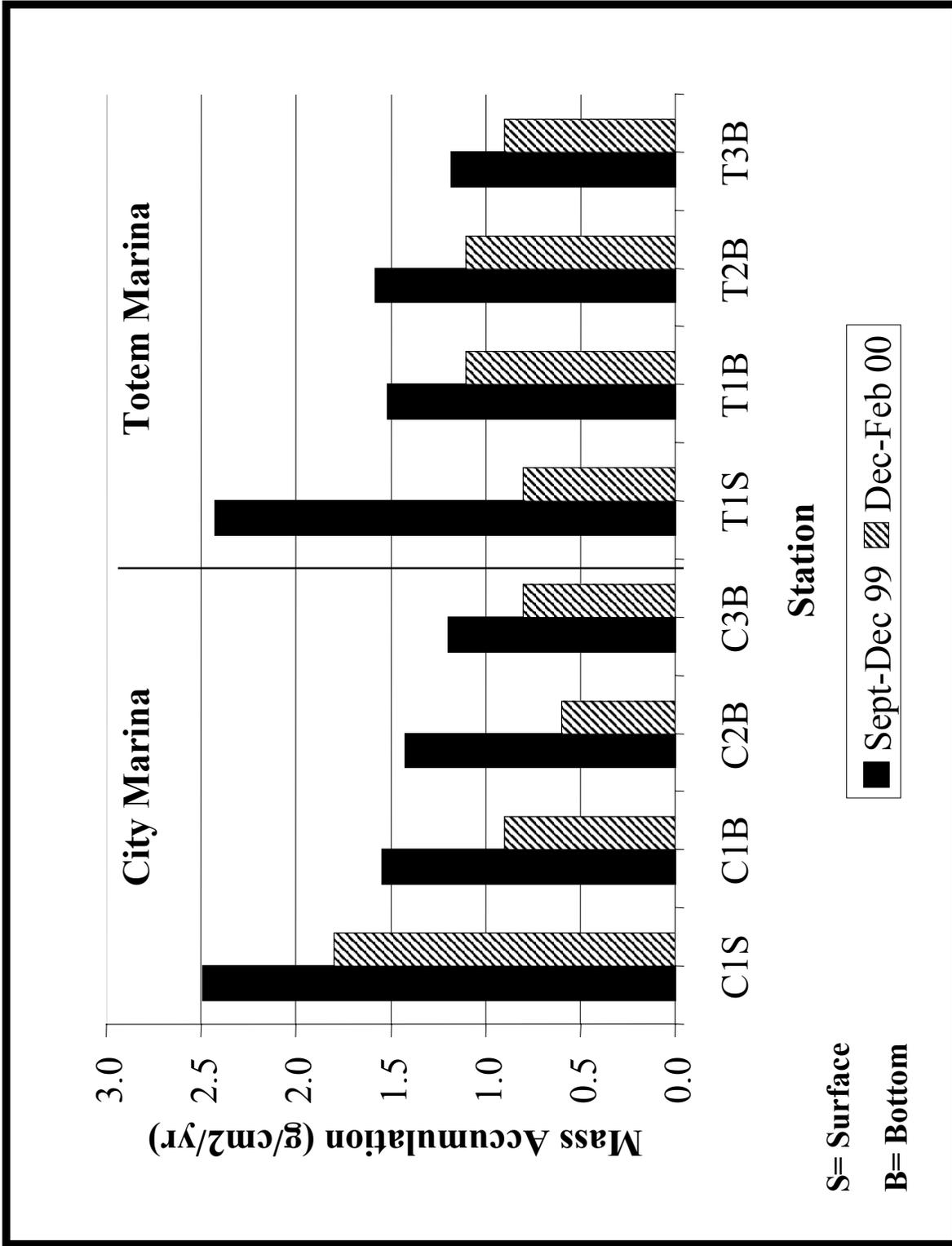


Figure 3. Sediment Trap Accumulation Rates.

Metals concentrations (copper, lead, mercury, zinc) associated with SPM were generally low in all samples, with the exception of mercury in and near City Marina. Mercury levels near City Marina exceeded 0.5 mg/kg in all samples tested. No substantial differences were noted between surface and bottom metals concentrations at City Marina. Bottom particulate metals concentrations were also similar inside and outside City Marina.

At Totem Marina the highest concentrations of copper, lead, and zinc were measured at the surface. Concentrations of all metals associated with SPM collected near the bottom in and around Totem Marina were similar.

Thirty-two individual semivolatile organics were detected in SPM. The majority of compounds quantified were polynuclear aromatic hydrocarbons (PAHs). In all instances, high molecular weight PAH (HPAH) concentrations exceeded low molecular weight PAH (LPAH) levels. This distribution is commonly observed in estuarine sediments, and usually indicates that the PAHs present have undergone some weathering. LPAH and HPAH levels were relatively consistent inside and outside both marinas.

In contrast to City Marina, surface concentrations of both LPAH and HPAH at Totem Marina were substantially higher than concentrations in bottom particulates. This might indicate that PAH concentrations associated with the freshwater layer in this area are elevated. Given the consistency of the remaining data, this result appears to be unusual and should be viewed with caution since it is only based on one composite sample.

Hydrocarbon identification results indicated that all particulate samples were similar from both marinas, in that the samples contained hydrocarbon components indicative of lube oil and weathered #2 diesel.

Besides the PAHs, 17 additional compounds were quantified in SPM. The majority of these detections were below 1000 ug/kg. Compounds present above 1000 ug/kg included three phthalates (butylbenzyl, di-n-octyl, and BEHP), benzoic acid, and coprostanol. Substantially higher concentrations of BEHP phthalate (up to 18000 ug/kg) were present in surface samples at both the head and mouth of the waterway compared to those collected near the bottom. This finding could indicate that higher concentrations of BEHP are associated with the surface freshwater layer in the waterway. BEHP concentrations associated with bottom particulates were similar inside and outside both marinas. However, higher concentrations were measured at City Marina compared to Totem Marina.

Tributyltin (TBT) levels ranged from 140 to 500 ug/kg with a mean of 270 ug/kg. The highest levels were consistently measured near the bottom inside both marinas. Somewhat higher levels of TBT were present in the vicinity of City Marina (mean= 370 ug/kg) compared to Totem Marina (mean= 170 ug/kg).

Bottom Sediments

Physical descriptions of the bottom sediment samples are included in Appendix A, Table A5. Most of the samples were brown to black silt with some sand and shell debris. A hydrogen sulfide odor was also noted in most samples. The results of analysis of bottom sediment samples collected from each of the sediment trap monitoring stations are shown in Appendix C, Tables C4-C5.

Relatively high TOC levels were present at both marinas, with concentrations ranging from 3.4 to 7.7% (mean= 5.0%). TOC levels were highest at the head of the waterway in the vicinity of City Marina. Grain size analysis indicated that all samples collected were composed primarily of fine grain material. The fines (silt + clay fraction) content of all samples was >69%.

As was the case for many contaminants in SPM, metals concentrations were typically lowest at the mouth of the waterway near Totem Marina. Elevated mercury concentrations (up to 0.73 mg/kg) were measured in all samples from the head of the waterway. Copper and zinc levels were slightly higher inside both marinas compared to the stations located outside the marinas.

Thirty-five semivolatile organics were quantified in sediments. Again, as was the case for SPM, the majority of compounds quantified were PAHs and closely related compounds (2-methylnaphthalene and dibenzofuran). PAH concentrations were quite variable in bottom sediments. Both LPAH and HPAH levels ranged over an order of magnitude in the waterway. Given the spatial variability in PAH levels, it is difficult to evaluate spatial patterns with any certainty. One relatively high sample was collected inside City Marina (LPAH= 45000 ug/kg and HPAH= 68000 ug/kg).

Hydrocarbon identification results indicated that all bottom sediment samples from the waterway were similar. They contained an unresolved envelope of peaks eluting in the lube oil range with several individual HPAH compounds representing the largest peaks. This pattern was interpreted to represent primarily weathered creosote. The term *lube oil range* in this analysis refers to a broad range of compounds that would include components of both refined and combusted petroleum products.

Besides the compounds noted above, BEHP was the only compound present above 1000 ug/kg. BEHP concentrations ranged from 1800 to 6800 ug/kg in the waterway. The mean concentration was 5700 ug/kg. BEHP levels tended to be higher at the head of the waterway. No difference was noted for BEHP in bottom sediments between levels inside and outside the two marinas.

TBT concentrations ranged from 160 ug/kg to 510 ug/kg, with a mean of 300 ug/kg. Higher levels were noted in the vicinity of City Marina compared to Totem Marina.

Discussion

Comparison to Sediment Quality Objectives

Chemicals exceeding the Commencement Bay Sediment Quality Objectives (CMBSQO) in particulates and bottom sediments are listed in Appendix C, Table C6. The number of individual chemicals exceeding the CMBSQO by sample type and location is shown in Figure 4. The greatest number of exceedances (21) was measured in bottom sediments inside City Marina. All but two of the exceedances measured were for PAHs. Dibenzofuran and BEHP were also above the CMBSQO in these samples. Substantially fewer violations (4-5) were measured in SPM at City Marina. This could indicate that much of CMBSQO violations are related to historical sources.

At Totem Marina fewer violations of the CMBSQOs were measured. In contrast to City Marina, the greatest number of individual exceedances (16) at Totem Marina were measured in the surface SPM. All of the violations measured except one (BEHP) were for PAHs. While this finding raises concern about the level of source control that has been achieved in this area of the waterway, it is only based on one composite sample and should be viewed with caution. Besides the violations noted for PAHs and BEHP, other chemicals of concern in the waterway are mercury, butyl benzyl phthalate, and benzoic acid.

The toxicity and bioaccumulation of TBT is a complex process that is affected by a number of factors, including organic carbon (OC) levels in sediment and water, 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 formerly adopted for TBT in marine sediments. In 1988 the Puget Sound Dredge Disposal Analysis (PSDDA) agencies developed an interim screening level (ISL) which was based on the best available knowledge of the chemical and its properties (Michelsen et al, 1996). The ISL was set at 30 ug/kg (as Sn). This corresponds to a concentration of 73 ugTBT/kg (reported as TBT-ion). Concentrations above the ISL required biological testing to be performed.

In 1996 an interagency work group was formed to re-evaluate the available information on TBT, with the goal of developing a site-specific cleanup level for Hylebos Waterway in Tacoma and Harbor Island in Elliott Bay in support of sediment cleanup activities. The cleanup level determined for Hylebos Waterway was based on an interstitial water concentration of 0.7 ugTBT/L, which was believed to protect many organisms from most acute effects from TBT (EPA, 1996). Applying EPA's equilibrium partitioning approach to this interstitial water concentration yields a bulk sediment cleanup concentration of 17,500 ugTBT(ion)/kg, OC. Converted to comparable units (ugTBT/kg, OC), TBT levels measured in Thea Foss Waterway ranged from 2510 to 6510 ugTBT/kg, OC which are all below the Hylebos Waterway cleanup level. It should be noted that the Hylebos Waterway criteria are only being provided here for informational purposes.

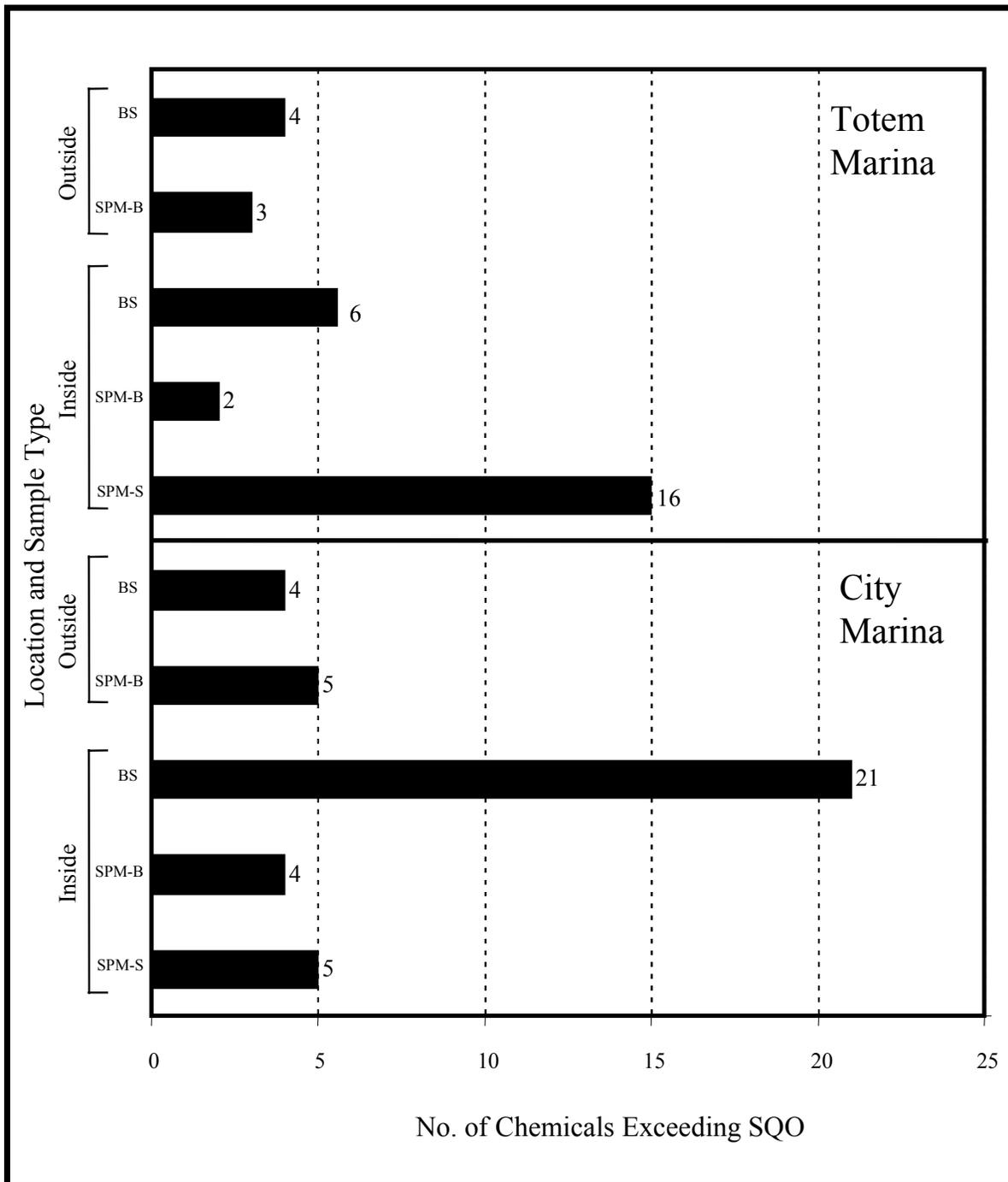


Figure 4. Number of Individual Chemicals Exceeding the Commencement Bay Sediment Quality Objectives by Sample Type and Location

At the present time sediments outside Hylebos Waterway are generally being evaluated using the PSDDA interstitial water screening concentrations of 0.15 ugTBT/L. Assuming a sediment OC content of 2%, this value is roughly equivalent to the original ISL for bulk sediment of 73 ugTBT/kg. For comparison, all samples from Thea Foss Waterway exceeded this level, ranging from 140 to 450 ugTBT/kg. The current use of interstitial water concentrations for evaluating TBT contamination is still under review by both Ecology's Sediment Management Standards and the PSDDA program. Based on comparison with the old ISL, the potential exists that interstitial water concentrations of TBT would, if actually determined, exceed the screening level of 0.15 ugTBT/L. Consequently, TBT should be considered a contaminant of concern in the waterway.

Comparison of Settling Particulate Matter to Bottom Sediments

In an attempt to evaluate whether marinas in Thea Foss Waterway could be isolated as contaminant sources, the distribution of PAHs, BEHP, and TBT between surface/bottom SPM and bottom sediments are compared in Figures 5-7. For the purpose of this analysis, surface particulates represent recent inputs, especially those associated with the buoyant freshwater layer. Bottom particulates represent a combination of recently deposited particulates and resuspended bottom sediments. Bottom sediments primarily represent historical inputs to the waterway. No attempt was made to do statistical comparisons of the data because of the limited number of samples collected.

The distribution of PAHs (Figure 5) outside both marinas was similar between particulates and bottom sediments. On average, at City Marina surface and bottom particulate levels inside the marina were similar to those measured in particulates and sediments outside the marina. Bottom sediments inside the marina tended to have the higher PAH levels. This suggests that PAH inputs were higher historically inside City Marina than are currently occurring.

At Totem Marina, while the magnitude of PAH concentrations in bottom SPM and sediments were similar inside and outside the marina, surface PAH levels were substantially elevated. This suggests that current freshwater inputs are an important source of PAHs in this area of the waterway, and raises concern over the level of source control achieved. The distribution of LPAH vs HPAH in this sample would also indicate that the PAHs have undergone weathering. Additional monitoring would be needed to determine whether the surface result at Totem Marina is an anomaly, and to determine the source of the elevated PAH levels observed.

BEHP levels collected during the present survey are displayed in Figure 6. Also included in Figure 6 are contaminant levels associated with bottom particulates outside each marina from monitoring conducted by Ecology between 1995-97 (Norton, 1997). At City Marina BEHP concentrations in bottom sediments are substantially lower inside the marina than outside. Bottom particulate concentrations are roughly equivalent inside and outside the marina. For both bottom sediments and particulates, slightly higher levels were present in the 1995-97 samples. The distribution of BEHP observed at City Marina suggests that a historical source of BEHP was

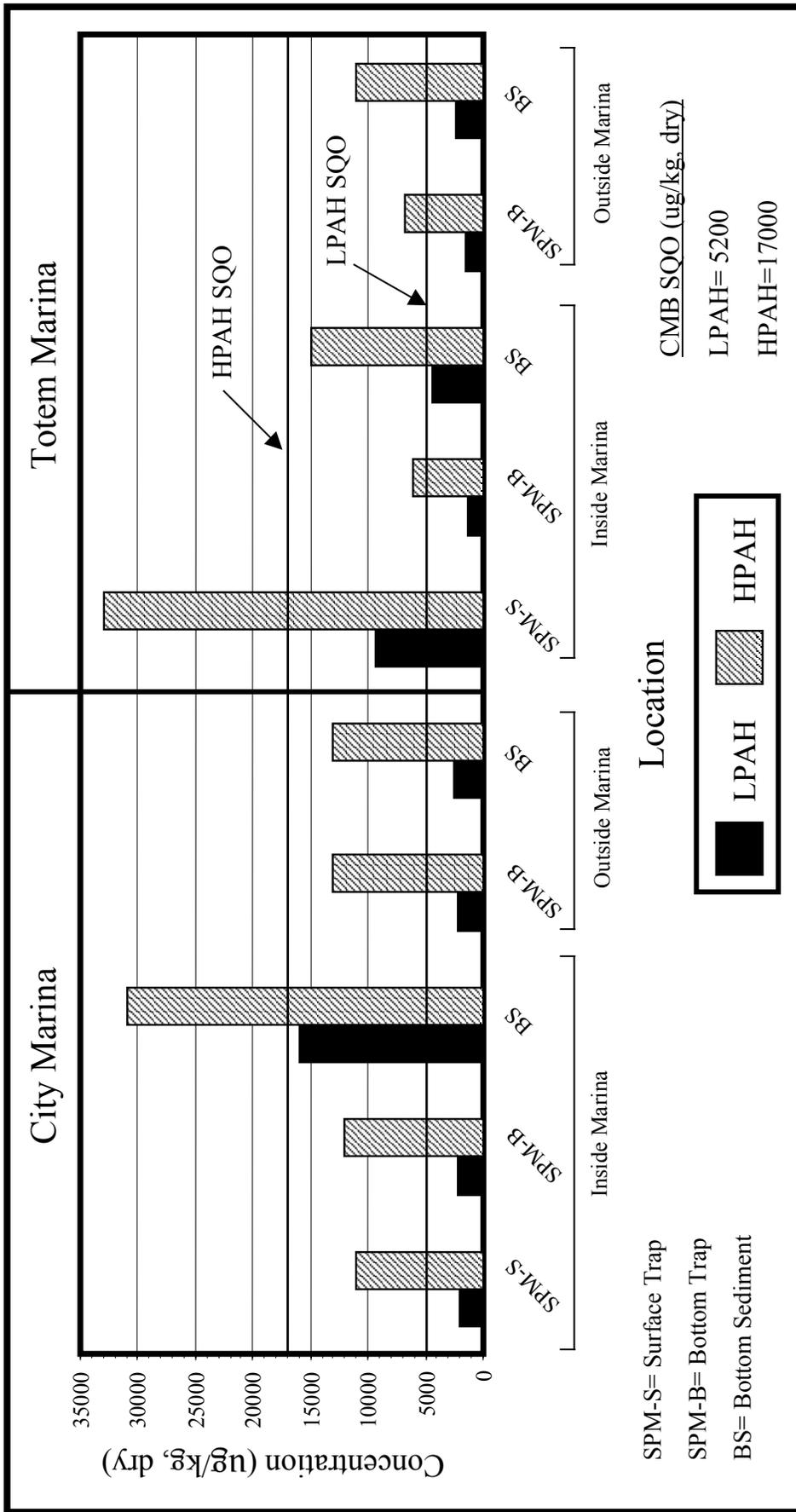


Figure 5. Comparison of LPAH and HPAH Concentrations in Surface Particulates, Bottom Particulates, and Bottom Sediments from Thea Foss Waterway.

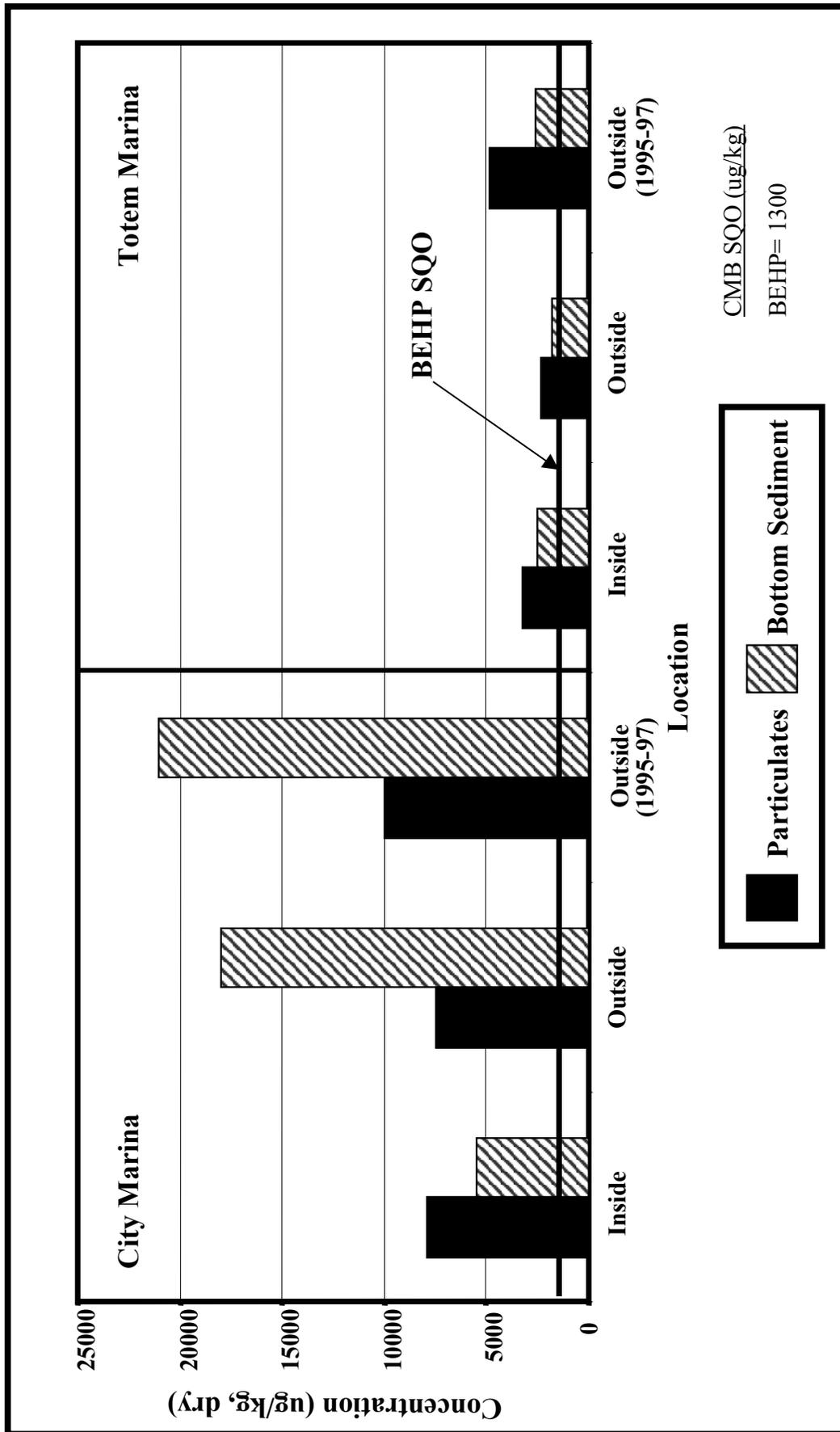


Figure 6. Comparison of Bis(2 Ethyl Hexyl)Phthalate Levels in Bottom Particulates and Bottom Sediments from Thea Foss Waterway.

present in the area outside City Marina. At Totem Marina no substantial difference was noted between bottom sediment and particulate concentrations of BEHP measured inside of outside the marina during this study. At both marinas the highest BEHP levels were measured in the surface SPM samples. These samples were also higher than those measured in bottom sediments. While this observation is based on a limited amount of data, it suggests an ongoing source (or sources) of BEHP is present in the waterway.

In the United States, TBT was used extensively since the 1960s in antifouling paints until restrictions on its use were imposed in 1988. The Organotin Antifouling Paint Control Act of 1988 specifically prohibited the application of these paints to non-aluminum vessels under 25 meters in length, and required paints to leach TBT at a rate no greater than 4 mg/cm²/day for larger vessels (EPA, 1996). Numerous studies in Puget Sound have documented that marinas and boat yards are a significant source of TBT in the marine environment. The distribution of TBT in the vicinity of City and Totem marinas in Thea Foss Waterway is shown in Figure 7. At City Marina, TBT levels in both particulates and bottom sediments were higher inside the marina compared to samples taken outside the marina during this current study and in 1995-97. These data indicate that a source of TBT was present in the marina and that no reduction in contaminant levels has occurred over time. At Totem Marina TBT levels were similar inside and outside the marina for both particulates and bottom sediments.

The contaminant patterns for PAHs, BEHP, and TBT do not seem to provide clear evidence that marinas can be isolated from other sources of these compounds inside Thea Foss Waterway. The data do seem to indicate that a source of TBT was present inside City Marina. The lack of flushing at the head of the waterway is probably a contributing factor to the pattern of TBT contamination observed in the waterway. The distribution of BEHP seems to indicate that the potential exists that an ongoing source (or sources) of BEHP are present in the waterway.

Comparison with Other Data on Contaminant Levels

To put the results of the present study into perspective, a comparison of contaminant levels in two marinas, Port Townsend and Cap Sante (Anacortes), reported in a 1989 study conducted by Battelle, with data from the Commencement Bay Sediment Trap Monitoring program, are presented in Table 3. The Battelle data were originally used to develop loading estimates for marinas in Thea Foss Waterway during the Round 3 Data Evaluation and Pre-Design Evaluation Report (City of Tacoma, 1999).

Comparison of the data indicates that Thea Foss Waterway had the highest TOC, lead, and zinc levels recorded in any of the three areas. LPAH and HPAH levels were similar between Thea Foss Waterway and Cap Sante Marina. Both LPAH and HPAH levels inside Port Townsend Marina were elevated by approximately a factor of 3 compared to the other sites. BEHP levels were not measured in the Battelle study. Compared to data from the Commencement Bay Sediment Trap Monitoring Program, BEHP concentrations in City Marina appear to be similar or slightly lower than the waterway average from 1995-97. Substantial lower levels were measured at Totem Marina.

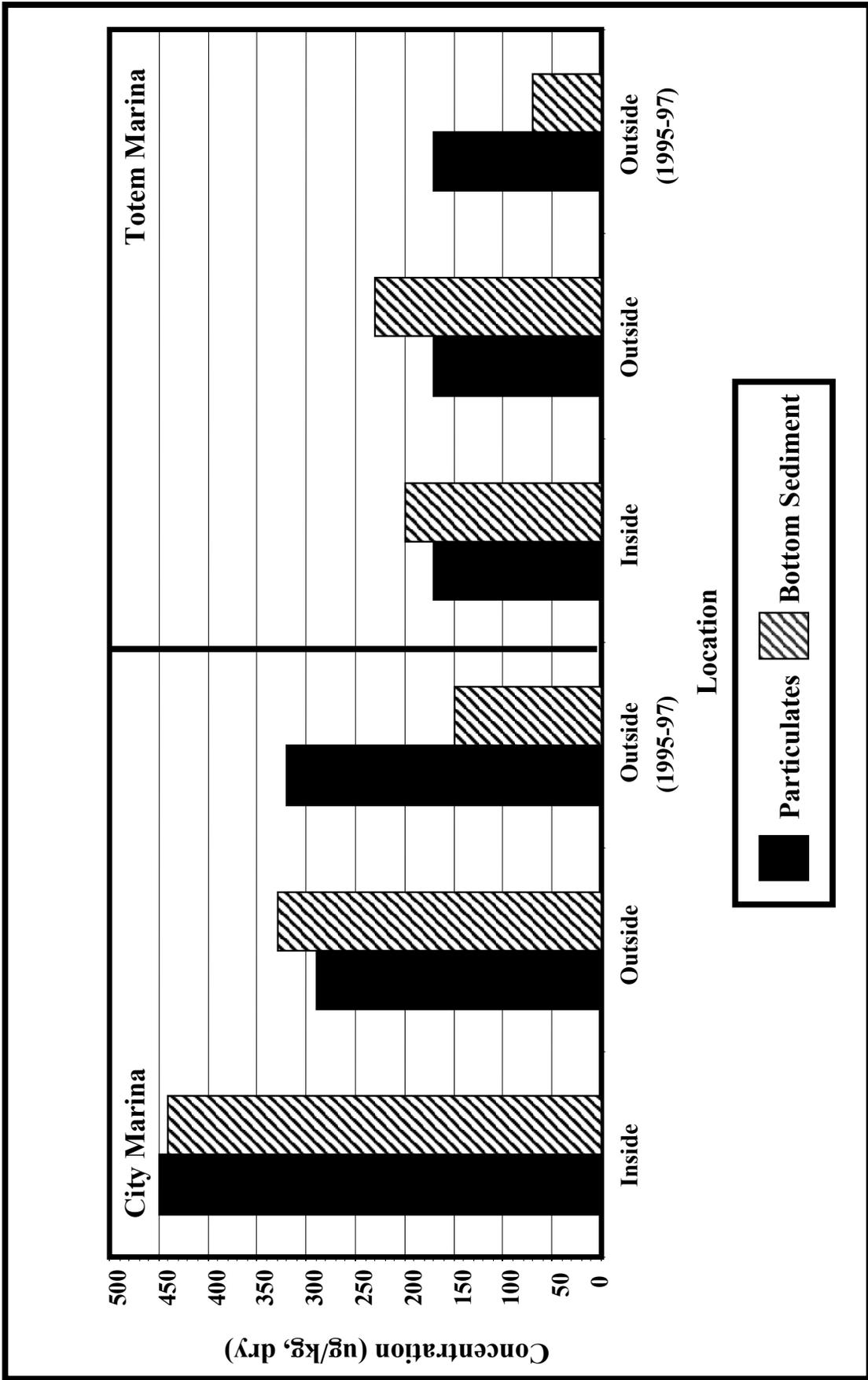


Figure 7. Comparison of Tributyltin Levels in Bottom Particulates and Bottom Sediments from Thea Foss Waterway.

Table 3. Comparison of Contaminant Levels in Settling Particulate Matter from Thea Foss Waterway with Data from the 1989 Battelle Marinas Study.

Source	N=	TOC (%)	Cu (mg/kg)	Pb (mg/kg)	Zn (mg/kg)	LPAH (ug/kg)	HPAH (ug/kg)	Bis(2EH)P (ug/kg)	TBT (ugTBT/kg)
Present Study¹									
Inside Marina									
City Marina	2	6.2	240	190	260	2100	12000	7900	400
Totem Marina	2	3.5	99	68	150	1400	6200	3200	150
Battelle, 1989²									
Port Townsend	4	5.1	250	35	210	11000	29000	-	1200
Cap Santa	4	4.2	94	35	170	2500	10000	-	1100
Outside Marina									
Present Study¹									
City Marina	1	6.1	140	200	250	2200	13000	7500	260
Totem Marina	1	3.8	100	73	120	1600	6800	2300	150
Thea Foss Waterway, 1997²									
1995-1997	9-28	5.9	130	170	210	3700	20000	10000	250
Battelle, 1989³									
Port Townsend	2	4.4	34	14	98	960	22000	-	71
Cap Santa	1	3.4	53	17	170	3100	11000	-	440

¹ = Bottom trap samples

- = Analyte not determined

Values shown are means when N>1

²Norton, 1997. Unpublished data from the Commencement Bay Sediment Trap Monitoring Program.

³Crececius et al., 1989. Contaminant Loading to Puget Sound from Two Marina's. EPA 910/9-89-014.

TBT levels inside Port Townsend and Cap Sante marinas were substantially elevated compared to Thea Foss Waterway. This finding is not unexpected since the Battelle data were collected shortly after the use of TBT in antifouling paints was restricted in the United States.

As previously mentioned, loading estimates for marinas in Thea Foss Waterway were developed using data from the 1989 Battelle study at Port Townsend and Cap Sante marinas. Both of these marinas are enclosed by breakwaters with only one outlet. The results of this study indicated that marinas are a source of selected contaminants to sediments (Crecelius et al., 1989). In contrast, marinas in Thea Foss Waterway are not enclosed, so water and particulates can flow freely into and out of the marinas. While the available information indicates that marinas can be sources of selected contaminants, there does not appear to be clear evidence to isolate marinas as unique sources of these contaminants within Thea Foss Waterway. Consequently, the data collected in this study most likely represent the combined flux of contaminants from all sources within the areas sampled. Based on violations of applicable sediment quality objectives, mercury, PAHs, BEHP, benzoic acid, and TBT are contaminants of concern in the waterway with generally higher contaminant levels at the head of the waterway (represented by City Marina) compared to the mouth (represented by Totem Marina).

Given the age of the Battelle data and the availability of site specific information with an expanded list of analytes, it would be more representative of present conditions in the waterway to use the data from this current study in any further refinements to loading evaluations for the waterway. A portion of this loading evaluation was performed for the waterway by Cosmopolitan Engineering Group and reported to the City of Tacoma in July 2000 (De Leon, 2000). Unfortunately, some of the semivolatile organics data were revised upward by the laboratory after this analysis was performed (see *Quality Assurance*, page 6). In addition, it appears that this analysis assumed that the entire contaminant flux measured was attributed to marinas in the waterway. Loading estimates from other potential sources in the area, such as storm drains, would be required to evaluate the relative contribution from individual sources.

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Conclusions

- In bottom sediments, 22 individual chemicals (primarily mercury, LPAHs, HPAHs, BEHP, and benzoic acid) were measured at concentrations above the Commencement Bay Sediment Quality Objectives (CMBSQO). A similar chemical suite (19) also exceeded the CMBSQO in SPM.
- Based on bulk sediment chemistry levels, tributyltin concentrations in all SPM and bottom sediment samples have the potential to exceed the Puget Sound Dredge Disposal Analysis recommended screening level of 0.15 ugTBT/L for interstitial water.
- Based on comparison with applicable sediment quality values, mercury, LPAHs, HPAHs, BEHP, benzoic acid, and TBT are contaminants of concern in the waterway.
- Based on data collected, there does not appear to be clear evidence that would isolate marinas from other sources of contaminants within Thea Foss Waterway. Consequently, the data in this study most likely represent the combined flux of contaminants from all sources within the areas sampled.
- The potential exists that an ongoing source (or sources) of BEHP is present in Thea Foss Waterway.

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Appendices

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Appendix A

Station Location and Sample Information

Table A1: Station Locations for Settling Particulate Matter Samples

Table A2: Station Locations for Bottom Sediment Samples

Table A3: Settling Particulate Matter Samples Submitted for Analysis
February 2000

Table A4: Bottom Sediment Samples Submitted for Analysis
February 2000

Table A5: Sediment Log for Bottom Sediment Samples

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Table A1: Station Locations for Settling Particulate Matter Samples.

Station ID	Latitude		Longitude		Depth @		Deployment Location	Description
	Deg	Min	Sec	Deg	Min	Sec		
City Marina								
C1S	47	14	54.24	122	25	55.68	16.5	Surface Between slips 41/42
C1B	47	14	50.82	122	25	54.96	20.9	Bottom South end near slip 27
C2B	47	14	54.84	122	25	56.34	20.2	Bottom North end of marina between slips 45/46
C3B	47	14	53.04	122	25	58.98	18.4	Bottom Outside marina west side Thea Foss WW
Totem Marina								
T1S	47	15	20.52	122	26	3.48	28.7	Surface End of pier
T1B	47	15	18.48	122	26	4.5	29.6	Bottom South end of marina between covered slips
T2B	47	15	22.56	122	26	5.64	30.4	Bottom North end below main office
T3B	47	15	20.82	122	26	2.52	30.7	Bottom Outside marina

Datum = WSG84

Table A2: Station Locations for Bottom Sediment Samples.

Station ID	Latitude		Longitude		Depth @		Description
	Deg	Min Sec	Deg	Min Sec	MLLW (ft)		
City Marina							
C1S-S	47	14 54.3	122	25 54.36	28.7		Below surface deployment between slips 41/42
C1B-S	47	14 50.7	122	25 55.14	29.6		South end near slip 27
C2B-S	47	14 54.84	122	25 56.58	30.4		North end of marina between slips 45/46
C3B-S	47	14 53.04	122	25 58.5	30.7		Outside marina west side of Thea Foss WW
Totem Marina							
T1S-S	47	15 20.58	122	26 3.18	16.5		Below surface deployment end of pier
T1B-S	47	15 18.42	122	26 4.44	20.9		South end of marina adjacent to covered slips
T2B-S	47	15 22.38	122	26 6	20.2		North end below main office
T3B-S	47	15 20.94	122	26 2.22	18.4		Outside marina

Datum = WSG84

Table A3: Settling Particulate Matter Samples Submitted for Analysis February 2000.

City Marina					
Station	Sample #	Quarter 1	Sample #	Quarter 2	Sample # Composite Sept 99 - Feb 00
C1B-	A	%S	B	%S	C
	68244		68245		68246
					TOC, Metals (4), Semiv., Butyltins, HCID
C2B-	A	%S	B	%S	C
	68247		68248		68249
					TOC, Metals (4), Semiv., Butyltins, HCID
C3B-	A	%S	B	%S	C
	68250		68252		68253
					TOC, Metals (4), Semiv., Butyltins, HCID
C1S-	A	%S	B	%S	C
	68254		68255		68256
					TOC, GS, Metals (4), Semiv., Butyltins, HCID
Totem Marina					
Station	Sample #	Quarter 1	Sample #	Quarter 2	Sample # Composite Sept 99 - Feb 00
T1B-	A	%S	B	%S	C
	68230		68231		68232
					TOC(Dup), Metals(4), Semiv., Butyltins, HCID- 68233
T2B-	A	%S	B	%S	C
	68234		68235		68236
					TOC, Metals (4), Semiv., Butyltins, HCID
T3B-	A	%S	B	%S	C
	68237		68239		68240
					TOC, Metals (4), Semiv., Butyltins, HCID
T1S-	A	%S	B	%S	C
	68241		68242		68243
					TOC, GS, Metals (4), Semiv., Butyltins, HCID

Quarter 1 = September 28 – December 1, 1999

Quarter 2 = December 1, 1999 – February 4, 2000

Metals(4) = copper, mercury, lead, and zinc

TOC = total organic carbon

GS = grain size

HCID = hydrocarbon identification

Table A4: Bottom Sediment Samples Submitted February 2000.

Station	Sample No	Analyte	Notes
City Marina			
C1B-S	68262	%S, TOC, GS, Metals(4), Semiv., Butyltins, HCID	
C2B-S	68263	%S, TOC, GS, Metals(4), Semiv., Butyltins, HCID	
C3B-S	68264	%S, TOC, GS, Metals(4), Semiv., Butyltins, HCID	
C1S-S	68265	%S, TOC, GS, Metals(4), Semiv., Butyltins, HCID	
Totem Marina			
T1B-S	68257	%S, TOC, GS, Metals(4), Semiv., Butyltins, HCID	
T1B-SD	68258	%S, TOC, GS, Metals(4), Semiv., Butyltins, HCID	Duplicate of T1B-S
T2B-S	68259	%S, TOC, GS, Metals(4), Semiv., Butyltins, HCID	
T3B-S	68260	%S, TOC, GS, Metals(4), Semiv., Butyltins, HCID	
T1S-S	68261	%S, TOC, GS, Metals(4), Semiv., Butyltins, HCID	

Metals(4) = copper, mercury, lead, and zinc

TOC = total organic carbon

GS = grain size

HCID = hydrocarbon identification

Table A5: Sediment Log for Bottom Sediment Samples.

Station ID	Grab #	Total Depth (ft)	Date	Time	Penetration	
					(cm)	Description
City Marina						
C1S-S	1	32	2/4/00	14:00	17	Brown silt layer over black sandy silt, H ₂ S
	2	21	2/4/00	14:10	17	Brown silt layer over black sandy silt, soft, H ₂ S, wood chunks
	3	18	2/4/00	14:20	17	Brown to black silt with wood debris, H ₂ S
C1B-S	1	24	2/4/00	12:30	17	Brown silt over black sandy material some shell
	2	23	2/4/00	12:40	17	Soft brown silt over black to brown sandy silt, H ₂ S
	3	27	2/4/00	12:45	16	Soft brown silt over black to brown sandy silt, H ₂ S, some oil sheen
C2B-S	1	30	2/4/00	13:00	16	Brown to black sandy silt, some debris
	2	30	2/4/00	13:05	16	Soft brown to black silt, red rock crab, sandy at depth
	3	30	2/4/00	13:15	16	Soft brown to black silt with some shell
C3B-S	1	28	2/4/00	13:30	16	Brown to black silt with some shell debris
	2	32	2/4/00	13:40	16	Brown to black silt with sand, organic debris, shell
	3	35	2/4/00	13:50	17	Brown to black sediment with plastic debris and shell
Totem Marina						
T1S-S	1	38	2/4/00	11:10	16	Brown to black sandy silt with some shell
	2	38	2/4/00	11:20	16	Brown to black sandy silt, stiff, worms, shell, fish line, etc.
	3	39	2/4/00	11:35	16	Brown to silty sand, shell debris
T1B-S	1	39	2/4/00	9:30	17	Brown sandy silt, some shell, black at depth
	2	39	2/4/00	9:40	16	Brown sandy silt, shell at surface, black at depth, worms at depth
	3	39	2/4/00	9:50	16	(Similar to number two)
T2B-S	1	39	2/4/00	10:05	17	Brown to black sandy silt, small shell debris on surface
	2	39	2/4/00	10:13	16	Brown to black stiff sandy silt with some shell debris
	3	39	2/4/00	10:20	16	Brown to black sandy silt with some shell, stiff
T3B-S	1	40	2/4/00	10:40	16	Brown to black silt with some sand and shell, paint chips (white)
	2	40	2/4/00	10:45	16	Brown to black silt with some sand and shell, black at depth
	3	38	2/4/00	10:55	17	Brown to black silt with some sand and shell, paint chips (red)

H₂S = Hydrogen sulfide

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Appendix B

Quality Assurance Information

Case Narratives

Table B1: Blind Field Duplicate Results for Bottom Sediments

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

March 23, 2000

Project: Thea Foss Marinas

Samples: 06-8243, 8256-65

Laboratory: Rosa Environmental

By: Pam Covey

Case Summary

These samples required eleven (11) Grain Size analyses on sediment samples using Puget Sound Estuary Protocol (PSEP) method with salt correction. The samples were received at the Manchester Environmental Laboratory and transported to the contract lab on February 16, 2000 for Grain Size analyses.

The analyses were reviewed for qualitative and quantitative accuracy, validity and usefulness. See narrative from Rosa for further explanation on sample analysis anomalies.

The results are acceptable for use as reported.

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

April 19, 2000

TO: Dale Norton
FROM: Catherine Bickle, Technician
THROUGH: Jim Ross, Chemist
SUBJECT: General Chemistry Quality Assurance memo for the Thea Foss Marina project.

SUMMARY

The data generated by the analyses of these samples can be used without qualifications.

SAMPLE INFORMATION

The Manchester Laboratory received samples 068230 - 068265 from the Thea Foss Marina project on 02-07-00 and 02-09-00 in good condition.

HOLDING TIMES

Analyses were performed within all applicable EPA holding times.

ANALYSIS PERFORMANCE

Instrument Calibration

Instrument calibration was performed before each analytical run and checked by initial calibration verification standard. All balances are calibrated yearly with calibration verification performed monthly.

Precision Data

The results of the triplicate analyses of the samples were used to evaluate the precision. The Relative Percent Differences (RPD) and the Relative Standard Deviation (RSD) were within their acceptance windows of $\pm 20\%$. The second batch of samples received did not contain enough sample to do triplicates for TOC 1040. The analyst was able to do a duplicate; which was also within the acceptance window of $\pm 20\%$.

Laboratory Control Sample (LCS) Analyses

LCS analyses were within their acceptance windows of +/- 20%.

Qualifiers

The “NAF” qualifier signifies “not analyzed for” as previously mentioned in the Precision Data section not enough sample was supplied to do triplicates.

Please call Catherine Bickle @ 871-8807 or Jim Ross 871-8808 with any questions or concerns about this project.

cc: Project File

Washington Department of Ecology
Manchester Environmental Laboratory
7411 Beach Drive East, Port Orchard, WA 98366

February 24, 2000

TO: Dale Norton
FROM: Jim Ross, Manchester Lab
SUBJECT: Metals Quality Assurance memo for the Thea Foss Marinas monitoring

SUMMARY

Data for this project met all quality assurance and quality control criteria and can be used without qualification.

SAMPLE RECEIPT

The samples were received by the Manchester Laboratory on 2/07/00

HOLDING TIMES

All analyses were performed within the specified holding time (28 days for Hg, 180 days 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 and blanks were within the relevant control limits.

PROCEDURAL BLANKS

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

SPIKED SAMPLE ANALYSES

All spike and duplicate spike recoveries met the acceptance criteria (75-125%).

PRECISION DATA

Precision estimates based on duplicate spike analysis were all within the acceptance criteria for duplicate analysis ($\pm 20\%$)

LABORATORY CONTROL SAMPLE (LCS) ANALYSES

All LCS analyses were within the acceptance criteria for the individual analytes.

Please call Jim Ross at (360) 871-8808 to further discuss this project.

Manchester Environmental Laboratory
7411 Beach Drive E., Port Orchard Washington 98366

April 10, 2000

Subject: Foss Marinas
Samples: 00068232, 236, 240, 243, 246, 249, *and-253, 256 - 265*
Project ID: 144100
Project Officer: Dale Norton
By: Greg Perez

SEMIVOLATILE ORGANICS

ANALYTICAL METHODS

The samples were extracted following the EPA CLP and SW-846 8270 procedure. The samples were cleaned up by Gel Permeation Chromatography followed by silica gel. Analysis was by capillary gas chromatography with mass spectrometry (GC/MS). Routine QA/QC procedures were performed with the analyses.

HOLDING TIMES

The samples were stored at 4 degrees C until extraction. They were extracted and analyzed within the recommended holding times.

BLANKS

Low levels of some analytes were detected in the laboratory blanks. An analyte is considered native to the sample when the on-column concentration is at least five times greater than in the associated method blanks. A phthalate is considered native to the sample when the concentration is at least ten times greater than in the associated method blanks.

SURROGATES, INTERNAL STANDARDS and MATRIX SPIKE AND MATRIX SPIKE DUPLICATE

Interferences affected recoveries of the surrogates and MS, MSDs. High levels of lipids in the samples affected chromatography, broadening peaks and enhancing the area counts of the internal standards. Early eluting surrogates were obscured in some cases. Deposits of lipids on the column and in the injection port caused degradation of some of the anilines. High levels of

PAHs in the samples elevated recoveries of those compounds. Some data has been qualified for these reasons.

Peak broadening affected identification and quantitation of certain closely eluting PAH pairs. Benzo(a)anthracene and chrysene, benzo(b)fluoranthene and benzo(k)fluoranthene did not fully resolve in some samples. In these cases an approximate integration was done and the result flagged as an estimate.

One sample needing dilution (068263) was inadvertently overlooked. A dilution will be run within the week and a report issued.

The data is acceptable for use as reported.

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 estimate.
- UJ - The analyte was not detected at or above the reported estimated result.
- REJ - The data are unusable for all purposes.
- NAF - Not analyzed for.
- N - There is evidence the analyte is present in the sample.
- NJ - There is evidence that the analyte is present. The associated numerical result is an estimate.
- B - This qualifier is used when the concentration of the associated value exceeds the known calibration range. The associated numerical result is an estimate.

bold - The analyte was present in the sample. (Visual Aid to locate detected compounds on report sheet.)

Manchester Environmental Laboratory
7411 Beach Drive E., Port Orchard Washington 98366

July 13, 2000

Subject: Foss Marinas dilutions
Samples: 00068263
Project ID: 144100
Project Officer: Dale Norton
By: Greg Perez

SEMIVOLATILE ORGANICS

ANALYTICAL METHODS

The samples were extracted following the EPA CLP and SW-846 8270 procedure. The samples were cleaned up by Gel Permeation Chromatography followed by silica gel. Analysis was by capillary gas chromatography with mass spectrometry (GC/MS). Routine QA/QC procedures were performed with the analyses.

HOLDING TIMES

The samples were stored at 4 degrees C until extraction. They were extracted and analyzed within the recommended holding times. These dilutions were run after the expiration of the 40 day extract holding time. No degradation was noted and no qualifiers were added.

BLANKS

Low levels of some analytes were detected in the laboratory blanks. An analyte is considered native to the sample when the on-column concentration is at least five times greater than in the associated method blanks. A phthalate is considered native to the sample when the concentration is at least ten times greater than in the associated method blanks.

SURROGATES, INTERNAL STANDARDS and MATRIX SPIKE AND MATRIX SPIKE DUPLICATE

No additional matrix spikes were analyzed. All other QA was acceptable.

COMMENTS

Peak broadening affected identification and quantitation of certain closely eluting PAH pairs. Benzo(a)anthracene and chrysene, benzo(b)fluoranthene and benzo(k)fluoranthene did not fully resolve in some samples. In these cases an approximate integration was done and the result flagged as an estimate.

The data is acceptable for use as reported.

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 estimate.
- UJ - The analyte was not detected at or above the reported estimated result.
- REJ - The data are unusable for all purposes.
- NAF - Not analyzed for.
- N - There is evidence the analyte is present in the 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. The associated numerical result is an estimate.
- bold** - The analyte was present in the sample. (Visual Aid to locate detected compounds on report sheet.)

Manchester Environmental Laboratory
7411 Beach Drive E., Port Orchard Washington 98366

December 5, 2000

Subject: Thea Foss Marinas
Samples: Data reissue
Project ID: 144100
Project Officer: Dale Norton
By: Greg Perez

SEMIVOLATILE ORGANICS

COMMENTS

The enclosed data is a correction of previously released results. A review of recently produced data revealed an error affecting past data. A change in the clean up procedure for semivolatiles was insufficiently documented and a small amount of sample loss was not properly taken into account in the final calculations.

We apologize for the inconvenience this has caused. Analytical and documentation procedures have been changed to prevent this from occurring in the future.

Manchester Environmental Laboratory
7411 Beach Dr E, Port Orchard Washington 98366

CASE NARRATIVE

February 15, 2000

Subject: Thea Foss Marina's Project
Sample(s): 00068232,36,40,43,46,49,53 and 00068256-65
Officer(s): Dale Norton
By: Bob Carrell
Organics Analysis Unit

HYDROCARBON IDENTIFICATION ANALYSES

ANALYTICAL METHOD(S)

Portions of these samples were extracted with methylene chloride and analyzed, along with various petroleum products, by capillary Gas Chromatography and with Flame Ionization Detection (GC/FID).

HOLDING TIMES

The samples were extracted and analyzed within the recommended holding times.

BLANKS

No target compounds/products were detected in the method blanks, thus demonstrating that the system was free from contamination.

RESULTS/COMMENTS

The results of these analyses are presented on the Analysis Report form accompanying this document. It should be noted that the following samples appeared to be similar in both content and concentration:

00068232 and 00068253
00068236 and 00068249
00068243, 00068246 and 00068256
00068257, 00068258 and 00068259
00068260 and 00068261
00068262, 00068263 and 00068265

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CASE NARRATIVE

March 30, 2000

Subject: Thea Foss Marinas Project

Sample(s): 00068232, 36, 40, 43, 46, 49, 53 and 56-65

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BUTYLTINS ANALYSIS

ANALYTICAL METHOD

These samples were extracted following Manchester Laboratory's standard operating procedure for the extraction of butyltins using a 50:50 mixture of hexane and ethyl acetate containing 0.05% tropolone by weight. The extracts were transferred to a 50 mL volumetric flask and the solvent was evaporated to dryness on the N-Evap. One milliliter of hexane was added to the flask and the butyltins were derivatized using the sodium tetraethylborate reaction outlined in Jiang et al., *J. Chromatogr. A* (1996) to the ethyl derivatives followed by a cleanup step utilizing silica gel. The analyses were done by capillary gas chromatography using atomic emission detection (GC/AED) monitoring the tin channel for the 271 nm frequency.

HOLDING TIMES

These samples were stored frozen, following the Puget Sound Estuary Program (PSEP), until extracted. All samples were analyzed within the maximum recommended method holding time of 40 days from extraction.

BLANKS

No target analytes were detected in the laboratory method blanks at the practical quantitation limit, demonstrating that the system was free from contamination.

SURROGATES

Although no surrogate recovery QC limits have been established for this method, our in-house limits are 50% - 150%. The surrogate recoveries for the more volatile surrogate, i.e. tripropyltin chloride, were low for samples 00068232 (28%), 00068236 (6%), 00068256 (43%), 00068257 (5%), 00068257 LDP1 (45%), 00068258 (39%), 00068259 (36%), 00068261 (40%), 00068264 (35%) and the two matrix spikes 00068260 LMX1 (35%) and LMX2 (39%). It is suspected that these samples may have experienced excessive blow-down after derivatization, which resulted in the low recoveries for the more volatile of the surrogates. This tends to be supported by the fact that samples 00068260 and 00068260 LDP1 had acceptable recoveries for this surrogate while the matrix spikes LMX1 and LMX2 did not. Since the tripropyltin surrogate recoveries were acceptable, no qualifiers were added as a result of the surrogate recoveries.

MATRIX SPIKES

No QC limits have been established for this method, however our in-house limits are 50%-150% for tributyltin and dibutyltin. The MS/MSD recoveries for tributyltin were low (36% and 37%), probably due to the low spiking amount versus the native amount present. Since the native amount is subtracted from the total amount detected to determine the percent recovery, the spiked amount should be 1-5 times the native concentration. This allows variances in concentrations in different aliquots to have minimal effect on the resultant calculation for recovery. The relative percent differences (RPD's) between the matrix spikes were acceptable. No qualifiers were added as a result of matrix spike recoveries or RPD's.

COMMENTS

A reference material was also extracted and analyzed along with these samples. It is a certified reference Canadian sediment known as PACS-2.

The PACS-2 has a certified tributyltin chloride value of 2687 +/- 356 ug/Kg dw and a certified dibutyltin dichloride value of 2790 +/- 380 ug/Kg dw. The results of two reference sample analyses are listed below.

OCS0073A1	2800 ug/Kg dw	tributyltin chloride
	2000 ug/Kg dw	dibutyltin dichloride
OCS0073A2	2800 ug/Kg dw	tributyltin chloride
	2000 ug/Kg dw	dibutyltin dichloride

It should also be noted that none of the data for this project is recovery corrected.

The data is useable as qualified.

DATA QUALIFIER CODES

- U - The analyte was not detected at or above the reported result.
- J - The analyte was positively identified. The associated numerical result is an estimate.
- UJ - The analyte was not detected at or above the reported estimated result.
- REJ - The data are unusable for all purposes.
- 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.
- NC - Not Calculated
- E - This qualifier is used when the concentration of the associated value exceeds the known calibration range.

Table B1: Blind Field Duplicate Results for Bottom Sediments

Marina Station Position Sample No. 06-	Totem T1B-S Inside 8257	Totem T1B-SD (Dup) 8258	RPD (%)
Conventionals (%)			
Total Solids	44.2	44.6	-0.9
Total Organic Carbon @ 70°C	3.7	3.7	0.0
Grain Size			
Gravel	0.8	0.5	46.2
Sand	24.6	30.4	-21.1
Silt	45.4	43	5.4
Clay	29.3	26.2	11.2
Metals (mg/kg,dry)			
Copper	129	123	4.8
Lead	116	116	0.0
Mercury	0.455	0.535	-16.2
Zinc	170	169	0.6
Semivolatiles (ug/kg, dry)			
Acenaphthene	63	513	-156.3
Acenaphthylene	102	233	-78.2
Naphthalene	275	795	-97.2
Fluorene	104	694	-147.9
Anthracene	305	544	-56.3
Phenanthrene	514	6838	-172.0
Sum LPAH	1363	9617	-150.3
Fluoranthene	1061	6229	-141.8
Benzo(a)anthracene	508	1027	-67.6
Pyrene	1653	6107	-114.8
Benzo(b)fluoranthenes	1279	2593 J	-67.9
Benzo(a)pyrene	639	1148	-57.0
Dibenzo(a,h)anthracene	175	290	-49.5
Indeno(1,2,3-cd)pyrene	492	769	-43.9
Benzo(g,h,i)perylene	450	757	-50.9
Sum HPAH	6233	18920 J	-100.9
1-Methylnaphthalene	66	179	-92.2
2-Methylnaphthalene	115	303 J	-90.0
Dibenzofuran	100	698	-149.9
Carbazole	44	428	-162.7
Retene	412	586	-34.9
4-Methylphenol	22 J	43	-64.6
Dimethyl phthalate	23 J	44	-62.7
Butylbenzylphthalate	90	164	-58.3
Bis(2EH)phthalate	1810	3202	-55.5
1,4-Dichlorobenzene	9.6 J	19 J	-65.7
Butyltins (ug/kg, dry)			
Tributyltin Chloride	160	210	-27.0
Dibutyltin Chloride	120	120	0.0
Monobutyltin Chloride	42	55	-26.8

J = Estimated concentration

RPD = Relative percent difference between duplicates

Appendix C

Summary of Analytical Results

Table C1: Sediment Accumulation Rates for Settling Particulate Matter

Table C2: Results of Analysis of Settling Particulate Matter

Table C3: Hydrocarbon Analysis of Settling Particulate Matter

Table C4: Results of Analysis of Bottom Sediments

Table C5: Hydrocarbon Analysis of Bottom Sediments

Table C6: Compounds Exceeding the Commencement Bay Sediment Quality Objectives or Other Applicable Guidelines in Settling Particulate Matter and Bottom Sediments

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Table C1: Sediment Accumulation Rates for Settling Particulate Matter.

Station Period	Deployment Days	Number Collection		SPM wet grms	SPM Percent Solids	BS Solids	SPM dry grms	Dry Density g/cm ³	Mass Accumulation g/cm ² /year	Accumulation Rate (cm/year)	
		Area cm ²	cm ² Deployed								
City Marina											
C1S	Quarter 1	65	157	174	40.0	33.9	69.6	0.42	2.5	5.9	
	Quarter 2	65	157	123	41.7	33.9	51.3	0.42	1.8	4.3	
C1B	Quarter 1	65	157	111	38.9	35.4	43.2	0.45	1.5	3.4	
	Quarter 2	65	157	65	37.7	35.4	24.5	0.45	0.9	2.0	
C2B	Quarter 1	65	157	102	39.0	39.7	39.8	0.52	1.4	2.7	
	Quarter 2	65	157	45	36.0	39.7	16.2	0.52	0.6	1.1	
C3B	Quarter 1	65	157	88	37.9	39.2	33.4	0.51	1.2	2.3	
	Quarter 2	65	157	59	37.6	39.2	22.2	0.51	0.8	1.5	
									Mean=	1.3	2.9
Totem Marina											
T1S	Quarter 1	65	157	167	40.6	44.8	67.8	0.62	2.4	3.9	
	Quarter 2	66	314	104	41.3	44.8	43.0	0.62	0.8	1.2	
T1B	Quarter 1	65	157	101	42.0	44.2	42.4	0.61	1.5	2.5	
	Quarter 2	65	157	72	41.7	44.2	30.0	0.61	1.1	1.8	
T2B	Quarter 1	65	157	99	44.6	45.9	44.2	0.64	1.6	2.5	
	Quarter 2	65	157	74	42.8	45.9	31.7	0.64	1.1	1.8	
T3B	Quarter 1	65	157	83	39.7	45.9	33.0	0.64	1.2	1.8	
	Quarter 2	65	157	58	41.0	45.9	23.8	0.64	0.9	1.3	
									Mean=	1.3	2.1

*= Predicted from Puget Sound Density Model (Crececius, 1989b)

Gross Accumulation (g/cm²/yr)= [(P/A)/D] x Y

P= Amount of material collected (dry grams)

A= Collection area of cylinder (cm²)

D= Number of days sediment trap was deployed

Y= Number of days in a year (365)

Quarter 1 = September 28 – December 1, 1999

Quarter 2 = December 1, 1999 – February 4, 2000

Table C2: Results of Analysis of Settling Particulate Matter.

Marina Station	Totem				City				CMB SQO (EPA, 1989)
	T1SC Surface Inside	T1BC Bottom Inside	T2BC Bottom Inside	T3BC Bottom Outside	C1SC Surface Inside	C1BC Bottom Inside	C2BC Bottom Inside	C3BC Bottom Outside	
Deployment Location									
Position									
Sample No. 06-	8243	8232	8236	8240	8256	8246	8249	8253	
Conventionals (%)									
Total Solids	41.0	41.9	43.7	40.4	40.9	38.3	37.5	37.8	
Total Organic Carbon @ 70°C	5.9	3.6	3.3	3.8	7.6	6.8	5.6	6.1	
Grain Size									
Gravel	2.0	-	-	-	5.8	-	-	-	
Sand	32.3	-	-	-	28.6	-	-	-	
Silt	26.8	-	-	-	24.8	-	-	-	
Clay	38.9	-	-	-	40.8	-	-	-	
Metals (mg/kg,dry)									
Copper	131	103	94.4	101	205	318	156	140	390
Lead	115	72.1	64.2	73.2	162	196	179	195	450
Mercury	0.235	0.300	0.262	0.414	0.590	0.522	0.539	0.652	0.59
Zinc	213	180	117	121	294	282	235	246	410
Semivolatiles (ug,kg, dry)									
Acenaphthene	624	65	26	62	83	34	121	97	500
Acenaphthylene	95	73	77	97	71	104	127	109	1300
Naphthalene	263	169	184	231	144	287	330	287	2100
Fluorene	879	97	108	110	113	149	197	132	540
Anthracene	4315 J	247	274	660	485	314	407	599	960
Phenanthrene	3184 J	651	771	431	1079	1079	1175	974	1500
Sum LPAH	9360 J	1302	1414	1591	1975	1933	2357	2198	5200
Fluoranthene	10614	1305	1227	1227	2654	2201	2453	2358	2500
Benzo(a)anthracene	2123 J	472	395	772	887	J 653	J 814	606	1600
Chrysene	3045 J	799	717	555	1375	J 1322	J 1514	1688	2800
Pyrene	8622	1314	1253	1392	2027	2227	2558	2453	3300
Benzo fluoranthenes	4219 J	1044	1028	1266	2497	J 2201	2330	2716	3600
Benzo(a)pyrene	2071	505	460	617	914	1131	1061	1122	1600
Dibenzo(a,h)anthracene	409	141	130	111	30	U 34	U 269	302	230
Indeno(1,2,3-cd)pyrene	788	396	364	360	392	570	704	766	690
Benzo(g,h,i)perylene	879	388	368	465	315	463	572	635	720
Sum HPAH	32770 J	6364	5942	6765 J	11061 J	10768 J	12275	12646	17000

Table C2: Results of Analysis of Settling Particulate Matter.

Marina Station Deployment Location Position Sample No. 06-	Totem						City						CMB SQO (EPA, 1989)	
	T1SC		T1BC		T3BC		C1SC		C2BC		C3BC			
	Surface Inside 8243 8243	Bottom Inside 8232 8236	Bottom Inside 61 101	Bottom Inside 76 65	Bottom Outside 73 8240	Surface Inside 8256 8246	Bottom Inside 95 8249	Bottom Inside 99 8253						
1-Methylnaphthalene	110	61	68	73		59	95	99	88					
2-Methylnaphthalene	211	J	101	115	118	110	166	171	151				670	
Dibenzofuran	483	76	77	77		92	119	128	109				540	
Carbazole	699	63	65	46		148	34	U	184				73	
Benzyl alcohol	66	UJ	29	UJ	30	30	UJ	30	UJ					
Retene	30	U	427	473	525	366	438	512	487					
Aniline	30	U	29	U	30	30	U	30	U					
Phenol	61	U	29	U	158	51	U	60	U				420	
Pyridine	305	U	288	U	297	298	U	335	U					
4-Methylphenol	206	19	J	26	88	30	U	107	211				670	
2,4-Dichlorophenol	30	U	29	U	30	30	U	34	U					
2,4-Dimethylphenol	30	UJ	29	UJ	30	30	UJ	30	UJ				29	
Pentaclorophenol	61	U	57	U	59	264	U	67	U				360	
Diethylphthalate	391	U	132	U	235	69	U	90	U				200	
Dimethyl phthalate	37	28	J	24	J	64	U	83	U				160	
Di-n-butyl phthalate	242	U	104	U	111	179	U	285	U				1400	
Butylbenzylphthalate	30	U	29	U	85	905	U	556	U				900	
Di-n-octyl Phthalate	2758	29	U	26	U	2184	U	34	U				6200	
Bis(2ethyl hexyl)phthalate	17661	3228	3080	2314		16095	J	9483	J				1300	
2-Chlorophenol	30	U	29	U	30	30	U	34	U					
1,3-Dichlorobenzene	30	U	29	U	30	30	U	34	U					
1,4-Dichlorobenzene	30	U	2.7	J	1.9	30	U	13	J				170	
1,2-Dichlorobenzene	30	U	29	U	30	30	U	34	U				110	
N-Nitroso-Di-N-Propylamine	30	U	29	U	30	30	U	34	U				50	
Nitrobenzene	30	UJ	29	UJ	30	30	UJ	34	UJ					
Isophorone	30	UJ	29	UJ	30	30	UJ	34	UJ					
2-Nitrophenol	30	UJ	29	UJ	43	30	UJ	34	UJ					
Bis(2-Chloroethoxy)Methane	30	U	29	U	30	30	U	58	U					
1,2,4-Trichlorobenzene	30	U	29	U	30	30	U	34	U					51
4-Chloro-3-Methylphenol	30	U	29	U	30	30	U	34	U					
2-Chloronaphthalene	30	U	29	U	30	30	U	34	U					
2-Nitroaniline	30	U	29	U	30	30	U	34	U					
2,4-Dinitrotoluene	30	U	29	U	30	30	U	34	U					
4-Chlorophenyl-phenylether	30	U	29	U	30	30	U	34	U					
4,6-Dinitro-2-Methylphenol	122	UJ	115	U	118	119	U	134	U					

Table C2: Results of Analysis of Settling Particulate Matter.

Marina Station Deployment Location Position Sample No. 06-	Totem						City						CMB SQO (EPA, 1989)				
	T1SC		T1BC		T2BC		T3BC		C1SC		C2BC			C3BC			
	Surface Inside	Bottom Inside		Surface Inside	Bottom Inside												
4-Bromophenyl-Phenylether	30	U	29	U	26	U	30	U	30	U	34	U	30	U	33	U	
Hexachlorobenzene	30	U	29	U	26	U	30	U	30	U	34	U	30	U	33	U	22
N-Nitrosodimethylamine	61	UJ	57	UJ	48	UJ	59	UJ	59	UJ	67	UJ	62	UJ	66	UJ	28
Bis(2-Chloroethyl)Ether	30	U	29	U	26	U	30	U	30	U	34	U	30	U	33	U	
2-Methylphenol	30	U	29	U	26	U	30	U	30	U	34	U	30	U	33	U	63
2,2'-Oxybis[1-chloropropane]	30	U	29	U	26	U	30	U	30	U	34	U	30	U	33	U	
Hexachloroethane	30	U	29	U	26	U	30	U	30	U	34	U	30	U	33	U	
Benzoic Acid	609	UJ	2279	J	1836	J	2880	J	2958	J	2149	J	2497	J	2271	J	650
4-Chloroaniline	30	U	29	U	26	U	30	U	30	U	34	U	30	U	33	U	
Hexachlorobutadiene	30	U	29	U	26	U	30	U	30	U	34	U	30	U	33	U	11
Hexachlorocyclopentadiene	30	U	29	U	26	U	30	U	30	U	34	U	30	U	33	U	
2,4,6-Trichlorophenol	30	U	29	U	26	U	30	U	30	U	34	U	30	U	33	U	
2,4,5-Trichlorophenol	30	U	29	U	26	U	30	U	30	U	34	U	27	NJ	33	U	
2,6-Dinitrotoluene	30	U	29	U	26	U	30	U	30	U	34	U	30	U	33	U	
3-Nitroaniline	30	UJ	29	UJ	26	UJ	30	UJ	30	UJ	34	UJ	30	UJ	33	UJ	
2,4-Dinitrophenol	305	UJ	288	U	262	U	297	U	298	U	335	U	308	U	331	U	
4-Nitrophenol	30	UJ	29	UJ	26	UJ	30	UJ	59	UJ	34	UJ	61	UJ	64	UJ	
4-Nitroaniline	30	UJ	29	UJ	26	UJ	30	UJ	30	UJ	34	UJ	30	UJ	33	UJ	
1,2-Diphenylhydrazine	30	U	29	U	26	U	30	U	30	U	34	U	30	U	62	U	
Caffeine	30	U	29	U	26	U	30	U	30	U	34	U	30	U	33	U	
Benzidine	30	U	29	U	26	U	30	U	30	U	34	U	30	U	33	U	
3,3'-Dichlorobenzidine	30	U	29	U	26	U	30	U	30	U	34	U	30	U	33	U	
3B-Coprostanol	61	U	57	U	3932	U	59	U	1322	U	67	U	62	U	66	U	
Butyltins (ug/kg, dry)																	
Monobutyltin Chloride	35		26		35		34		35		50		47		48		
Dibutyltin Chloride	80		61		56		68		150		210		180		140		
Tributyltin Chloride	160		190		140		170		300		500		400		290		
Tetrabutyltin	5.8	U	5.8	U	5.6	U	5.7	U	5.8	U	13	U	6.3	U	6.5	U	

- = Not analyzed

U = Not detected at detection limit shown

J = Estimated concentration

UJ = Estimated detection limit

NJ = Presumptive evidence of material- estimated concentration

Bold = Value exceeds Commencement Bay Sediment Quality Objective (EPA, 1989)

Table C3: Hydrocarbon Analysis of Settling Particulate Matter.

Station	Sample No.	Description
City Marina		
C1B	68246	Contains lube oil, weathered #2 diesel oil, and three unidentified gasoline range compounds.
C2B	68249	Contains lube oil, weathered #2 diesel oil, and late eluting homologous series of peaks in the paraffin wax range.
C3B	68253	Contains lube oil and weathered #2 diesel oil.
C1S	68256	Contains lube oil and weathered #2 diesel oil.
Totem Marina		
TB1B	68232	Contains lube oil and weathered #2 diesel oil.
TB2B	68236	Contains lube oil and weathered #2 diesel and a late eluting homologous series of peaks in the paraffin wax range.
TB3B	68240	Contains lube oil with several unidentified peaks.
TB1S	68243	Contains lube oil and weathered #2 diesel oil.

Table C4: Results of Analysis of Bottom Sediments.

Marina Station Position Sample No. 06-	Totem				City				CMB SQO (EPA, 1989)	
	T1S-S Inside	T1B-S Inside	T1B-SD (Dup)	T2B-S Inside	T3B-S Outside	C1S-S Inside	C1B-S Inside	C2B-S Inside		C3B-S Outside
Conventional (%)										
Total Solids	44.8	44.2	44.6	45.9	45.9	33.9	35.4	39.7	39.2	
Total Organic Carbon @ 70°C	3.9	3.7	3.7	3.4	3.7	6.8	7.7	5.9	6.3	
Grain Size										
Gravel	3.9	0.8	0.5	4.7	0.1	1.1	0.6	1.0	5.4	
Sand	25	24.6	30.4	22.2	18.4	21.7	21.7	29.7	21.4	
Silt	45	45.4	43	44.5	56.5	47	49.7	43.9	48.3	
Clay	26.1	29.3	26.2	28.5	25.1	30.2	28	25.5	24.9	
Metals (mg/kg,dry)										
Copper	131	129	123	115	114	191	174	184	155	390
Lead	116	116	116	90.7	116	220	248	231	246	450
Mercury	0.464	0.455	0.535	0.390	0.529	0.607	0.624	0.663	0.733	0.59
Zinc	181	170	169	152	139	336	315	292	270	410
Semivolatiles (ug,kg, dry)										
Acenaphthene	278	63	513	137	112	123	99	3715	159	500
Acenaphthylene	418	102	233	164	176	146	142	349	154	1300
Naphthalene	743	275	795	456	545	418	391	803	486	2100
Fluorene	318	104	694	203	145	191	138	7110	177	540
Anthracene	1166	305	544	606	463	522	427	1575	629	960
Phenanthrene	1531	514	6838	1001	850	1088	813	31300	887	1500
Sum LPAH	4454	1363	9617	2567	2291	2488	2010	44852	2492	5200
Fluoranthene	2836	1061	6229	2149	1444	2906	1810	22100	2166	2500
Benzo(a)anthracene	1627	508	1027	1018	766	797 J	625	3732	679 J	1600
Chrysene	2245	24 U	1966	1470	1079	1844 J	1349	3785	1636	2800
Pyrene	4881 J	1653	6107	3141	2358	3924	2654	28000	2975	3300
Benzo fluoranthenes	2577 J	1279	2593 J	2549 J	2219	2897 J	2427	5568	2610 J	3600
Benzo(a)pyrene	2027	639	1148	1148	1105	1375 J	1088	2105	1096	1600
Dibenzo(a,h)anthracene	694	175	290	365	367	33 U	356	299	348 J	230
Indeno(1,2,3-cd)pyrene	1009	492	769	676	766	186 J	825	1218	856 J	690
Benzo(g,h,i)perylene	1053	450	757	667	800	650 J	667	1253	706 J	720
Sum HPAH	18949 J	6257	20886 J	13183 J	10904	14574 J	11801	68025	13037 J	17000

Table C4: Results of Analysis of Bottom Sediments.

Marina Station Position Sample No. 06-	Totem				City				CMB SQO (EPA, 1989)	
	T1S-S	T1B-S	T1B-SD	T2B-S	T3B-S	C1S-S	C1B-S	C2B-S		C3B-S
	Inside 8261	Inside 8257	(Dup) 8258	Inside 8259	Outside 8260	Inside 8265	Inside 8262	Inside 8263		Outside 8264
1-Methylnaphthalene	172	66	179	95	145	103	101	686	123	
2-Methylnaphthalene	250 J	115	303 J	183 J	246 J	191	179	1253	193	670
Dibenzofuran	169	100	698	205	144	150	112	3202	131	540
Carbazole	117	44	428	73	71	108	30 U	425	144	
Benzyl alcohol	23 UJ	24 UJ	26 UJ	25 UJ	28 UJ	33 U	30 UJ	30 U	30 UJ	73
Retene	731	412	586	532	896	369	566	30 U	600	
Aniline	23 U	24 U	26 U	25 U	28 U	33 U	30 U	30 U	30 U	
N-nitrosodiphenylamine	23 U	24 U	26 U	25 U	28 U	44	30 U	30 U	30 U	28
Pyridine	236 U	244 U	260 U	256 U	REJ	327 U	305 U	304 U	305 U	
Phenol	44 U	24 U	43 U	28 U	51 U	33 U	64 U	64 U	305 U	420
4-Methylphenol	151	22 J	43	20 J	76	60	90	90	59	670
2,4-Dichlorophenol	23 U	24 U	26 U	25 U	28 U	33 U	30 U	30 U	30 U	
2,4-Dimethylphenol	23 UJ	24 UJ	26 UJ	25 UJ	28 UJ	33 UJ	30 UJ	17 J	30 UJ	29
Pentachlorophenol	80 NJ	49 U	95	100	80 NJ	65 U	61 U	87	61 U	360
Diethylphthalate	280 U	133 U	133 U	78 U	627 U	104 U	87 U	69 U	64 U	200
Dimethyl phthalate	28	23 J	44	41	30	59	105	55	46	160
Butylbenzylphthalate	124	90	164	95	175	275	515	231	369	900
Di-n-octyl Phthalate	23 U	59	26 U	25 U	28 U	33 U	30 U	30 U	30 U	6200
Di-n-butyl phthalate	186 U	71 U	107 U	77 U	253 U	137 U	160 U	117 U	164 U	1400
Bis(2EH)phthalate	2906	1810	3202	2053	1801	5742	6751 J	4115	4785	1300
2-Chlorophenol	23 U	24 U	26 U	25 U	28 U	33 U	30 U	30 U	30 U	
1,3-Dichlorobenzene	23 U	24 U	26 U	25 U	28 U	33 U	30 U	30 U	30 U	170
1,4-Dichlorobenzene	30	9.6 J	19 J	13 J	16 J	15 J	21 J	37	39	110
1,2-Dichlorobenzene	23 U	24 U	26 U	25 U	28 U	33 UJ	30 U	3.0 J	30 U	50
N-Nitroso-di-n-propylamine	23 U	24 U	26 U	25 U	28 U	33 U	30 U	30 U	30 U	
Nitrobenzene	23 UJ	24 UJ	26 UJ	25 UJ	28 UJ	33 UJ	30 UJ	30 UJ	30 UJ	
Isophorone	23 UJ	24 UJ	26 UJ	25 UJ	28 UJ	33 UJ	30 UJ	30 UJ	30 UJ	
2-Nitrophenol	23 UJ	24 UJ	26 UJ	25 UJ	28 UJ	33 UJ	30 UJ	30 UJ	30 UJ	
Bis(2-Chloroethoxy)Methane	23 UJ	24 U	26 U	25 U	28 U	33 U	30 U	30 U	30 U	51
1,2,4-Trichlorobenzene	23 U	24 U	26 U	25 U	28 U	33 U	30 U	30 U	30 U	
4-Chloro-3-Methylphenol	23 U	24 U	26 U	25 U	28 U	33 U	30 U	30 U	30 U	
2-Chloronaphthalene	23 U	24 U	26 U	25 U	28 U	33 U	30 U	30 U	30 U	
2-Nitroaniline	23 U	24 U	26 U	25 U	28 U	33 U	30 U	30 U	30 U	
2,4-Dinitrotoluene	23 U	24 U	26 U	25 U	28 U	33 U	30 U	30 U	30 U	
2,4-Dinitro-2-Methylphenol	94 UJ	97 U	104 UJ	103 UJ	111 UJ	131 U	122 U	122 U	122 U	
4-Bromophenyl-Phenylether	23 U	24 U	26 U	25 U	28 U	33 U	30 U	30 U	30 U	22
Hexachlorobenzene	23 U	24 U	26 U	25 U	28 U	33 U	30 U	30 U	30 U	
Bis(2-Chloroethyl)Ether	23 U	24 U	26 U	25 U	28 U	33 U	30 U	30 U	30 U	
2-Methylphenol	23 U	24 U	6.4 J	25 U	28 U	33 U	30 U	7 J	1.7 J	63
2,2'-Oxybis[1-chloropropane]	23 U	24 U	26 U	25 U	28 U	33 U	30 U	30 U	30 U	
Hexachloroethane	23 U	24 U	26 U	25 U	28 U	33 U	30 U	30 U	30 U	

Table C4: Results of Analysis of Bottom Sediments.

Marina Station Position Sample No. 06-	Totem				City				CMB SQO (EPA, 1989)	
	T1S-S Inside 8261	T1B-S Inside 8257	T1B-SD (Dup) 8258	T2B-S Inside 8259	T3B-S Outside 8260	C1S-S Inside 8265	C1B-S Inside 8262	C2B-S Inside 8263		C3B-S Outside 8264
Benzoic Acid	472 UJ	565 UJ	519 UJ	512 UJ	REJ	793 UJ	974 UJ	974 J	794 UJ	650
4-Chloroaniline	23 U	24 U	26 U	25 U	28 U	33 U	30 U	30 U	30 U	
Hexachlorobutadiene	23 U	24 U	26 U	25 U	REJ	33 U	30 U	30 U	30 U	11
Hexachlorocyclopentadiene	23 U	24 U	26 U	25 U	28 U	33 U	30 U	30 U	30 U	
2,4,6-Trichlorophenol	23 U	24 U	26 U	25 U	28 U	33 U	30 U	30 U	30 U	
2,4,5-Trichlorophenol	23 U	24 U	26 U	25 U	28 U	36	30 U	30 U	30 U	
2,6-Dinitrotoluene	23 U	24 U	26 U	25 U	28 U	33 U	30 U	30 U	30 U	
3-Nitroaniline	23 UJ	24 UJ	26 UJ	25 UJ	28 UJ	33 UJ	30 UJ	30 UJ	30 UJ	
2,4-Dinitrophenol	236 UJ	244 U	260 UJ	256 UJ	278 UJ	327 U	305 U	304 U	305 U	
4-Nitrophenol	23 UJ	487 UJ	26 UJ	25 UJ	28 UJ	33 UJ	30 UJ	30 UJ	30 UJ	
4-Nitroaniline	23 UJ	24 UJ	26 UJ	25 UJ	28 UJ	33 UJ	30 UJ	30 UJ	30 UJ	
1,2-Diphenylhydrazine	23 U	24 U	26 U	25 U	28 U	33 U	30 U	30 U	30 U	
Caffeine	23 U	24 U	26 U	25 U	28 U	33 U	30 U	30 U	30 U	
Benzidine	23 U	24 U	26 U	25 U	28 U	33 U	30 U	30 U	30 U	
3,3'-Dichlorobenzidine	23 U	24 U	26 U	25 U	28 U	33 U	30 U	30 U	30 U	
3B-Coprostanol	47 U	49 U	52 U	51 U	56 U	65 U	61 U	61 U	61 U	
Butyltins (ug/kg, dry)										
Tetrabutyltin	5.2 U	5.4 U	5.4 U	5.4 U	5.3 U	6.7 U	13 U	6 U	5.8 U	
Tributyltin Chloride	220	160	210	210	230	440	510	380	330	
Dibutyltin Chloride	100	120	120	92	88	230	220	180	170	
Monobutyltin Chloride	39	42	55	43	39	53	26	38	44	

U = Not detected at detection limit shown

J = Estimated concentration

UJ = Estimated detection limit

NJ = Presumptive evidence of material, estimated concentration

REJ = Rejected value

Bold = Value exceeds Commencement Bay Sediment Quality Objective (EPA, 1989)

Table C5: Hydrocarbon Analysis of Bottom Sediments.

Station	Sample No.	Description
City Marina		
C1B-S	68262	Contains a unresolved envelope of peaks eluting in the lube oil range with fluoranthene and pyrene as the largest peaks. Suggests that this sample contains weathered creosote.
C2B-S	68263	Contains a unresolved envelope of peaks eluting in the lube oil range with fluoranthene, pyrene and phenathrene as the largest peaks. Suggests that this sample contains weathered creosote.
C3B-S	68264	Contains a unresolved envelope of peaks eluting in the lube oil range with fluoranthene, pyrene, and phenathrene as the largest peaks. Suggests that this sample contains weathered creosote. A late eluting homologous series of peaks in the paraffin wax range is also present.
C1S-S	68265	Contains a unresolved envelope of peaks eluting in the lube oil range with fluoranthene and pyrene as the largest peaks. Suggests that this sample contains weathered creosote.
Totem Marina		
T1B-S	68257	Contains a unresolved envelope of peaks eluting in the lube oil range with fluoranthene and pyrene as the largest peaks. Suggests that this sample contains weathered creosote.
T1B-S (Duplicate)	68258	Contains a unresolved envelope of peaks eluting in the lube oil range with fluoranthene and pyrene as the largest peaks. Suggests that this sample contains weathered creosote.
T2B-S	68259	Contains a unresolved envelope of peaks eluting in the lube oil range with fluoranthene and pyrene as the largest peaks. Suggests that this sample contains weathered creosote.
T3B-S	68260	Contains a unresolved envelope of peaks eluting in the lube oil range with fluoranthene, pyrene, and phenathrene as the largest peaks. Suggests that this sample contains weathered creosote.
T1S-S	68261	Contains a unresolved envelope of peaks eluting in the lube oil range with fluoranthene, pyrene, and phenathrene as the largest peaks. Suggests that this sample contains weathered creosote.

Table C6: Compounds Exceeding the Commencement Bay Sediment Quality Objectives or Other Applicable Guidelines in Settling Particulate Matter and Bottom Sediments.

City Marina			Totem Marina		
SPM Surface	SPM Bottom ¹	Sediment	SPM Surface	SPM Bottom ¹	Sediment
Inside			Inside		
Mercury	Dibenzo (a,h)anthracene	Mercury	Acenaphthene	Bis(2EH)phthalate	Phenanthrene
Fluoranthene	Indeno(1,2,3-cd)pyrene	Acenaphthene	Fluorene	Benzoic Acid	LPAH
Butylbenzyl Phthalate	Bis(2EH)phthalate	Fluorene	Anthracene	Tributyltin	Fluoranthene
Bis(2EH)phthalate	Benzoic Acid	Anthracene	Phenanthrene		Pyrene
Benzoic Acid	Tributyltin	Phenanthrene	LPAH		Dibenzo(a, h)anthracene
Tributyltin		LPAH	Fluoranthene		Bis(2EH)phthalate
		Fluoranthene	Benzo(a)anthracene		Tributyltin
		Benzo(a)anthracene	Chrysene		
		Chrysene	Pyrene		
		Pyrene	Benzo fluoranthenes		
		Benzo fluoranthenes	Benzo(a)pyrene		
		Benzo(a)pyrene	Dibenzo (a,h)anthracene		
		Dibenzo(a,h)anthracene	Indeno(1,2,3-cd)pyrene		
		Indeno(1,2,3-cd)pyrene	Benzo(g,h,i)perylene		
		Benzo(g,h,i)perylene	HPAH		
		HPAH	Bis(2EH)phthalate		
		2-Methylnaphthalene	Tributyltin		
		Dibenzofuran			
		N-nitrosodiphenylamine			
		Bis(2EH)phthalate			
		Benzoic Acid			
		Tributyltin			
Outside			Outside		
Not Tested	Mercury	Mercury	Not Tested	Butylbenzyl Phthalate	Dibenzo(a,h)anthracene
	Dibenzo(a,h)anthracene	Dibenzo(a,h)anthracene		Bis(2EH)phthalate	Indeno(1,2,3-cd)pyrene
	Indeno(1,2,3-cd)pyrene	Indeno(1,2,3-cd)pyrene		Benzoic Acid	Benzo(g,h,i)perylene
	Bis(2EH)phthalate	Bis(2EH)phthalate		Tributyltin	Bis(2EH)phthalate
	Benzoic Acid	Tributyltin			Tributyltin
	Tributyltin				

SPM = Settling particulate matter

Sediment = Bottom sediment

¹= Bottom traps pooled inside marina