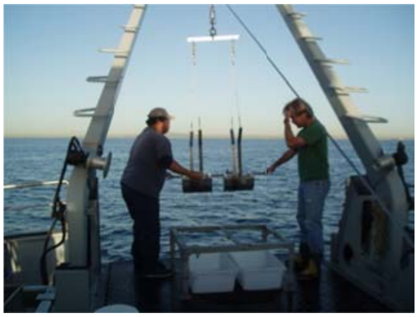
chapter 4

SEDIMENT GEOCHEMISTRY



Chapter 4
SEDIMENT GEOCHEMISTRY

INTRODUCTION

The Orange County Sanitation District's (District) Ocean Monitoring Program (OMP) requires assessments of sediment quality, including the distribution and concentration of chemical contaminants in bottom sediments within the monitoring area. The objectives are to determine the presence, magnitude, and spatial extent of wastewater-related changes to sediment characteristics and their possible relation to the health of biological communities. This information is then used to determine compliance with the District's NPDES ocean discharge permit (see box).

Both natural and anthropogenic processes affect the physical and chemical properties of sediments. The outfall pipe and the associated ballast rock make one of the largest artificial reefs in southern California. The outfall structure alters current flow and sediment characteristics near the pipe (e.g., grain size and sediment geochemistry). Wastewater discharge is one anthropogenic factor that can affect sediment quality. Discharged effluent contains a variety of organic and inorganic contaminants, including pesticides and metals (Anderson et al. 1993; OCSD 1985, 2003). Changes in the amounts and types of chemical contaminants discharged to the ocean, as well as the proportion of wastewater particles that settle and accumulate on the seafloor, may be reflected in sediments near the outfall. Periodic measurements of the physical, chemical, and toxicological characteristics of sediments are used to assess these changes and can identify temporal and spatial trends.

Compliance Criteria Pertaining to Sediment Geochemistry Contained in the District's NPDES Ocean Discharge Permit (Order No. R8-2004-0062, Permit No. CAO110604).

Criteria		Description
C.3.d	Inert Solids	The deposition of inert solids in marine sediments shall not degrade benthic communities.
C.4.c	Dissolved Sulfides	Dissolved sulfide concentrations shall not be elevated to concentrations resulting in degradation to biota.
C.4.d	COP Table B Substances	Substances found in California Ocean Plan Table B shall not cause degradation to biota.
C.4.e	Organics in Sediments	The concentration of organic material in sediments shall not be increased to levels resulting in degradation of marine life.
C.5.a	Marine Biological Communities	Marine communities, including invertebrates, fishes, and algae shall not be degraded.

The District has undertaken three projects in the last 7 years that have the potential to significantly affect effluent characteristics. The first was the August 2002 initiation of effluent disinfection by chlorination with hypochlorite bleach followed by de-chlorination with sodium bisulfate. The second was the January 2008 Ground Water Replenishment System (GWRS) water reclamation project that decreased the volume of effluent discharged into the ocean from 237 million gallons per day (MGD) in 2006-07 to 151 MGD in 2009-10. While the effluent volume has decreased the mass balance of contaminants being discharged is approximately the same, which means that the contaminants are more concentrated than before GWRS. Third, the District has been under a consent decree to achieve full secondary treatment standards by 2012. This effort was initiated in 2002 with the utilization of existing secondary treatment capacity. Presently, effluent quality is near the 30 mg/L secondary treatment levels for total suspended solids (TSS) and approximately 45 mg/L for biological oxygen demand (BOD). What affect, if any, these treatment changes have had or might have on sediment characteristics and biota are still being assessed.

METHODS

The District collects sediment samples for physical, chemical, and toxicity analyses. Single samples are collected quarterly at 10 stations along the 60-meter (m) contour (outfall depth) and annually in summer at an additional 39 stations that range in depth from 40 to 303 m (Figure 4-1). The purpose of the quarterly surveys is to assess outfall influence along the 60 m (outfall depth) contour and to determine long-term trends, while the annual survey is to assess the spatial extent of the influence of the effluent discharge throughout the monitoring area. The annual survey assessment included the quarterly station data and the 39 annual stations (n=49 stations).

Sediments were collected using a paired 0.1 m^2 Van Veen grab sampler. The top 2 cm of the sediment was collected into specific sample containers for individual chemical and toxicity analyses using a stainless steel scoop. All sediment chemistry samples (metals. organics, TOC, grain size, and dissolved sulfides) were placed in coolers on wet ice and then transferred to the District's Environmental Laboratory and Ocean Monitoring Division for analysis.

Concentrations of metals, chlorinated pesticides, polychlorinated biphenyls (PCB), polycyclic aromatic hydrocarbons (PAH), total organic carbon (TOC), and dissolved sulfides were measured in each sediment sample. Total DDT (tDDT) represents the summed concentrations of o,p'- and p,p'- [2,4- and 4,4'-] isomers of DDD, DDE, and DDT), total PCB (tPCB) represents the summed concentrations of 45 congeners, and total chlorinated pesticides (tPest) represents the sum of alpha- and cis-chlordane, cis- and trans-nonachlor, hexachlorobenzene, aldrin, dieldrin, endrin, gamma-BHC, heptachlor, heptachlor epoxide, and mirex. Total linear alkylbenzenes (tLABs), which are commonly found in detergents and serve as useful markers for sewage, were also measured to better distinguish changes in sediment quality attributable to the wastewater discharge. For summed concentrations, undetected components (i.e., concentrations below the analytical detection limits) were treated as zero. When all component concentrations were undetected, the corresponding total concentrations were assumed to be zero. Single analytes not detected during analysis were given the value of one-half the detection limit for statistical analysis. Sediment chemistry and grain size samples

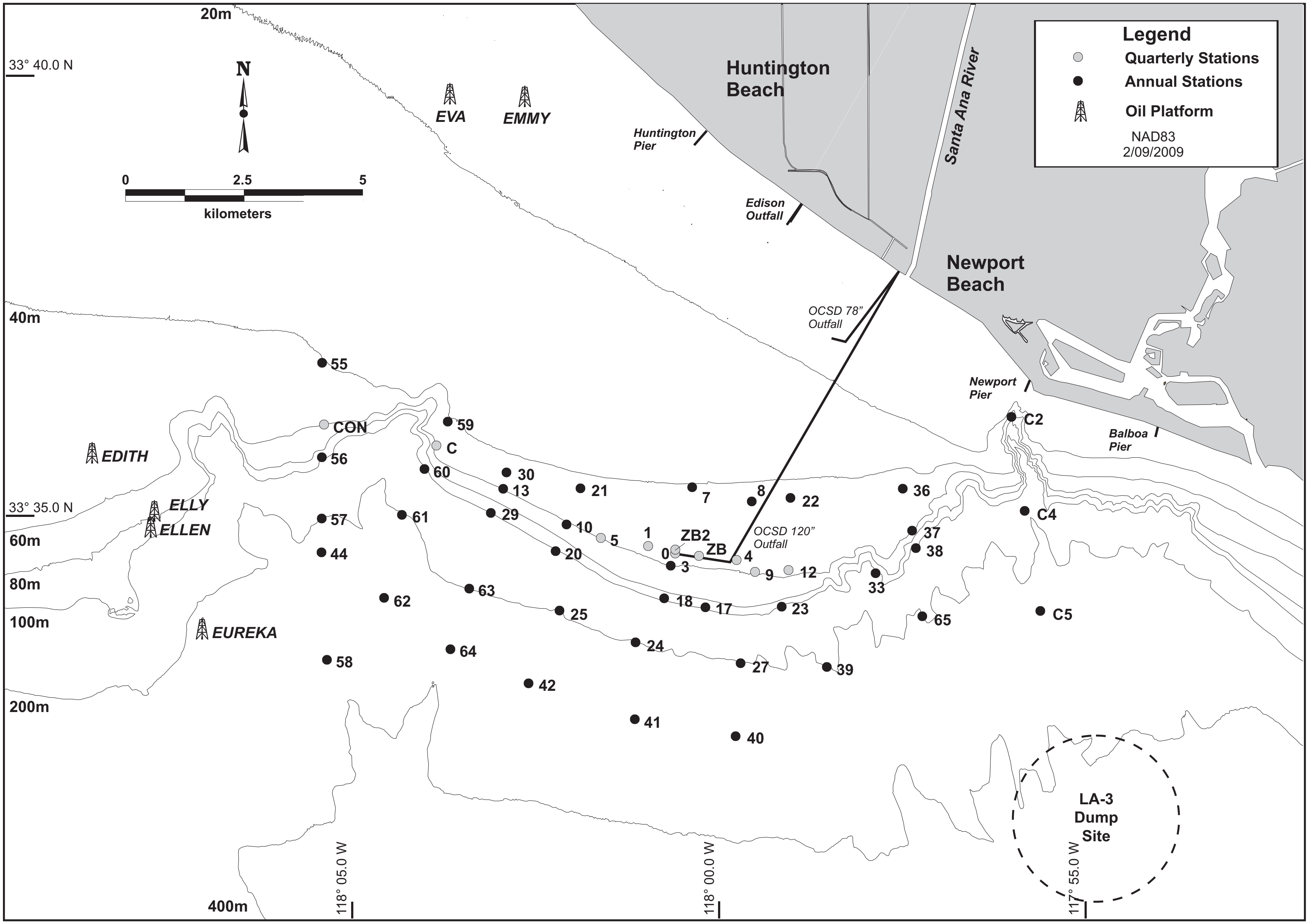


Figure 4-1. Sediment geochemistry sampling stations for annual and quarterly surveys, 2009-10.

Orange County Sanitation District, California.

were processed and analyzed using performance-based and EPA-recommended methods. Samples for dissolved sulfide were analyzed in accordance with procedures outlined in Schnitker and Green (1974) and Standard Methods 20th Edition (1998).

The District's NPDES ocean discharge permit states that the concentrations of substances contained in Table B of the California Ocean Plan (COP) and the concentration of organic substances shall not be increased to levels that would degrade marine life. The COP does not contain numeric sediment quality criteria and there are no numeric sediment contaminant limits in the District's NPDES discharge permit. Sediment contaminant concentrations were evaluated against sediment quality guidelines known as Effects Range-Low (ERL) and Effects Range-Median (ERM) (Long et al. 1995) and the mean ERM quotient (mERMq) method (Long et al. 1998). The ERL/ERM guidelines were developed for the National Oceanic and Atmospheric Administration (NOAA) National Status and Trends Program as non-regulatory benchmarks to aid in the interpretation of sediment chemistry data and to compliment toxicity, bioaccumulation, and benthic community assessments (Long and MacDonald 1998). The ERL is defined as the 10th percentile concentration of a chemical in sediment below which a toxic effect is unlikely. An ERM is the 50th percentile concentration above which a toxic effect frequently occurs (Long et al. 1995).

In addition to the direct measurement of chemical contaminants in the sediments, the District also conducted laboratory sediment toxicity tests as a measure of sediment quality. Sediment toxicity was tested at all quarterly stations in October 2009 and at a subset (n=5) of the quarterly stations in January 2010 using whole sediments for the 10-day *Eohaustorius estuarius* amphipod survival test. Amphipods were exposed to test and control sediments and the percent survival in each were determined. Toxicity threshold criteria were selected to be consistent with the Bight'98 Sediment Toxicity Program (Bay et al. 2000). A difference of 20–50% was considered a moderately toxic response, while differences greater than 50% were considered highly toxic.

Because chemical contaminants tend to co-occur in sediments and toxicity can be related to exposures to multiple contaminants, Long et al. (1998) developed the mean ERM quotient (mERMq) to improve the ability to use contaminant concentrations to predict toxicity. The mERMq is the average of specific compound concentrations divided by their corresponding ERM. Based on the recommendations in Long et al. (1998), the minimum level of significance for mERMq analysis was set at 0.11. A mERMq of 0.1 to 1.0 corresponds to a 32% probability of high sediment toxicity and 16.5% of marginal sediment toxicity, or a 48% likelihood of the sediment exhibiting some degree of toxicity. A mERMq of greater than 1.0 corresponds to a 71% probability of high sediment toxicity and 6% of marginal sediment toxicity, or a 77% likelihood of some degree of sediment toxicity. The mERMq was also employed as an assessment benchmark in this analysis.

Spatial trends for the July 2009 annual station data were assessed graphically by sediment character or analyte using contour maps and statistically by correlation-based principal components analysis (PCA) using the PRIMER v6 statistical software package. Depth-related gradients and relationships between chemical compounds and physical sediment characteristics were assessed with using Pearson Product Moment Correlation using the Minitab®

Statistical Software package. Temporal trends were assessed graphically. Data was transformed where appropriate. Statistical significance was set at $p \leq 0.05$. A more complete summary of methods for the analyses and the indices used in this chapter are presented in Appendix A.

RESULTS AND DISCUSSION

The following is a summary of the July 2009 annual survey and the four quarterly surveys.

Correlation Analysis

Relationships of sediment physicochemical characteristics to tLAB sediment concentration were assessed using Pearson correlation analysis since LABs and wastewater are strongly associated (SAIC 2003). Significant correlations between tLAB and sediment measures suggest, but do not prove, cause-effect relationships with the discharge of treated wastewater. A significant correlation of a sediment measure to tLAB, but not station depth suggests a discharge-related influence. A correlation with station depth, but not tLAB indicates a depositional influence likely associated with sediment grain size or non-water influences.

In July 2009, similar to previous years, station depth was highly correlated with percent fines ($R = 0.81$) and median phi ($R = 0.77$) due to the depositional pattern associated with sediment grain size. Correlations to percent fines will be reported as a surrogate for station depth in spatial analyses.

Spatial Analysis

<u>Linear Alkylbenzenes (LAB)</u>
In July 2009, concentrations of total LABs (tLAB) were generally higher within the zone of initial dilution (ZID) than other mid-shelf stations, but unlike previous years the highest concentrations were found outside the ZID (Table 4-1, Figure 4-2). Concentrations ranged from 9 mg/kg at mid-shelf Station 37 to 628 mg/kg at slope Station 25 (Table B-13). The highest tLAB values were found in upcoast slope and San Gabriel Canyon areas, at within-ZID stations, and to a lesser extent in the Newport Canyon. Concentrations were elevated at several upcoast canyon and slope stations (e.g., Station 24, 25, 44, 57, 58, and 62). This suggests upcoast transport with deposition in the San Gabriel Canyon, consistent with predominant sub-tidal currents below 30 m. Total LABs were weakly, but significantly correlated with percent fines ($R = 0.35$, $P = 0.01$) and moderately correlated with median phi ($R = 0.55$).

Along the 60 m contour tLABs were generally highest at ZID stations and decreased with increasing distance from the outfall in both directions along the 60 m contour (Table 4-2; Figure 4-3). Within-ZID concentration means were approximately five times greater than non-ZID stations.

<u>Sediment Grain Size</u>
Grain size distributions typically follow a pattern of larger grain size inshore and downcoast of the diffuser and become finer offshore and into deeper waters with depositional environments, such as the Newport and San Gabriel Canyons. In July 2009, as in previous years, sediment grain size varied with bathymetry and proximity to the outfall and followed expected patterns (Table 4-1, Figure 4-2).

Larger grain size and a lower percentage of fines were found near the outfall. This is due in part to scouring by currents and contributions from coarse-grained shell hash (i.e., the calcareous tubes of worms and mollusk shells). Correlation analysis found significant relationships for station depth to percent fines ($R = 0.81$) and

Table 4-1. Annual concentrations of sediment organic contaminants (µg/kg) compared to Effects Range–Low* (ERL) and Effects Range–Median* (ERM) values, and measurements of sediment physical characteristics at the District's annual stations in 2009-10.

Orange County Sanitation District, California

Station	Depth	Total LAB (ug/kg)	Median Phi	Fines (%)	TOC (%)	Sulfides (mg/kg)	Total PAH (ug/kg)	Total DDT (ug/kg)	Total Pest (ug/kg)	Total PCB (ug/kg)
Shallow Shelf (40 – 46 meters)										
7	41	25.3	4.12	42.9	0.39	3.24	39.6	**3.09**	ND	1.67
8	44	87.0	4.17	44.3	0.43	4.13	44.8	**9.63**	ND	2.44
21	44	15.9	3.82	36.8	0.32	4.02	28.7	**1.97**	ND	0.650
22	45	20.3	4.23	51.8	0.40	5.70	61.9	**7.50**	ND	0.820
30	46	21.0	3.71	33.6	0.31	3.08	72.2	**4.23**	ND	4.82
36	45	10.3	4.09	45.6	0.43	2.67	79.3	**5.14**	ND	2.04
55	40	22.2	2.92	5.71	0.18	3.99	164	**3.21**	ND	1.05
59	40	20.4	3.36	18.4	0.27	3.98	30.9	**4.61**	ND	4.22
	Average	27.8	3.80	34.9	0.341	3.85	65.2	**4.92**	ND	2.21
Mid-Shelf Within-ZID (56 – 60 meters)										
0 *	56	344	3.47	14.8	0.47	6.67	1430	**4.68**	ND	15.0
4 *	56	64.0	3.50	13.5	0.31	3.37	24.4	1.26	0.750	0.950
ZB *	56	173	3.58	16.3	0.32	2.85	615	1.55	ND	1.82
ZB2 *	56	214	3.62	17.6	0.38	10.5	75.8	**2.87**	ND	11.1
	Average	199	3.54	15.6	0.370	5.85	536	**2.59**	0.188	7.22
Mid-Shelf Non-ZID (56 – 60 meters)										
1 *	56	55.3	3.85	26.2	0.38	3.44	70.3	**2.59**	ND	5.67
3	60	109	3.65	18.3	0.36	5.05	37.5	**1.61**	ND	4.41
5 *	59	35.7	3.86	38.7	0.29	4.17	43.7	**4.65**	0.310	3.60
9 *	59	32.9	3.42	15.5	0.43	4.02	ND	1.34	ND	0.610
10	60	67.5	4.21	51.1	0.39	4.28	33.3	**2.56**	ND	2.95
12 *	58	15.9	3.28	3.93	0.33	4.89	36.0	**1.82**	ND	0.130
13	59	77.6	4.05	41.0	0.33	6.04	41.3	**2.85**	ND	1.22
37	56	8.80	2.84	15.0	0.28	5.25	22.8	**4.97**	ND	1.51
C *	56	36.1	3.75	23.4	0.61	4.56	41.7	**3.32**	ND	0.130
C2	56	14.6	5.06	91.8	1.77	35.0	208	**20.1**	ND	6.55
CON *	59	22.6	3.87	26.9	0.38	3.81	34.1	**3.36**	ND	ND
	Average	43.3	3.80	32.0	0.505	7.32	56.9	**4.47**	0.028	2.43
Outer Shelf (91–-100 meters)										
17	91	31.9	3.54	24.1	0.35	5.58	38.0	**3.12**	ND	0.790
18	91	14.1	3.96	29.4	0.35	5.90	26.2	**4.87**	ND	1.13
20	100	34.8	4.29	64.8	0.50	6.00	43.8	**9.10**	ND	3.10
23	100	99.7	3.37	17.7	0.29	7.20	20.9	**4.30**	ND	0.550
29	100	43.8	4.37	71.1	0.54	2.97	57.3	**7.01**	ND	2.86
33	100	16.1	3.56	31.8	0.43	2.98	51.1	**5.73**	ND	1.46
38	100	14.4	4.12	54.5	0.51	5.86	61.2	**5.60**	ND	1.36
56	100	50.9	3.96	47.5	0.48	5.25	71.1	**9.27**	ND	3.02
60	100	4.5	4.12	54.9	0.50	5.85	57.6	**7.14**	ND	3.98
	Average	34.5	3.92	44.0	0.439	5.29	47.5	**6.24**	ND	2.03

Table 4-1 Continues.

Table 4-1 Continues.

Station	Depth	Total LAB (ųg/kg)	Median Phi	Fines (%)	TOC (%)	Sulfides (mg/kg)	Total PAH (ųg/kg)	Total DDT (ųg/kg)	Total Pest (ųg/kg)	Total PCB (ug/kg)
Slope (187 – 241 meters)										
24	200	271	4.70	84.6	0.94	9.29	68.7	**15.2**	ND	3.85
25	200	928	6.63	91.8	1.29	6.88	105	**9.85**	ND	4.09
27	200	21.3	4.41	68.1	0.69	3.14	58.0	**18.2**	ND	3.24
39	200	14.3	3.62	30.7	0.47	3.27	53.0	**6.75**	ND	2.56
44	241	557	6.27	96.4	2.00	20.4	243	**24.2**	ND	9.52
57	200	231	5.57	91.5	1.64	16.0	133	**15.2**	ND	11.5
61	200	70.4	4.87	85.7	1.25	9.78	86.4	**18.9**	ND	4.41
63	200	60.8	4.78	86.0	1.08	4.46	113	**12.9**	ND	5.55
65	200	54.9	4.82	76.2	0.98	8.12	104	**15.6**	ND	3.07
C4	187	57.6	5.48	83.6	1.47	14.9	171	**11.4**	8.50	3.07
	Average	227	5.12	79.5	1.18	9.62	114	**14.8**	0.850	5.09
Basin (296 – 300 meters)										
40	303	71.0	4.82	86.1	1.13	4.35	88.2	**7.49**	ND	2.15
41	303	59.2	4.89	84.0	1.27	13.9	81.1	**7.85**	ND	2.18
42	303	117	5.26	92.5	1.62	8.61	169	**20.9**	ND	2.03
58	300	180	5.96	97.0	2.05	12.9	199	**31.1**	ND	12.1
62	300	200	6.01	96.8	1.97	11.2	193	**20.6**	ND	8.60
64	300	73.0	5.02	87.5	1.34	6.47	79.9	**16.7**	4.09	13.8
C5	296	109	6.51	97.8	2.01	36.2	162	**17.4**	ND	4.30
	Average	116	5.50	91.7	1.63	13.4	139	**17.4**	0.584	6.45

Individual and average values greater than the ERL are bolded. Annual stations n = 1.

ND = Not Detected

* Long et al. 1995

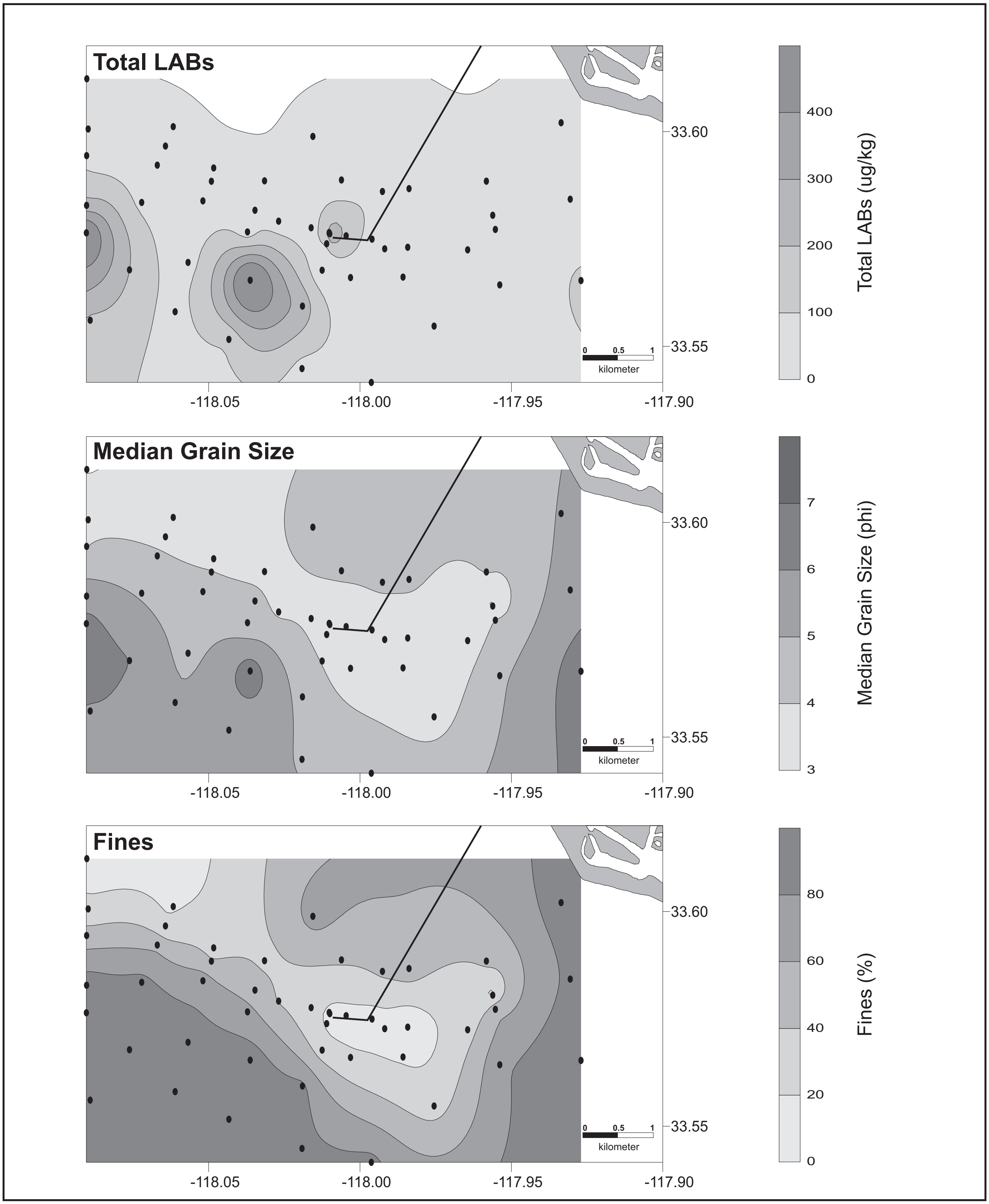


Figure 4-2. **Spatial distributions of total linear alkyl benzenes (tLAB), median grain size (phi), and fine sediments (% less than 62 micron diameter) during July 2009.**

Orange County Sanitation District, California.

Table 4-2. Average annual concentrations of sediment organic contaminants and measurements of sediment physical characteristics at the District's quarterly stations in 2009-10.

Orange County Sanitation District, California

Station	Depth	tLAB (ųg/kg)	Median Phi	Fines (%)	TOC (%)	Sulfides (mg/kg)	Total PAH (ųg/kg)	Total DDT (ųg/kg)	Total Pest (ųg/kg)	Total PCB (ųg/kg)
Within-ZID Stations										
0	56	261	3.45	11.9	0.558	10.8	467	**3.19**	0.019	16.7
4	56	55.9	3.48	16.5	0.303	4.42	105	1.11	0.282	0.792
ZB	56	185	3.54	17.4	0.305	6.69	114	0.893	ND	6.58
ZB2	56	305	3.54	16.7	0.411	12.2	346	**3.13**	ND	20.7
Average	56	202	3.50	15.6	0.394	8.53	258	**2.08**	0.075	11.2
Non-ZID Stations										
1	56	66.5	3.73	27.1	0.367	4.95	61.9	**2.02**	ND	4.71
5	59	37.7	3.86	38.7	0.346	3.29	105	**2.33**	0.026	1.87
9	59	32.4	3.45	18.0	0.296	3.40	53.4	1.51	0.063	0.883
12	58	37.5	3.35	13.7	0.296	4.69	138	**2.44**	ND	0.683
C	56	22.2	3.64	27.2	0.361	2.71	60.3	**4.62**	ND	0.578
CON	59	26.6	3.70	25.8	0.356	2.57	53.4	**4.26**	ND	1.07
Average	58	37.2	3.62	25.1	0.337	3.60	78.7	**2.86**	0.015	1.63
Sediment Quality Guideline and Reference Values										
[1]ERL		NA	NA	NA	NA	NA	4,022	1.58	NA	22.7
[1]ERM		NA	NA	NA	NA	NA	44,792	46.1	NA	180
[2]Bight'03 Mid-depth AWM		NA	NA	45.0	0.75	NA	60.3	**36.0**	NA	2.4
[2]Bight'03 Large POTW AWM		NA	NA	38.0	0.83	NA	118	**316**	NA	**29.0**

Values greater than the ERL are bolded.
Quarterly stations n = 6
Total LAB only collected in July 2009 (1 rep).
NA = Not Applicable, ND = Not Detected, AWM = Area Weighted Mean
[1]Long et al. (1995)
[2] Schiff et al. (2006)

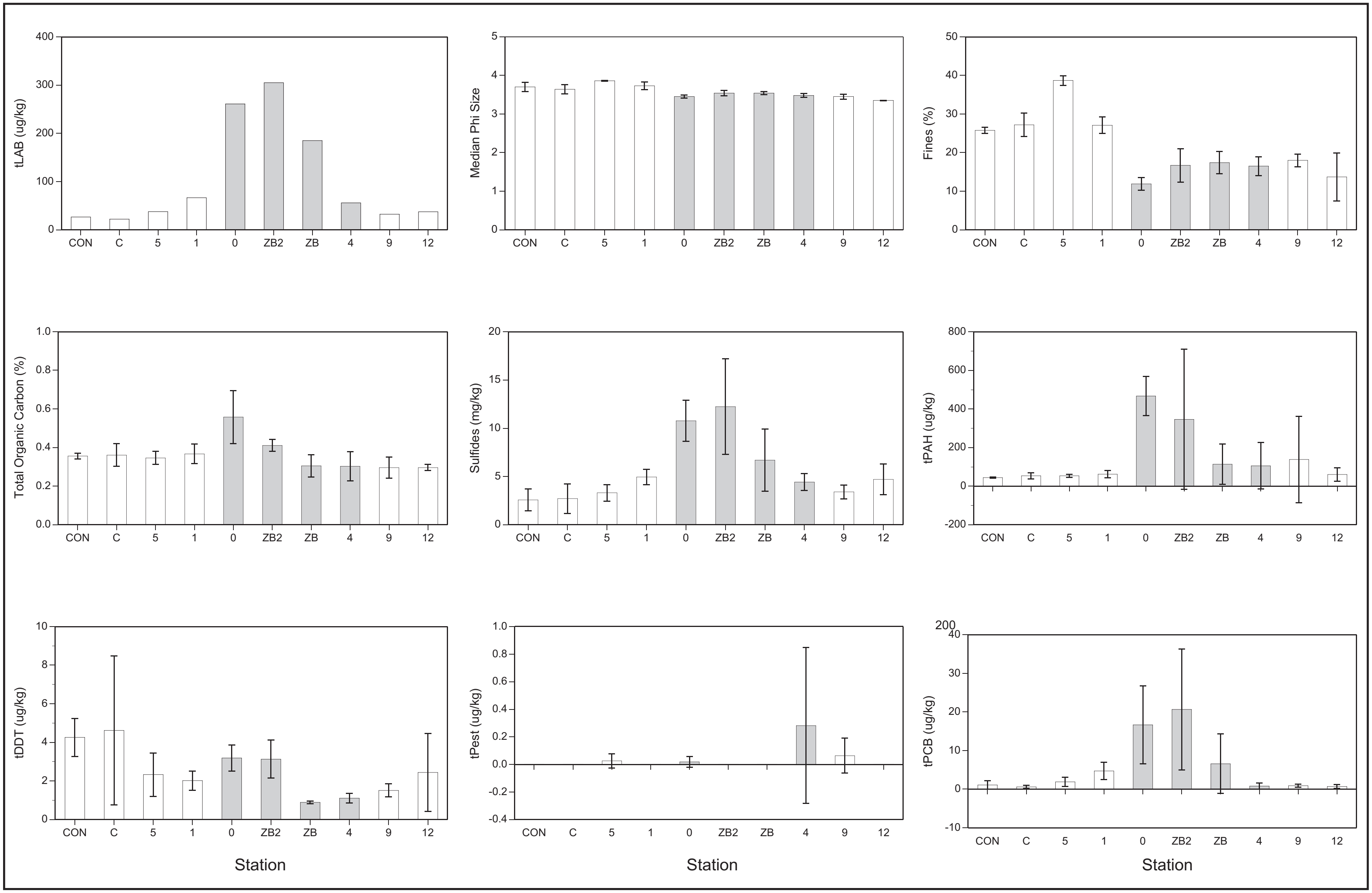


Figure 4-3. **Distribution of mean and standard deviation values for total LAB (ug/kg), median phi, fines (%), total organic carbon (%), dissolved sulfides (mg/kg), total PAH (ug/kg), total DDT (ug/kg), total pesticides (ug/kg), and total PCB (ug/kg) in sediments at the 60 m shelf stations during 2009-10.**
Stations plotted from north to south (left to right). ZID stations indicated in grey.

Orange County Sanitation District, California.

median phi (R = 0.77). Total LAB concentrations were significantly correlated with median phi (R = 0.55) and percent fines (R = 0.35) suggesting that the wastewater discharge affected grain size distributions in the monitoring area.

Non-ZID quarterly station means for median phi ranged from 3.35 at Station 12 to 3.86 at Station 5, while proportions of percent fines (silt and clay) ranged from 14% at Station 12 to 39% at Station 5. The highest mean value for percent fines was lower than the Bight'03 mid-shelf station mean and comparable to the large POTW (LPOTW) mean (Table 4-2). Median phi and percent fines were higher upcoast from the outfall (Figure 4-3).

<u>Sediment Organic Content</u>

Total Organic Carbon (TOC)

In July 2009, sediment TOC concentrations ranged from 0.18% at northern shelf Station 55 to 2.05% at basin Station 58 in the San Gabriel Canyon (Table 4-1). There was a slight increase in TOC in sediments at the outfall terminus, but concentrations generally increased with depth (Figure 4-4). This pattern is expected since wastewater particles tend to settle out near the point of discharge and sediment organic carbon content tends to increase with decreased grain size and increased percent fines. Correlation analysis found significant relationships of TOC to depth (R = 0.83), percent fines (R = 0.88), and tLAB (R = 0.45) indicating that sediment grain size is the primary factor determining sediment TOC concentrations, though the outfall discharge is a contributing factor.

At the non-ZID quarterly stations, sediment TOC ranged from 0.30% at Stations 9 and 12 to 0.37% at Station 1 (Table 4-1; Figure 4-3). All quarterly station means were below the Bight'03 mid-depth and POTW means of >0.75 (Table 4-2).

Dissolved Sulfides

In the annual survey, sediment sulfide concentrations remained low and ranged from 3 mg/kg at Station 36 to 36 mg/kg at Station C5 (Table 4-1). Compared to shelf stations, sulfide concentrations were elevated in the submarine canyons and some slope and basin stations, which is consistent with a depositional, deep-water environment (Figure 4-4). Higher concentrations at stations upcoast and offshore of the outfall diffuser, consistent with sub-thermocline currents, suggest a discharge-related pattern. However, correlation analysis showed significant relationships of dissolved sulfides to station depth (R = 0.41) and percent fines (R = 0.56), but not to tLAB concentrations suggesting that non-discharge related influences are more important in sediment sulfide distribution.

Sediment sulfide concentrations at non-ZID quarterly stations ranged from 2.57 mg/kg at Station CON to 4.95 mg/kg at Station 1 (Table 4-2; Figure 4-3). The pattern of sediment sulfide levels along the 60 m contour suggests an outfall influence, though the low concentration at non-ZID stations are not likely biologically relevant (compare tLAB to Sulfides in Figure 4-3).

<u>Organic Contaminants</u>

Polycyclic Aromatic Hydrocarbons (PAH)

In July 2009, sediment total PAH (tPAH) concentrations were highest at stations within the ZID and nearest the diffuser terminus and fairly uniform on the remaining portion of the shelf, slope, and basin areas (Table 4-1, Figure 4-4). Concentrations ranged from not detected at Station 9 to 1430 µg/kg at Station 0. Correlation analysis showed a significant relationship of tPAH with tLAB (R = 0.41), but not with station depth or percent fines, indicating an outfall influence. All tPAH concentrations in the monitoring area were well below the ERL value, indicating a low

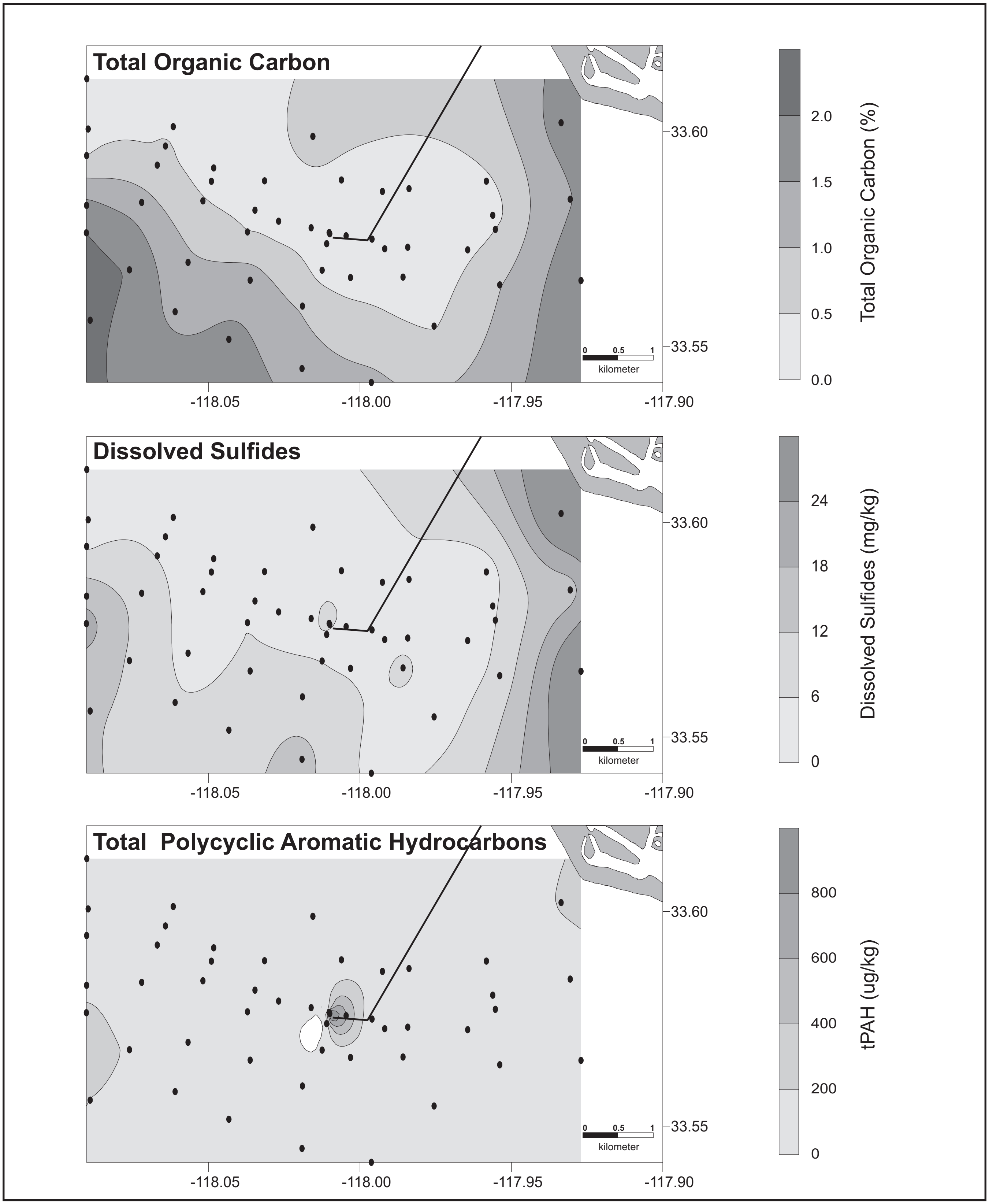


Figure 4-4. **Spatial distributions of total organic carbon (TOC), dissolved sulfides (mg/kg), and total polycyclic aromatic hydrocarbons (ug/kg) during July 2009.**

Orange County Sanitation District, California.

probability of sediment toxicity due to PAHs.

Mean tPAH concentrations at non-ZID quarterly stations ranged from 53 µg/kg at Station 9 and CON to 138 µg/kg at Station 12 (Figure 4-3). Non-ZID station means were comparable to Bight'03 mid-depth and LPOTW means. All concentrations were well below the ERL indicating a low probability of sediment toxicity (Table 4-1).

Chlorinated Pesticides

Total DDT (tDDT) continued to be the dominant pesticide detected in the sediments. While the use of DDT has been banned since the 1970's, it is still present in the sediments in the Districts monitoring area due to the long half-life of the compound and its breakdown products. DDT tends to adhere to fine particles, so these contaminants tend to be found in higher concentrations in deeper, depositional areas (e.g., San Gabriel Canyon) where fine sediments accumulate.

In July 2009, tDDT concentrations ranged from 1.26 µg/kg at within-ZID Station 4 to 31.1 µg/kg at Station 58 (Table 4-1). Concentrations were generally higher in sediments inshore of the outfall diffuser than along the 60 m contour, and increased with depth, with no outfall pattern indicated (Figure 4-5). Forty-six of the 49 stations sampled in July 2009 exceeded the ERL of 1.56 µg/kg. All concentrations were below the ERM, as well as the Bight'03 mid-depth and LPOTW means. This was consistent with previous monitoring years and within the range of background values reported by other regional monitoring studies (Schiff and Gossett 1998, Noblet et al. 2002). Correlation analysis showed a significant relationships of tDDT with station depth (R = 0.76), percent fines (0.84), and a smaller, but significant relationship with tLAB (R = 0.35).

Non-ZID quarterly station means for tDDT ranged from 1.51 µg/kg at Station 9 to 4.62 µg/kg at Station C (Table 4-2) with no outfall pattern indicated (Figure 4-3). Historically, tDDT has been found to be highly variable between years (OCSD 2003). The lack of outfall influence is consistent with results from previous years and the legacy contaminant properties of DDT.

In July 2009, only 4 of 49 stations had measurable concentrations of other chlorinated pesticides (tPest) with no discernable outfall influence (Table 4-1; Figure 4-5). Correlation analysis showed no significant relationships of tPest with station depth, percent fines, or tLAB.

Non-ZID quarterly station means for tPest ranged from 0.03 µg/kg at Station 5 to 0.06 µg/kg at Station 9 (Table 4-2; Figure 4-3). Historically, pesticides other than DDT are generally not detected at most stations and when they are detected it is very near the detection limit. In the 2008-09 monitoring year, pesticides were measureable at all 60 m stations, primarily in October 2008 and January 2009. The reason for that increase in chlorinated pesticides is not known, but it appears to be returning to more normal levels in 2009-10. Further, fish tissue contaminant analysis conducted in July 2009 showed a decrease in the measureable concentrations of tPest in fish tissues from July 2008 (see Chapter 6).

Polychlorinated Biphenyls (PCB)

In July 2009, sediment concentrations of total PCB (tPCB) ranged from not detected at Station CON to 13.8 µg/kg at Station 64 with concentrations generally increasing with increasing depth and proximity to the outfall (Figure 4-5). This pattern is consistent with previous monitoring years (OCSD 2009). No stations exceeded the ERL and most station concentrations were below the SCBPP non-POTW average and Bight'98 area weighted mean (Table 4-1).

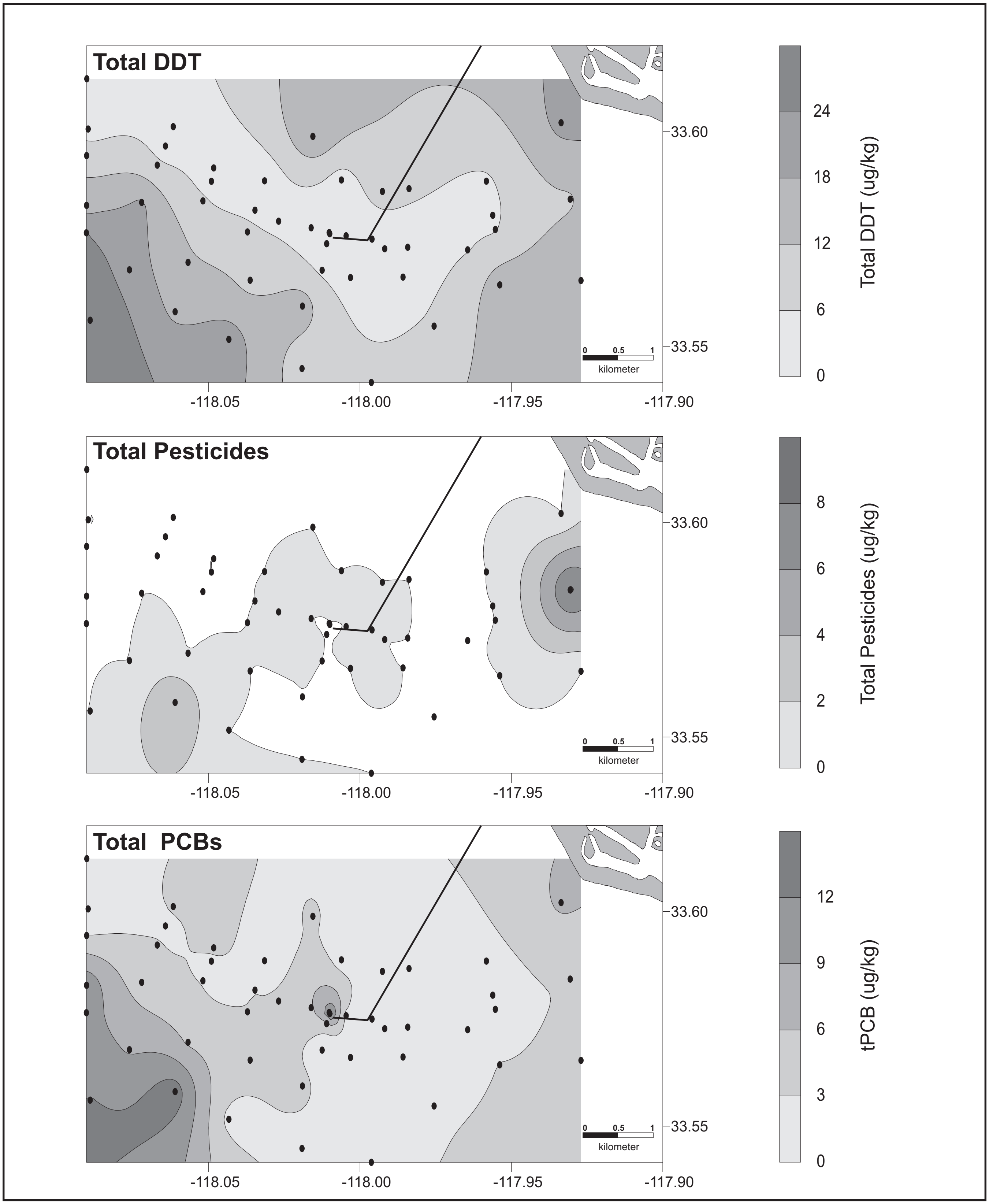


Figure 4-5. **Spatial distributions of total DDT (tDDT), total pesticides, and total PCB (tPCB) concentrations (ug/kg) during July 2009.**

Orange County Sanitation District, California.

Correlation analysis showed a moderate relationship to tLAB (0.51) and lesser relationships to depth (R = 0.37) and percent fines (R = 0.38) indicating an outfall influence. PCB is a legacy contaminant with a continued presence in coastal ocean sediments due to historic uses and discharges.

Quarterly non-ZID station mean tPCB concentrations ranged from 1.07 µg/kg at Station CON to 4.71 µg/kg at Station 1 (Table 4-2). Mean concentrations were highest at ZID Stations 0, ZB, and ZB2 and decreased outside the ZID with increasing distance from the outfall pipe. All non-ZID stations had tPCB concentrations well below the ERL.

Metals

In July 2009, as in previous years, two basic patterns were observed in sediment metal concentrations: 1) those showing grain size/depth-related patterns with no clear outfall effect indicated (Group A metals), and 2) those showing some degree of outfall influence (Group B metals). Some metals may switch groups from year-to-year (e.g., copper), possibly due to variability in concentration and oceanographic conditions affecting deposition. Figure 4-6 presents contour plots of the spatial distribution of representative Group A and Group B metals (copper and mercury, respectively). Group A metals included arsenic, beryllium, chromium, copper, lead, nickel, selenium, and zinc. Group B included cadmium, mercury, and silver. All metals showed significant correlations to tLABs, with all but mercury and silver significantly correlated with station depth, and all but silver also correlated with percent fines. The stronger correlations to tLAB and lesser correlations to station depth and percent fines were found in Group B metals. The exception to this is cadmium, which showed a moderate outfall signal and was more strongly correlated with station depth (0.70) and percent fines (0.74) than with tLAB (0.61). Copper and nickel concentrations exceeded their respective ERLs at several stations, generally those located within the canyons and slope areas (Table 4-3). Contour plots for metals not presented in Figure 4-6 can be found in Appendix B (Figure B-11).

Quarterly station mean sediment concentrations for metals were below ERL values for all stations (Table 4-4; Figure 4-7).

Principal Components Analysis (PCA)

Principal Components Analysis (PCA) was performed using the July 2009 annual station data, including the 10 quarterly stations (n = 49 stations). PCA identified 8 station groups that generally followed depth gradients, the influences of the Newport and San Gabriel Canyons, and the outfall diffuser terminus (Figures 4-8 and 4-9). Stations included within each station group are listed in Table 4-5. Station Group 1 (SG1) consists of within-ZID Station 0 only and was characterized by having the greatest concentrations of tPAH, tLAB, tPCB, and silver, and second greatest in mercury. SG2 contains within-ZID Station ZB2 only and was characterized by having the greatest mercury concentration and elevated concentrations of dissolved sulfides, cadmium, and copper. SG3 had 2 mid-shelf stations; 1 within-ZID (Station 4) and 1 non-ZID (Station 5). These stations separated out primarily due to measureable concentrations of organochlorine pesticides and to a lesser extent percent fines and tDDT levels. SG4 consists of slope Station 27 only and was characterized by lower than average concentrations in all analytes, markedly so for dissolved sulfides, copper, silver, and zinc. SG5 consists of 4 San Gabriel Canyon stations (44, 57, 58, and 62) and Newport Canyon Station C5. SG5 was primarily characterized by elevated concentrations of dissolved sulfides, tLABs, and the metals arsenic, silver, and mercury. The elevated tLAB concentration and the

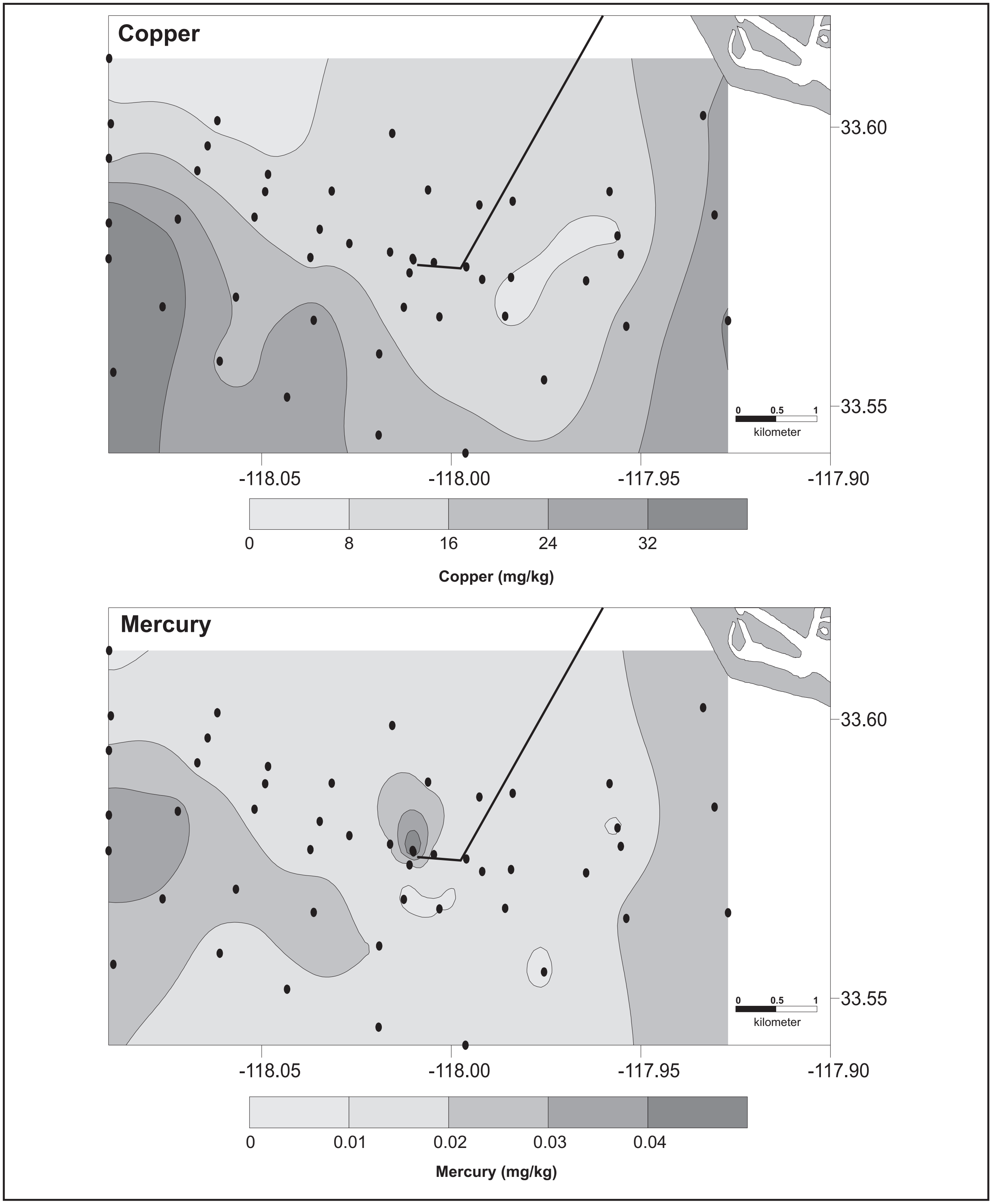


Figure 4-6. **Spatial distributions of copper (mg/kg) and mercury (mg/kg) during July 2009.**

Orange County Sanitation District, California.

Table 4-3. Annual concentrations of sediment metals (mg/kg) at the District's annual stations in 2009-10 compared with Effects Range–Low* (ERL) and Effects Range–Median* (ERM) values.

Orange County Sanitation District, California.

Station	Depth (m)	As	Be	Cd	Cr	Cu	Pb	Hg	Ni	Se	Ag	Zn
Shallow Shelf (40 – 46 meters)												
7	41	3.60	0.227	0.234	18.2	9.54	6.10	0.018	9.13	0.444	0.177	39.1
8	44	3.46	0.244	0.294	17.7	10.1	5.84	0.016	9.30	0.467	0.168	39.8
21	44	3.23	0.230	0.214	18.4	9.21	5.94	0.015	8.68	0.410	0.185	39.3
22	45	3.76	0.265	0.245	18.9	9.83	6.32	0.014	10.1	0.452	0.148	43.2
30	46	3.07	0.220	0.185	17.5	8.89	5.74	0.018	8.32	0.388	0.162	36.2
36	45	3.99	0.278	0.267	19.8	10.0	6.70	0.016	10.9	0.556	0.105	43.8
55	40	2.19	0.179	0.100	13.7	4.58	7.15	0.008	6.72	0.354	0.044	25.9
59	40	2.45	0.198	0.162	16.3	6.81	4.54	0.015	7.71	0.423	0.098	30.5
	Average	**3.22**	**0.230**	**0.213**	**17.6**	**8.62**	**6.04**	**0.015**	**8.86**	**0.437**	**0.136**	**37.2**
Mid-Shelf Within-ZID (56 – 60 meters)												
0 *	56	3.23	0.291	0.824	23.3	16.1	7.62	0.051	11.3	0.473	0.221	54.9
4 *	56	2.56	0.292	0.257	18.5	9.07	4.19	0.011	9.33	0.403	0.144	40.5
ZB *	56	2.45	0.248	0.462	17.0	8.44	4.95	0.014	8.77	0.329	0.124	45.4
ZB2 *	56	2.88	0.277	0.669	20.5	13.9	5.45	0.057	9.47	0.451	0.252	50.1
	Average	**2.78**	**0.277**	**0.553**	**19.8**	**11.9**	**5.55**	**0.033**	**9.72**	**0.414**	**0.185**	**47.7**
Mid-Shelf Non-ZID (56 – 60 meters)												
1 *	56	2.65	0.244	0.377	19.3	12.0	5.37	0.019	9.16	0.446	0.350	44.2
3	60	2.49	0.254	0.328	20.4	11.7	4.70	0.014	8.93	0.396	0.233	46.3
5 *	59	3.03	0.273	0.294	21.7	12.8	5.67	0.016	10.5	0.465	0.242	44.9
9 *	59	2.60	0.293	0.181	19.2	8.54	4.42	0.011	8.88	0.429	0.129	39.9
10	60	3.18	0.288	0.318	24.0	13.8	6.18	0.019	12.0	0.493	0.277	48.9
12 *	58	2.41	0.269	0.171	18.0	7.95	4.41	0.010	8.61	0.412	0.119	37.5
13	59	3.02	0.247	0.255	19.9	10.4	5.59	0.016	9.90	0.443	0.186	43.1
37	56	2.51	0.247	0.158	14.1	7.03	4.24	0.008	9.12	0.382	0.068	40.8
C *	56	3.10	0.263	0.214	20.9	9.94	5.41	0.013	10.6	0.457	0.274	43.3
C2	56	6.49	0.529	0.679	31.8	23.7	13.4	0.026	**21.9**	0.908	0.173	109
CON *	59	3.28	0.254	0.186	21.6	10.1	5.72	0.015	10.7	0.460	0.145	43.3
	Average	3.16	0.287	0.287	21.0	11.6	5.92	0.015	10.9	0.481	0.200	49.2
Outer Shelf (91–-100 meters)												
17	91	3.03	0.311	0.182	20.9	9.42	4.90	0.010	11.0	0.491	0.110	45.8
18	91	2.47	0.309	0.210	21.7	10.0	5.05	0.009	11.3	0.477	0.124	46.8
20	100	2.87	0.302	0.354	23.0	13.6	6.32	0.016	12.6	0.537	0.226	51.5
23	100	2.74	0.275	0.216	18.3	7.63	4.47	0.013	9.61	0.461	0.086	39.9
29	100	3.60	0.308	0.319	24.5	14.7	7.15	0.018	12.7	0.553	0.256	52.6
33	100	3.58	0.291	0.323	18.4	9.22	5.28	0.011	11.0	0.512	0.110	47.1
38	100	3.73	0.304	0.382	20.7	10.9	6.16	0.015	12.3	0.548	0.128	49.9
56	100	3.11	0.320	0.289	26.3	14.2	6.77	0.021	13.3	0.588	0.204	51.6
60	100	3.30	0.315	0.323	25.4	14.3	6.60	0.017	12.9	0.552	0.229	51.7
	Average	**3.16**	**0.304**	**0.289**	**22.1**	**11.6**	**5.86**	**0.014**	**11.9**	**0.524**	**0.164**	**48.5**

Table 4-3 Continues.

Table 4-3 Continued.

Station	Depth (m)	As	Be	Cd	Cr	Cu	Pb	Hg	Ni	Se	Ag	Zn
Slope (187 – 241 meters)												
24	200	3.46	0.490	0.491	36.7	20.5	8.88	0.020	18.9	0.897	0.274	69.4
25	200	4.34	0.497	0.672	45.9	28.3	11.7	0.026	**21.9**	1.12	0.440	78.4
27	200	3.18	0.424	0.372	30.5	15.0	6.82	0.015	16.2	0.715	0.173	58.7
39	200	3.10	0.302	0.284	21.9	10.0	5.43	0.009	12.3	0.527	0.097	49.5
44	241	6.19	0.586	0.954	52.6	**40.7**	16.5	0.035	**26.0**	1.50	0.750	100
57	200	5.22	0.554	0.837	55.0	**40.3**	14.5	0.036	**25.3**	1.29	0.820	91.7
61	200	5.06	0.489	0.731	42.7	29.2	10.8	0.033	**21.2**	1.05	0.504	78.5
63	200	4.22	0.432	0.589	39.0	23.5	10.5	0.023	18.2	0.877	0.398	68.8
65	200	4.99	0.443	0.671	29.0	19.0	8.49	0.022	17.9	0.821	0.228	68.5
C4	187	7.52	0.612	0.719	39.7	25.6	11.5	0.028	**23.2**	1.12	0.262	91.9
Average		**4.73**	**0.483**	**0.632**	**39.3**	**25.2**	**10.5**	**0.025**	**20.1**	**0.992**	**0.395**	**75.5**
Basin (296 – 300 meters)												
40	303	3.63	0.454	0.509	33.8	20.4	9.08	0.014	19.1	1.04	0.219	68.7
41	303	4.50	0.503	0.521	40.3	21.5	9.35	0.015	20.3	1.15	0.233	72.5
42	303	4.62	0.490	0.648	43.9	24.7	11.0	0.017	**21.5**	1.28	0.320	78.7
58	300	6.17	0.596	0.768	57.9	**36.5**	14.0	0.023	**28.0**	1.51	0.490	94.5
62	300	6.72	0.604	0.911	50.8	**37.7**	15.3	0.029	**26.2**	1.59	0.635	96.2
64	300	4.95	0.450	0.583	36.3	22.7	9.85	0.016	**20.5**	1.21	0.274	74.8
C5	296	6.99	0.610	0.992	49.9	32.9	14.8	0.028	**26.5**	1.59	0.453	103
Average		**5.37**	**0.530**	**0.705**	**44.7**	**28.1**	**11.9**	**0.020**	**23.2**	**1.34**	**0.375**	**84.1**
SEDIMENT QUALITY GUIDELINES												
ERL		8.20	NA	1.20	81.0	34.0	46.7	0.15	20.9	NA	1.00	150
ERM		70.0	NA	9.60	370	270	218	0.70	51.6	NA	3.70	410

Individual values greater than the ERL are bolded.
NA = Not applicable.
Annual stations n = 1.
***** Long et al. 1995

Table 4-4. Average concentrations of sediment metals (mg/kg) at the District's quarterly stations in 2009-10.

Orange County Sanitation District, California.

Station	As	Be	Cd	Cr	Cu	Pb	Hg	Ni	Se	Ag	Zn
Within-ZID Stations											
0	2.93	0.252	0.779	21.1	13.4	6.98	0.042	9.65	0.408	0.511	48.5
4	2.81	0.247	0.244	16.1	8.24	3.84	0.011	7.80	0.353	0.124	38.1
ZB	2.70	0.255	0.406	17.1	8.95	3.68	0.031	8.59	0.343	0.165	43.0
ZB2	3.08	0.278	0.744	22.0	14.5	5.07	0.027	9.69	0.445	0.234	53.6
Average	2.88	0.258	0.543	19.1	11.3	4.89	0.028	8.93	0.387	0.259	45.8
Non-ZID Stations											
1	2.66	0.261	0.364	20.0	12.3	5.40	0.020	9.20	0.386	0.259	43.1
5	3.13	0.269	0.298	19.9	12.0	5.43	0.016	10.1	0.395	0.239	44.7
9	2.67	0.261	0.192	17.3	8.23	4.12	0.012	8.33	0.352	0.123	38.1
12	2.69	0.256	0.186	16.9	8.02	4.31	0.011	8.44	0.358	0.117	37.4
C	3.33	0.254	0.217	19.4	9.20	5.50	0.019	9.58	0.404	0.142	41.9
CON	3.10	0.265	0.189	19.6	9.42	5.38	0.013	10.0	0.404	0.125	42.2
Average	2.93	0.261	0.241	18.9	9.86	5.02	0.015	9.28	0.383	0.168	41.2
Sediment Quality Guideline and Reference Values											
[1] ERL	8.20	NA	1.20	81.0	34.0	46.7	0.15	20.9	NA	1.00	150
[1] ERM	70.0	NA	9.60	370	270	218	0.70	51.6	NA	3.70	410
[2] Bight'03 Mid-depth AWM	4.1	0.62	0.36	36	12	7.4	0.10	14	1.2	0.11	47
[2] Bight'03 Large POTW AWM	3.2	0.64	0.76	37	20	9.2	0.14	10	0.98	0.39	51

Values greater than the ERL are bolded. Quarterly stations n = 6.
NA = Not Applicable, ND = Not Detected, AWM = Area Weighted Mean
[1] Long et al. (1995)
[2] Schiff et al. (2006)

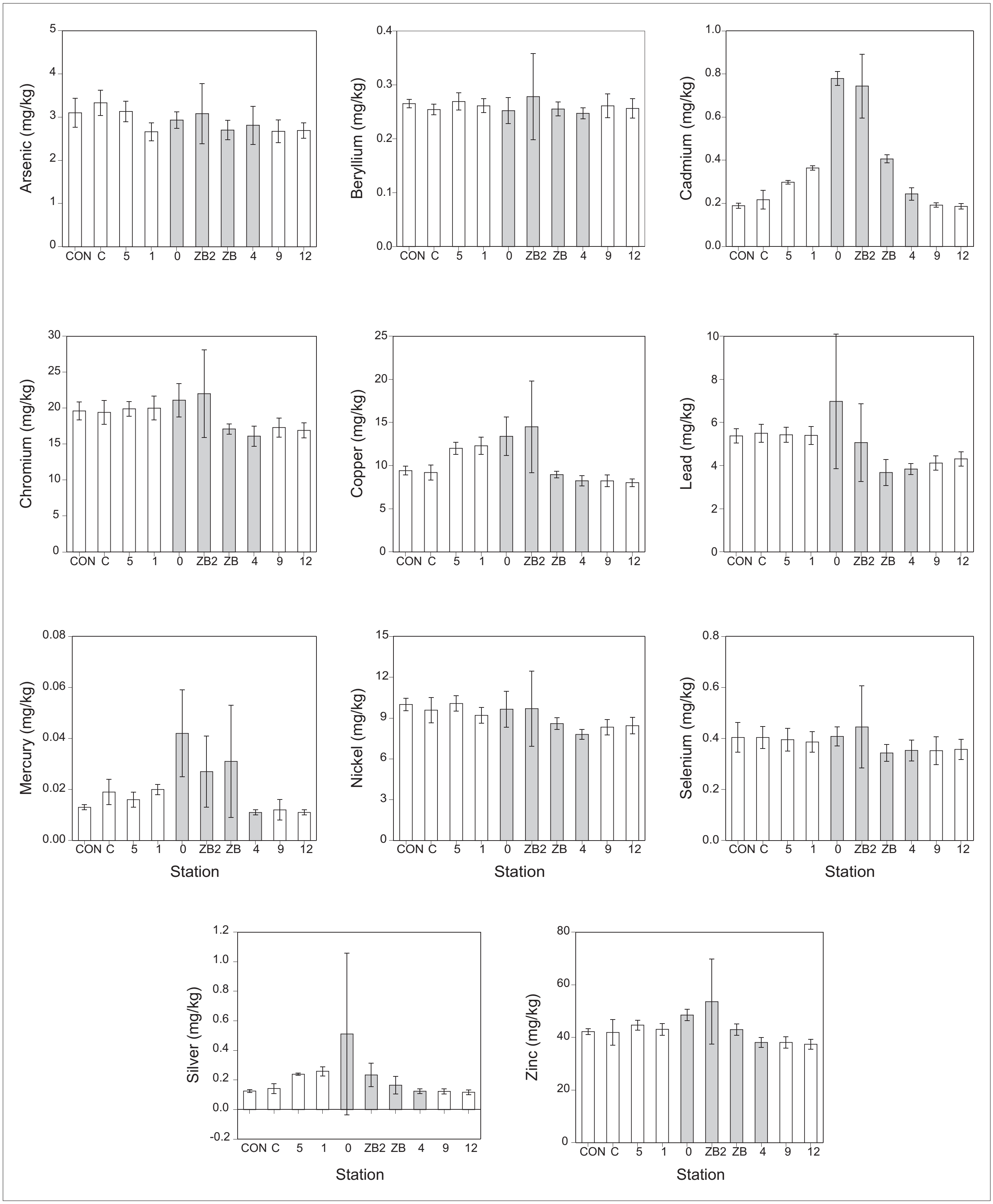


Figure 4-7. Distribution of mean and standard deviation values (mg/kg) for arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, and zinc in sediments at the 60 m shelf stations during 2009-10.

Stations plotted from north to south (left to right). ZID stations indicated in gray.

Orange County Sanitation District, California.

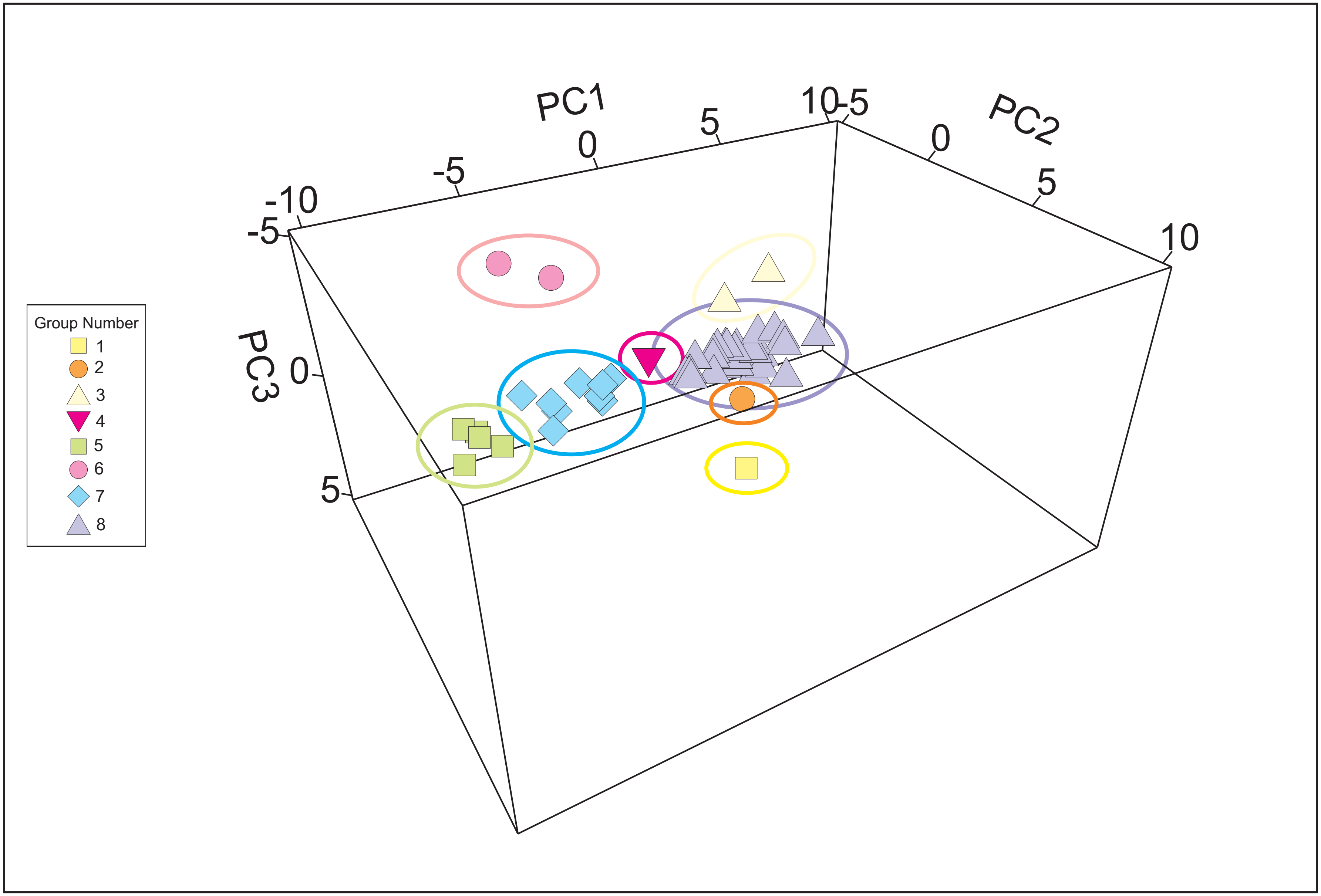


Figure 4-8. **Principal components analysis (PCA) station plot. Station symbols correspond to PCA station groupings (group numbers).**

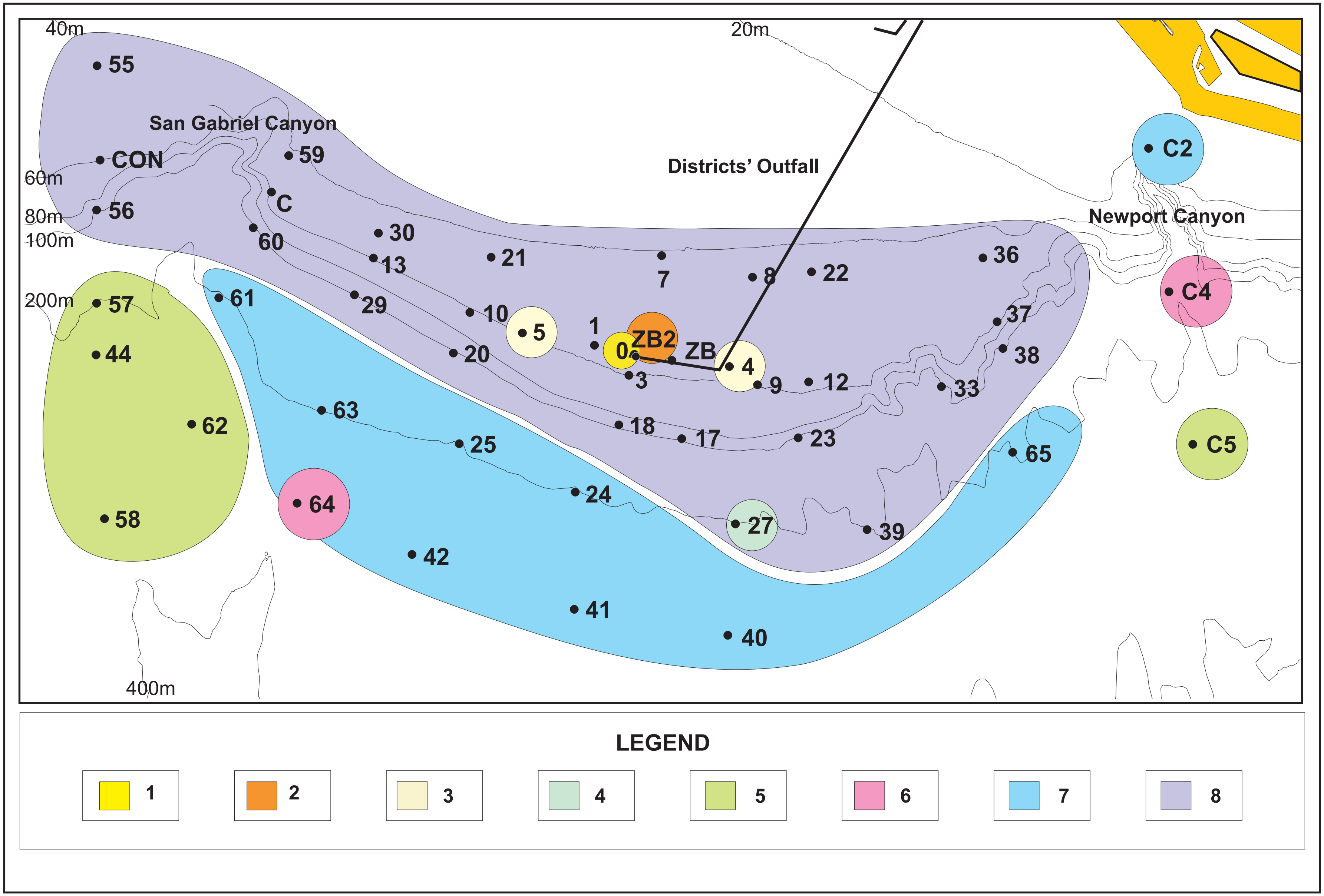


Figure 4-9. **Map of station groups from principal components analysis for July 2009.**

Table 4-5. Station groups identified by principal components analysis on the annual stations in July 2009.

Orange County Sanitation District, California.

Station Group	Stations	Subgroup 1	Subgroup 2	Subgroup 3
1	0			
2	ZB2			
3	4, 5			
4	27			
5	44, 57, 58, 62, C5	44		
6	64, C4			
7	24, 25, 40, 41, 42, 61, 63, 65, C2	25, 42, 64, C2	24, 40, 41, 63, 65	
8	1, 3, 7, 8, 9, 10, 12, 13, 17, 18, 20, 21, 22, 23, 29, 30, 33, 36, 37, 38, 39, 55, 56, 59, 60, C, CON, ZB	ZB	55	9, 12, 37, 59

n = 49

fact that arsenic, silver, and mercury correlated significantly with tLAB suggests an outfall influence in the San Gabriel Canyon and is consistent with predominant upcoast-flowing sub-tidal currents below 30 m (SAIC, 2009). SG6 was made up of basin Station 64 and Newport Canyon Station C4 and was characterized by measureable concentrations of organochlorine pesticides and elevated levels of arsenic, dissolved sulfides, and beryllium. SG7 has 8 slope stations (24, 25, 40, 41, 42, 61, 63, and 65) plus Newport Canyon Station C2. This group is characterized by higher concentrations of dissolved sulfides, tLAB, and higher median phi scores. SG8 contains the remaining 28 shallow and mid-shelf stations and grouped primarily due to similar tLAB, dissolved sulfides, and mercury concentrations. SG8 had the lowest mean concentrations for all analytes.

It should be noted that while some analytes were higher in some groups than in others that the majority were below, or well below, concentrations that are considered harmful to marine life. The exceptions are the legacy contaminants tDDT and tPCB.

Long-term (Temporal) Trend Analysis

Long-term trends for all parameters showed no noteworthy changes from those reported last year (OCSD 2008; Figure 4-10). Parameter values in 2009-10 were all within the range of long-term variability seen in the 60 m stations. Beryllium and nickel are increasing in all station groups indicating area-wide sources. Dissolved sulfides, tDDT, tPCB, cadmium, lead, selenium, and silver are decreasing in all station groups. The remaining parameters are increasing in some station groups and decreasing in others. The magnitude of inter-annual variability at these stations is dependent on the parameter, but is generally similar among all stations groups for a given parameter. All 2009-10 parameter values are within the range of long-term variability and are at concentrations that are not of biological concern (i.e., below ERL values) in non-ZID station groups with the exception of the legacy contaminant tDDT.

Some parameters have distinctive long-term trends. Percent TOC is increasing over time at all station groups except the within-ZID group nearest the outfall terminus (WZU). The overall decreasing trend in this group is due to a single high value in 1997-98. When this value was removed, all five station groups had a similar increase over time of about 0.2% since 1999 indicating an unidentified area-wide influence apparently unrelated to the outfall. Chromium is increasing in all non-ZID station groups, while within-ZID groups show a slight decrease over time. Mercury concentrations at WZU in 2009-10 decreased markedly from 2008-09. Following the high mercury concentrations in 2005-06, the District conducted a study and determined that the high concentrations were likely the result of the small sample volume (0.5 mg) used for the analysis. The sample volume was increased to 5.0 mg, which lessened the variability in the results (OCSD 2008). The District began accepting de-watering flows from San Diego Creek with increased selenium in 2003. However, selenium concentrations in the monitoring area are decreasing over time indicating that these additional flows into the treatment plant are not causing an adverse environmental effect.

Sediment Toxicity

Whole-sediment toxicity testing was conducted on sediments collected during the October 2009 and January 2010 surveys. Significant toxicity was found with the 10-day amphipod survival test at within-ZID Station 0 in October 2009 with a percent difference from the control of 22.7% (Table 4-6). The percent difference in

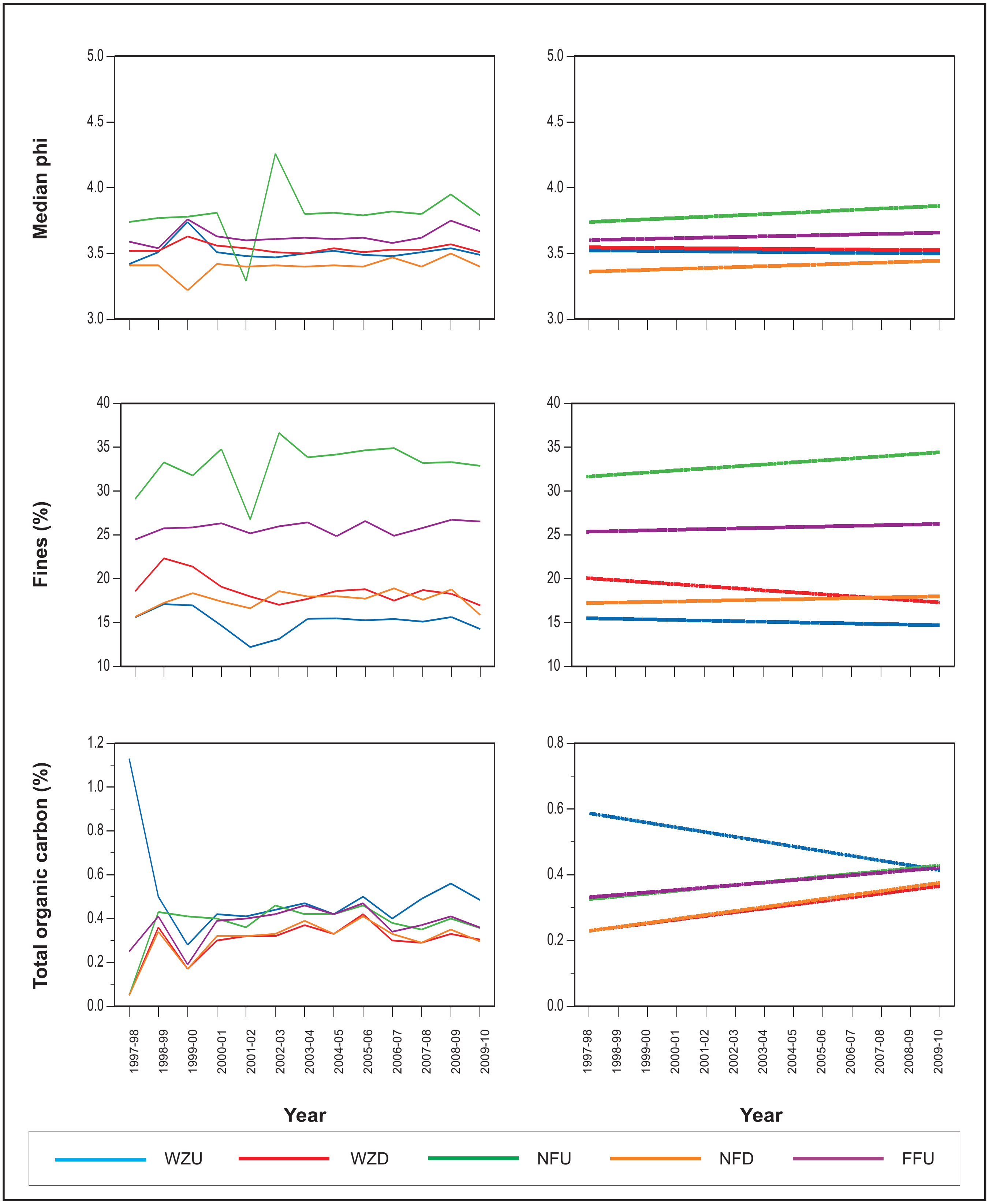
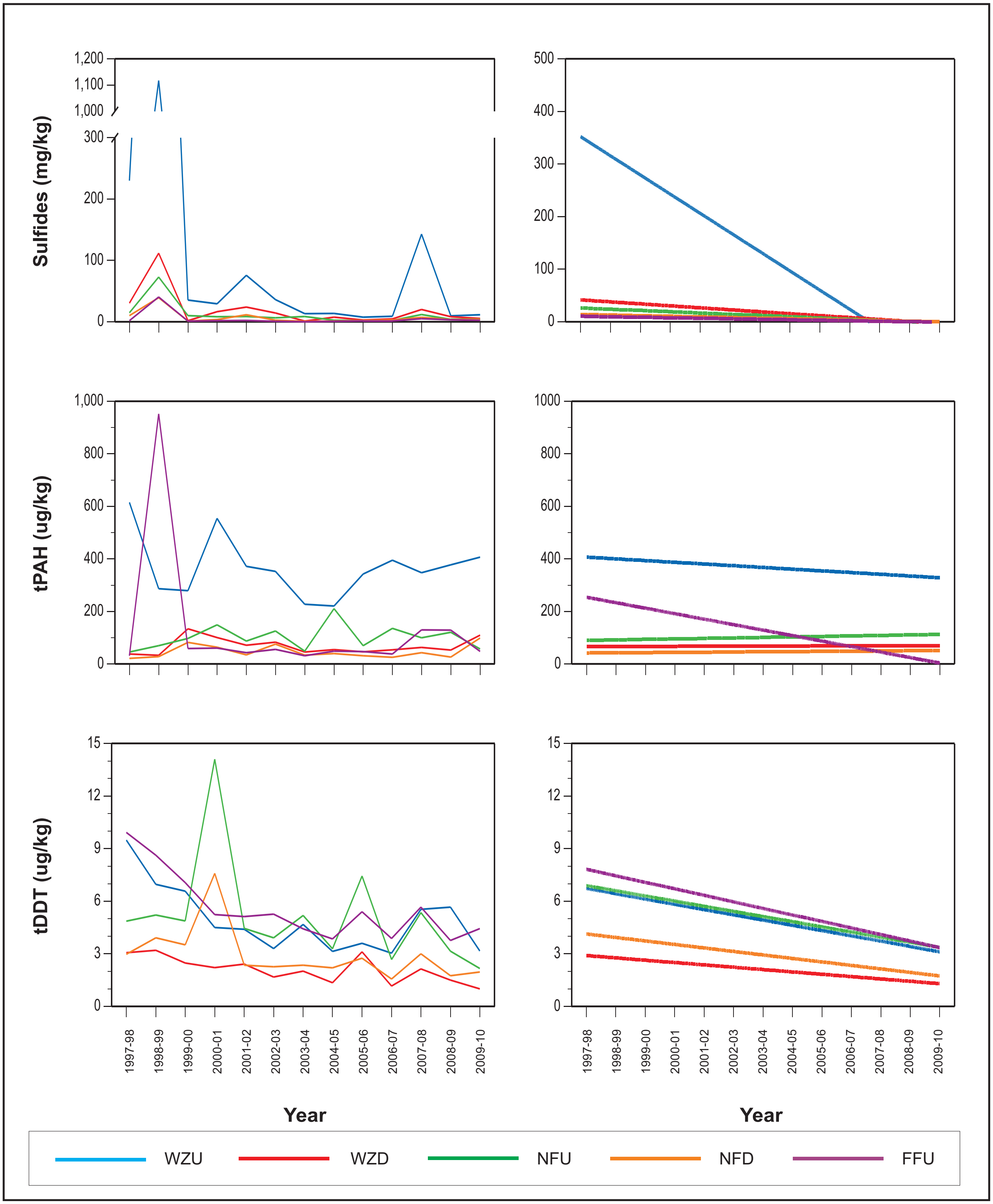


Figure 4-10. **Changes over time for total DDT, total PCB, total PAH, median phi, % fines, sulfides[1], total organic carbon, arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, and zinc in sediments at the 60 m shelf station groups during 1997–2010.**

[1]Sulfides analysis performed as acid volatile sulfides from 1997 through 2006 and as dissolved sulfides for 2007 and 2008.



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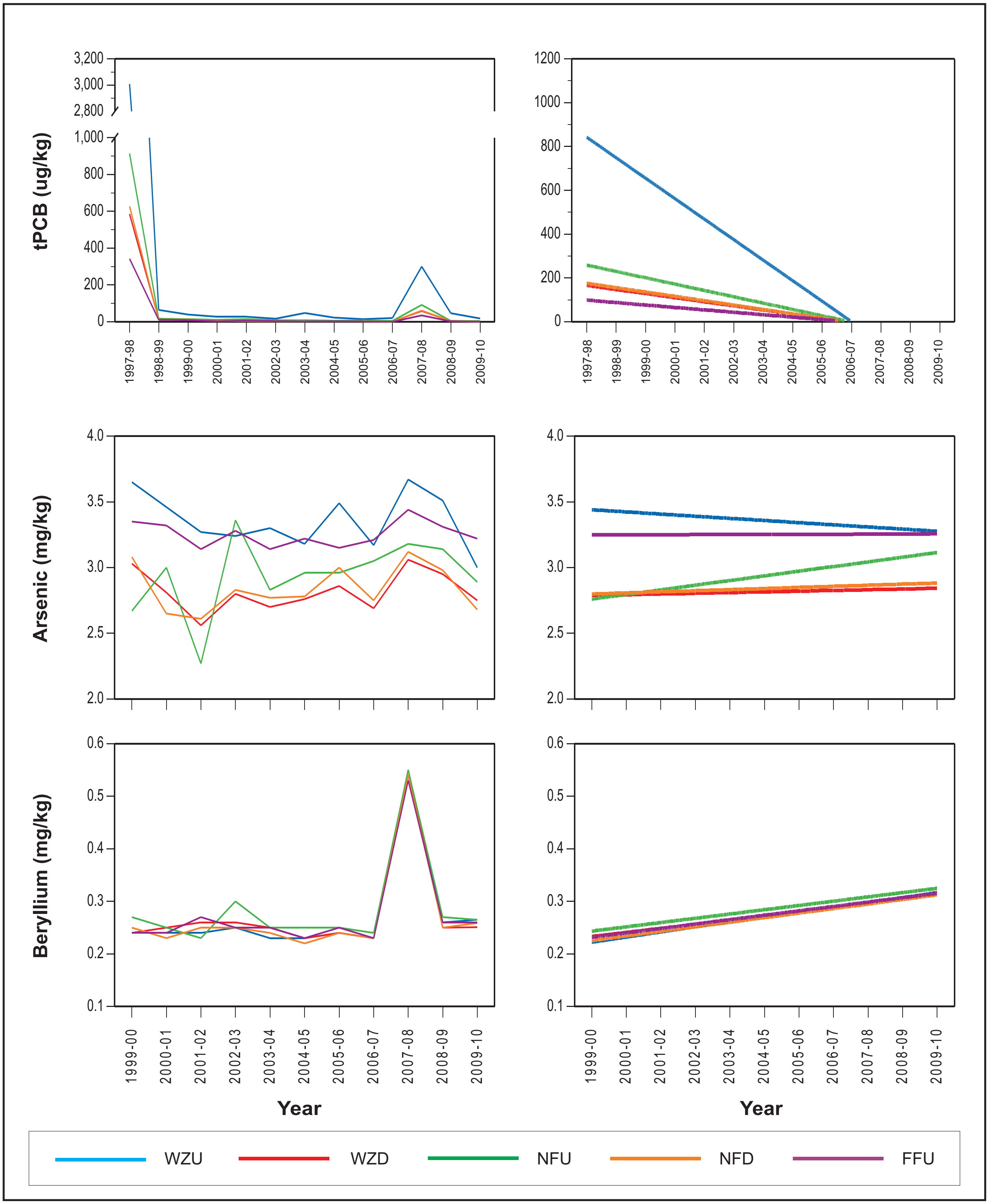

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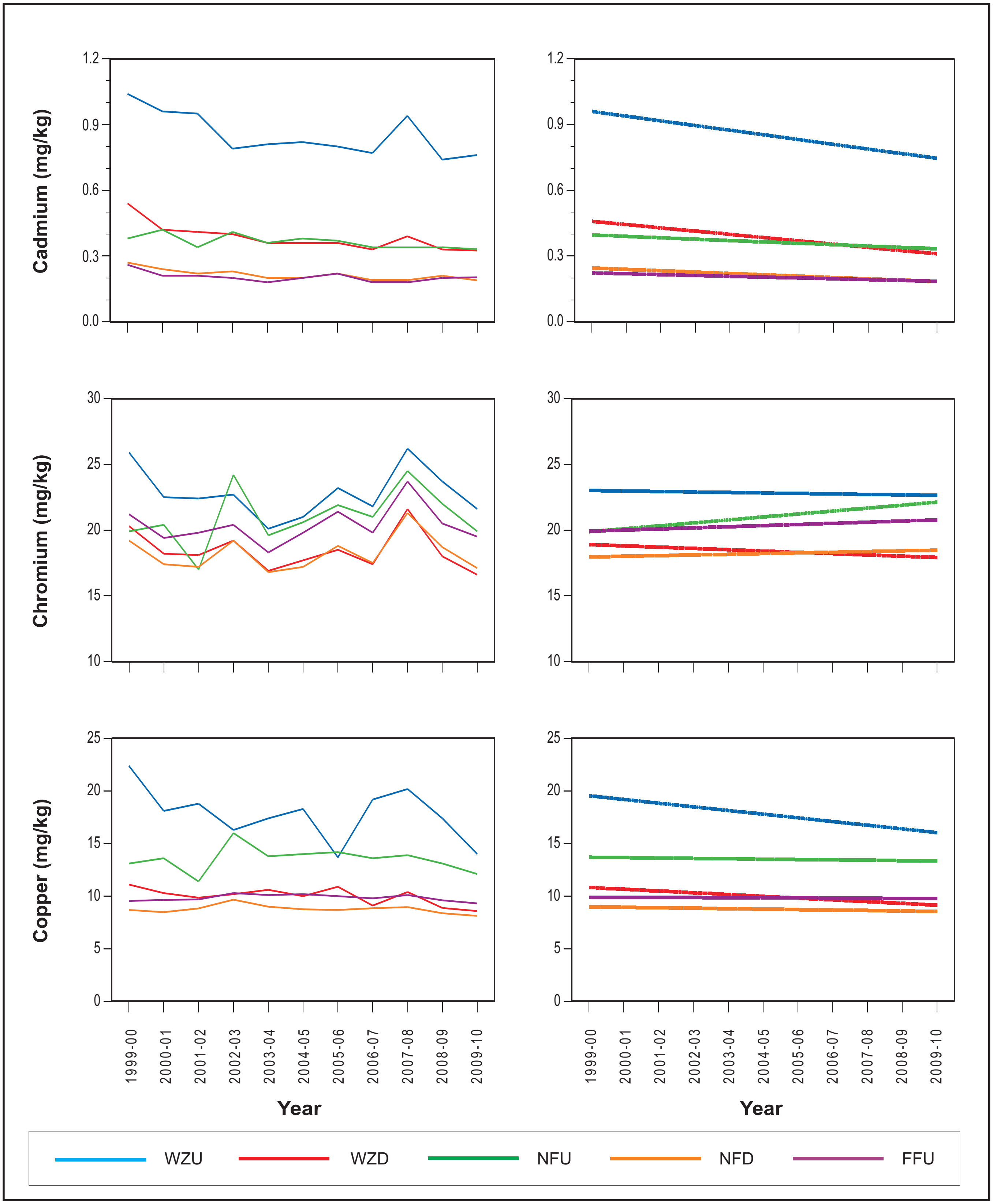

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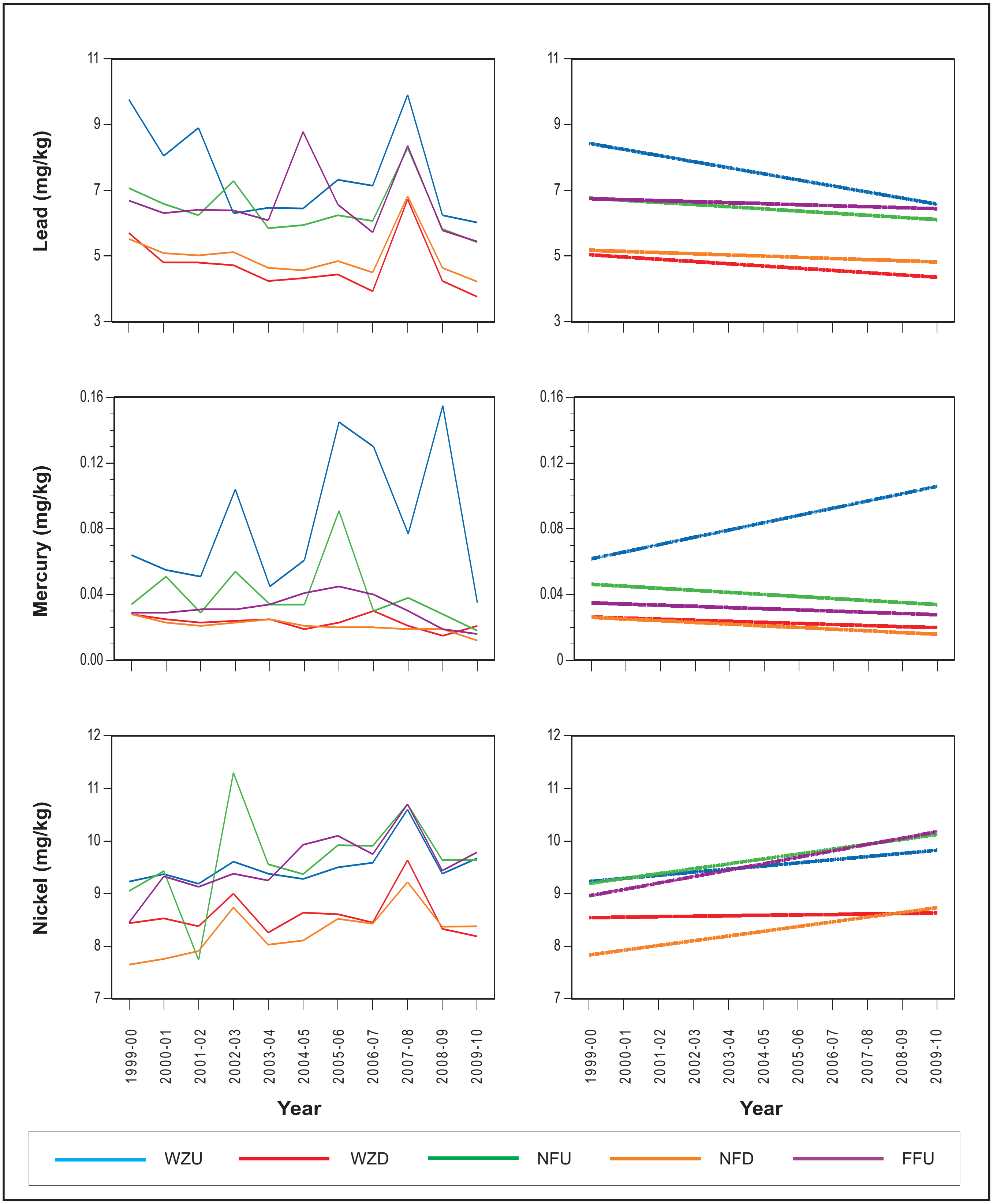

Figure 4-10 Continued.

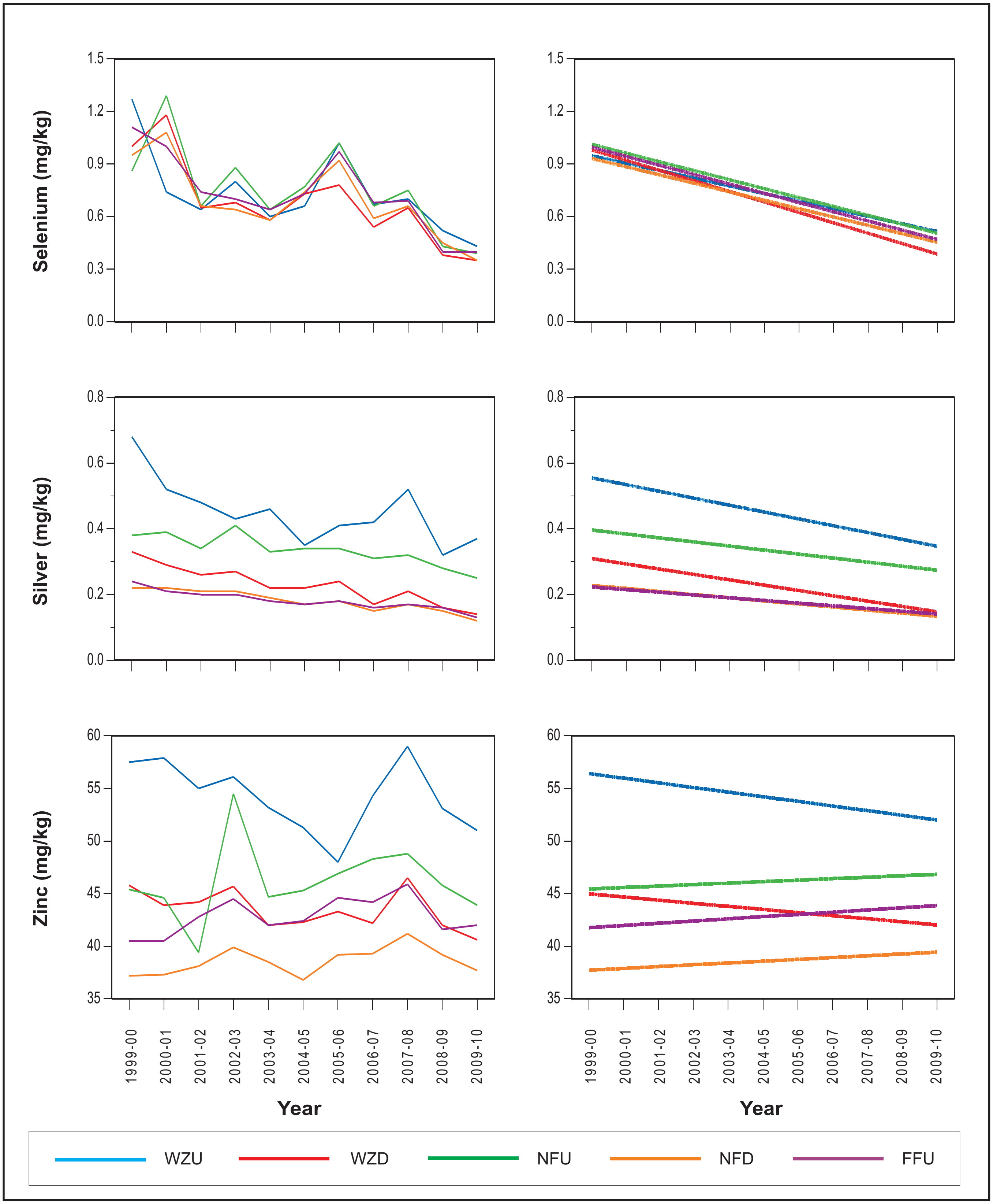

Figure 4-10 Continued.

Table 4-6. Sediment toxicity test results for October 2009 and January 2010. Whole-sediment (amphipod) test results given as test sediment percent difference from home sediment.

Orange County Sanitation District, California.

Date	Station									
	CON	C	5	1	ZB2	0	ZB	4	9	12
January 2010	1.0	NS	NS	3.0	1.0	NS	0	NS	1.0	NS
October 2009	4.1	-2.1	-2.1	2.1	1.0	**22.7**	2.1	1.0	1.0	3.1
Historical Results										
January 2009	0	6.6	4.4	-2.2	5.5	2.2	4.4	4.4	-2.2	1.1
January 2008	0	9.0	3.0	3.0	3.0	3.0	-2.0	4.0	-1.0	-3.0
October 2006*	-5.8	5.8	1.2	-4.6	-4.6	-1.2	3.5	2.3	1.2	2.3
2005-06 Mean	1.5	0.5	0.5	-0.5	0.5	2.5	3.5	5.6	-0.5	1.5
2004-05 Mean	1.0	3.0	5.0	7.0	6.0	6.0	-1.0	5.0	1.0	1.0
2003-04 Mean	3.0	10.0	5.0	4.0	5.0	5.0	8.0	5.0	4.0	3.0
2002-03 Mean	2.7	10.3	5.0	3.7	5.3	5.3	8.0	5.0	4.0	3.3

Negative values represent values greater than 100% of home sediment. Bolded values represent significant toxicity.
Amphipod test results that are >20% different and $p<0.05$ from the control = toxic response (Bay et al. 2000)
* Results prior to July 2006 are means based on quarterly testing. Beginning in the 2006-07 monitoring year, only one quarter per year is tested. The quarter to be tested is chosen at random with the provision that a quarter will not be tested in consecutive years.
NS = Not Sampled

amphipod survival between station and control sediment was less than 5% for all other stations in both surveys, indicating very low acute toxicity.

In 2009-10, no samples showed the potential for moderate toxicity (i.e., mERMq>0.11; Table 4-7). mERMq values ranged from 0.02 to 0.08 with station means ranging from 0.02 to 0.06.

CONCLUSIONS

The results from the 2009-10 monitoring year were generally consistent with those of previous years and generally showed good sediment quality in the monitoring area. There are mostly decreasing trends over time in organic chemical constituents, with most concentrations below the ERL and ERM thresholds. Metal constituents outside the ZID are generally at concentrations below that of biological concern with no clear outfall-related temporal trends. Principal Components Analysis indicated that stations grouped primarily by station depth, proximity to the outfall, and proximity to the Newport and San Gabriel Submarine Canyons. Mean ERMq analysis indicated a low probability of sediment toxicity in the monitoring area outside the ZID. Overall, results suggested that there were some minor discharge-related impacts to sediment quality, but they are mainly localized near the outfall and in some deeper, depositional areas, such as the San Gabriel Canyon.

As discussed in Chapter 5 (Macrobenthic Invertebrate Communities) and Chapter 6 (Trawl Communities), biological communities were not degraded outside the ZID. However, infaunal invertebrate communities within the ZID classify as degraded and several non-ZID stations closest to the ZID show evidence of impacts to community health (see Chapter 5). These changes appear to be discharge-related, as evidenced by their proximity to the outfall and sediment toxicity at within-ZID Station 0. However, they do not correlate to sediment physical and chemical characteristics measured by the ocean monitoring program. The relationship between these altered conditions and the discharge are currently under investigation.

Wastewater discharge effects are indicated in degrading invertebrate community health, though the magnitude of these effects outside the ZID is minimal. These sediment geochemistry results coupled with the results from infaunal community assessments indicate that currently measured sediment conditions and contaminants do not account for the observed biological changes, but that effluent discharge is responsible. However, due to the minimal impact outside the ZID permit criterion C.5.a was met (see Chapter 2).

Table 4-7. Mean ERMq values for sediment contaminant concentrations, 2009-10.

Orange County Sanitation District, California.

Survey	Station									
	CON	**C**	**5**	**1**	**ZB2**	**0**	**ZB**	**4**	**9**	**12**
April 2010	0.03	0.03	0.03	0.03	0.04	0.05	0.03	0.03	0.02	0.02
January 2010	0.02	0.02	0.03	0.03	0.05	0.06	0.04	0.03	0.02	0.02
October 2009	0.03	0.03	0.03	0.03	0.06	0.04	0.03	0.03	0.02	0.02
July 2009	0.03	0.03	0.03	0.04	0.07	0.08	0.03	0.03	0.03	0.02
Historical Results										
2009-10 Mean	0.03	0.03	0.03	0.03	0.06	0.06	0.03	0.03	0.02	0.02
2008-09 Mean	0.05	0.04	0.04	0.04	0.08	**0.11**	0.05	0.03	0.04	0.04
2007-08 Mean	0.03	0.03	0.04	0.04	0.05	0.06	0.03	0.3	0.03	0.02

Values less than or equal to 0.10 indicate a low potential for toxicity, between 0.11–1.0 indicate moderate potential for toxicity, and >1.00 indicates a high probability for toxicity (Long et al. 1998). Bolded values indicate potentially toxic sediment conditions.

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