

## 5.0 SEDIMENT CHEMISTRY

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Sediment chemical results, consisting of organic compounds and metals for creek and reference areas, are presented in this section. Results describe distribution patterns within the creek and identify chemicals of potential concern (COPCs) through comparison with reference sediments. Final chemicals of concern (COCs) are identified in Section 7, synthesizing toxicity, sediment chemistry, and bioaccumulation results. Surface sediment distributions are examined in relation to distance from active and historic combined sewer overflows (CSOs) and across surveys, which include wet and dry weather events. The distribution of subsurface sediment chemicals is discussed qualitatively to estimate the vertical extent of contamination in the creek. Results are organized into chemical suites, consisting of metals, polycyclic aromatic hydrocarbons (PAH), organochlorine pesticides, and polychlorinated biphenyl (PCB) congeners. Surface and subsurface sediment results for each station are presented in Appendices A1 and A2, respectively. Distribution plots for surface and subsurface data are presented in Appendices B1 and B2.

Sediment chemicals measured in October 1998 and April 2000 are compared to the upper 95th percentile predictive limits (UPL) calculated using reference site data collected during the 2000 survey. October 1998 creek data are included in this comparison since only one reference site was used in the 1998 survey, and because the 1998 and 2000 surveys were conducted during wet weather. Sediment data from the single dry weather study in October 1999 are compared to the upper 95<sup>th</sup> UPL calculated using synoptically collected reference data. This approach is similar to the reference envelope tolerance limit used to evaluate amphipod toxicity results (see Section 4). Comparisons of creek and reference area sediments are made using total organic carbon (TOC) normalized data (e.g., ng or µg [chemical] per gram TOC in dry weight). This approach is consistent with methods used to address varying TOC concentrations in other sediment investigations (Schwartz et al. 1994; MacDonald 2000). All other presentations and discussions of chemical data are based on sediment dry weight.

Yosemite Creek chemicals of potential concern (COPCs) are presented in Section 5.4. This list includes individual (e.g., lead) and sums of chemicals (e.g., total PCBs) that exceed reference area UPLs and one-half of the corresponding effects-range-median (½-ERM) value (Long et al. 1995) in two or more surveys. Final chemicals of concern (COCs) are identified in Section 7 following exposure evaluations for those chemicals known to bioaccumulate in the aquatic food web (see Section 6).

### 5.1 REFERENCE AREA

San Francisco Bay reference area sediments were sampled at one location in October 1998, six locations in October 1999 and five locations in April 2000. Locations and sample inventory for each station are shown in Figure 2-1 and Table 2-2 (Section 2), respectively. These primarily fine-grained, low-TOC sediments were relatively free of contamination across all three surveys. Metal concentrations were commensurate with pristine sediments located along the California coast and elsewhere, except for copper, mercury, nickel and silver, which were elevated 2 to 8 times at in-bay reference sites (Table 5-1), presumably from historic mining activities and in the

case of mercury, from historic manufactured gas plants. Mean reference area concentrations were in excellent agreement with Regional Monitoring Program (RMP) data collected from 1993 to 1997 from a total of 32 San Francisco Estuary stations, including five locations sampled in this study.

Reference area concentrations of total PCB<sub>20</sub> (sum of 20 congeners), total DDT (sum of six metabolites) and total Chlordane (sum of four compounds) were similar to background concentrations measured in nearshore sediments of relatively unimpacted areas (Table 5-2). Trace concentrations of these ubiquitous anthropogenic contaminants to otherwise pristine sediments are largely from atmospheric fallout and stormwater runoff. These and other chlorinated hydrocarbons are found at trace concentrations in areas far-removed from human populations, including the mid-Pacific Ocean and the Antarctic (Kennicut et al. 1992).

Reference sediment concentrations of the sum of 13 PAH compounds (total PAH<sub>13</sub>) were moderately elevated compared to other pristine areas (Table 5-2); however, at less than 1 part-per-million (i.e., <1000 ng·g<sup>-1</sup>), concentrations were well below recognized threshold levels (e.g., ERL, ERM). Background concentrations measured at in-bay reference stations are most likely from atmospheric fallout of fossil fuel combustion particulates (Battelle 2003).

**Table 5-1. Mean metal concentrations for reference sites (all 3 surveys) and other areas.**

Metal ( $\mu\text{g}\cdot\text{g}^{-1}$ )	Reference Area	San Francisco Bay <sup>1</sup>	Clean California Coast <sup>2</sup>	Southwest English Estuary <sup>2</sup>	Continental Crust <sup>3</sup>
Arsenic	6.98	5.65 - 10.6	12	6.4	2
Cadmium	0.32	0.23 - 0.89	0.33	0.23	0.2
Chromium	96.4	64 - 123.4	22	30	126
Copper	38.1	18.9 - 53.7	18.3	7	45
Lead	18.0	7.7 - 42	10	25	15
Mercury	0.23	0.09 - 0.53	0.04	0.03	0.06
Nickel	86.7	59.9 - 109.2	-	17	56
Selenium	0.25	0.06 - 0.65	-	0.11	0.12
Silver	0.52	0.01 - 0.56	-	0.07	0.07
Zinc	103.2	61.7 - 181.3	43	59	40

<sup>1</sup>ranges in mean concentrations from SFEI RMP Report 1999 ([http://www.sfei.org/rmp/1999/RMP99\\_Results.pdf](http://www.sfei.org/rmp/1999/RMP99_Results.pdf));

<sup>2</sup>from Kennish (1997); <sup>3</sup>from Wedepohl (1995)

**Table 5-2. Mean organic chemical(s) concentrations for reference sites (all 3 surveys) and other "clean" areas.**

Organic Chemical(s) ( $\text{ng}\cdot\text{g}^{-1}$ )	Reference Area	San Francisco Bay <sup>1</sup>	Clean California Coast <sup>2</sup>	North Atlantic <sup>2</sup>	Baltic Sea <sup>2</sup>
Total PAH	732	83.8 - 2695.5	160	120	258
Total DDT	5.67	0.39 - 17.84	5-30	0.4	2
Total Chlordane	0.9	0.18 - 7.77	-	-	-
Dieldrin	0.7	ND - 1.07	-	-	-
Total PCB <sub>20</sub>	7.84	0.45 - 41.77	1-13	15	8.4-10.8

<sup>1</sup>ranges in mean concentrations from SFEI RMP Report 1999 ([http://www.sfei.org/rmp/1999/RMP99\\_Results.pdf](http://www.sfei.org/rmp/1999/RMP99_Results.pdf));

<sup>2</sup>adopted from Table 2.1, Appendix 2 in Kennish (1997)

## 5.2 YOSEMITE CREEK

Yosemite Creek sediments were sampled at 13 locations in 1998, spanning from the creek end to the creek mouth. Six stations located between the historic CSO to the reconfigured CSO near Fitch Street, along with Stations 4C and 5N were resampled in 1999 and 2000. Sampling locations are shown in Figure 2-1, Section 2 for all surveys. In addition to the creek area, three surface sediment stations sampled by the U.S. Navy in May 2001 (see Section 2.1.1) were included with the April 2000 data set in this investigation following a request by the Regional Board. Selected results for these stations are presented in Appendix A1 (Hunters Point Validation Study). A total of 32 surface sediment samples in and around Yosemite Creek were analyzed between the SFPUC and U.S. Navy studies.

Subsurface cores were collected to the target depth of 4 ft at two (1N and 4C) out of the five stations due to refusal. Core depths reached 2 ft at Stations 2N and 3S, and 3 ft at Station 5N. It was not possible to quantify vertical distributions throughout the creek due to the incomplete data set. Instead vertical trends were evaluated for individual cores that reached a minimum of depth of 3 ft, producing three core segments.

Yosemite Creek chemical concentrations often decreased with depth and displayed no clear trends with distance from the creek end. However, lead, zinc, mercury, PCBs and several organochlorine pesticides were elevated in two or more surveys at multiple stations, including historic CSO 41 at the creek end, reconfigured CSO 40 located mid-creek, and CSO 42 at the creek mouth. The highest chemical concentrations in surface sediments were measured at either Station 3N, opposite CSO 40, or at Station 5N near the creek mouth. In general, surface sediment chemical concentrations were highest in 1998, and diminished with time, except for a single station (5N) that had the highest concentration for many contaminants in April 2000.

Table 5-3 shows Pearson correlation results for selected contaminants using results from all surveys, including the three Navy stations (n=32). Many organic as well as inorganic contaminants were significantly correlated with TOC; however, similar relationships were not observed for grain size characteristics, including percent fines. These results indicate that many Yosemite Creek contaminants are sequestered in sediment organic material and may not be readily bioavailable to aquatic biota.

**Table 5-3. Correlation results for selected chemicals with TOC and grain size (n=32).**

	Cadmium	Copper	Lead	Mercury	Nickel	Zinc	Total PAH <sub>13</sub>	Total Chlordane	Total DDT	Total Dieldrin	Total PCB <sub>20</sub>
<b>Percent fines</b>											
r	0.15	<b>0.33</b>	0.19	0.25	<b>0.52</b>	<b>0.32</b>	0.16	0.17	0.12	0.08	0.12
p	0.359	0.033	0.234	0.116	0.001	0.044	0.304	0.278	0.454	0.598	0.449
<b>TOC</b>											
r	<b>0.42</b>	<b>0.59</b>	<b>0.63</b>	<b>0.60</b>	0.28	<b>0.63</b>	<b>0.52</b>	<b>0.49</b>	<b>0.52</b>	<b>0.69</b>	<b>0.39</b>
p	0.007	<0.001	<0.001	<0.001	0.072	<0.001	0.001	0.001	<0.001	<0.001	0.012

r=correlation coefficient; p=probability; **bold**=significant positive correlation at p< 0.05.

### 5.3.1 Metals

**Surface results.** Metal concentrations for Yosemite Creek surface sediments are summarized in Table 5-4. Mercury was the only metal besides nickel with concentrations that exceeded its ERM guideline value. Creek sediments with mercury concentrations above the ERM of  $0.7 \mu\text{g}\cdot\text{g}^{-1}$  were found at Stations 3S and 3N ( $0.94$  and  $0.73 \mu\text{g}\cdot\text{g}^{-1}$ , respectively) in 1998, and at Station 5N in April 2000 (Figure 5-1). Stations 3S and 3N also had moderately high concentrations of TOC (e.g.,  $>2\%$ ), which would tend to concentrate mercury in these sediments. An ERM equivalent concentration was recorded at Station 1N near the creek end in 1998. Mercury concentrations measured outside the creek mouth (from the Navy study) ranged from  $0.466$  to  $0.559 \mu\text{g}\cdot\text{g}^{-1}$ , similar to average concentrations measured within the creek. Surface sediment distributions of mercury shown in Figure 5-1 are representative of general patterns observed for other metals between surveys showing: 1) no consistent trend between years; 2) localized contamination at only a few stations (i.e., 5N); and 3) consistent evidence that contaminants are not broadcast from the creek mouth to South Basin.

Nickel was the only other metal that exceeded the ERM value; however, nickel concentrations typically exceed the ERM of  $51.6 \mu\text{g}\cdot\text{g}^{-1}$  in reference areas throughout the bay both in this and other studies (Table 5-5; Hunt et al. 1998a).

Selenium, like mercury, is a trace element of concern due to its high potential for bioaccumulation. Selenium concentrations within the creek ranged from  $0.16$  to  $0.96 \mu\text{g}\cdot\text{g}^{-1}$ , with an average concentration of  $0.39 \mu\text{g}\cdot\text{g}^{-1}$ . ERM guidelines have not been developed for selenium; however, concentrations below  $0.33 \mu\text{g}\cdot\text{g}^{-1}$  are reported as uncontaminated background for San Francisco Bay sediments (Walters and Gartner 1985). The average reference sediment concentration across all surveys was  $0.25 \mu\text{g}\cdot\text{g}^{-1}$ .

Other metals, including copper, lead and zinc were elevated compared to corresponding reference area sediments in 1999 and 2000. None of these metals exceeded the corresponding ERM value in surface sediments, however, lead and zinc consistently exceeded  $\frac{1}{2}$ -ERM. Elevated concentrations of lead and zinc almost always were found together, while elevated concentrations of copper were less frequent and uncorrelated with any other metals. Co-occurring lead and zinc often indicate either a common source or a common partitioning mechanism for the two metals. One of the most common sources of lead and zinc is from auto emissions (e.g., trace lead from fuel and catalytic converters) and particulate matter from brakes via stormwater runoff.

**Table 5-4. Surface metal results, all surveys (n=32 stations) ( $\mu\text{g}\cdot\text{g}^{-1}$ , ppm dry weight).**

Metal	Minimum	Maximum	Maximum Station	Mean	Standard Deviation	ERM <sup>1</sup>	Reference Mean <sup>2</sup>
Arsenic	5.16	12.0	1N	8.95	1.68	70	7.29
Cadmium	0.37	1.69	1N	0.76	0.30	9.6	0.32
Chromium	93.0	202	SB-01	133	23.7	370	96.4
Copper	69.8	141	5S	97.0	14.9	270	39.3
Lead	69.3	197	1N	130	26.4	218	18.2
Mercury	0.35	1.21	5N	0.59	0.17	0.71	0.24
Nickel	55.7	152	2S	91.3	16.1	51.6	86.4
Selenium	0.16	0.96	1N	0.39	0.16	NA	0.25
Silver	0.33	1.06	1N	0.59	0.16	3.7	0.31
Zinc	164	316	1N	221	32.8	410	105

<sup>1</sup> Long et al. (1995); <sup>2</sup>=mean reference concentration for all 3 surveys

**Subsurface results.** Subsurface metal distributions were complex, indicating localized inputs to the creek with varying periodicity. For example, mercury concentrations varied with depth and station, with the upper 0-1 ft composite at the creek end showing the highest concentration ( $1.49 \mu\text{g}\cdot\text{g}^{-1}$ ), followed by the 1-2 ft segment from Station 3S and the 0-1 ft core from Station 5N (Table 5-5, Figure 5-2). Vertical trends in individual cores were opposite those reported for Islais and Mission Creeks, which also receive CSO inputs (Battelle 2003), with many Yosemite concentrations actually decreasing with depth. Similar distributions were observed for chromium, copper, lead and zinc, with the highest concentrations of these metals measured in the 0-1 ft core segment at Station 1N. In general, metal concentrations measured below 2 ft were commensurate with in-bay reference surface sediment concentrations; however, additional subsurface data are needed to confirm this trend since several of the lower core segments were not collected.

**Table 5-5. Mean concentrations of lead, mercury and zinc in subsurface sediments ( $\mu\text{g}\cdot\text{g}^{-1}$ , ppm dry weight).**

Depth	Lead		Mercury		Zinc	
	Mean	Max. Station; Concentration	Mean	Max. Station; Concentration	Mean	Max. Station; Concentration
0-1 ft	293.4	1N; 811.0	0.66	1N; 1.49	371.4	1N; 830.0
1-2 ft	266.4	3S; 636.0	0.55	3S; 0.98	333.8	3S; 678.0
2-3 ft	61.2	4C; 169.3	0.25	4C; 0.63	117.3	4C; 230.4
3-4 ft	8.8	4C; 8.8	0.06	4C; 0.07	73.4	1N; 84.0

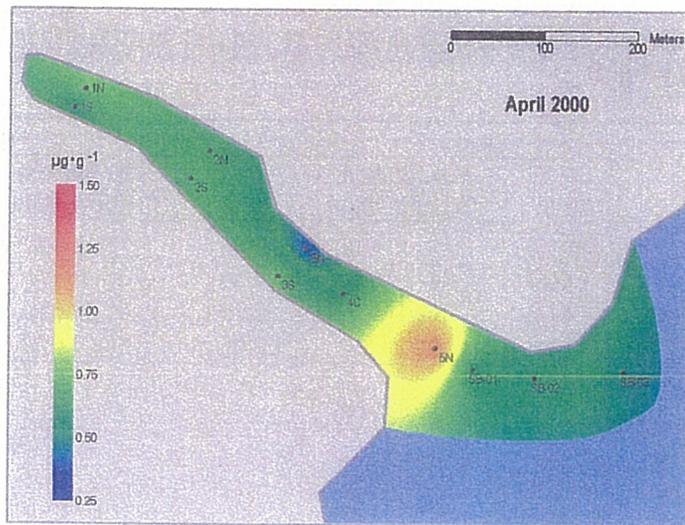
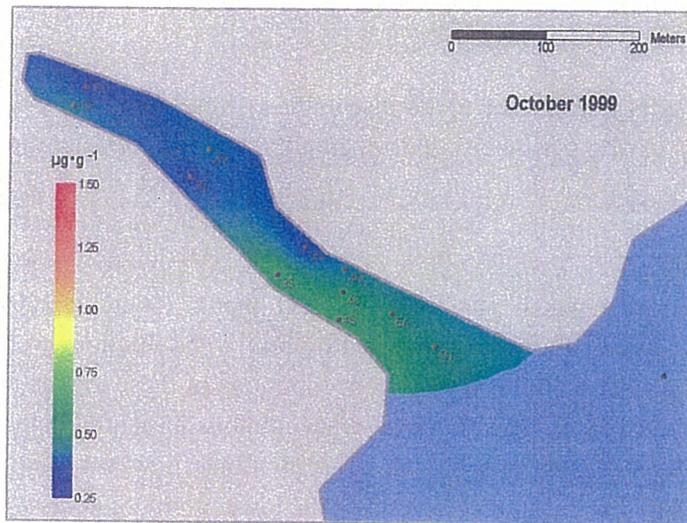
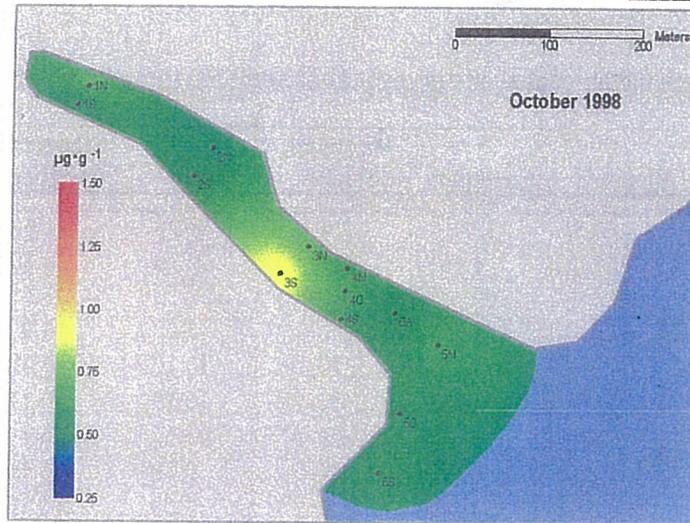


Figure 5-1. Surface sediment distributions of mercury – 1998 (wet), 1999 (dry) & 2000 (wet).

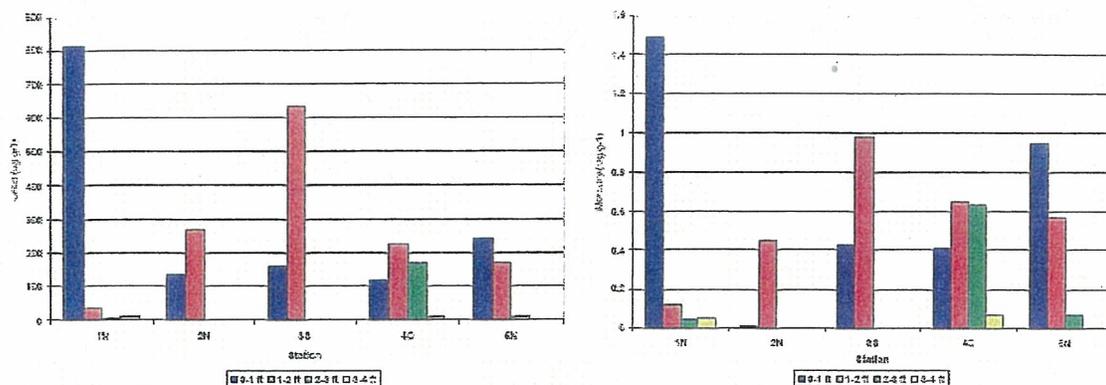


Figure 5-2. Subsurface distributions of lead and mercury - October 1998.

### 5.3.2 Polycyclic Aromatic Hydrocarbons (PAH)

Total PAHs are reported as the sum of 13 compounds (total PAH<sub>13</sub>) and the sum of all 41 PAH compounds measured (total PAH<sub>41</sub>). Total PAH<sub>13</sub>, high molecular weight (HMW) PAH, and low molecular weight (LMW) PAH were calculated to compare creek results with corresponding ERM values. High and low molecular weight PAHs correspond to the sum of six and seven PAH compounds identified in Long et al. (1995), respectively.

**Surface results.** Yosemite Creek total PAH<sub>13</sub> concentrations, like metals, displayed complex distribution patterns throughout the creek (Figure 5-3) and were significantly correlated with sediment TOC but not percent fines (Table 5-3). The highest PAH concentration was measured at Station 5N in 2000 (Total PAH<sub>41</sub> = 16,163 ng·g<sup>-1</sup>). Except for this station, PAHs measured in 2000 generally displayed similar concentrations to those measured in previous years. All of the creek sediments had total PAH<sub>13</sub> concentrations well below one-fourth the ERM value of 44,792 ng·g<sup>-1</sup>. Creek surface sediments also were well below separate ERM guideline values for HMW and LMW PAHs. Concentrations for these weight classes exceeded the corresponding ½-ERM values for Station 5N in April 2000 only. PAH results for all creek surface sediments are summarized in Table 5-6.

Concentrations of HMW PAH compounds were roughly 5-6 times higher than LMW PAH compounds, indicating pyrogenic sources presumably from partially combusted fossil fuels. All known PAH carcinogens, cocarcinogens, and tumor producers are HMW PAH compounds (Eisler 2000). These HMW PAHs typically accumulate in coastal sediments through atmospheric deposition (e.g., soot particles) and stormwater runoff. Other sources of HMW PAHs include asphaltines, coal tar, and creosote.

**Subsurface results.** Elevated concentrations of subsurface PAH were unrelated to surface concentrations, with the highest concentration occurring at the 0-1 ft core segment at Station 1N. With a total PAH<sub>13</sub> concentration of 18,790 ng·g<sup>-1</sup>, this single core interval had concentrations 10-1000 times higher than other Yosemite Creek sediment samples, and was the only subsurface sample that exceeded ERM guideline of 9600 ng·g<sup>-1</sup> for HMW PAH (Table 5-7).

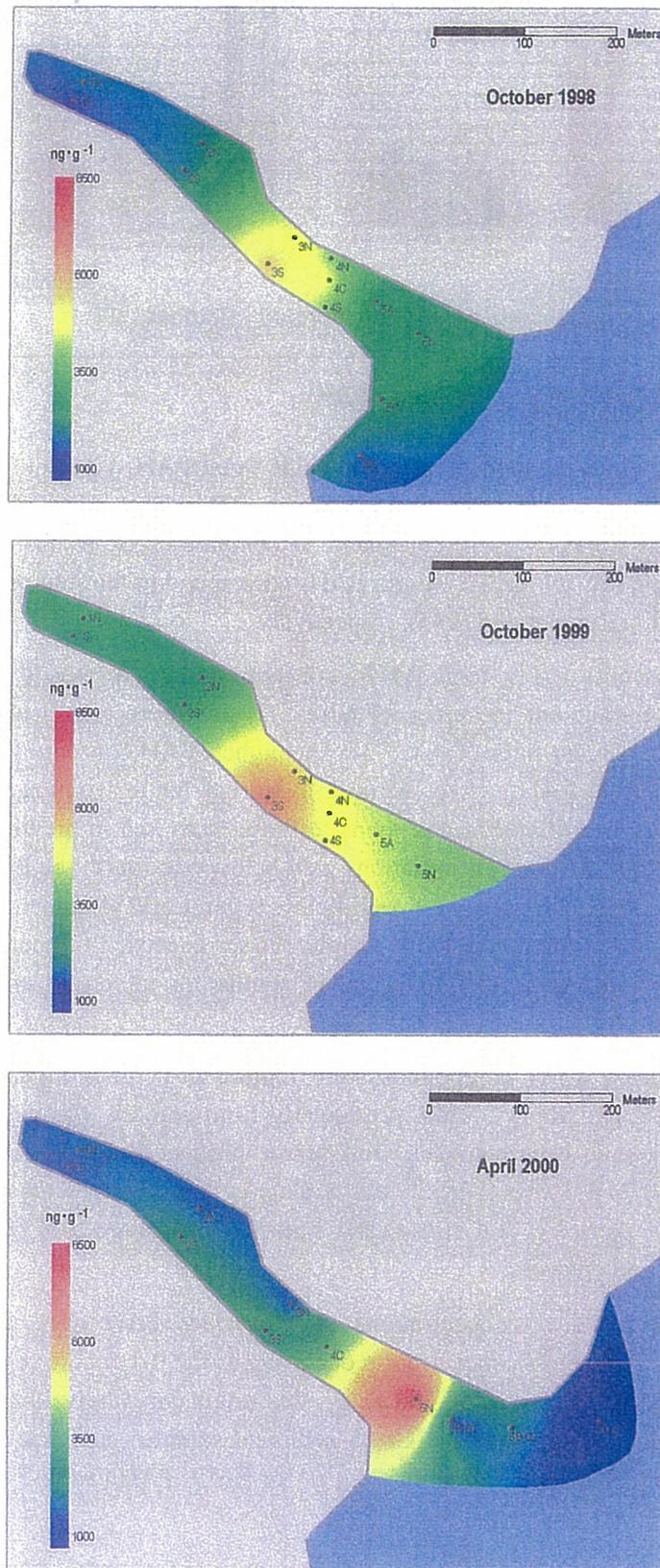


Figure 5-3. Surface sediment distributions of Total PAH<sub>13</sub> – 1998 (wet), 1999 (dry), 2000 (wet).

Table 5-6. Surface sediment PAH results, all surveys (n=32 samples) (ng·g<sup>-1</sup>, ppb dry weight).

Parameter	Mean	Minimum	Maximum	Maximum Station	ERM <sup>1</sup>	Reference Mean <sup>2</sup>
LMW PAH	412	131	1731	5N	3,160	101
HMW PAH	2209	799	6730	5N	9,600	562
Total PAH <sub>13</sub>	2622	930	8461	5N	44,792	663
Total PAH <sub>41</sub> *	6934	3679	16153	5N	none	1,518

<sup>1</sup> Long et al. (1995); <sup>2</sup>=mean reference concentration for all surveys; \* US Navy stations not included, as < 41 PAHs were measured

Table 5-7. PAH results in subsurface sediments (ng·g<sup>-1</sup>, ppb dry weight).

Depth	LMW PAH		HMW PAH		Total PAH <sub>13</sub>	
	Mean	Max. Station; Concentration	Mean	Max. Station; Concentration	Mean	Max. Station; Concentration
0-1 ft	849	1N; 2610	4722	1N; 16,180	5571	1N; 18,790
1-2 ft	715	3S; 1191	5895	1N; 3345	4059	1N; 4977
2-3 ft	4820	4C; 1626	2691	4C; 7930	4317	4C; 12,750
3-4 ft	32	4C; 39	65	4C; 114	97	4C; 153

### 5.3.3 Polychlorinated Biphenyls (PCBs)

**Surface results.** Total PCB<sub>20</sub> (sum of 20 congeners) was weakly but significantly correlated with TOC (Table 5-3). Polychlorinated biphenyls are nonionic organic compounds, which generally increase with increasing TOC due to their relative insolubility in water and high affinity for organic matter, and typically show strong positive correlations with TOC in marine sediments. Summary results for total PCB<sub>20</sub> in surface sediments are shown in Table 5-8. Total PCB<sub>20</sub> concentrations ranged from 85 to 1317 ng·g<sup>-1</sup> in surface sediments from the creek, averaging 473.6 ng·g<sup>-1</sup>, with a maximum concentration measured at Station 5N in April 2000 during wet weather. All stations located within the creek proper had total PCB<sub>20</sub> concentrations above the ERM value of 180 ng·g<sup>-1</sup>. Most laboratory studies using benthic invertebrates produce negligible mortality at concentrations several orders of magnitude above this concentration (Dillon and Burton 1992; Brieger and Hunter 1993). Regardless, all creek concentrations were at least an order of magnitude higher than mean reference station concentrations, indicating PCBs as a COPC for Yosemite Creek.

Surface sediment distributions for total PCB<sub>20</sub> in Yosemite Creek were relatively homogeneous, except for elevated concentrations measured at Station 2S in 1998 and 1999, and at Station 5N in 2000 (Figure 5-5 and Appendix B1). Similarly, distributions of individual congeners were fairly consistent between surveys and stations with several exceptions. First, the two more toxic coplanar congeners measured, PCB 77 and 126, were reported only in the 1999 survey. Second, PCBs measured at Station 5N, differed in individual congener distributions and presumably source, from all other creek stations.

Coplanar congeners are always present at significantly lower concentrations in environmental samples than non-coplanar PCB congeners, and are often below detection limits. The modified gas chromatography with electron capture detector (GC/ECD) method used in this study is a preferred EPA and NOAA method. However, it does not provide reliable detection of trace level coplanar PCBs, due to non-target compound interference and co-elution. This is likely the reason why these congeners were detected in several of the 1999 samples, but were not detected in any of the 1998 or 2000 samples (i.e., laboratory misidentification). Gas chromatography with mass spectrometric detection (GC/MS) should be used for reliable quantification of coplanar PCBs.

Differences in PCB type between Station 5N and the remaining creek stations were confirmed using principal components analysis (PCA), a standard non-parametric statistical test (Sokal and Rohlf 1998) used primarily for pattern recognition. Figure 5-4 plots the two major PCA vectors, revealing three relatively distinct station groupings based on similarities in distributions of individual congeners in each sample. Station 5N differs from other samples in that it is relatively enriched in PCB congener 153, with relatively lower concentrations of mid- and lower-molecular weight congeners. PCBs in this sample more closely resemble Aroclor 1260, while other creek samples more closely resemble a mixture of Aroclors 1254 and 1260. PCB distributions for the three samples collected outside the creek mouth (US Navy samples) more closely resemble Aroclor 1260, with minor contributions from Aroclor 1254. All Yosemite Creek samples are very different from Aroclors 1248 and 1242. Standard (unweathered) Aroclor samples (e.g., A1254) are included in this analysis (Figure 5-4).

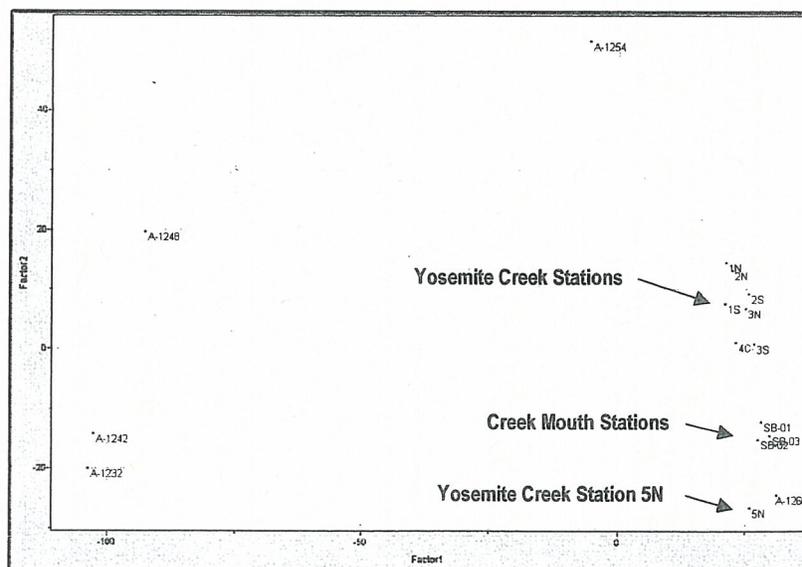
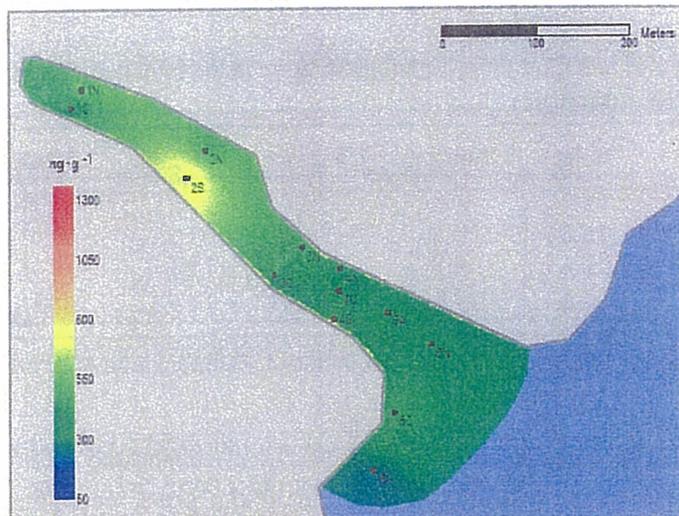
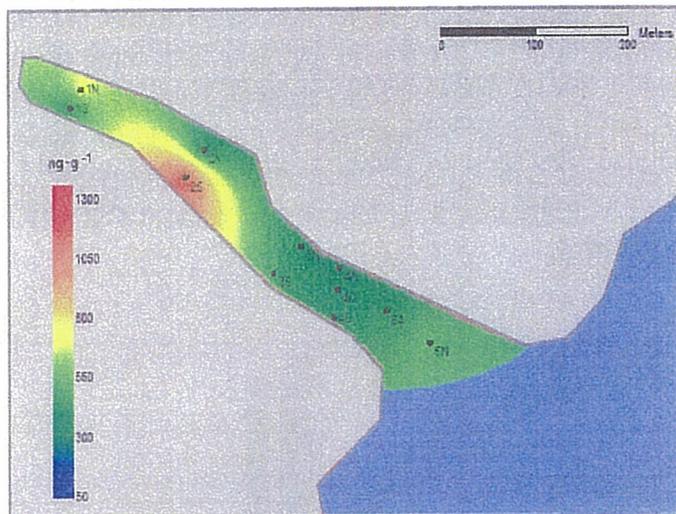


Figure 5-4. PCA results for Yosemite Creek surface sediment PCB data. Station groupings indicate different PCB congener distributions.

Total PCBs (20 compounds, ppb), October 1998



Total PCBs (20 compounds, ppb), October 1999



Total PCBs (20 compounds, ppb), April 2000

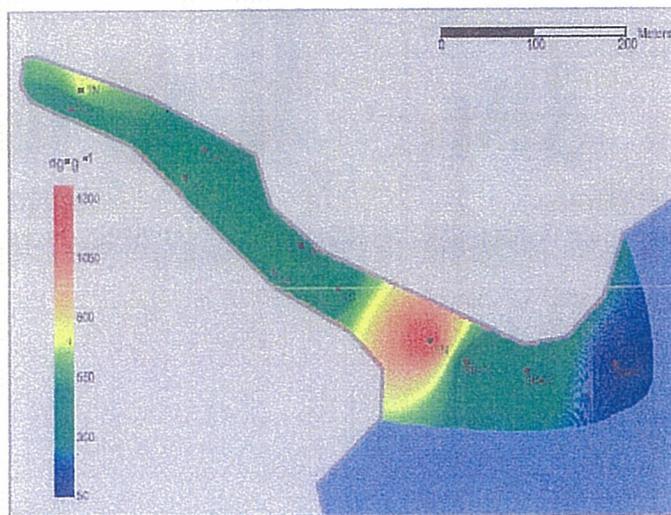


Figure 5-5. Surface sediment distributions of Total PCB<sub>20</sub> – 1998 (wet), 1999 (dry), 2000 (wet).

Table 5-8. Total PCB<sub>20</sub> and selected chlorinated pesticides in surface sediments, all surveys (n=32) (ng·g<sup>-1</sup>, ppb dry weight).

Parameter	Mean	Minimum	Maximum	Maximum Station	ERM <sup>1</sup>	Reference Mean
Total DDT	58.7	4.5	142.1	2S	100	4.27
Total Chlordane <sup>2</sup>	36.2	10.3	88.1	1N	6	0.33
Dieldrin	22.1	0.1	110.0	2S	8	0.67
Total PCB <sub>20</sub>	473.6	85.0	1317.3	5N	180*	7.84

<sup>1</sup>=source Long et al. (1995); <sup>2</sup>=US Navy stations not included; \*combination of Aroclor and congener data

**Subsurface results.** The concentration of total PCB<sub>20</sub> in subsurface sediments showed a clear elevation (2356 ng·g<sup>-1</sup>) in the 0-1 ft core interval at the creek end (Table 5-9, Figure 5-6) compared to all other subsurface samples. Concentrations exceeded the ERM of 180 ng·g<sup>-1</sup> in the upper core segments at all stations except 3S, located across from CSO. In general, the highest concentrations were measured in the 0-1 ft core segments, indicating recent but not necessarily current inputs of PCBs, as surface sediment concentrations were significantly lower. Subsurface concentrations recorded from the deepest cores (i.e., 3-4 ft; mean=12.6 ng·g<sup>-1</sup>) were commensurate with reference area surface concentrations. Subsurface total PCB distributions showed no clear pattern with distance from historical or current CSOs (Figure 5-6), indicating varied historical inputs of PCBs.

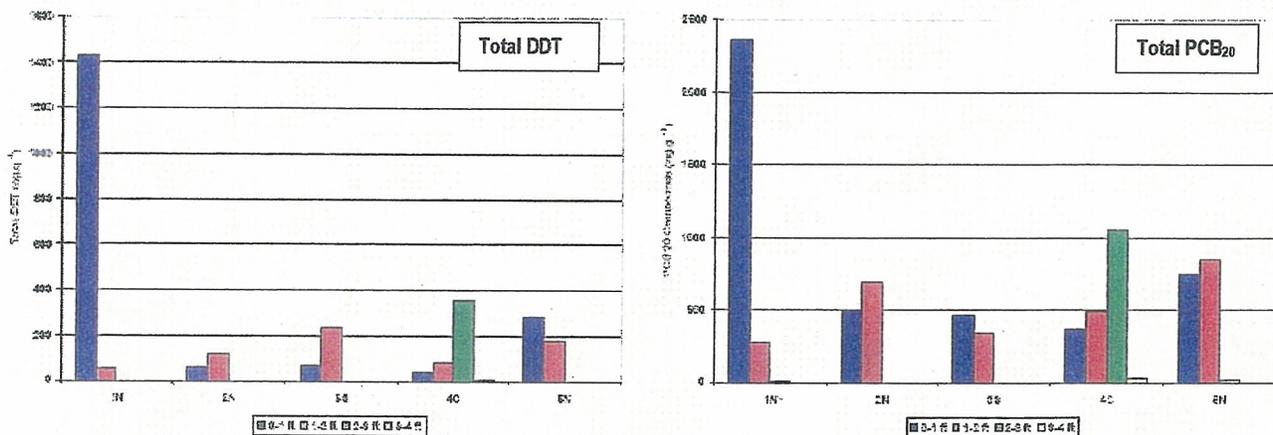


Figure 5-6. Subsurface sediment distributions of total DDT and total PCB<sub>20</sub> – October 1998.

**Table 5-9. Mean concentrations of Dieldrin, total Chlordane, total DDT and total PCB<sub>20</sub> in subsurface sediments (ng·g<sup>-1</sup>, ppb dry weight).**

Depth	Dieldrin		Total Chlordane		Total DDT		Total PCB <sub>20</sub>	
	Mean	Max. Station; Concentration	Mean	Max. Station; Concentration	Mean	Max. Station; Concentration	Mean	Max. Station; Concentration
0-1 ft	119	1N; 370	72.6	1N; 208	377.9	1N; 1430	888	1N; 2356
1-2 ft	78.4	3S; 120	40.6	3S; 68.8	131.9	3S; 235	529	5N; 857
2-3 ft	6.8	4C; 20.0	3.6	4C; 10.4	119.2	4C; 356	358	4C; 1053
3-4 ft	<0.4	1N; <0.4	<0.3	1N; <0.4	1.2	4C; 2.2	13	4C; 23

### 5.3.4 Organochlorine Pesticides

Many chlorinated pesticides were below analytical detection limits or <0.5 ng·g<sup>-1</sup> in creek sediments, including Aldrin, Endrin, Lindane, Mirex, and some of the individual Chlordane and DDT compounds. Total Chlordane (sum of four compounds), total DDT and Dieldrin were routinely measured at concentrations exceeding 25 ng·g<sup>-1</sup>, and were significantly correlated with TOC (Table 5-3). Nearly all of the detected pesticides decreased consistently with time and distance from the creek end, indicating that these relic contaminants may be waning. Surface distributions for the most elevated pesticides, total Chlordane, Dieldrin and total DDT in April 2000, are shown in Figure 5-7; distributions for all three surveys are shown in Appendix B1. Summary results for these pesticides in surface sediments are presented in Table 5-8; subsurface results are summarized in Table 5-9.

**Chlordane.** Chlordane, like other non-polar organic compounds, has an affinity for organic matter and was moderately correlated with TOC for all samples ( $r=0.49$ ,  $p<0.001$ ). The strength of this relationship greatly increased when only those sediments with Chlordane concentrations greater than 20 ng·g<sup>-1</sup> were evaluated (i.e.,  $r=0.93$ ,  $p<0.001$ ).

Total Chlordane averaged 34 ng·g<sup>-1</sup> in surface sediments for all surveys (Table 5-8). The three stations outside of the creek mouth were not included, as the U.S. Navy study measured different Chlordane analytes than SFPUC. The highest concentration was measured at Station 1N at 88.1 ng·g<sup>-1</sup>, with decreased concentrations measured with distance from the creek end.

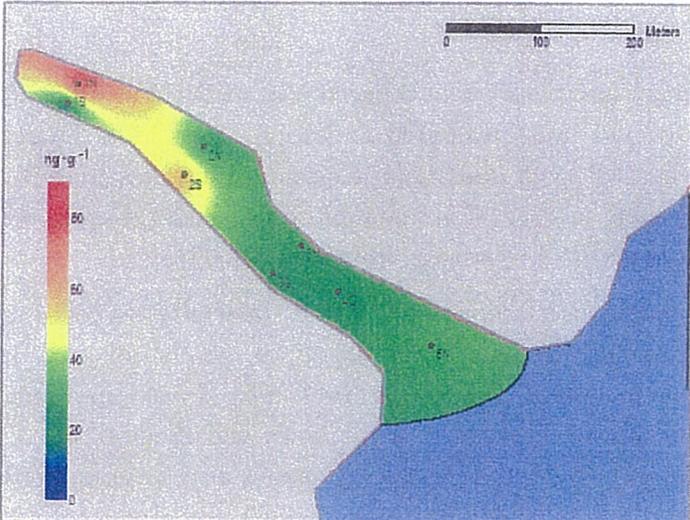
Shallow subsurface concentrations in the creek exceeded surface levels, with a maximum concentration of 208 ng·g<sup>-1</sup> recorded from the 0-1 ft core interval at Station 1N. However, total Chlordane concentrations decreased in deeper intervals, returning to background levels in the two 3-4 ft cores (Table 5-9, Appendix B2). The most prevalent isomers of Chlordane were alpha- and gamma-Chlordane, and trans-Nonachlor. Heptachlor and Heptachlor epoxide were not detected in any creek sediments (ca. <0.06 ng·g<sup>-1</sup>).

**DDT.** Total DDT (sum of six compounds) averaged 58.7 ng·g<sup>-1</sup> in Yosemite Creek surface sediments, with a maximum of 142.5 ng·g<sup>-1</sup> at Station 2S (Table 5-8). The major metabolites contributing to total DDT were 4,4-DDD and 4,4-DDE in all samples. Total DDT subsurface concentrations in the top two feet were consistently higher than surface concentrations, trending

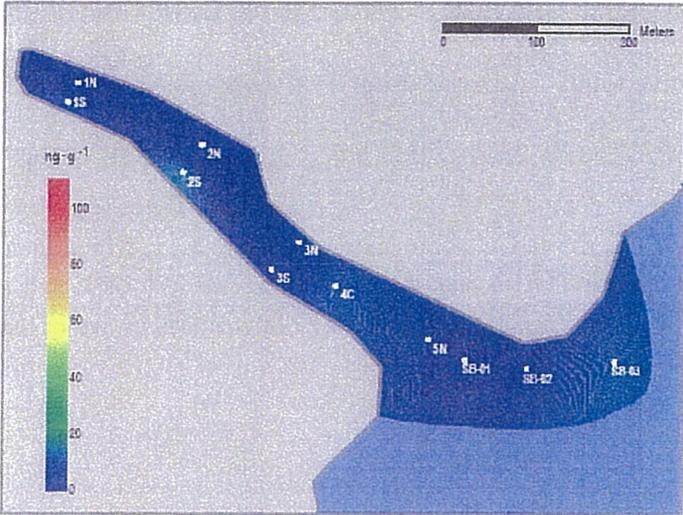
to reference concentrations in the deeper cores (Figure 5-6). The maximum subsurface concentration was recorded from the 0-1 ft core interval at the creek end (Station 1N, 1431 ng·g<sup>-1</sup>) (Table 5-9). Comparatively lower total DDT concentrations in surface sediments indicate a trend of declining DDT in more recent sediment deposits.

All surface sediments had total DDT concentrations well below the Regional Board criterion of 100 µg·g<sup>-1</sup> organic carbon (adopted from Schwartz et al. [1994]). The station with the highest DDT concentration (2S at 142.5 ng·g<sup>-1</sup>) had a corresponding TOC concentration of 2.3% (i.e., 0.023), producing a normalized concentration of 6.19 µg·g<sup>-1</sup> organic carbon.

Total Chlordane (ppb), April 2000



Total Dieldren (ppb), April 2000



Total DDT (ppb), April 2000

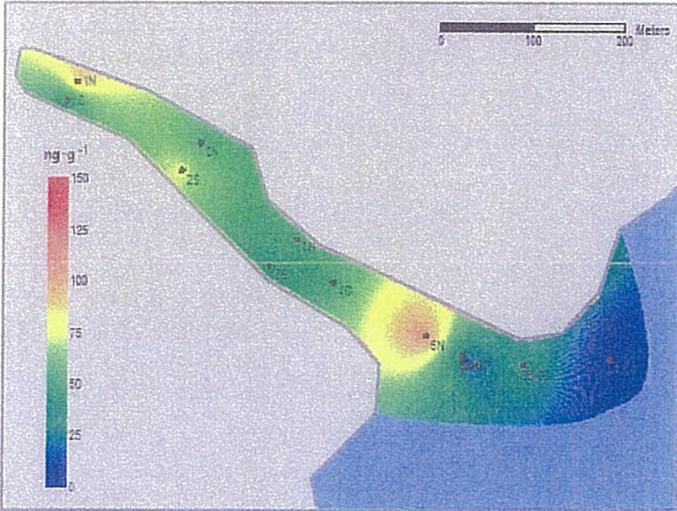


Figure 5-7. Surface sediment distributions of total Chlordane, Dieldrin and total DDT in April 2000.

**Dieldrin.** The average surface sediment concentration of Dieldrin was  $23.8 \text{ ng}\cdot\text{g}^{-1}$  for all surveys, with a maximum of  $110 \text{ ng}\cdot\text{g}^{-1}$  measured at Station 2S in 1998. Nearly all surface sediment concentrations decreased with time and distance from the creek end, with the highest concentrations measured in 1998. Concentrations throughout the creek were substantially lower in 1999 and 2000 (Appendix A1), ranging from  $3.5$  to  $22.0 \text{ ng}\cdot\text{g}^{-1}$ .

The upper subsurface concentrations (i.e., 0-2 ft) generally exceeded surface concentrations; however, concentrations decreased with depth for nearly all core intervals, returning to background levels in the two 3-4 ft intervals (Table 5-9). A maximum concentration of  $370 \text{ ng}\cdot\text{g}^{-1}$  was recorded from the 0-1 ft segment at the creek end (Station 1N). Comparatively reduced surface concentrations along with temporal reductions across surveys reflect declining Dieldrin inputs from recent sediment deposits.

#### 5.4 YOSEMITE CREEK CHEMICALS OF POTENTIAL CONCERN (COPCs)

Upper 95<sup>th</sup> predictive limits calculated using TOC-normalized reference site data are shown in Table 5-10 for all surveys. TOC-normalized results for individual creek stations are compared to these survey-specific values for all target analytes, except for PCBs, PAHs and selected pesticides (e.g., DDT) which were compared to values for summed analytes (e.g., total PCBs). Chemicals of potential concern for Yosemite Creek are shown in Table 5-11, which identifies those stations (in red) that exceed both the TOC-normalized reference site 95<sup>th</sup> UPL and  $\frac{1}{2}$ -ERM. Chemicals of potential concern are those compounds exceeding both criteria in two or more surveys.

Table 5-10. Reference Site TOC-normalized 95<sup>th</sup> upper predictive limits (UPLs) for selected contaminants.

Contaminant	October 1998 <sup>1</sup> 95 <sup>th</sup> UPL	October 1999 95 <sup>th</sup> UPL	April 2000 95 <sup>th</sup> UPL
<b>Metals (<math>\mu\text{g}\cdot\text{g}^{-1}</math>)</b>			
Arsenic	1139	1179	1192
Cadmium	58.5	41.1	61.3
Chromium	9966	11,116	10,275
Copper	5959	6928	6329
Lead	2374	2912	2213
Mercury	39.2	32.4	40.5
Nickel	8664	10,088	8641
Selenium	45.2	29.3	46.8
Silver	55.9	87.3	28.5
Zinc	12385	14,891	12,903
<b>Organics (<math>\text{ng}\cdot\text{g}^{-1}</math>)</b>			
Total PAH <sub>13</sub>	128546	128361	134,872
LMW PAH <sup>2</sup>	19394	18,216	22,595
HMW PAH <sup>3</sup>	109295	112,581	114,760
Dieldrin	144.4	250.6	20.6
Endrin	20.6	34.7	20.6
Total Chlordane	43.2	70.5	20.6
Total DDT	1183	944	1283
Total PCB <sub>20</sub>	1755	1952	1336

<sup>1</sup>=calculated using 1998 and 2000 reference data; <sup>2</sup>=LMW PAH = total of 7 low molecular weight PAHs; <sup>3</sup>=HMW PAH = total of 6 high molecular weight PAHs; TOC-normalized=mass of chemical·g<sup>-1</sup> TOC; samples with < 1% TOC were normalized using 1% TOC.

Three out of 11 metals qualified as COPCs, with lead the most ubiquitous. Mercury and zinc exceeded COPC criteria at only a single station each (i.e., 5N and 1N, respectively). Zinc and mercury concentrations were only slightly higher than corresponding reference site UPLs (i.e., exceedance factor <2), while lead concentrations were typically 3-4 times greater.

Concentrations of chlorinated pesticides – total Chlordane, total DDT and Dieldrin, were elevated compared to reference area UPLs, as well as corresponding ½-ERM values. The designation of total Chlordane as the most problematic creek contaminant in Table 5-11 is somewhat misleading. Relatively high exceedance factors (>15) for this COPC are driven by extremely low or non-detect reference area concentrations (e.g., <0.05 ng·g<sup>-1</sup>). Additionally, the ERM criterion is suspect, as the 6 ng·g<sup>-1</sup> criterion initially published in Long and Morgan (1991) was later retracted by its authors (Long et al. 1995). The final designation of total Chlordane as a COC should rely on refined criteria; however, Chlordane guidelines for the protection of marine biota may be inadequate because of lack of published data (Eilser 2002).

Similar to Chlordane, the designation of Dieldrin as a COPC is due to extremely low reference area concentrations, especially in the April 2000 study. Many reference area concentrations were undetected at sub-part-per-billion levels, producing significant differences in creek concentrations

at the low part-per-billion level. Creek concentrations should be examined relative to risk-based thresholds to determine if these statistical differences are biologically meaningful.

Besides total Chlordane, total PCB<sub>20</sub> was the only other COPC that exceeded both UPL and ½-ERM criteria in all surface samples. In general, concentrations were highest in April 2000, indicating the recalcitrance of these chlorinated hydrocarbons.

Section 7 presents final COCs, which refines the COPC list using bioaccumulation results from Section 6.

**Table 5-11. Surface sediment COPCs and ratios for TOC-normalized result / reference site 95<sup>th</sup> UPL.**

COPC	Survey Year	1N	1S	2N	2S	3N	3S	4C	5N
Lead	1998	3.12	2.80	2.54	2.79	2.34	2.44	2.28	2.62
	1999	3.31	2.88	2.89	2.89	3.60	4.37	2.11	3.92
	2000	6.45	3.29	4.47	3.84	5.61	2.85	4.22	4.09
Mercury	1998	0.79	0.68	0.64	0.63	0.72	0.89	0.73	1.03
	1999	0.62	0.82	0.78	0.81	1.08	1.57	0.90	1.05
	2000	1.36	0.73	0.98	1.08	0.94	0.94	1.21	2.21
Zinc	1998	1.03	0.92	0.80	0.75	0.79	0.73	0.74	0.92
	1999	1.06	0.93	0.79	0.93	1.34	1.45	0.78	1.05
	2000	1.77	1.05	1.21	1.11	1.56	0.93	1.41	1.12
Total Chlordane	1998	79.9	23.2	37.4	52.4	46.5	31.7	25.8	36.7
	1999	64.0	27.2	22.2	54.2	35.0	48.0	15.4	39.2
	2000	155.1	17.8	38.5	93.6	69.2	33.0	55.1	59.0
Total DDT	1998	3.33	1.83	2.72	5.13	2.30	1.88	1.85	3.65
	1999	4.75	4.15	4.87	6.44	3.39	5.28	1.64	6.16
	2000	5.19	1.06	2.32	3.84	3.56	1.58	3.08	6.41
Dieldrin	1998	17.7	9.7	13.8	32.5	11.2	8.2	10.1	12.3
	1999	3.5	2.4	1.5	6.1	8.0	4.5	1.5	5.6
	2000	24.6	4.5	7.8	19.0	24.3	7.0	18.0	23.4
Total PCB <sub>20</sub>	1998	14.1	9.5	13.0	19.5	10.8	8.5	9.3	12.9
	1999	19.1	11.8	9.9	41.5	16.4	21.1	8.9	20.7
	2000	39.3	10.2	17.9	25.4	20.2	13.4	22.9	72.7

**Bold:** > reference upper 95% UPL and > ½-ERM; Blue=wet weather event; Red=recurrent contamination measured in ≥2 surveys

## 6.0 BIOACCUMULATION IN CLAMS

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This section presents results from chemical analyses of bentnose clam *Macoma nasuta* tissues following 28-day laboratory exposures to surface sediments collected from Yosemite Creek and reference sites in April 2000. Dry weight tissue results are presented in Appendix A3.

The bentnose clam was chosen as an appropriate test species for reasons presented in Section 2.2.2.4. Additionally, *Macoma nasuta* bioaccumulation tests are in the process of standardization by EPA and will become be the primary benchmark test species for near coastal waters. Chemicals of potential concern (COPCs) identified in Section 5 and known to bioaccumulate in the food web are examined, consisting of mercury, PCBs, Chlordane, DDT and Dieldrin. The two remaining COPCs, lead and zinc, were not measured in clam tissue, hence their final COC designation relies on sediment data only. Published studies have indicated that although lead is bioaccumulated from water by plants and animals, there is little supporting evidence that it biomagnifies through food chains (Branica and Konrad 1980; Settle and Patterson 1980 as referenced in Eisler 1988). The biomagnification potential for zinc is similarly low (Eisler 2002).

Evaluation of chemical bioaccumulation in clams relies primarily on statistical comparisons of individual station results to the upper 95<sup>th</sup> predictive limit (UPL) calculated using dry weight tissue concentrations for the five reference stations tested during the April 2000 survey. This method is similar to that used to identify sediment COPCs in Section 5, except tissue concentrations are compared. Tissue concentrations are associated with corresponding sediment concentrations through the use of biota-sediment accumulation factors (BSAFs), to evaluate the biomagnification potential of COPCs in the aquatic food web.

It is important to note that there are several different ways to interpret bioaccumulation data, including: 1) an estimate of direct uptake from sediment into the test organism or a proxy; and 2) a predictive measure of transfer across trophic levels. When evaluating direct uptake from sediment, tissue concentrations are compared to various criteria that are established on a wet or dry weight basis, and data must be converted if they are reported in dissimilar units. In general, if tissue data are used to estimate the amount of contaminant in the test organism as a food source, wet weight concentrations are used (as they represent the unadjusted concentration per mass of prey). Dry weight tissue concentrations are often used when comparing data across species or studies. When examining transfer between organisms, results are often based on lipid weight, following the assumption that many contaminants concentrate in the fatty tissues of animals. Summary statistics for bioaccumulation data and comparisons between creek and reference tissue are presented on a dry weight basis, to provide consistency with raw data presented in the appendices as reported by the laboratories, and to compare with dry weight values reported in the literature. Evaluation of BSAFs are on a lipid weight basis following guidance from the EPA (1996).

Moisture in clam tissue ranged from 87.8 to 91.0% with a mean of 90.1%; and dry weight lipids ranged from 4.5 to 7.7%, with a mean of 6.0%. Therefore, with respect to COPCs, dry weight tissue

concentrations are roughly an order of magnitude (15x) greater than wet weight tissue concentrations; and lipid weight concentrations are approximately 17x greater than dry weight concentrations. There were minimal differences in results for creek and reference comparisons due to variances in normalization. In general, the same creek tissues were elevated compared to reference tissues, for dry weight, wet weight and lipid weight data.

## 6.1 Overview

Chemical concentrations in clam tissues varied considerably for Yosemite Creek, as a function of chemical type, sample location and physical features of the exposure sediment. For all data combined, lipid-normalized tissue concentrations of chlorinated COPCs were strongly correlated with TOC-normalized sediment concentrations, but not to sediments normalized to fine grain sediments (Table 6-1). This suggests that sediment organic content influences the direct uptake of these persistent compounds in biota.

Mercury, the only metal examined, was not appreciably concentrated in any creek tissues. Bioaccumulation of mercury in the aquatic food chain has been a concern since elevated levels of methyl-mercury in fish tissue from a highly contaminated Japanese harbor were discovered to have toxic effects in humans in 1956. Elevated fish concentrations and increasing trends in mercury in shellfish have been observed in multi-year monitoring programs conducted in the San Francisco Estuary, resulting in a 303(d) impaired water body listing.

Total PCB<sub>20</sub> (sum of 20 congeners) concentrations were elevated in all Yosemite Creek tissues compared to reference tissue concentrations. Concentrations of chlorinated organic compounds in tissues, including PCBs, depend on many organism-related factors including, size, lipid content, trophic level, mode of ingestion, metabolism and diet. Total PCB<sub>20</sub> concentrations found lethal to fish in laboratory experiments range from 10 to 300  $\mu\text{g}\cdot\text{g}^{-1}$  dry weight (or 10,000 to 300,000  $\text{ng}\cdot\text{g}^{-1}$ ) (Rice and O'Keefe 1995). Similar to mercury, elevated PCBs in fish also contributed to the 303(d) impaired water body listing for the San Francisco Estuary.

Dry weight concentrations of chlorinated pesticides, Dieldrin, DDT and Chlordane, were elevated in all Yosemite Creek tissues compared to reference tissue concentrations. These relic pesticides are all highly fat soluble, with a propensity to bioaccumulate in marine organisms. DDT and its metabolites have been detected in aquatic organisms from every coastal state and from nearly every estuary in the U.S., as well as from many offshore and deep-sea locations. Chlordane is a broad-spectrum poison that affects many organisms. The 1986-1987 Bioaccumulation Study of the U.S. EPA found high levels in fish and shellfish collected from 60 estuaries and coastal marine sites in the U.S., ranging from 6910 to 409,000  $\text{ng}\cdot\text{g}^{-1}$  dry weight and 7500 to 42,500  $\text{ng}\cdot\text{g}^{-1}$  wet weight, respectively (Kennish 1997). Results from NOAA's National Status and Trends Program from 1984 and 1990 suggest that Dieldrin is less ubiquitous than DDT and Chlordane, but persists on the west coast at high part-per-billion levels, and is commonly found in shellfish at the low part-per-million level (O'Conner and Ehler 1991).

Table 6-1. Correlation results for COPCs in lipid-normalized tissue vs. normalized sediment – all data combined (n=13).

	Tissue – lipid normalized				
	Mercury	Total Chlordane	Total DDT	Dieldrin	Total PCB <sub>20</sub>
<b>Sediment – percent fines normalized</b>					
Correlation coefficient (r)	-0.19	0.32	0.28	0.45	0.33
Probability (p)	0.527	0.292	0.360	0.122	0.268
<b>Sediment - TOC normalized</b>					
Correlation coefficient (r)	-0.12	<b>0.97</b>	<b>0.81</b>	<b>0.94</b>	<b>0.80</b>
Probability (p)	0.71	<0.001	<0.001	<0.001	0.001

Bold =significant positive correlation at  $p < 0.05$ .

## 6.2 Reference Area

Dry weight COPC concentrations in tissues exposed to reference area sediments (Table 6-2) were very low, commensurate with concentrations in marine organisms from pristine coastal environments (Kennish 1997). Total Chlordane was below detection limits (i.e.,  $< 0.7 \text{ ng}\cdot\text{g}^{-1}$  dry weight) at reference station South Site and only slightly above detection limits at two other Yosemite stations. Only total DDT and total PCB<sub>20</sub> exceeded  $10 \text{ ng}\cdot\text{g}^{-1}$  dry weight for the organic contaminants. Mean total DDT and total PCB<sub>20</sub> dry weight concentrations of  $10.3$  and  $27.0 \text{ ng}\cdot\text{g}^{-1}$  correspond to wet weight concentrations of approximately  $0.7$  and  $2 \text{ ng}\cdot\text{g}^{-1}$ , respectively, for these tissues. Mercury was extremely low, with the maximum dry weight concentration of  $0.24 \mu\text{g}\cdot\text{g}^{-1}$  recorded for Tubbs Island. Table 6-2 summarizes Reference Area results and includes 95<sup>th</sup> upper predictive limits (UPL) for sediment COPCs that were measured in tissues.

Table 6-3 shows dry weight BSAFs for Reference Area data. Although BSAFs provide insight on bioaccumulation potential in tissues exposed to contaminated sediments, they are less meaningful when sediment chemical concentrations are extremely low, such as those reported for the reference area. Mercury and total Chlordane were the only two COPCs that had mean BSAFs values under unity (1.0).

Table 6-2. Reference Area – summary statistics for COPC tissue dry weight concentrations (5 stations)

COPC	Minimum	Maximum	Maximum Station	Mean	95 <sup>TH</sup> UPL
Mercury ( $\mu\text{g}\cdot\text{g}^{-1}$ )	0.18	0.24	Tubbs Island	0.20	0.26
<b>Chlorinated COPCs (<math>\text{ng}\cdot\text{g}^{-1}</math>)</b>					
Dieldrin	0.8	2.4	North Site	1.3	2.7
Total DDT	2.2	14.1	Paradise	10.3	21.3
Total Chlordane	<0.7	3.0	North Site	1.1	4.0
Total PCB <sub>20</sub>	10.5	36.7	Paradise	27.0	51.0

UPL=upper predictive limit

Table 6-3. Reference Area – summary statistics for biota-sediment accumulation factors (BSAFs) (n=5).

COPC	Minimum	Maximum	Maximum Station	Mean	Standard Deviation
Mercury	0.11	0.40	Tubbs Island	0.18	0.02
Dieldrin	0.47	1.44	North Site	0.70	0.42
Total DDT	0.15	4.34	Paradise	1.12	1.80
Total Chlordane	0.42	1.83	North Site	0.76	0.60
Total PCB <sub>20</sub>	0.60	28.47	Paradise	6.41	12.34

### 6.3 Yosemite Creek

Tissues exposed to sediments collected from Stations 1N and 2S, near the creek end, accumulated the highest chemical concentrations in Yosemite Creek. Sediments from these stations were primarily fine-grained with moderate concentrations of TOC, and did not differ significantly from remaining creek sediments. Four chlorinated COPCs (total PCB<sub>20</sub>, total Chlordane, total DDT, & Dieldrin) that were elevated in sediments were significantly elevated in clam tissues at Stations 1N and 1S relative to reference tissues. The remaining chlorinated pesticides were not detected at the sub-part-per-billion level in tissue (<1 ng·g<sup>-1</sup>). Summary statistics for bioaccumulating chemicals measured in tissues are shown in Table 6-4. Mercury, the only metal measured, was detected at sub-part-per-million dry weight concentrations in both creek and reference tissues. Sediment chlorinated COPC concentrations normalized to TOC were strongly correlated with corresponding tissue concentrations (correlation coefficient [ $r^2$ ] ranged from 0.80 to 0.97), supporting the contention that sediment physical features influence the uptake of these persistent chemicals. Tissue mercury, however, did not associate with either percent fines or TOC-normalized sediment mercury ( $r^2 = -0.19$  and  $-0.12$ , respectively). Figure 6-1 graphically presents the strongest associations (linear regression) between tissue concentrations and sediment chemical concentrations normalized to either percent fines or TOC.

BSAFs at all Yosemite Creek Stations were less than unity (one) for all COPCs, except 1S for Dieldrin, with a BSAF of only 1.12. These very small biota sediment accumulation factors indicate that COPCs may not readily biomagnify at the bottom of the Yosemite Creek food web (Table 6-5).

Table 6-4. Yosemite Creek – summary statistics for COPC tissue dry weight concentrations (n=8).

COPC	Minimum	Maximum	Maximum Station	Mean	Reference 95 <sup>TH</sup> UPL
Mercury ( $\mu\text{g}\cdot\text{g}^{-1}$ )	0.13	0.23	1N	0.18	0.26
<b><u>Chlorinated COPCs (<math>\text{ng}\cdot\text{g}^{-1}</math>)</u></b>					
Dieldrin	12.0	31.0	2S	20.5	2.7
Total DDT	43.5	171.6	1N	87.0	21.3
Total Chlordane	24.9	91.8	1N	42.5	4.0
Total PCB <sub>20</sub>	381.4	1030.9	1N	591.5	51.0

UPL=upper predictive limit

Table 6-5. Yosemite Creek – summary statistics for biota-sediment accumulation factors (BSAFs) (n=8).

COPC	Minimum	Maximum	Maximum Station	Mean	Standard Deviation
Mercury	0.03	0.09	3S	0.07	0.02
Dieldrin	0.30	1.12	1S	0.62	0.25
Total DDT	0.18	0.65	1S	0.39	0.16
Total Chlordane	0.19	0.56	1S	0.31	0.12
Total PCB <sub>20</sub>	0.13	0.46	1S	0.32	0.11

BSAFs = dry weight tissue concentration/dry weight sediment concentration (calculated for each station)

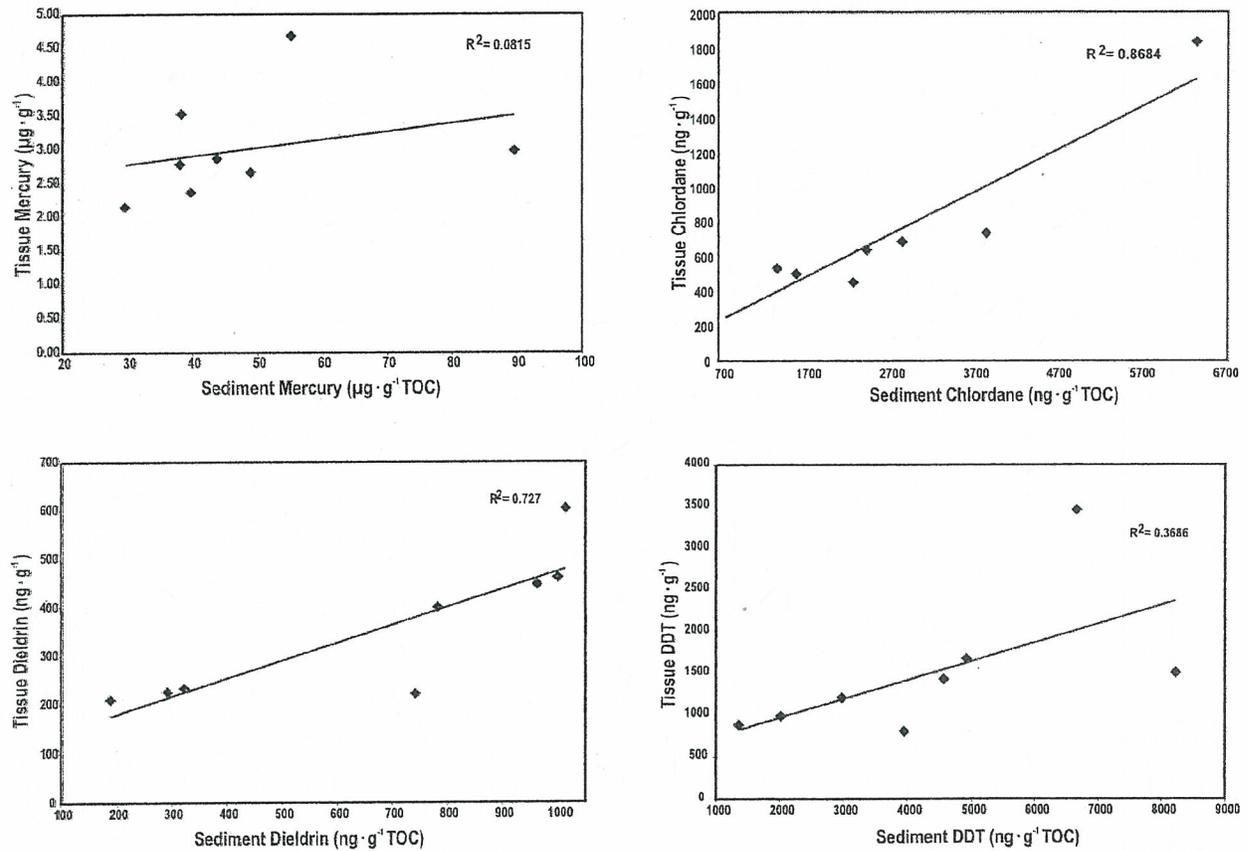


Figure 6-1. *Macoma* tissue concentration compared to sediment concentration normalized to TOC or percent fines. Red line represents best linear regression.

### 6.3.1 Mercury

None of the tissues exposed to Yosemite Creek sediments exceeded the reference UPL for mercury of  $0.26 \mu\text{g} \cdot \text{g}^{-1}$  dry weight (Figure 6-2).

Average dry weight concentrations of mercury in creek tissues at  $0.18 \mu\text{g} \cdot \text{g}^{-1}$  were comparable to both in-bay reference tissues and to average concentrations recorded in the related bivalve species *Mytilus*

(i.e.,  $0.24 \pm 0.08 \mu\text{g}\cdot\text{g}^{-1}$ ), collected from relatively clean sediments from U.S. and Canadian waters (Fowler 1990). BSAFs ranged from 0.03 to 0.09 and averaged 0.07 (Table 6-5).

There was no significant correlation between tissue and sediment mercury concentrations for Yosemite Creek; however, this is not unexpected as all concentrations were low and fairly uniform.

### 6.3.2 Polychlorinated Biphenyls (PCBs)

Total PCB<sub>20</sub> concentrations in creek tissue ranged from 381.4 to 1030.9 ng·g<sup>-1</sup> (Table 6-4) with an average concentration of 591.5 ng·g<sup>-1</sup> (dry weight). Tissue concentrations for all stations exceeded the reference UPL of 51.0 ng·g<sup>-1</sup> dry weight (Figure 6-2), with the highest concentrations observed at Station 1N. Although elevated compared to in-bay reference tissues, creek tissue concentrations were significantly lower than many concentrations reported for bivalves collected from other populated shorelines (Table 6-6). Lipid-normalized total PCB<sub>20</sub> concentrations in the eight Yosemite Creek tissue samples did not correlate well with TOC-normalized sediment total PCB<sub>20</sub> concentrations (Figure 6-1). A mean BSAF of 0.32 indicates that these contaminants may not biomagnify in the local food web.

The relative abundances of individual congeners in tissue samples generally were consistent with abundances in the sediments. The lower and higher chlorinated congeners typically were undetected, or present at low part-per-billion concentrations, whereas, the pentachloro- and hexachloro-biphenyls (especially congener numbers 101, 118, 138, and 153) were detected the most frequently. Two of the more toxic coplanar congeners measured, PCB 77 and PCB 126 (3,3',4,4'-tetrachlorobiphenyl and 3,3',4,4',5-pentachlorobiphenyl, respectively), were not detected in any Yosemite Creek tissues.

**Table 6-6. Ranges of PCB and DDT concentrations (ng·g<sup>-1</sup> dry weight) in the mussel *Mytilus* and closely related species (adapted from Fowler 1990).**

Study Area	Total PCB <sub>20</sub>		Total DDT	
	Minimum	Maximum	Minimum	Maximum
Baltic Sea	179	778	62	739
North Sea	106	362	15	143
Irish Sea	57	1070	92	590
English Channel	380	480	35	112
US Northwest Atlantic	10	6808	2.8	1109
US Pacific Coast	607	2052	5.4	1077
Northeast Atlantic (France)	96	1345	-	-
Mediterranean (Spain)	10.8	1264	60	288

### 6.3.3 Chlorinated Pesticides

**DDT.** Tissues exposed to sediments from all stations were statistically elevated compared to the reference UPL of 21.3 ng·g<sup>-1</sup> dry weight (Figure 6-2). Total DDT (sum of 2,4'- and 4,4'- DDT, DDE, and DDD isomers) dry weight concentrations ranged from 43.5 to 171.6 ng·g<sup>-1</sup>, averaging 87.0 ng·g<sup>-1</sup> in creek tissues. Maximum dry weight concentrations reported for related species exposed to sediment from other

populated areas reach concentrations over six times higher than the maximum Yosemite Creek concentration (Table 6-6). Lipid-normalized total DDT in tissue associated more strongly with sediment DDT normalized to total organic carbon ( $r^2 = 0.81$ ) than it did with sediment normalized to fine sediments ( $r^2 = 0.28$ ). The BSAF was well below unity, indicating that this nationally ubiquitous contaminant likely does not biomagnify in the local food web.

In general, the breakdown products of DDT (i.e., DDD and DDE) displayed the highest concentrations in tissues, consistent with DDT distribution patterns in sediment.

**Chlordane.** All creek tissues exceeded the reference UPL of  $4.0 \text{ ng}\cdot\text{g}^{-1}$  dry weight (Figure 6-2). Total Chlordane concentrations, like total PCB<sub>20</sub>, were highest in clam tissues from creek end Station 1N. Dry weight concentrations for all tissues ranged from  $24.9$  to  $91.8 \text{ ng}\cdot\text{g}^{-1}$ , averaging  $42.5 \text{ ng}\cdot\text{g}^{-1}$ . Alpha-, cis-, and trans-Chlordane were the dominant forms measured. Heptachlor and Heptachlor epoxide were not detected in any tissues. Tissue Chlordane was highly correlated with TOC normalized sediment chlordane concentrations, with a correlation coefficient squared ( $r^2$ ) value of  $0.87$  (Figure 6-1). BSAFs ranged from  $0.13$  to  $0.46$  (mean= $0.32$ ) indicating that this pervasive contaminant may not biomagnify in the local food web.

**Dieldrin.** All tissues exposed to Yosemite Creek sediments were significantly elevated compared with the reference UPL of  $2.7 \text{ ng}\cdot\text{g}^{-1}$  dry weight. Dieldrin dry weight concentrations in creek tissues ranged from  $12.0$  to  $31.0 \text{ ng}\cdot\text{g}^{-1}$  (mean= $20.5 \text{ ng}\cdot\text{g}^{-1}$ ).

Tissue concentrations of Dieldrin were more strongly correlated with sediment Dieldrin concentrations normalized to TOC compared to percent fines normalized sediment (Figure 6-1). The BSAF for Dieldrin was highest (mean= $0.62$ ) of the chlorinated compounds measured in tissue (Table 6-5); however, with the exception of station 1S (BSAF= $1.12$ ), all values were less than unity ( $1.0$ ) indicating a low biomagnification potential for sediment-dwelling organisms exposed to Dieldrin at Yosemite Creek.

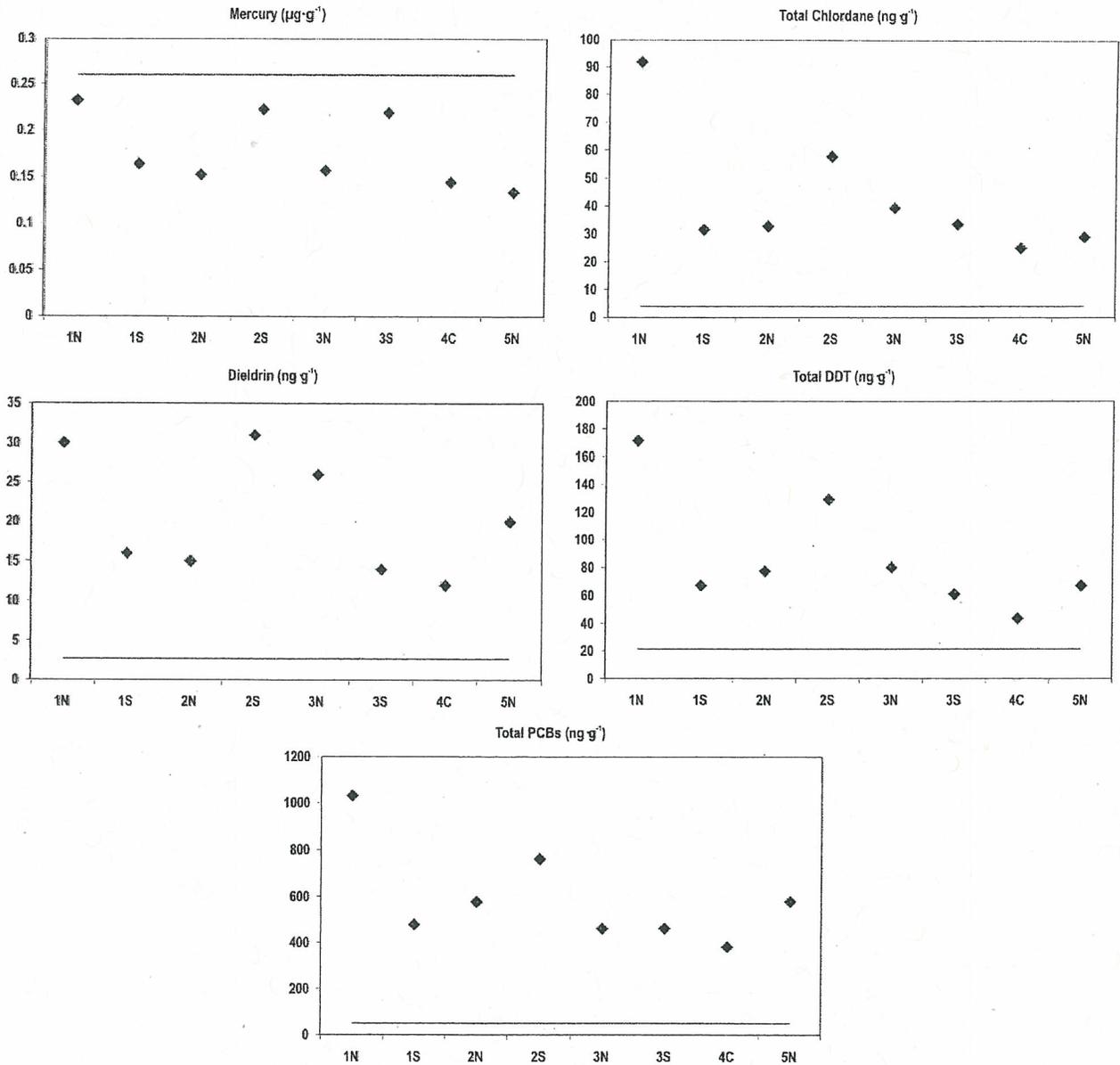


Figure 6-2. Yosemite Creek tissue concentrations compared to the reference tissue 95<sup>th</sup> UPL (red line) (all results are dry weight).

## 6.4 Conclusions

Chlorinated pesticides and PCBs were statistically elevated in tissues exposed to creek sediments compared to tissues exposed to in-bay reference sediments. However, biota-sediment accumulation factors were significantly less than unity (one) for all samples (except Dieldrin 1.12 at Station 1S), indicating that these chemicals may not biomagnify through the local food web. Mercury creek tissue concentrations were commensurate or lower than reference tissue concentrations.



## 7.0 ECOLOGICAL RISK ASSESSMENT

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This section will be completed following review and comments of other sections by the San Francisco Regional Water Quality Control Board.

## 8.0 SUMMARY AND CONCLUSIONS

This section synthesizes results presented in Sections 4 through 6, finalizing the list of chemicals of concern (COCs) identified as “potential” in Section 5. Data gaps are categorized by general type and spatial location necessary to meet the study objectives presented in Section 1.1, fulfilling a request by the Regional Board. Detailed recommendations for additional studies are withheld, since the future ecological setting of Yosemite Creek is unclear and dependent on restoration plans presently under consideration by the California State Parks Foundation.

### 8.1 DESIGNATION OF FINAL COCs

Table 8-1 identifies final COCs, taking into account toxicity and bioaccumulation results from Sections 4 and 6, respectively. Final COC designation of bioaccumulating compounds relies on tissue results where only those COCs that are elevated in creek tissues compared to reference tissues are retained. Potentially toxic non-bioaccumulating COCs (e.g., lead and zinc) are classified as COCs if sediment chemical concentrations and toxicity are elevated in same sediment sample. Mercury, which can bioaccumulate and exert toxic effects, is evaluated under both scenarios.

Three metals (Table 8-1) are retained as COCs based on toxicity and elevated sediment concentrations; however, coincident results occur only at Station 3S (mid-creek) in 1999, and at three different stations in 2000 (1S and 2S – at the creek end and 4C near the creek mouth [zinc only]). In contrast, the three chlorinated pesticides and total PCB<sub>20</sub>, qualify as COCs for all creek stations based on elevated concentrations in sediments and tissues.

**Table 8-1. Results and decision matrix for final COC designation.**

COPC <sup>1</sup>	Sediments exceed Reference UPL and ½-ERM	Tissues exceed Reference UPL	Toxicity exceeds Reference UPL <sup>2</sup>	Final COC
Lead	Yes	na	Yes	Yes
Mercury	Yes	No	Yes	Yes
Zinc	Yes	na	Yes	Yes
Dieldrin	Yes	Yes	Na	Yes
Total Chlordane	Yes	Yes	Na	Yes
Total DDT	Yes	Yes	na	Yes
Total PCB <sub>20</sub>	Yes	Yes	na	Yes

na=not applicable; <sup>1</sup>=based on surface sediment concentrations (Section 5); <sup>2</sup>=based on concurrent toxicity and elevated sediment chemistry at one or more stations

### 8.2 STUDY OBJECTIVES AND IDENTIFICATION OF DATA GAPS

Environmental data that are missing but essential to complete the study objectives presented in Section 1.1 are identified. Study Objective 1 was to “define the horizontal extent of contamination and toxicity under both wet and dry weather conditions in creek sediments”. This objective was met even without October 1998 toxicity data, since wet weather conditions were evaluated in the April 2000

survey. October 1998 toxicity data were rejected because of possible predation of test animals by resident polychaetes. Eight sediment toxicity stations were sampled in 1999 and resampled in 2000, producing results for 16 acute 10-day amphipod tests. Although inclusion of chronic tests would better define sediment toxicity, acute tests provide semi-conservative screening results appropriate for this level of investigation and are consistent with other studies. One such study, the Regional Board's Bay Protection and Toxic Cleanup Program (BPTCP), relied almost exclusively on the same 10-day acute test to define toxicity throughout the San Francisco Estuary (Hunt et al. 1998). In addition, national sediment quality benchmark ERMs and ERLs are based almost entirely on results from 10-day amphipod tests (Long et al. 1995).

Thirteen sediment chemistry stations were sampled 1 to 3 times each from October 1998 to April 2000, producing 29 sediment samples, excluding the three Navy stations sampled in May 2001. Four major historical creek contaminant classes were analyzed: metals, PAHs, chlorinated pesticides and PCBs. The October 1998 survey had an expanded analyte list, which included aliphatic hydrocarbons, linear alkylbenzenes (sewage tracers), and PCB Aroclors. The spatial coverage provided from the three combined surveys is sufficient to define the horizontal extent of contamination, even though the most recent data from this investigation were collected four years ago. These data should provide a conservative estimate of current conditions since temporal trends over the three year study indicate that contaminant concentrations are decreasing.

Study Objective 2 was "to define the vertical extent of contamination in Yosemite Creek." Five sediment cores were collected, with only two attaining the target depth of 4 ft. One core penetrated to 3 ft and the remaining two cores reached 2 ft. The two 4-ft cores were collected at opposite ends of the creek, providing depth coverage for the more contaminated surface areas. The most contaminated surface sediment station (5N) was sampled to a depth of 3 ft. The two full-depth cores suggest that COC concentrations return to background concentrations between 3 and 4 ft. It is not unreasonable to assume that this pattern extends throughout the creek, including the mid-creek section. However, mid-creek sediment data to 4 ft should be collected to more fully define the vertical extent of contamination. Mean COC concentrations for each depth strata are summarized in Table 8-2.

**Table 8-2. Mean COC concentrations in Yosemite Creek subsurface sediments (dry weight).**

Depth (ft)	Lead (ppm)	Mercury (ppm)	Zinc (ppm)	Dieldrin (ppb)	Total Chlordane (ppb)	Total DDT (ppb)	Total PCB <sub>20</sub> (ppb)
0-1	293.4	0.66	371.4	119	72.6	377.9	888
1-2	266.4	0.55	333.8	78.4	40.6	131.9	529
2-3	61.2	0.25	117.3	6.8	3.6	119.2	358
3-4	8.8	0.06	73.4	<0.4	<0.3	1.2	13

Objective 3, "to identify chemicals of concern", was met in this section.

Objective 4 was "to determine if existing data are of sufficient quality, quantity and type to conduct a screening ecological risk assessment for creek sediments." The California State Parks Foundation has

current plans to create 35 acres of new wetlands, encompassing Yosemite Creek (CSPFS 2003). If successful, this creek will transform from a narrow channel surrounded by abandoned lots and light industry into a habitat capable of supporting myriad wetland flora and fauna. Regardless of the eventual habitat type, the current data set consisting of sediment chemical and invertebrate tissue concentrations should support a screening ecological risk assessment, especially if existing data are representative of current conditions.

### 8.3 CONCLUSIONS

Yosemite Creek is a complicated environment which reflects injury from historical receipt of standard industrial contaminants, presumably from combined sewer overflows, storm-water runoff, aerial fallout, sediment erosion, and the resuspension and transport of contaminated sediments. However, upgrades to the CSO system, elimination of the use of several environmental contaminants (e.g., PCBs and chlorinated pesticides), near site source removal, and improvements in general air quality likely have contributed to the overall reduction of contaminant concentrations in surface sediments compared with buried sediments. This trend is observed in creek surface sediments collected from three surveys over an 18 month period.

Contaminant concentrations in surface sediments remain elevated compared with in-bay reference sites. However, reduced surface sediment COC concentrations compared to shallow (0-2 ft) subsurface concentrations indicate that creek conditions have recently improved. Relatively higher concentrations in the 1-2 ft cores for all stations (except 1S at the creek end) indicate that buried contaminants are not being transported to overlying waters or to the South Basin; however, additional core data (from 2-4 ft) in the mid-creek region and age-dating information (e.g., Pb<sup>210</sup> dating) are needed to confirm this.

Based on the number and types of COCs identified in Table 8-1, a screening ecological risk assessment should be performed using existing data, focusing primarily on impacts to higher organisms via the food web. Bioaccumulation data showed elevated concentrations of chlorinated hydrocarbons in all clams exposed to creek sediments as compared with reference tissues. Biological impact cannot be inferred from these statistical comparisons alone and additional investigation is needed to determine the potential for transfer and impacts to higher organisms. An ecological risk assessment would be an appropriate study to determine if higher order predators are at risk from creek COCs through trophic transfer. For example, existing bioaccumulation data coupled with conservative assumptions of prey exposure, contaminant bioavailability, and site use could be used to determine if creek sediments pose unacceptable risk to invertebrate-eating birds, such as diving ducks or the Clapper Rail (important if the creek is converted to wetland habitat). Existing SFPUC data are suitable to perform this analysis without collecting additional field data.

In summary, the following information and/or studies are recommended to complete sediment investigations at Yosemite Creek:

- Collect 2-3 mid-creek subsurface sediment cores and analyze for identified COCs and age-date.
- Collect 1 subsurface sediment core at the creek mouth for age-dating only.

- Use existing data to conduct an ecological risk assessment for both constructed wetland and channel uses.
- Evaluate the need to conduct a human health risk assessment with stakeholders and the Regional Board.

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