CHAPTER 5. SEDIMENT CHEMISTRY

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I. INTRODUCTION

The primary objective of the sediment monitoring program is to evaluate the extent to which chemical and physical characteristics of sediments are affected by the pollutants in the treated wastewater discharged from HTP. Trends are determined from this information, then linked to changing treatment practices. This monitoring program, under the guidelines of HTP's current NPDES permit, includes measurement of grain size, total organic carbon (TOC), total organic halides (TOX), dissolved sulfide, cyanide, and priority pollutants (9 metals and 89 organic compounds) in sediments from designated offshore stations of Santa Monica Bay.

Continuous improvements in quality of wastewater discharge into the Bay have resulted in cleaner surface deposits in Santa Monica Bay and its vicinity for the past decade. Increased removal of solids coupled with industrial waste control programs have resulted in higher quality effluent (Schafer 1989) and recovery of benthic communities to more natural conditions (Stull et al. 1986, CLA, EMD 1989-1994a, 1995a, 1997a, 1998, and 2000). Since abatement of sludge disposal into Santa Monica Bay in 1987, levels of some contaminants have diminished in surface sediments around the old sludge outfall and biological recovery in the old sludge field is well underway (CLA, EMD 1989-1994a, 1995a, 1997a, 1998, 2000 and Thompson 1992).

During Summer of 1997 and 1998, the Environmental Monitoring Division (EMD) participated in the Bight'98 Regional Monitoring Survey, and the Santa Monica Bay Sediment Core Study which was a joint effort of the United States Geological Survey (USGS), the Southern California Coastal Water Research Project (SCCWRP), and the City of Los Angeles' Environmental Monitoring Division. The United States Environmental Protection Agency, the Los Angeles Regional Water Quality Control Board, and the City of Los Angeles agreed upon a cost neutral resource exchange in an effort to fulfill the sampling and analytical requirements of the Bight'98 Survey and USGS Sediment Core Study. All of the NPDES compliance sediment chemistry stations for 1997 and most of the 1998 compliance stations were substituted by stations selected by the regional program. Only five sampling sites from the existing program were retained, during the 1998 Summer survey, to maintain continuity with historical data.

In the Summer survey of 2001 and 2002, samples from all 44 NPDES permit mandated sites were collected for sediment quality monitoring. During this monitoring period, the sampling grid used for the benthic monitoring program was modified from an equidistant, depth- contour based grid of 44 stations to a combination fixed/random station array in order to more effectively assess the impact of HTP's full secondary treated discharge to the Santa Monica Bay. Twenty four fixed stations from the current NPDES permit's original sampling array were retained to maintain historical continuity to help distinguish naturally occurring changes from the changes related plant's discharge. Two sets of 20 randomly placed stations - to be sampled during

alternating years - were included for increased sensitivity and resolution of changes in the vicinity of the Plant's discharge.

In this chapter, results of analyses on sediment samples collected during Summer 2001 and 2002 are presented. The data were examined for spatial and temporal patterns of contamination around the HTP's 5-Mile and 7-Mile Outfalls. These concentrations were compared with background levels in the Southern California Bight and other urbanized areas. Some changes are to be expected due to the 1987 cessation of sludge discharge into the Bay.

II. MATERIALS AND METHODS

A. FIELD SAMPLING

Single samples of sediment were collected from 44 offshore stations each during the 2001 (Figure 5-1a) and 2002 (Figure 5-1b) Summer survey. Out of these offshore stations, 24 were fixed stations from the current NPDES permit's original sampling array. For both 2001 and 2002 surveys, the same set of 24 fixed stations was used, but two separate sets of 20 randomly placed stations were used.

Details of sample collection, preservation, and storage are described in Appendix C along with precise descriptions of all analytical procedures. Only general procedures are mentioned below.

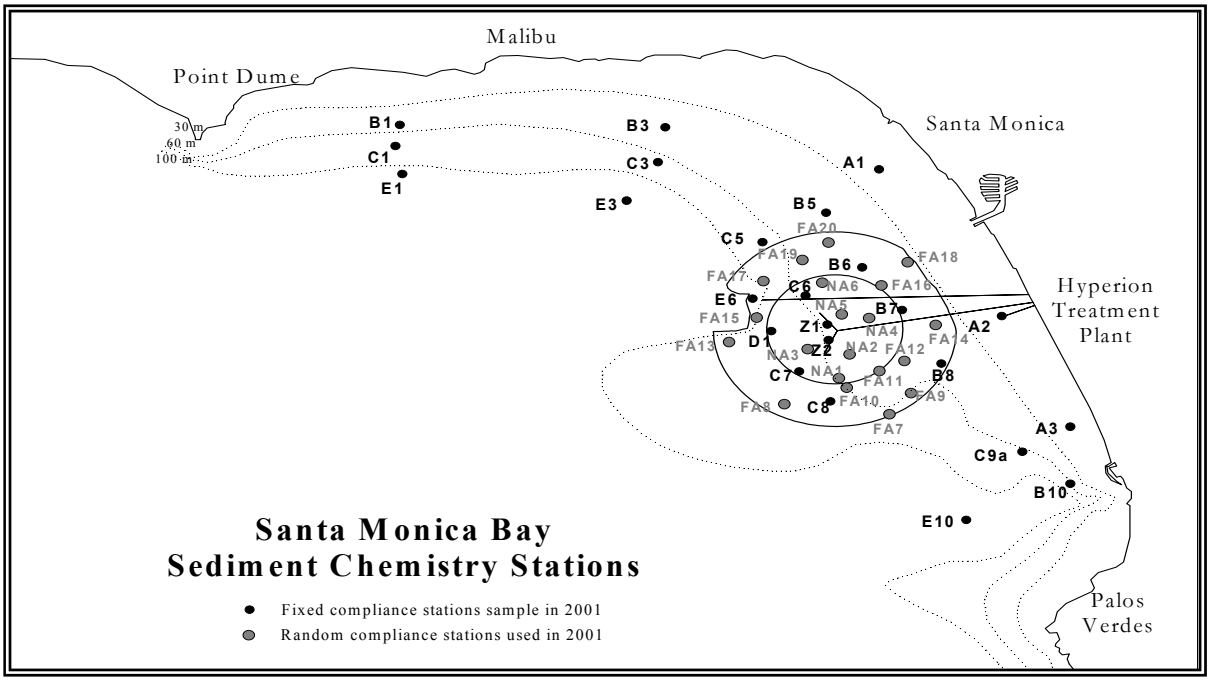

Figure 5-1a. Sediment chemistry stations sampled in Santa Monica Bay during 2001 .

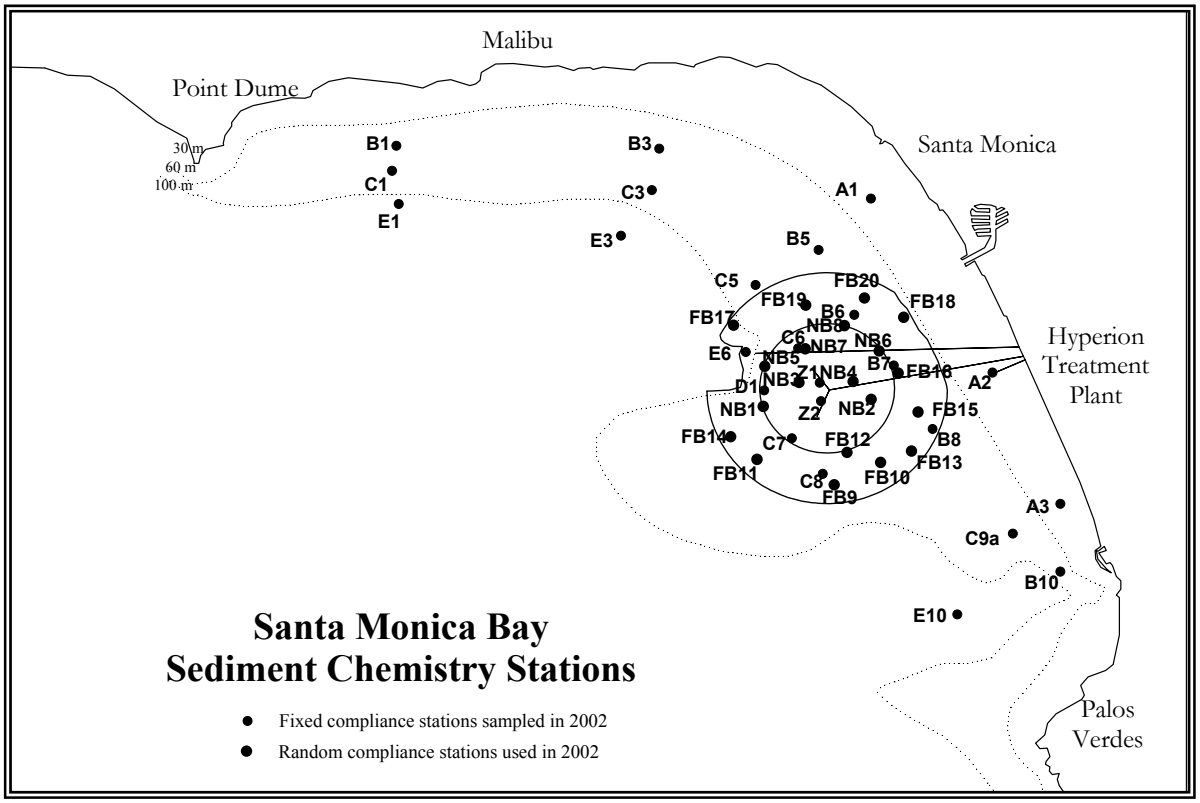

Figure 5-1b. Sediment chemistry stations sampled in Santa Monica Bay during 2002.

B. LABORATORY PROCEDURES

Sediment grain size was measured by particle size analyzer. Analyses were performed to determine percentages of gravel (particles >2 mm), sand (particles 63 μm – 2 mm), silt (particles 4 – 62 μm), and clay (particles <4 μm).

Dissolved sulfide was measured with the methylene blue colorimetric method (APHA 1992, Part 4500-S^{2-} D). Cyanide was measured by the Method 9013 described in EPA SW-846 (1986, 3rd Edition). TOC was analyzed using a TOC analyzer after persulfate digestion (APHA 1992, Part 5310 C).

For metal analysis the sediments were first digested in acids and then analyzed using Inductively Coupled Plasma (ICP) spectroscopy.

For organic priority pollutants, the sediments were solvent-extracted and concentrated prior to instrument analysis. Base/neutral and acid extractable organic compounds (BNA's) were analyzed by Gas Chromatograph/Mass Spectrometer (GC/MS). Organochlorine pesticides and polychlorinated biphenyls (PCB's) were analyzed using a Gas Chromatograph (GC) equipped with electron capture detectors (ECD).

Total organic halides (TOX) were analyzed by Mitsubishi TOX analyzer using EPA Method 9020.

C. DATA ANALYSIS

Metals and organic contaminants have a greater affinity for finer grained sediments like silts and clays. Increased levels of fine sediments could correspondingly have higher levels of contaminants. To compensate for this, sediment chemistry data were normalized using the methods described by NOAA in their National Status and Trends Program (NOAA 1988). Following this technique, raw dry weight based sediment data were normalized by dividing the analyte concentrations by the weight of silt and clay (particles less than 63 μm in diameter). Data are not normalized when the silt and clay fraction of the sediment was less than 20%. This is done to prevent misleadingly high values in sandy samples (NOAA 1988). Sediments containing less than 20% silt and clay were found at eight stations (A1, A2, A3, C7, D1, FA8, and FA10) in 2001, and six stations (A1, A2, A3, D1, NB1, and NB5) in 2002 (Tables 5-1a and 5-1b).

III. RESULTS

A. GRAIN SIZE

For the Summer survey of 2001 and 2002, sediments in the Bay were heterogeneous, mainly comprised of varying levels of sand and silt (Tables 5-1a and 5-1b; Figures 5-2a and 5-2b). Fine grained sediments, mostly silt, were found in the northwestern part of the Bay along the Malibu shelf at stations B1, C1, and E3 and then graded to muddy sands in central and southern portions of the Bay. Sands and gravel were dominant at the inshore stations A1 to A3, and in the area of station C7 and Short Bank (D1), at stations C5 to C9a and outfall stations Z1 and Z2 located along the 60-meter depth contour, and at stations B8 and B10 (Tables 5-1a and 5-1b). Grain size measurement data at fixed sampling stations of the 2001 survey were similar to those of the 2002 study (Figures 5-2a and 5-2b).

The following random stations, sampled in 2001, NA1, NA3, NA6, FA8, FA10, FA13, FA17, and FA19 were mostly sandy, and the other stations were sandy silt (Table 5-1a and Figure 5-1a). In the 2002 survey, random stations, NB5, NB7, FB12, FB17, FB18, and FB19 were mostly sandy, and the rest were sandy silt (Table 5-1b and Figure 5-1b).

B. TOTAL ORGANIC CARBON, CYANIDE, AND SULFIDE

During Summer survey of 2001 and 2002, total organic carbon (TOC) was detected at all 44 sites; cyanide was not detected at any station in 2001, and at only one station (NB2) in 2002; and dissolved sulfide was found only at Station E6 (near 7-Mile Outfall) in 2001 and was not detected at any station in 2002 (Tables 5-2a and 5-2b). In 2001, maximum concentrations of TOC (64,860 mg/kg, dry wt.) occurred at the old sludge field (station E6) located at the terminus of the 7-Mile Outfall. Similarly highest concentration of TOC (58,944 mg/kg, dry wt.) was also found at station E6 in 2002.

C. PRIORITY POLLUTANTS METALS AND ORGANICS

Out of 98 priority pollutants, 19 were detected in sediments collected at the 44 sampling sites during Summer of 2001 (Table 5-2a), and 14 were found in sediments collected in the Summer 2002 survey (Table 5-2b). A complete list of priority pollutants analyzed is presented in Appendix D.

Table 5-1a. Grain size distribution of sediments in Santa Monica Bay survey during 2001.

	Percent Composition					Percent Composition			
Station	Gravel	Sand	Silt	Clay	Station	Gravel	Sand	Silt	Clay
A-1	34.6	62.5	2.4	0.5	Z-1	0	57.2	37.5	5.3
A-2	0	84.1	12.8	3.1	Z-2	0	77.2	19.8	3.0
A-3	0	87.3	10.3	2.4					
					FA-7	0.7	52.0	40.1	7.2
B-1	0	25.6	63.1	11.2	FA-8	0	84.3	13.0	2.7
B-3	0	40.3	50.5	9.2	FA-9	0	32.2	59.5	8.2
B-5	0	47.7	44.4	7.9	FA-10	12.2	70.6	14.7	2.5
B-6	0	47.3	44.7	8.0	FA-11	0	57.8	36.9	5.2
B-7	0	38.5	53.1	8.4	FA-12	0	39.1	52.7	8.2
B-8	0	65.9	28.0	6.0	FA-13	0	69.1	24.2	6.7
B-10	0	52.6	39.9	7.5	FA-14	0	53.2	39.4	7.4
					FA-15	0	54.3	39.4	6.3
C-1	0	21.0	67.1	11.8	FA-16	0	42.6	49.7	7.8
C-3	0	58.9	33.6	7.5	FA-17	0	74.3	21.3	4.3
C-5	0	75.7	19.6	4.8	FA-18	0	57.8	35.6	6.6
C-6	0	68.0	27.3	4.7	FA-19	0	68.7	25.5	5.7
C-7	0	88.1	9.9	2.0	FA-20	0	35.1	37.9	7.0
C-8	0.1	66.7	27.6	5.6					
C-9A	0	68.0	25.4	6.6	NA-1	0	79.7	17.2	3.0
					NA-2	0	47.5	46.6	6.0
D-1	4.3	85.6	8.3	1.8	NA-3	0	72.5	23.9	3.6
					NA-4	0	41.7	50.4	7.9
E-1	0	45.2	44.1	10.7	NA-5	0	52.4	41.2	6.4
E-3	0	26.5	60.8	12.7	NA-6	0	70.3	24.7	4.9
E-6	0	46.5	46.4	7.1					
E-10	0	44.3	44.3	11.5					

Table 5-1b. Grain size distribution of sediments in Santa Monica Bay survey during 2002.

	Percent Composition					Percent Composition			
Station	Gravel	Sand	Silt	Clay	Station	Gravel	Sand	Silt	Clay
A-1	56.2	39.0	4.1	0.7	Z-1	0	58.5	36.4	5.2
A-2	0.0	90.1	8.3	1.6	Z-2	0.0	68.9	27.4	3.8
A-3	0.0	89.7	8.7	1.7					
					FB-9	0.7	57.1	35.6	6.6
B-1	0.0	24.8	64.1	11.0	FB-10	0.0	34.2	57.6	8.2
B-3	0.0	41.9	50.6	7.6	FB-11	9.2	55.5	29.2	6.1
B-5	0.0	48.8	43.2	8.0	FB-12	0.0	71.5	24.2	4.3
B-6	0.0	50.2	41.9	7.9	FB-13	0.0	44.1	47.8	8.1
B-7	0.0	42.6	49.4	8.0	FB-14	0.1	54.3	37.9	7.7
B-8	0.1	67.3	26.6	6.0	FB-15	0.0	48.7	43.7	7.7
B-10	0.0	57.8	36.1	6.1	FB-16	0.0	44.6	48.5	6.9
					FB-17	0.0	67.2	28.1	4.6
C-1	0.0	22.2	67.0	10.8	FB-18	0.0	66.2	33.1	5.7
C-3	0.0	59.0	33.5	7.5	FB-19	0.0	68.8	26.4	4.8
C-5	0.0	74.2	21.2	4.6	FB-20	0.0	55.9	37.4	6.8
C-6	0.0	70.8	24.8	4.4					
C-7	0.0	79.4	16.6	4.0	NB-1	33.0	55.6	9.6	1.8
C-8	0.0	71.5	23.1	5.4	NB-2	0.0	40.8	51.6	7.6
C-9A	0.0	66.6	27.0	6.4	NB-3	0.0	53.7	40.5	5.8
					NB-4	0.0	45.1	48.1	6.8
D-1	6.2	83.3	8.8	1.7	NB-5	0.0	87.3	10.8	2.0
					NB-6	0.0	44.9	48.3	6.8
E-1	0.0	49.8	41.5	8.7	NB-7	0.0	72.6	23.3	4.1
E-3	0.0	26.2	62.3	11.4	NB-8	0.0	63.2	31.7	5.0
E-6	0.0	35.5	56.0	8.4					
E-10	0.1	49.8	39.3	10.8					

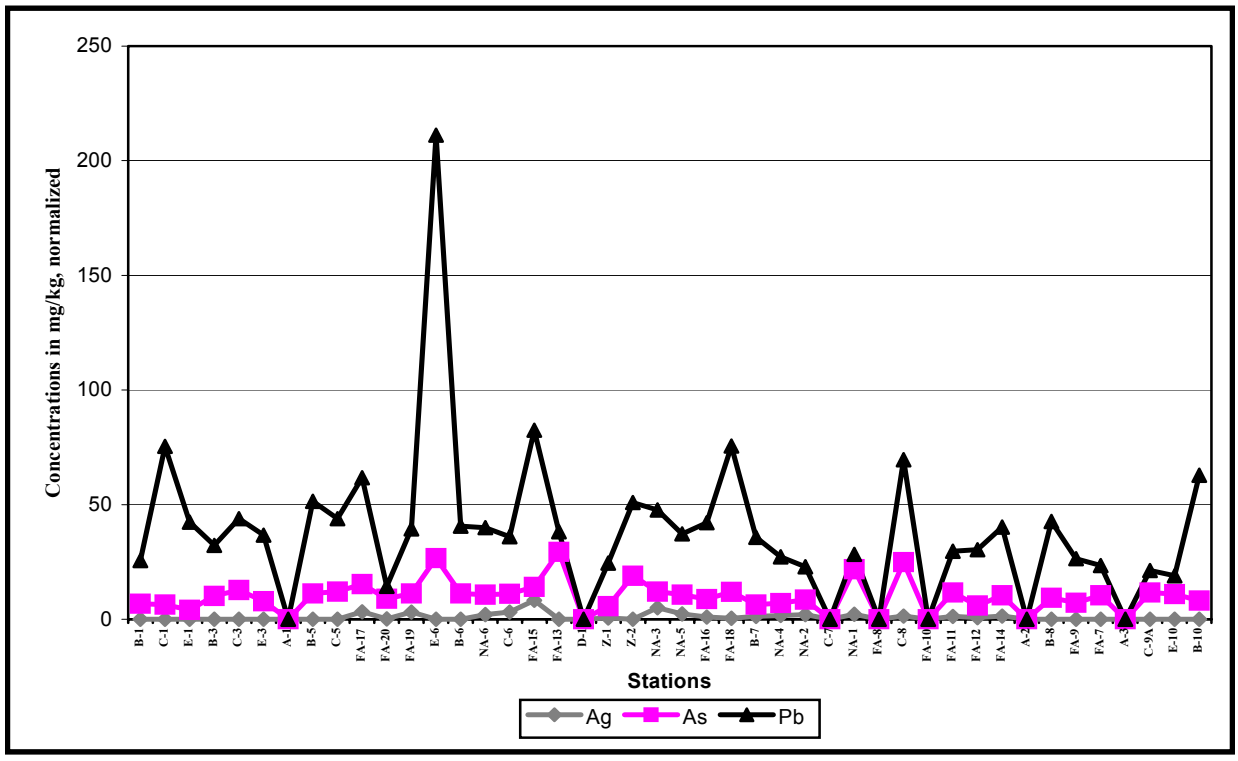

Figure 5-2a. Percentage of Silt + Clay in surface sediment of Santa Monica Bay in Summer 2001.

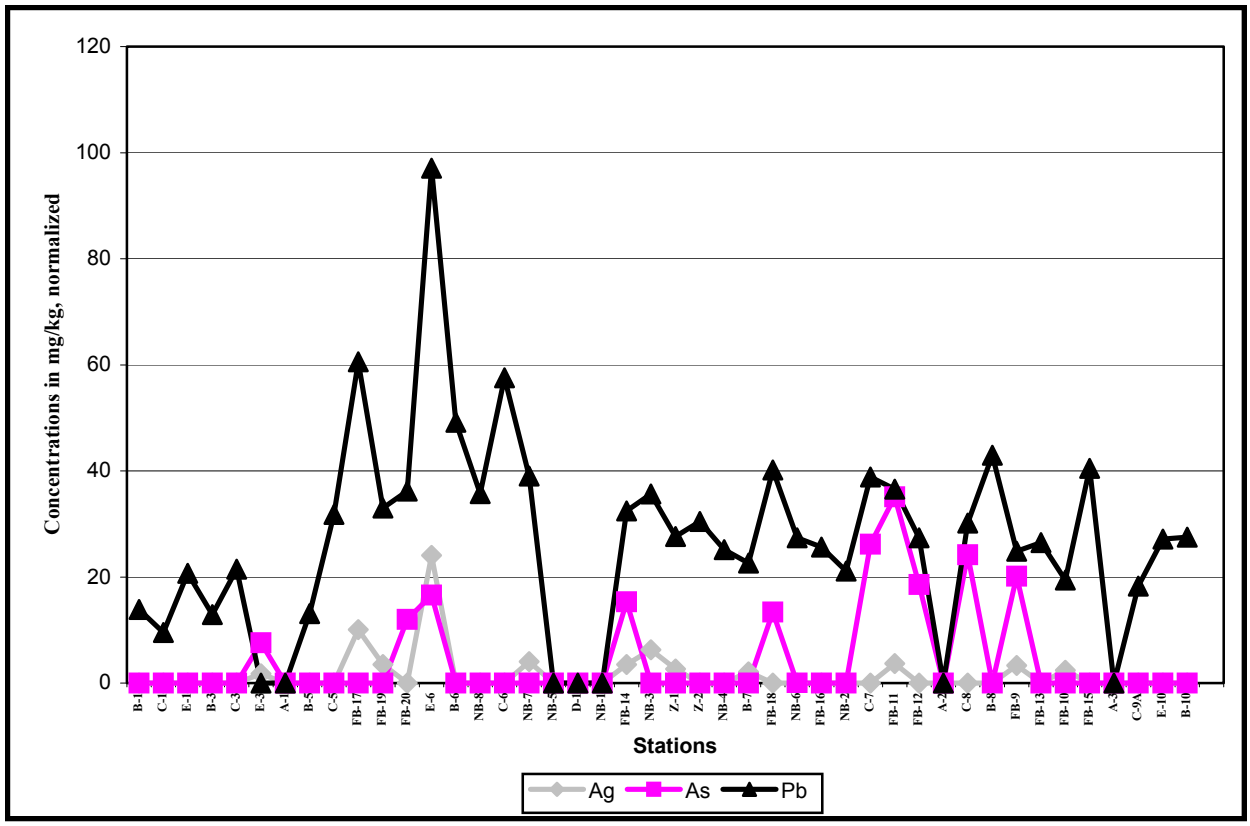

Figure 5-2b. Percentage of Silt + Clay in surface sediment of Santa Monica Bay in Summer 2002.

1. Metals

In the 2001 Summer survey, all nine priority pollutant metals were detected in the sediments of the Santa Monica Bay. Six priority pollutant metals Arsenic (As), chromium (Cr), copper (Cu), lead (Pb), nickel (Ni), and zinc (Zn) were detected at all 44 sediment sampling sites. Except for silver (Ag), all other metals analyzed were present in 90% or more of the sediment sites sampled in 2001. Ag was present less frequently (59%) in the stations surveyed. Mercury (Hg) was detected at 43 stations (except station FA14) and cadmium (Cd) at 40 stations.

In the 2001 survey, eight metals (As, Cd, Cu, Hg, Ni, Pb, and Zn) reached their maximum concentration at station E6 (in the vicinity of 7-Mile Outfall), and basically followed a similar distribution pattern of gradually reduced concentrations at stations surrounding station E6 (Figures 5-3a to 5-7a). Ag was not detected at E6. The concentration of Cr was the highest at station Z2 located in the vicinity of 5-Mile Outfall (Figure 5-4a).

Similar to 2001 survey, all nine priority pollutant metals were detected in the sediments of the Bay during the 2002 Summer survey (Table 5-2b).

In the 2002 Summer survey, Cr, Hg, Ni, and Zn were detected in sediments collected at all 44 stations. Next most frequently detected metals were Pb (43 stations) and Cu (42 stations), followed by As, Cd, and Ag (Table 5-2b and Figures 5-3b to 5-7b). Pb was not detected only at station E3. Maximum concentrations of all nine metals, except As, were detected at station E6. The highest concentration of As was at station FB11. The distribution patterns of sediment metal concentrations in the Bay were similar to that observed in 2001 survey. In general, compared to 2002 survey, the concentrations of the metals (except Cr and Ag) in 2001 survey were significantly higher (Table 5-2a and 5-2b).

2. Pesticides and PCB's

In the Summer 2001 survey, all six derivative products of DDT (o,p'-DDE, p,p'-DDE, o,p'-DDD, p,p'-DDD, o,p'-DDT, and p,p'-DDT) were distributed throughout the Bay (Table 5-2a, and Figure 5-7a). The derivative p,p'-DDE which was detected at 38 stations, predominated with its highest concentration reaching 244 μg/kg at station E10. The p,p'-DDT derivative was also detected frequently in the sediments but compared to p,p'-DDE, its concentration in the sediments was much lower (Table 5-2a). The concentration (370 μg/kg) of total detected derivatives of DDT was also highest at E10 (Figure 5-7a). γ-chlordane was detected only at station E6 with a concentration of 58 μg/kg (Table 5-2a).

In the 2001 survey, the PCB compounds were represented by the Arochlor 1260 group. These compounds have typically been found at elevated concentrations around the outfalls; the highest concentrations of Arochlor 1260 were detected at Station E6 (107 μg/kg) and at Station FA15 (74.4 μg/kg) in the vicinity of 7-mile Outfall (Figure 5-7a).

In Summer 2002 survey, four derivative products of DDT (o,p'-DDE, p,p'-DDE, p,p'-DDD, and p,p'-DDT) were detected in the sediments of the Bay, and the derivative p,p'-DDE was most dominant, occurring at 42 sampling sites (Table 5-2b, and Figure 5-7b). The highest concentration (300 μg/kg) was found at station E10 located in the southern region of the Bay.

The other two derivatives (p,p'-DDD and o,p'-DDE) were detected in the sediments at 15 and 17 stations, respectively. No other pesticides were detected in 2002.

Among PCB compounds monitored in 2002, only Arochlor 1260 was detected in the sediment samples only at 5 out of 44 stations in the Bay with the highest concentration of 110 μg/kg at 7-Mile station E6 (Table 5-2b, and Figure 5-7b).

3. Base/Neutral and Acid Extractable Compounds (BNA's)

Among the 57 BNA's analyzed in 2001 and 2002, Di-N-butylphthalate was detected only at station A1 in 2001. Bis(2-ethylhexyl) phthalate were detected in both stations A1 and A2 in 2001 (Table 5-2a and 5-2b). No BNA compounds were detected in the 2002 survey.

D. TOTAL ORGANIC HALIDES (TOX)

TOX was detected in sediments at 43 stations (except station FA13) in Santa Monica Bay during 2001 survey, and at all 44 sampling sites in 2002. The spatial trends of TOX in 2001 and 2002 were displayed in Figures 5-9a and 5-9b. The highest level of TOX was found at station C-8 in both 2001 and 2002.

Table 5-2a. Pollutants detected in sediments of Santa Monica Bay, Summer 2001. Concentrations normalized against fine grain. Unit = mg/kg

Priority Pollutants	No. Stations Detected *	Santa Monica Bay		Dana Pt.
		AVE**	Range***	Ref
Metals				
As	44	11.68	4.05-29.32	29.75
Cd	40	2.27	ND-17.93	1.37
Cr	44	103.78	33.82-282.28	141.1
Cu	44	58.59	11.58-521.50	30.2
Pb	44	45.20	14.32-211.21	51.4
Hg	43	0.52	ND-4.36	0.63
Ni	44	32.70	9.75-82.8	25.45
Ag	26	1.10	ND-8.32	1.87
Zn	44	132.61	44.06-467.29	169
Base Neutral/Acids				
Di-N-Butylphthalate	1	ND	ND	
Bis(2-ethylhexyl)phthalate	2	ND	ND	
Pesticides & PCBs				
o,p'-DDE	3	0.0039	ND-0.116	
p,p'-DDE	38	NA	ND-0.244	
o,p'-DDD	1	0.0003	ND-0.011	
p,p'-DDD	4	0.0015	ND-0.019	
o,p'-DDT	2	0.0002	ND-0.00758	
p,p'-DDT	23	0.008	ND-0.035	
Arochlor 1260	2	0.0049	ND-0.107	0.020
γ-Chlordane	1	NA	ND-0.058	
Others				
TOX	43	8.46	ND-27.87	
TOC	44	13464	6673-64860	
CN	0	ND	ND	
Dissolved Sulfide	0	ND	ND	

ND = Not Detected, NA = Not Available.

* These numbers include the stations with <20% silt plus clay.

**Concentrations below detection limits were taken as zero, and stations with <20% silt plus clay were excluded.

*** Stations with <20% silt plus clay were excluded.

Table 5-2b. Pollutants detected in sediments of Santa Monica Bay, Summer 2002. Concentrations normalized against fine grain. Unit = mg/kg.

Priority Pollutants	No. Stations Detected *	Santa Monica Bay		Dana Pt.
		AVE**	Range***	Ref
Metals				
As	10	4.98	ND-35.13	29.75
Cd	19	2.04	ND-13.06	1.37
Cr	44	114.89	54.59-305.90	141.1
Cu	42	51.07	13.18-321.43	30.2
Pb	43	31.05	ND-97.05	51.4
Hg	44	0.48	0.012-2.02	0.63
Ni	44	32.14	22.49-52.48	25.45
Ag	14	1.77	ND-24.07	1.87
Zn	44	124.56	75.90-322.98	169
Base Neutral/Acids	0	ND		
Pesticides & PCBs				
o,p'-DDE	17	0.010	ND-0.05	
p,p'-DDE	42	0.101	ND-0.30	
p,p'-DDD	15	0.006	ND-0.03	
p,p'-DDT	6	0.003	ND-0.03	
Arochlor 1260	5	0.012	ND-0.11	0.020
Others				
Dissolved Sulfide	0	ND	ND	
CN	1	NA	ND-0.71	
TOX	44	13.00	3.94-32.14	
TOC	44	18134.00	9462-58944	

ND = Not Detected, NA = Not Available.

* These numbers include the stations with <20% silt plus clay.

**Concentrations below detection limits were taken as zero, and stations with <20% silt plus clay were excluded.

*** Stations with <20% silt plus clay were excluded.

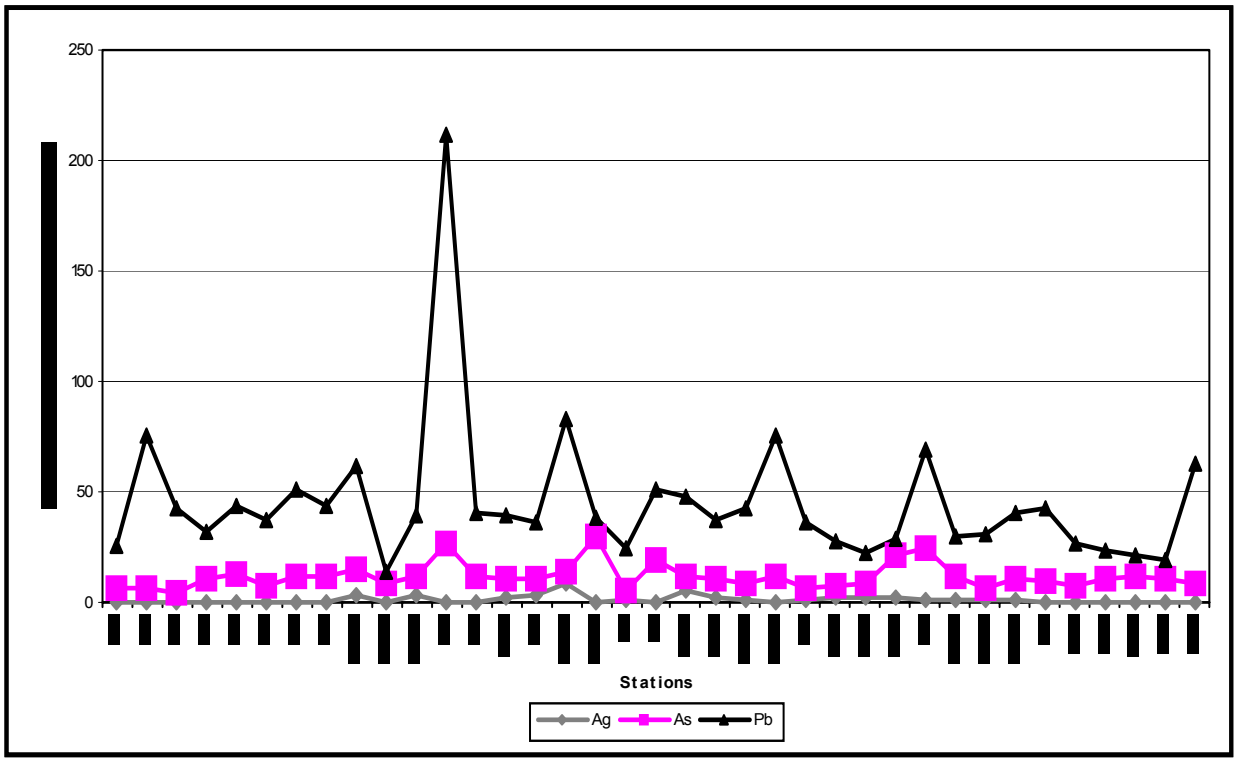

Figure 5-3a. Concentration of Ag, As, and Pb in surface sediments of Santa Monica Bay in Summer 2001.

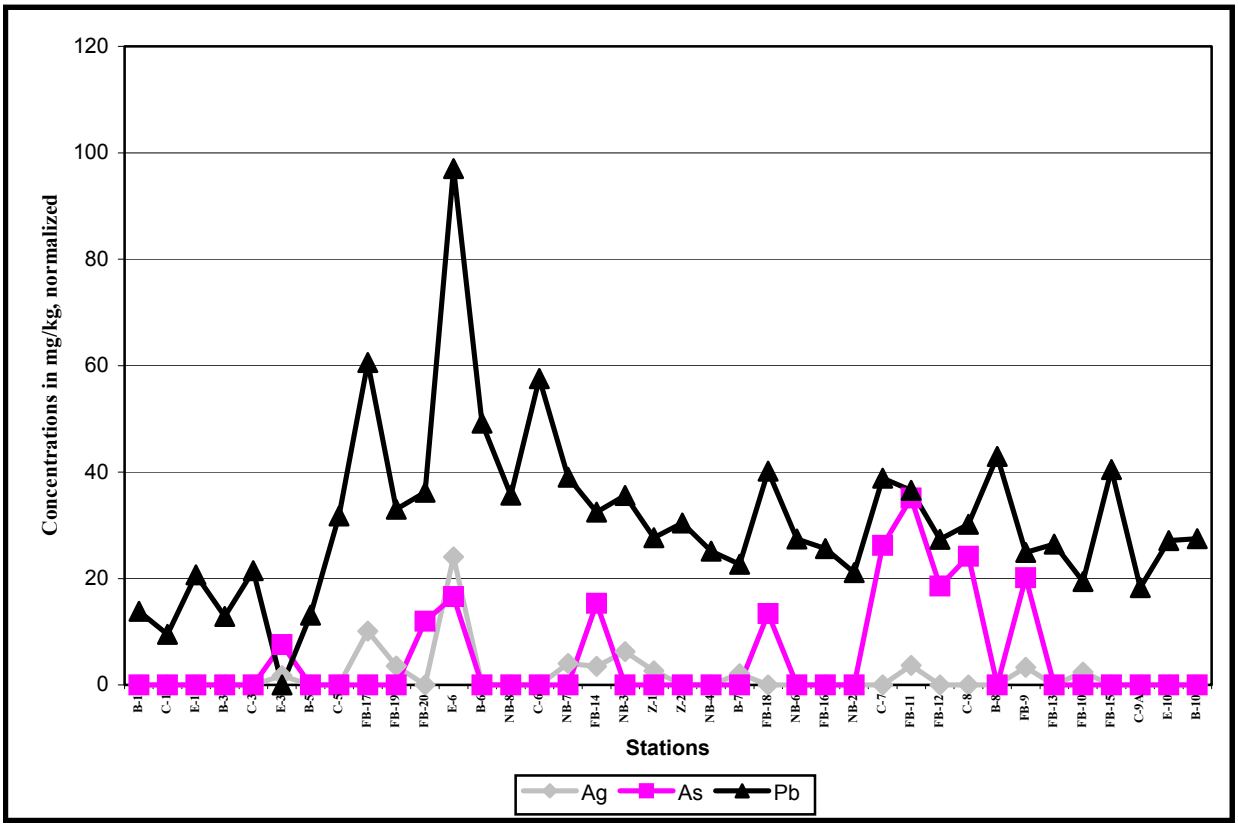

Figure 5-3b. Concentration of Ag, As, and Pb in surface sediments of Santa Monica Bay in Summer 2002.

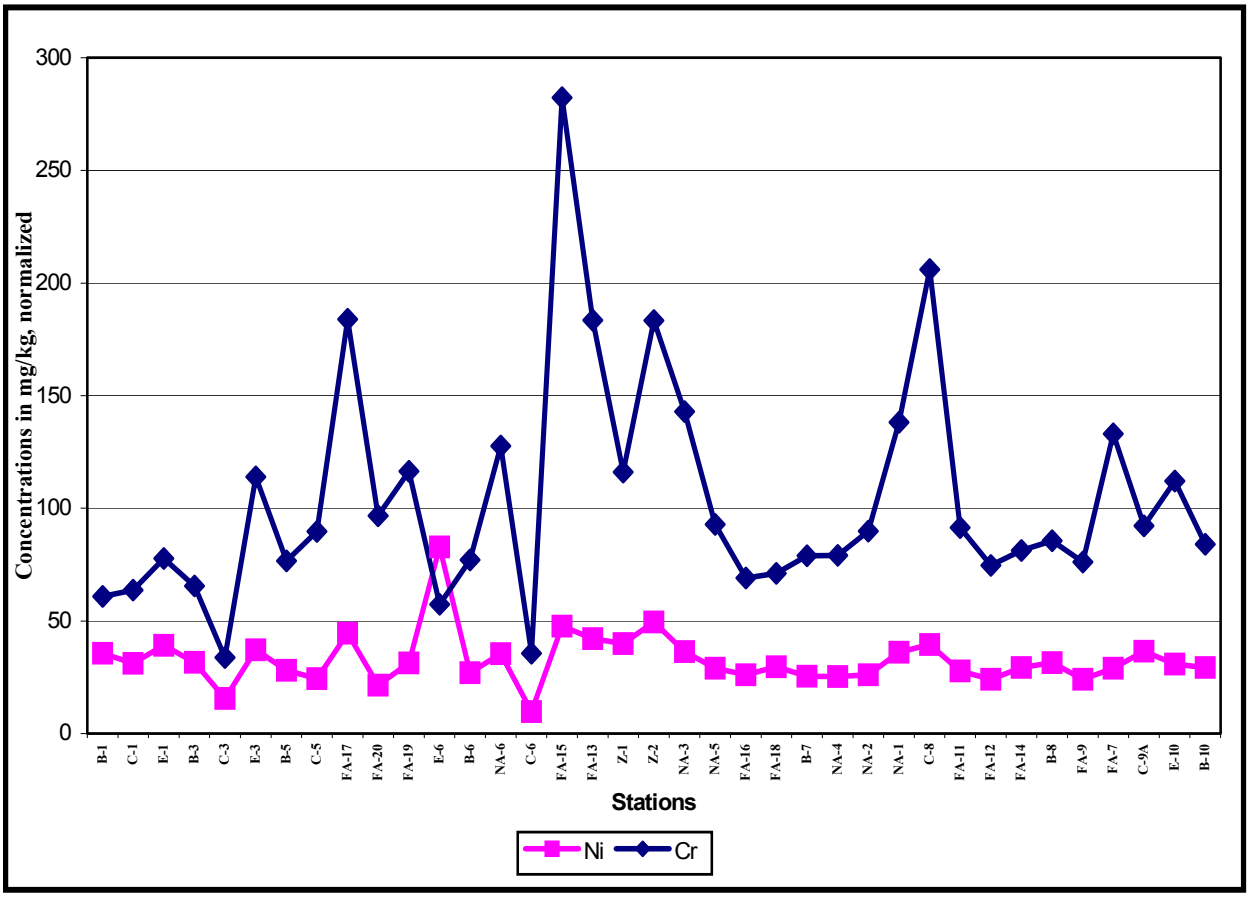

Figure 5-4a. Concentration of Ni and Cr in surface sediments of Santa Monica Bay in Summer 2001.

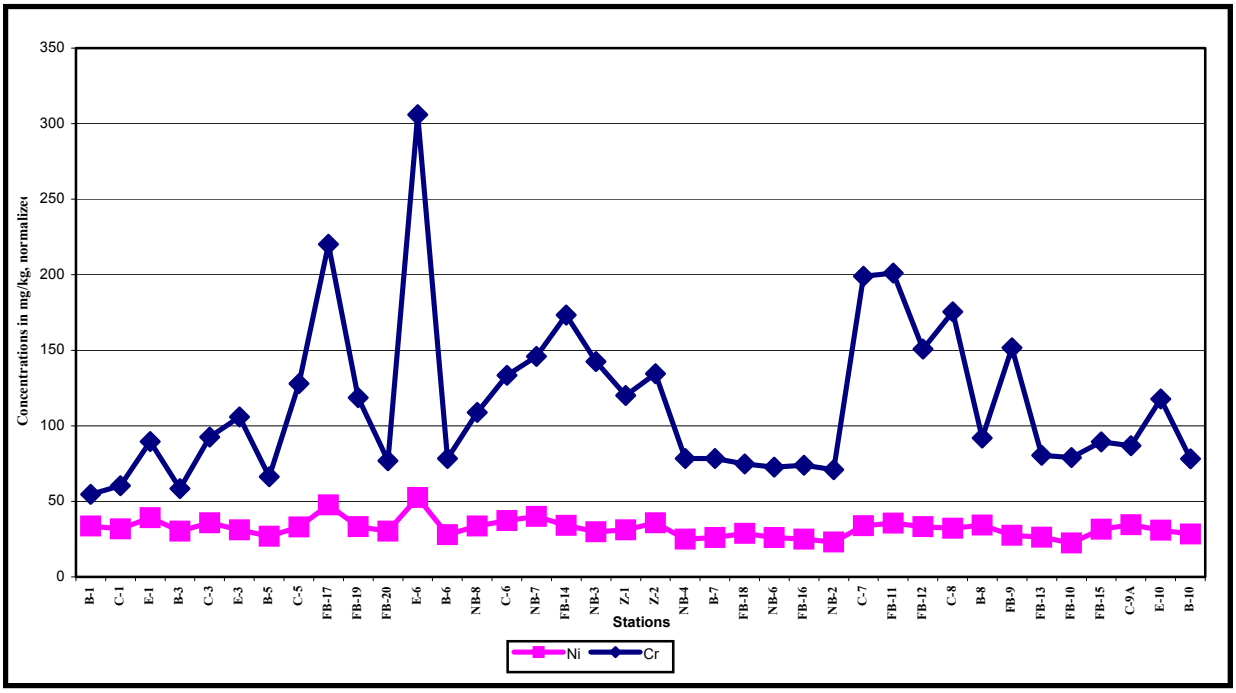

Figure 5-4b. Concentration of Ni and Cr in surface sediments of Santa Monica Bay in Summer 2002.

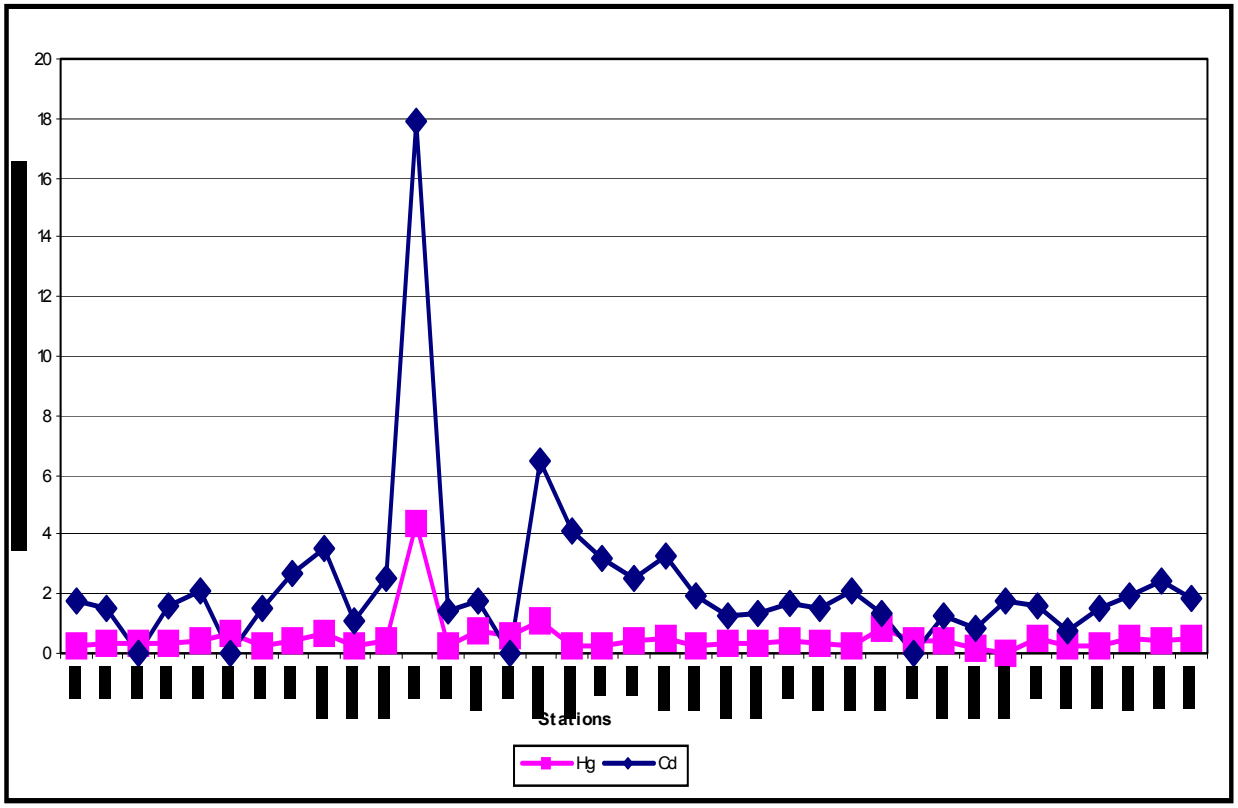

Figure 5-5a. Concentration of Hg and Cd in surface sediments of Santa Monica Bay in Summer 2001.

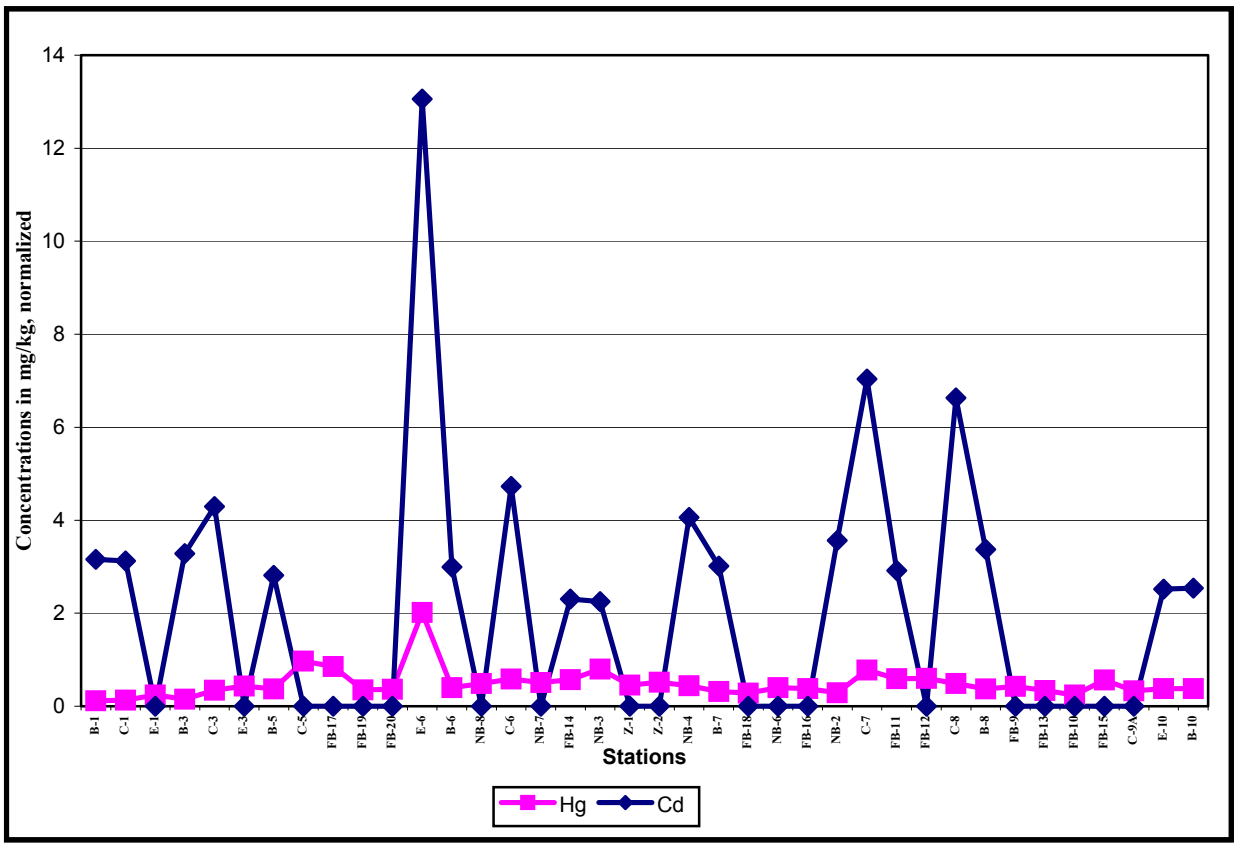

Figure 5-5b. Concentration of Hg and Cd in surface sediments of Santa Monica Bay in Summer 2002.

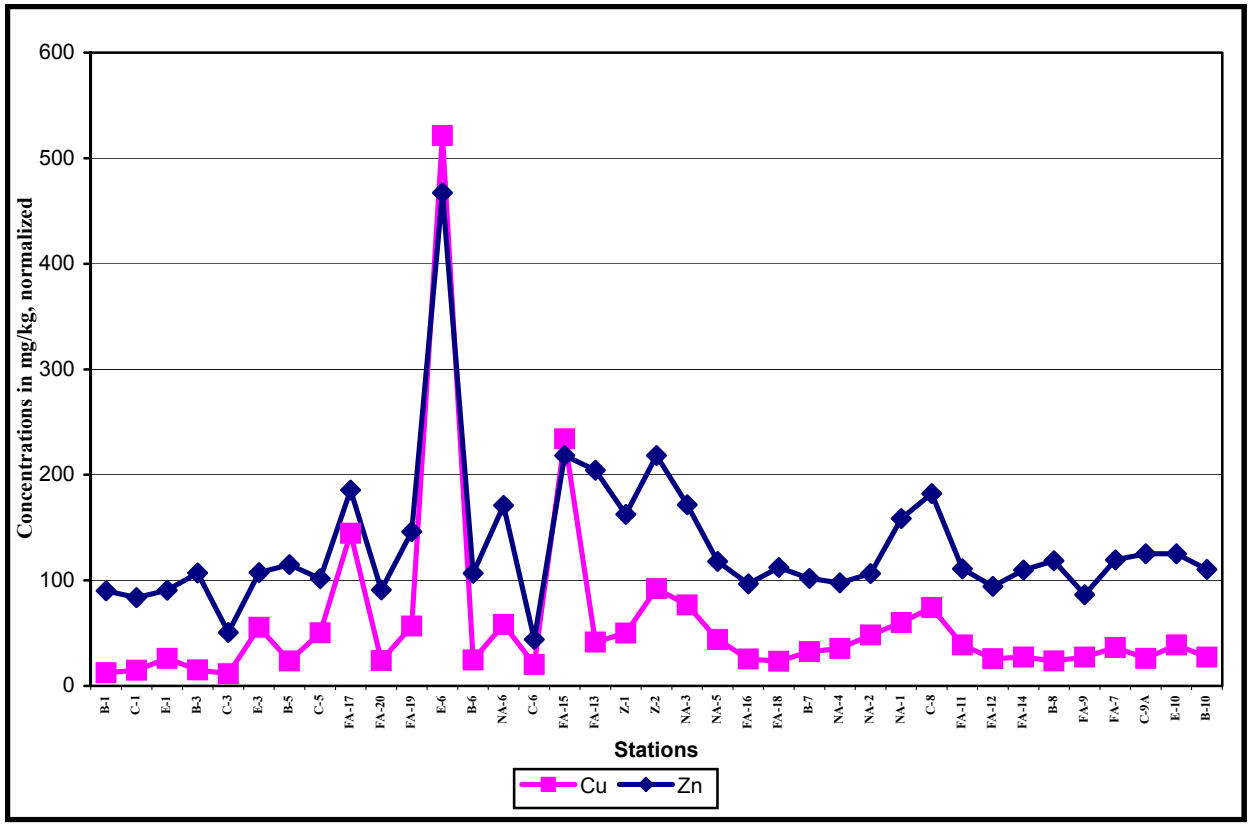

Figure 5-6a. Concentration of Cu and Zn in surface sediments of Santa Monica Bay in Summer 2001.

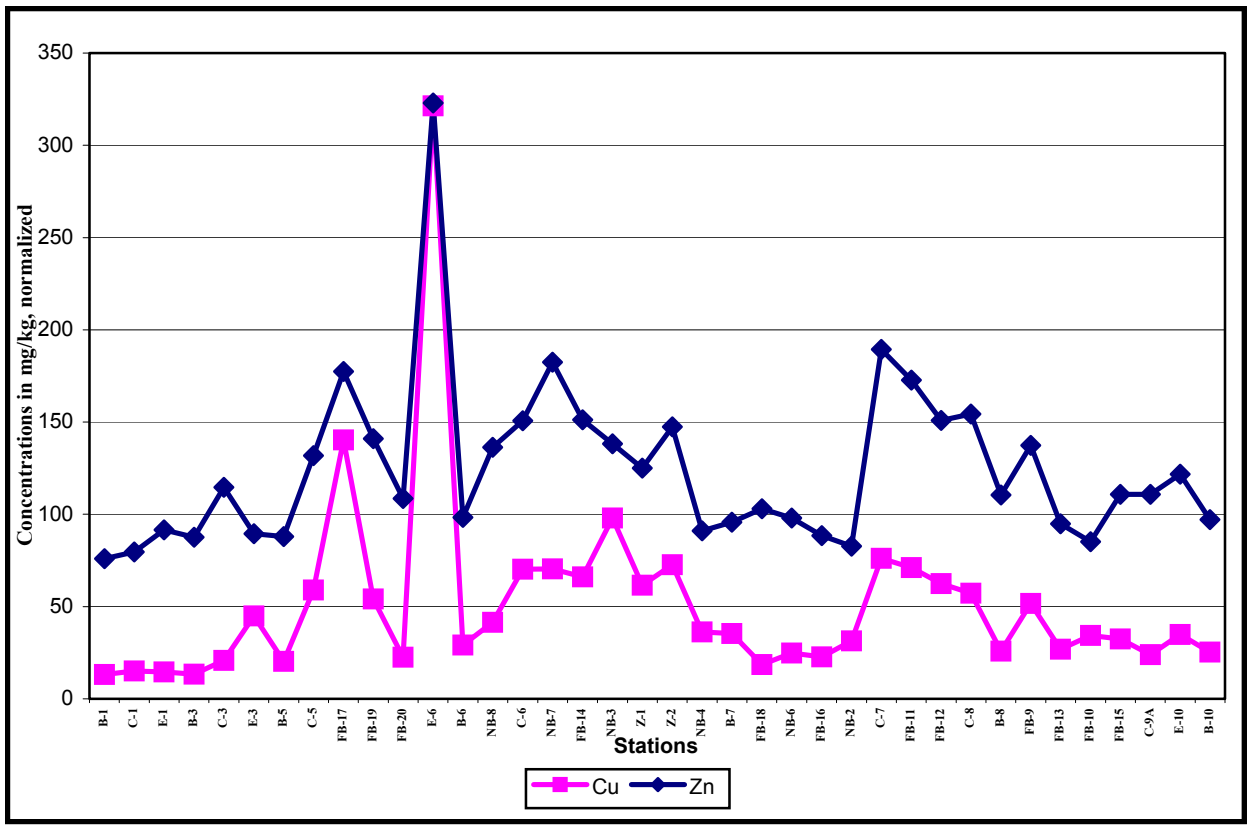

Figure 5-6b. Concentration of Cu and Zn in surface sediments of Santa Monica Bay in Summer 2002.

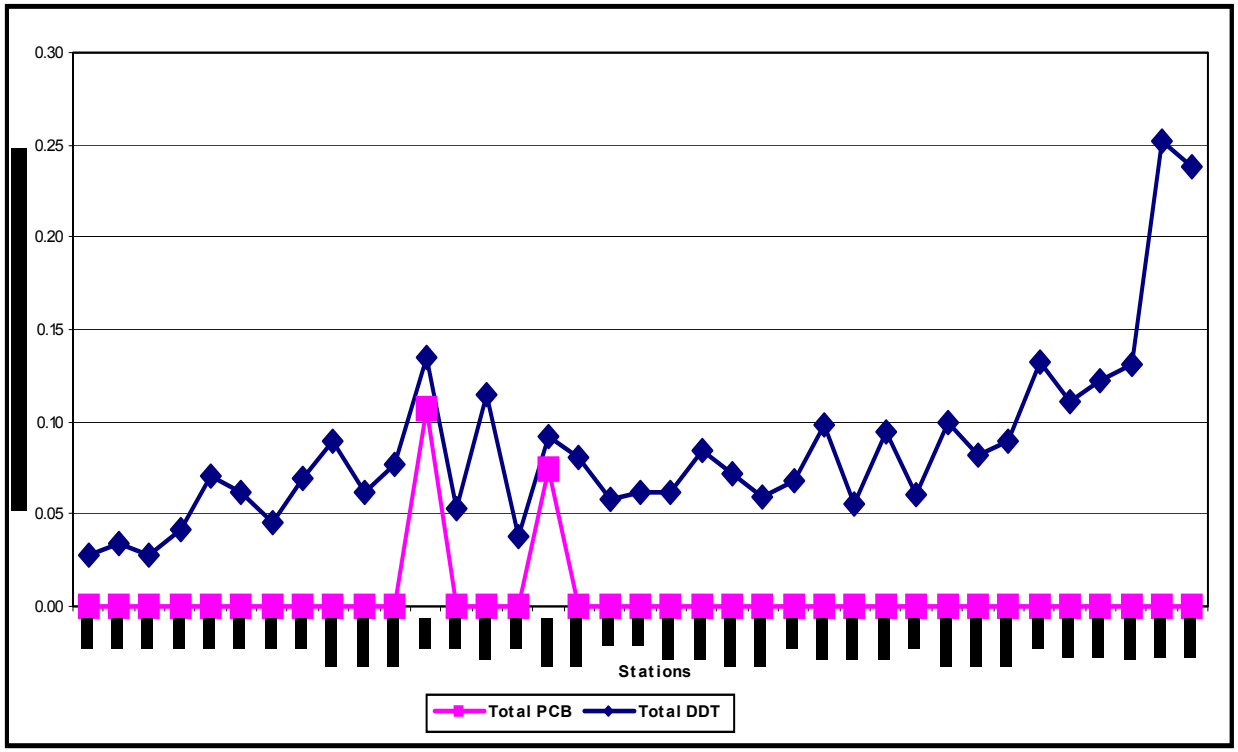

Figure 5-7a. Concentration of total PCB and total DDT in surface sediments of Santa Monica Bay in Summer 2001.

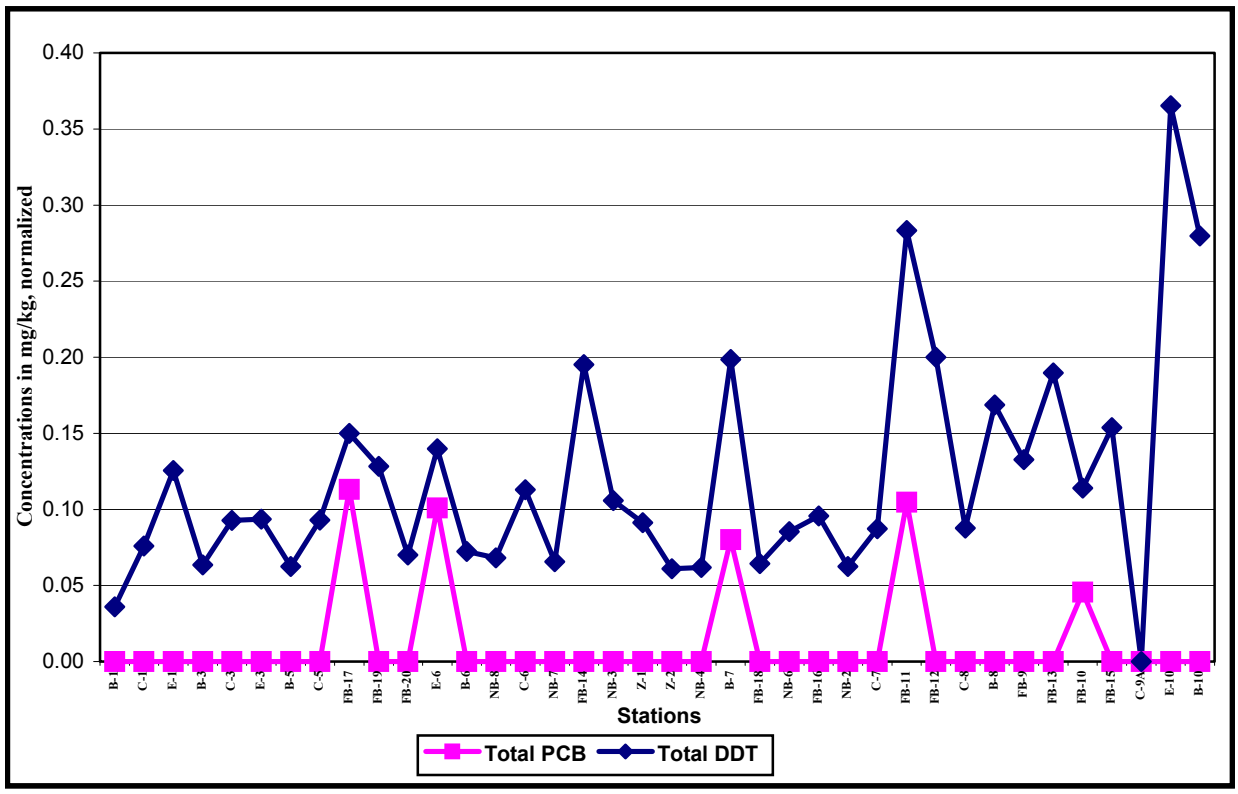

Figure 5-7b. Concentration of total PCB and total DDT in surface sediments of Santa Monica Bay in Summer 2002.

E. TEMPORAL TRENDS

The trends of chromium, cadmium, zinc, and copper in 1987 (sludge discharge discontinued at the end of the year) and from 1992 through 2002 are shown in Figures 5-10, 5-11, 5-12 and 5-13; these four metals were the only elements having a historical database spanning this period. Mostly, concentrations of Cr, Cu, and Zn in 1987 and from 1992 to 1998 were greater at the 5-Mile Outfall (average of concentrations at Z1 and Z2 stations) than at the reference site (station C1), located at the same depth (60 m) on the Malibu shelf. Starting in 1999, the levels of these three metals at 5-Mile were lower than at C1. Linear regression analyses were applied on all four metals at both 5-Mile and reference site (C1) (Figures 5-10 to 5-13). All of 1997 NPDES compliance sediment chemistry stations were source exchanged with USGS Survey and no 1997 data points were shown in Figures 5-10 to 5-13. Significant decreasing trends were shown for all metals at 5-Mile versus increasing trends for Cr, Cd and Zn at C1. The level of Cu at C1 was decreasing from 1992 to 2002. The 1999 sediment metal data, at the outfall sites and especially at the reference site; were significantly higher for Cr, Cu, and Zn than in most other years. Cu and Cd were not detected at C1 in 2000 and no Cd at was detected at the 5-Mile in 2002.

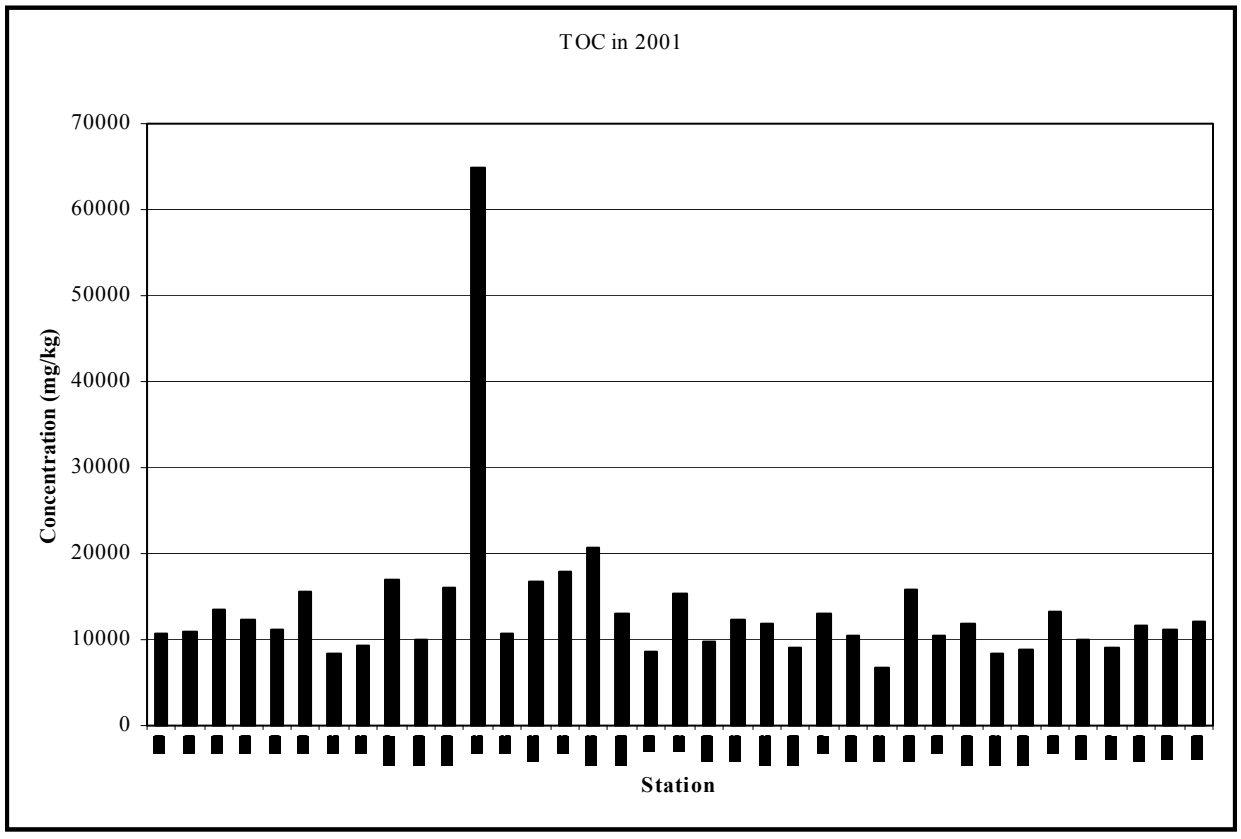

Figure 5-8a. Concentration of TOC in surface sediments of Santa Monica Bay in Summer 2001

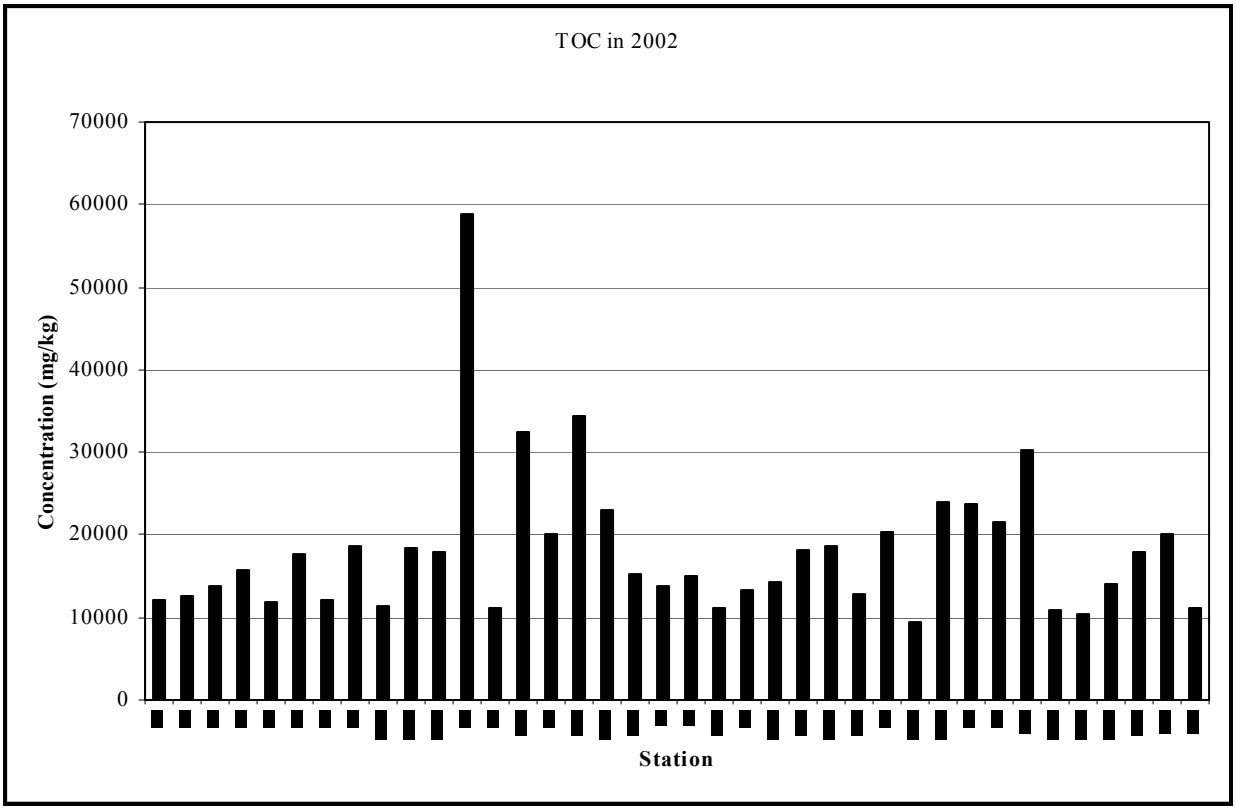

Figure 5-8b. Concentration of TOC in surface sediments of Santa Monica Bay in Summer 2002.

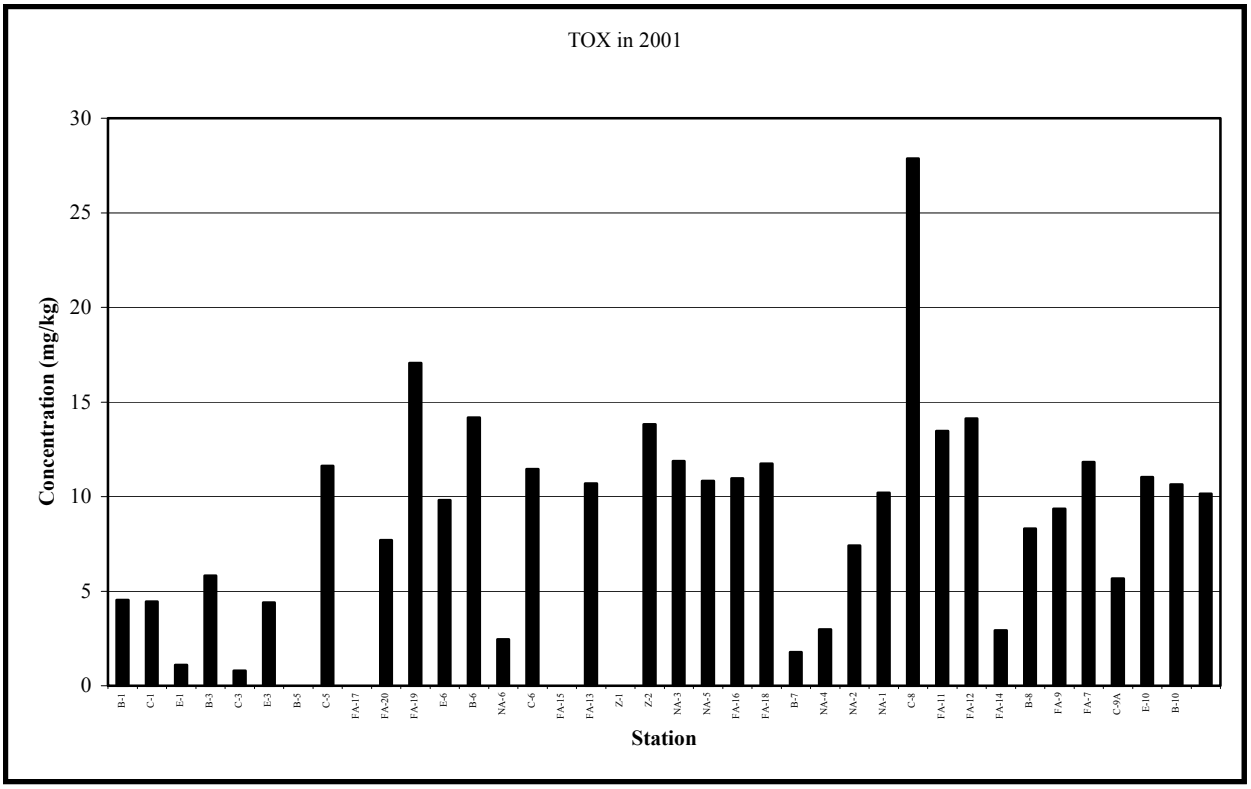

Figure 5-9a. Concentration of TOX in surface sediments of Santa Monica Bay in Summer 2001.

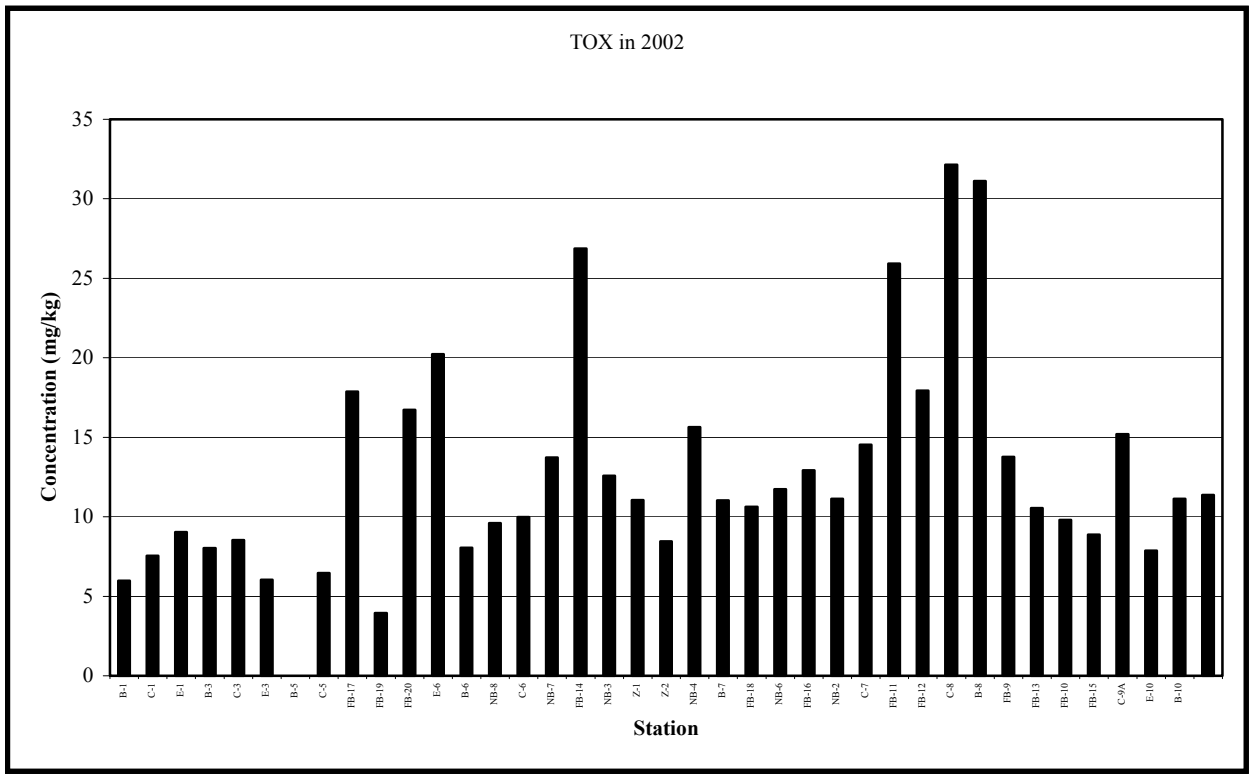

Figure 5-9b. Concentration of TOX in surface sediments of Santa Monica Bay in Summer 2002.

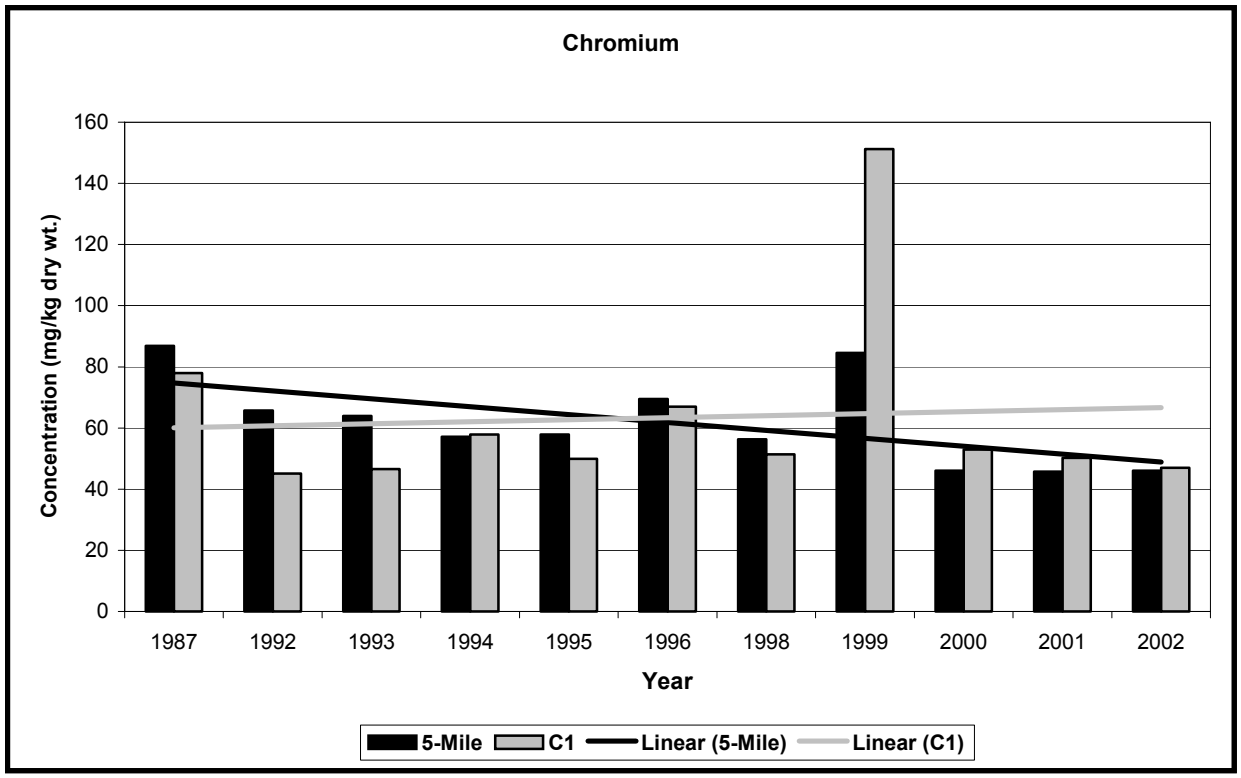

Figure 5-10. Average concentration of chromium in sediments at 5-Mile and northern reference site (C1) in 1987 and from 1992 to 2002.

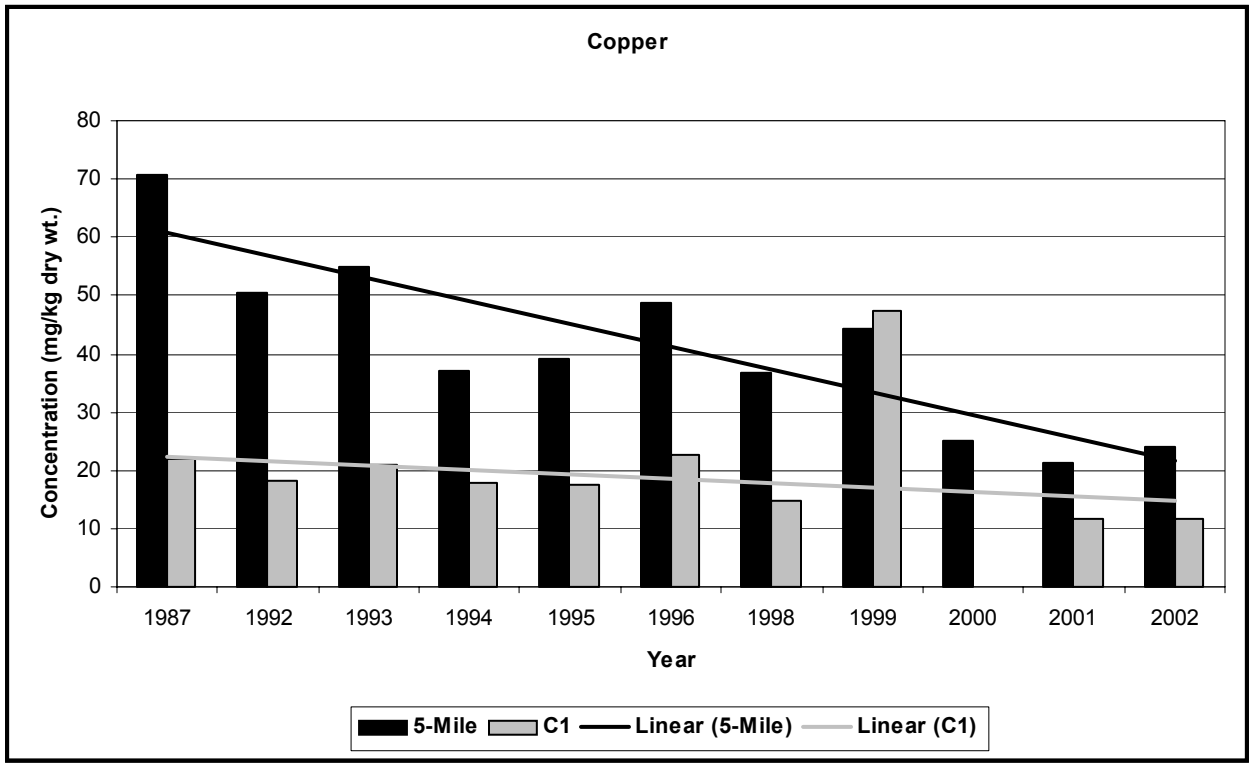

Figure 5-11. Average concentration of copper in sediments at 5-Mile and northern reference site (C1) in 1987 and from 1992 to 2002.

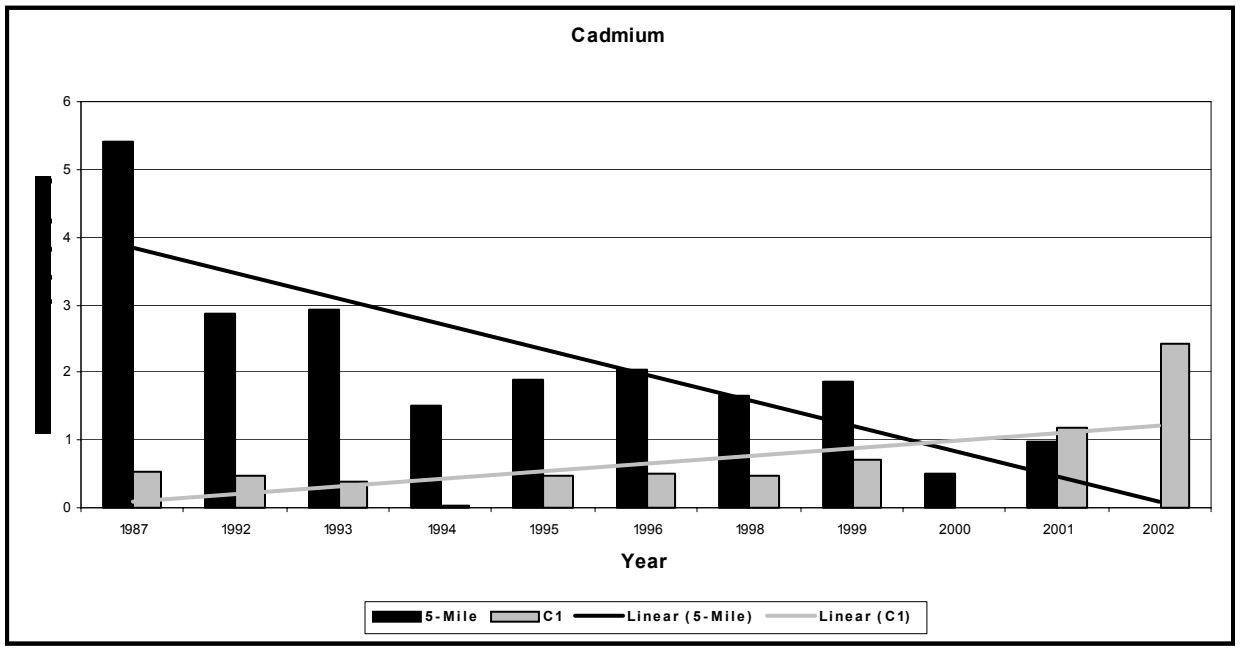

Figure 5-12. Average concentration of cadmium in sediments at 5-Mile and northern reference site (C1) in 1987 and from 1992 to 2002.

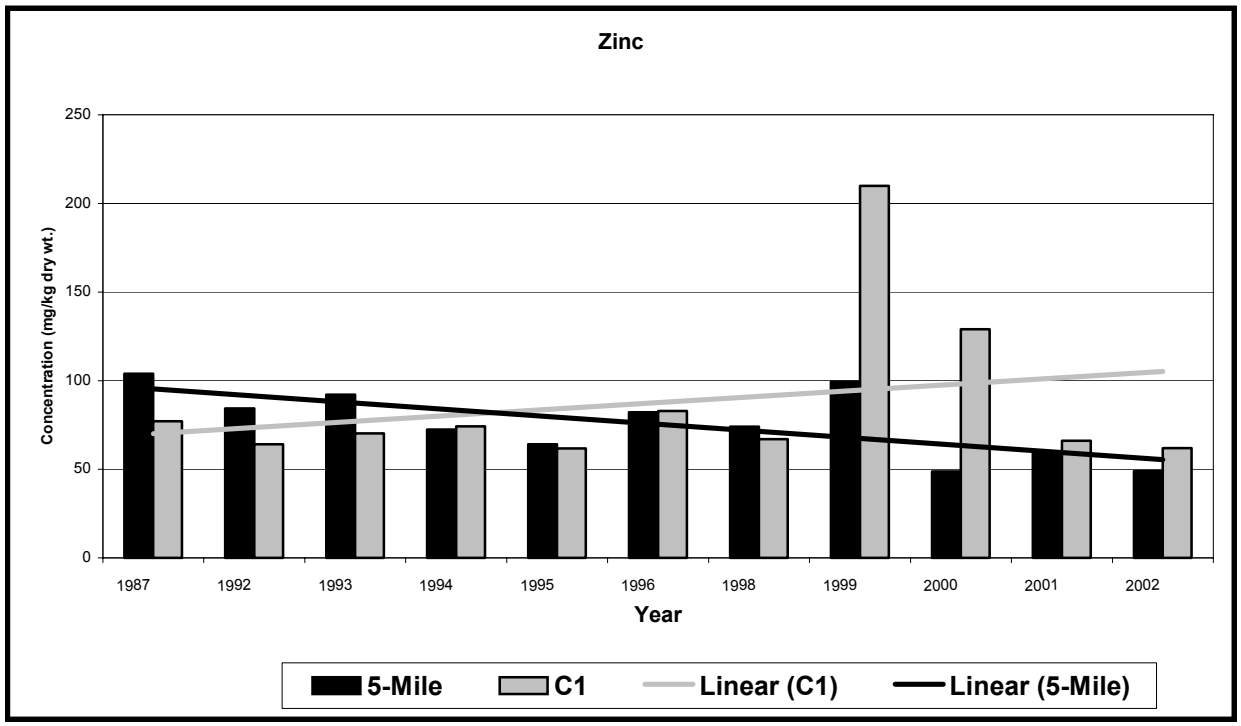

Figure 5-13. Average concentration of zinc in sediments at 5-Mile and northern reference site (C1) in 1987 and from 1992 to 2002.

IV. DISCUSSION

For the Summer 2001 and 2002 survey of Santa Monica Bay, sediment around 7-Mile Outfall (station E6) had elevated levels of metals, DDT derivatives, and the chlorinated hydrocarbon PCB 1260 (Figures 5-2 to 5-7). Compared with the reference sites in Santa Monica Bay (station C1) and offshore Dana Point (NOAA 1988), concentrations of most of these outfall contaminants were several fold higher in sediments near the 5-Mile sites (Z2) and one or two orders of magnitude higher at station E6 (Table 5-3). Elevated concentrations of these pollutants around the outfalls are expected because of their affiliation with effluent particles (Katz and Kaplan 1981). The sediment metal data at 7-Mile Outfall in 1999 was significantly higher for Cu, Cd, Hg, and Ag than other years (Table 5-3). In addition to the outfall areas, the derivatives of DDT, mainly p,p'-DDE, and PCBs were concentrated in the southern portion of the Santa Monica Bay (Stations B10 and C9a). This is consistent with the northward transport of this organic from the Palos Verdes Shelf (Mearns and Young 1983) and dumpsites in the San Pedro Basin (Venkatesan et.al 1996).

Chen et al. (1974) reported that metals, absorbed onto effluent particles, were concentrated in sediments near outfalls. In 2001 and 2002 survey, metal pollutants were widely distributed, but somewhat more concentrated on 7-Mile and 5-Mile Outfalls (stations E6 and Z2), similar to the distribution of TOC. Many of these metals occur in the dissolved state in HTP's wastewater (Chen et al. 1974; EMD, unpublished data), which could account for their wide distribution in the Bay. Additionally, these metals could be introduced into the Bay from other sources

including aerial fallout, storm drains and other Outfalls. The aerial deposition of trace metals on Santa Monica Bay was estimated as: Cr = 0.19 tons/yr; Cu = 1.28 tons/yr; Pb = 0.98 tons/yr; Ni = 0.68 tons/yr; and Zn = 4.65 tons/yr (Lu et al. 2003).

Table 5-3. Contaminant levels at outfall and reference sites. Concentrations (mg/kg for metals: μg/kg for organics) normalized against sediment fine grains.

	Outfall Sites								Reference Sites	
Contaminants	**7-Mile (E6)**				**5-Mile (Z2)**				**C1**	**Dana Point***
	1999*	**2000**	**2001**	**2002**	**1999**	**2000**	**2001**	**2002**	**2002**	**1988**
Cu	5620	520	522	321	159	71.7	92.1	72.8	15.2	29.75
Cd	274	1.73	17.9	13.1	6.7	1.94	2.50	ND	3.12	1.37
Hg	31.9	1.56	4.36	2.02	1.0	0.38	0.41	0.51	0.13	0.63
Ag	563	54.7	ND	24.1	ND	8.09	ND	ND	ND	1.87
S^{-2} (mg/L)	13.4	0.56	ND	ND	ND	ND	ND	ND	ND	NA
O,P'-DDD	35.7	ND	11.2	ND	12.3	ND	ND	ND	ND	NA
P,P'-DDD	19.9	43.7	ND	15.5	5.55	8.13	ND	ND	10.3	NA
O,P'-DDE	20.6	84.2	116	14.0	14.6	23.8	ND	ND	10.3	NA
P,P'-DDE	186	436	ND	110	74.6	110	61.4	60.9	55.3	NA
P,P'-DDT	50.9	ND	ND	ND	7.90	ND	ND	ND	ND	NA
Total DDT	313	564	127	40.5	115	142	61.4	60.9	75.9	NA
Total PCB	490	978	107	100	137	237	ND	ND	ND	20.27

***: 1984-87 Reference site survey (NOAA 1988)**
ND = Not detected
NA = Not available

*The analyses had been repeated and the results were confirmed. The extra-ordinary metal levels might be related to the high level of dissolved sulfide found in the sediment.

To assess the biological impact of the sediment contaminants of Santa Monica Bay, the metals, DDTs and PCBs levels of the sediments were compared with the Effective Range- Low (ER-L), and the Effective Range-Median (ER-M) values (Long et al 1995). The ER-L, and ER-M values correspond, respectively, to bulk sediment concentrations below which effects to benthic organisms are rarely observed (ER-L) and levels above which effects are frequently observed or expected (ER-M). With respect to ER-L and ER-M of the metals, the sediments at the 5-Mile site are not expected to have biological impact on benthic organisms. With respect to organics, DDTs and PCBs the sediments around the 5-Mile Outfall may have some biological impacts (Tables 5-4a and 5-4b).

As shown in Table 5-4a, in the 2001 survey of metal pollutants, the average concentrations and the concentrations at the 5-mile Outfall site were below their ER-M values. Except lead, silver, and zinc in 5-Mile, other metal pollutants exceeded ER-L values. The average concentrations of DDTs in the sediments in the Bay as well as at the 5-Mile site exceeded ER-M values. Average concentrations of PCBs in the sediments on the other hand were lower than the ER-L values.

In the Summer survey of 2002 (Table 5-4b), the Bay sediments and the 5-Mile Outfall, concentrations of all metals were below their ER-M values. The average metal concentrations and the metal concentrations at 5-Mile Outfall site were above ER-L values except for As, Pb, and Zn for both and Cd for 5-Mile sample. The average concentrations of total DDTs in the Santa Monica Bay sediments and at 5-Mile were above the ER-M values. However, the average concentrations of total PCBs were below ER-L values in the Bay sediments and at the 5-Mile site.

Concentrations of chromium (Figure 5-10), copper (Figure 5-11), cadmium (Figure 5-12) and zinc (Figure 5-13) in sediments around HTP's 5-Mile Outfall (average of concentrations at stations Z1 and Z2) have steadily decreased (through linear regression analysis) since 1987. This is most likely due to improvements in HTP's effluent quality (Chapter 2: Effluent Quality) since 1986. Pollutant levels have diminished in the old sludge field since termination of the 7-Mile sludge Outfall in 1987. Thompson (1991) reported that concentrations of several metals (e.g., silver) and PCB's in the vicinity of the 7-Mile Outfall have diminished to half their pre-termination levels. Metals tend to have a long residence time in surface sediments. In fact, Young (1978) measured a median half-life of 6 years for several metals in sediments near the White Point Outfall on the Palos Verdes Shelf. With the implementation of full secondary treated effluent starting in November 1998, one would expect further reduction of wastewater discharge related pollutants in the Bay, particularly around the 5-Mile Outfall. However, except cadmium in sediments around 5-Mile outfall, no other metals showed significant reduction and the levels of chromium and zinc had slight improvement from the 2000 to the 2002 survey (Figures 5-10 to 5-13). Given natural processes and the continued high quality of HTP's effluent, levels of contaminants in surface sediments should continue diminishing around the outfall over time.

Table 5-4a. Concentration of metals and organic pollutants detected in sediments of Santa Monica Bay, Summer 2001, with comparison to Effective Levels* (ER-L and ER-M). Concentrations in dry weight. Unit = mg/kg

PRIORITY POLLUTANTS	NO. STATIONS DETECTED	SANTA MONICA BAY AVE.*	SANTA MONICA BAY 5-MILE	ER-L**	ER-M**
Metals					
Arsenic	44	11.7	12.4	8.2	70.0
Cadmium	40	2.27	2.86	1.2	9.6
Chromium	44	104	150	81.0	370
Copper	44	58.6	71.1	34.0	270
Mercury	43	0.52	0.33	0.15	0.7
Lead	44	45.2	37.7	46.7	218
Nickel	44	32.7	44.8	20.9	51.6
Silver	26	1.10	0.30	1.0	3.7
Zinc	44	133	191	150	410
Pesticides and PCBs					
Total DDT	38	0.085	0.060	0.0016	0.0461
Total PCBs	2	0.0049	ND	0.0227	0.180

NA = Not Available; ND = Not Detected; Total DDTs = Sum of detected DDT derivatives; Total PCBs = Sum of detected PCB Aroclors

*Average of 44 stations. These numbers include the stations with <20% silt+clay. Concentrations below detection limit were taken as zero. For 5-Mile, data of outfall station Z2 was used.

** Source: Long et.al. (1995)

Table 5-4b. Concentration of metals and organic pollutants detected in sediments of Santa Monica Bay, Summer 2002, with comparison to Effective Levels* (ER-L and ER-M). Concentrations in dry weight. Unit = mg/kg

PRIORITY POLLUTANTS	**NO. STATIONS DETECTED**	**SANTA MONICA BAY AVE.***	**SANTA MONICA BAY 5-MILE***	**ER-L****	**ER-M****
Metals					
Arsenic	10	4.98	ND	8.2	70.0
Cadmium	19	2.04	ND	1.2	9.6
Chromium	44	115	127	81.0	370
Copper	42	51.1	67.2	34.0	270
Mercury	44	0.48	0.48	0.15	0.7
Lead	43	31.1	29.1	46.7	218
Nickel	44	32.1	33.6	20.9	51.6
Silver	14	1.77	1.32	1.0	3.7
Zinc	44	125	136	150	410
Pesticides and PCBs					
Total DDTs	42	0.120	0.080	0.0016	0.0461
Total PCBs	5	0.012	ND	0.0227	0.180

NA = Not Available; ND = Not Detected; Total DDTs = Sum of detected DDT derivatives; Total PCBs = Sum of detected PCB Aroclors

* Average of 43 stations. These numbers include the stations with <20% silt plus clay. Concentrations below detection limit were taken as zero. For 5-Mile, data of outfall station Z2 was used.

** Source: Long et.al. (1995).

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