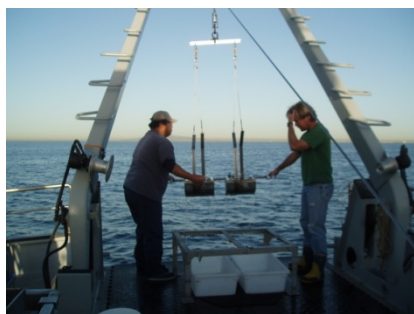


chapter 4

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).

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

<u>Criteria</u>	<u>Description</u>
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.

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.

The District has undertaken 3 projects in the last 7 years that have the potential to significantly affect effluent characteristics. The first was the initiation of effluent disinfection by chlorination with hypochlorite bleach followed by de-chlorination with sodium bisulfate, which began in August 2002. The second was the Ground Water Replenishment System (GWRS) water reclamation project that was initiated in January 2008. This has decreased the volume of effluent discharged into the ocean from 237 million gallons per day (MGD) in 2006-07 to 212 MGD in 2007-08 and to 167 MGD in 2008-09. 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 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 biological oxygen demand (BOD). What affect, if any, these treatment changes will have on sediment characteristics and biota are still being assessed.

METHODS

The District collects sediment samples for physical, chemical, and toxicity analyses. 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). Single samples were collected at the quarterly stations. 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 m² 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. Linear alkylbenzenes (LABs), 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

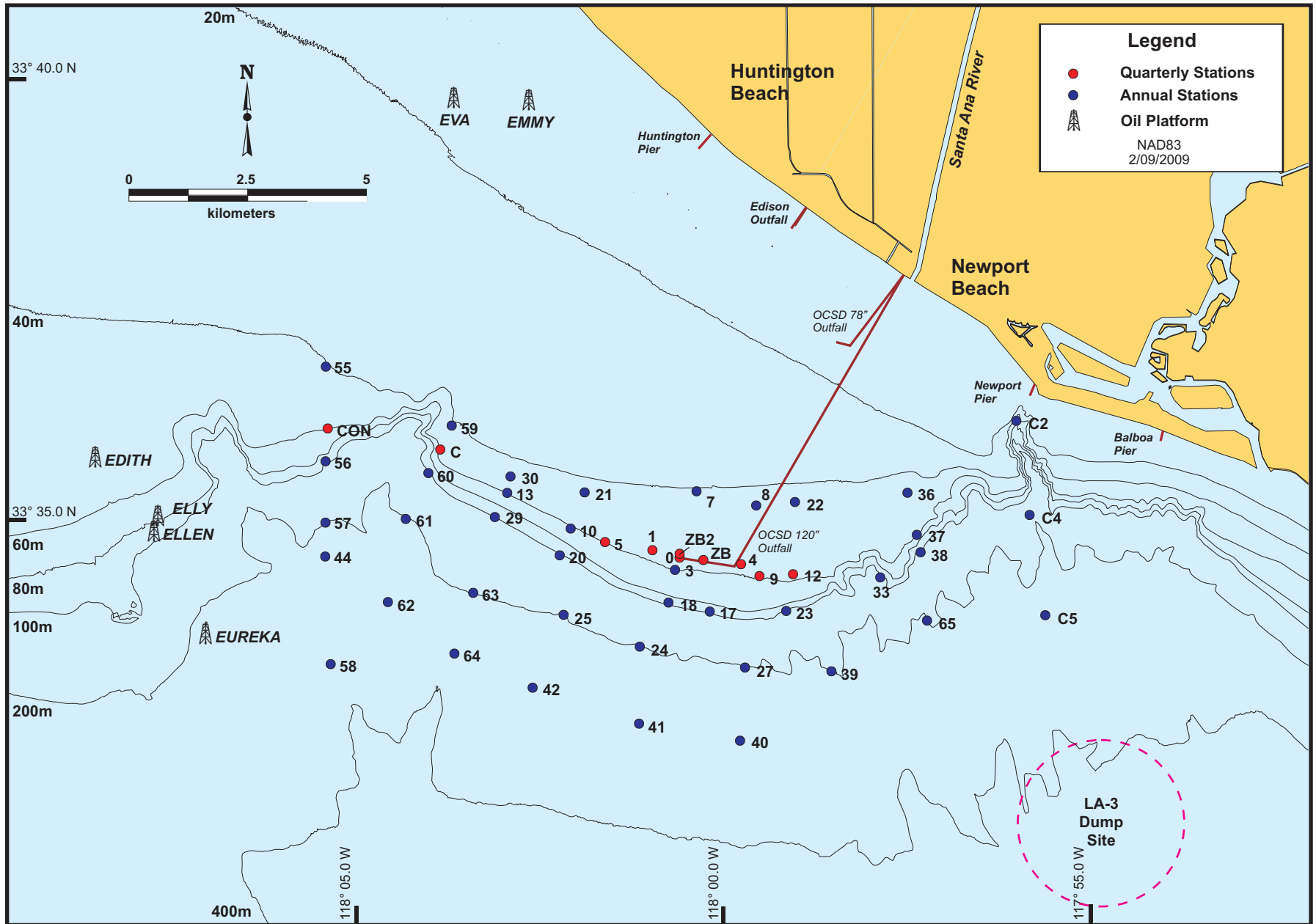


Figure 4-1. Sediment geochemistry sampling stations for annual and quarterly surveys, 2008-09.

analysis were given the value of one-half the detection limit for statistical analysis. Sediment chemistry and grain size samples 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 in January 2009 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 2008 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 2008 annual survey and the four quarterly surveys. Results of the July 2008 annual survey are presented in Appendix B, Table B-13 (sediment physical characteristics and organic contaminants) and Table B-14 (sediment metals). Relationships of sediment geochemistry measures and sediment physical characteristics to tLAB sediment concentration is performed using Pearson correlation analysis since LABs and wastewater are strongly associated (SAIC 2003). These results are reported below. Significant correlations between tLAB and sediment measures suggest, but do not prove cause-effect relationships with the outfall discharge of treated wastewater. Correlation analysis showed no significant relationship of tLAB sediment concentration and station depth. Thus, when there is a significant correlation of a sediment measure to tLAB, but not station depth it suggests a discharge-related influence. When there is a correlation with station depth, but not tLAB it indicates a depositional influence likely associated with sediment grain size (see below).

Spatial Analysis

Linear Alkylbenzenes (LAB)

Concentrations of total LABs (tLAB) were highest within the zone of initial dilution (ZID) followed closely by stations in the San Gabriel Submarine Canyon (Figure 4-2). This suggests upcoast transport with deposition in the San Gabriel Canyon, consistent with predominant sub-tidal currents below 30 m (SAIC, 2009). In July 2008, tLAB concentrations ranged from 25 $\mu\text{g}/\text{kg}$ at Station 55, located inshore of the San Gabriel Canyon, to 502 $\mu\text{g}/\text{kg}$ at Station 0 at the outfall terminus. LAB concentrations were not correlated with station depth or percent fines, but were weakly correlated with median phi (0.34), which is expected due to larger grain sizes in and near the ZID.

In the quarterly surveys, tLAB concentrations were highest at ZID stations and decreased with increasing distance from the outfall in both directions along the 60 m contour (Table 4-1; Figure 4-3). Within-ZID concentrations were between approximately 2 to 8 times greater than non-ZID stations.

Sediment Grain Size

Grain size distributions typically follow a pattern of larger grain size inshore and downcoast of the diffuser and become finer as you move offshore and into deeper, depositional environments, such as the Newport Canyon. In July 2008, as in previous years, sediment grain size varied with bathymetry and proximity to the outfall (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

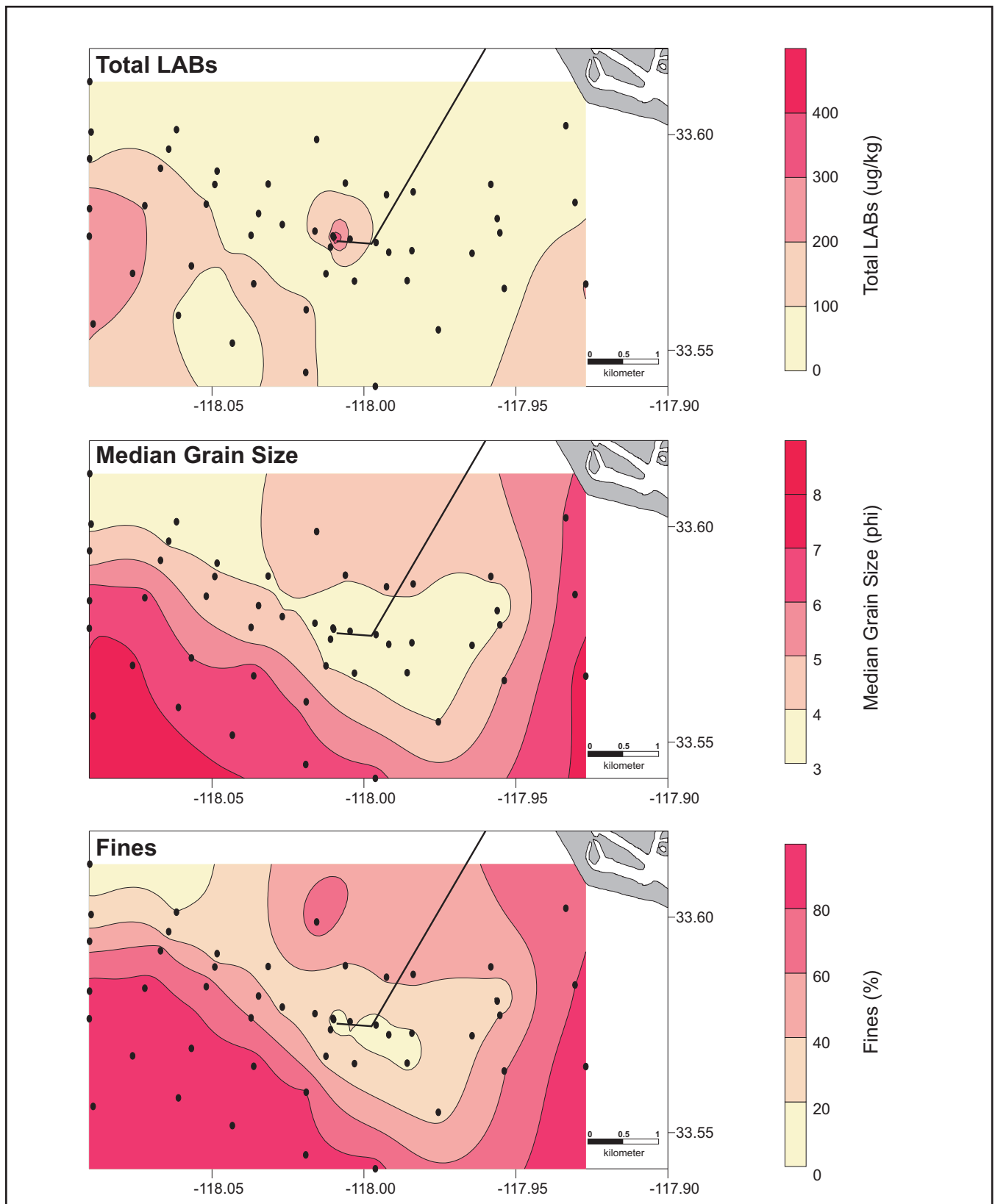


Figure 4-2. Spatial distributions of total linear alkyl benzenes (tLAB), median grain size (phi), and fine sediments (% less than 62 micron diameter) during July 2008.

Orange County Sanitation District, California.

Table 4-1. Average annual concentrations of sediment organic contaminants and measurements of sediment physical characteristics at the District's quarterly stations in 2008-09.

Values greater than the ERL are bolded. Quarterly stations n = 4; Total LAB only collected in July 2008 (1 rep).

Orange County Sanitation District, California

Station	Depth	tLAB (µg/kg)	Median Phi	Fines (%)	TOC (%)	Sulfides (mg/kg)	Total PAH (µg/kg)	Total DDT (µg/kg)	Total Pest (µg/kg)	Total PCB (µg/kg)
Within-ZID Stations										
0	56	502	3.52	14.7	0.57	7.46	525	6.38	8.03	75.3
4	56	90.6	3.49	16.1	0.33	3.90	48.5	1.49	0.958	3.16
ZB	56	166	3.65	20.4	0.34	12.8	59.3	1.50	1.72	6.00
ZB2	56	229	3.56	16.5	0.54	11.7	230	4.93	1.42	17.5
Average	56	247	3.56	16.9	0.45	8.97	216	3.58	3.03	25.5
Non-ZID Stations										
1	56	123	3.83	27.4	0.39	4.58	201	3.10	0.552	5.25
5	59	53.1	4.07	39.2	0.40	3.21	41.8	3.20	0.620	4.17
9	59	63.2	3.51	17.8	0.33	4.07	21.3	1.49	1.12	4.39
12	58	67.0	3.50	19.8	0.37	3.32	32.9	2.00	1.09	3.22
C	56	67.0	3.67	25.9	0.44	2.16	44.9	2.80	0.887	2.41
CON	59	62.9	3.82	27.5	0.39	4.17	212	4.74	1.95	2.63
Average	58	72.7	3.73	26.3	0.39	3.59	92.3	2.89	1.04	3.68
Sediment Quality Guideline and Reference Values										
¹ ERL		N/A	N/A	N/A	N/A	N/A	4,022	1.58	N/A	22.7
¹ ERM		N/A	N/A	N/A	N/A	N/A	44,792	46.1	N/A	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
N/A = Not Applicable, ND = Not Detected, AWM = Area Weighted Mean										
¹ Long et al. (1995)										
² Schiff et al. (2006)										

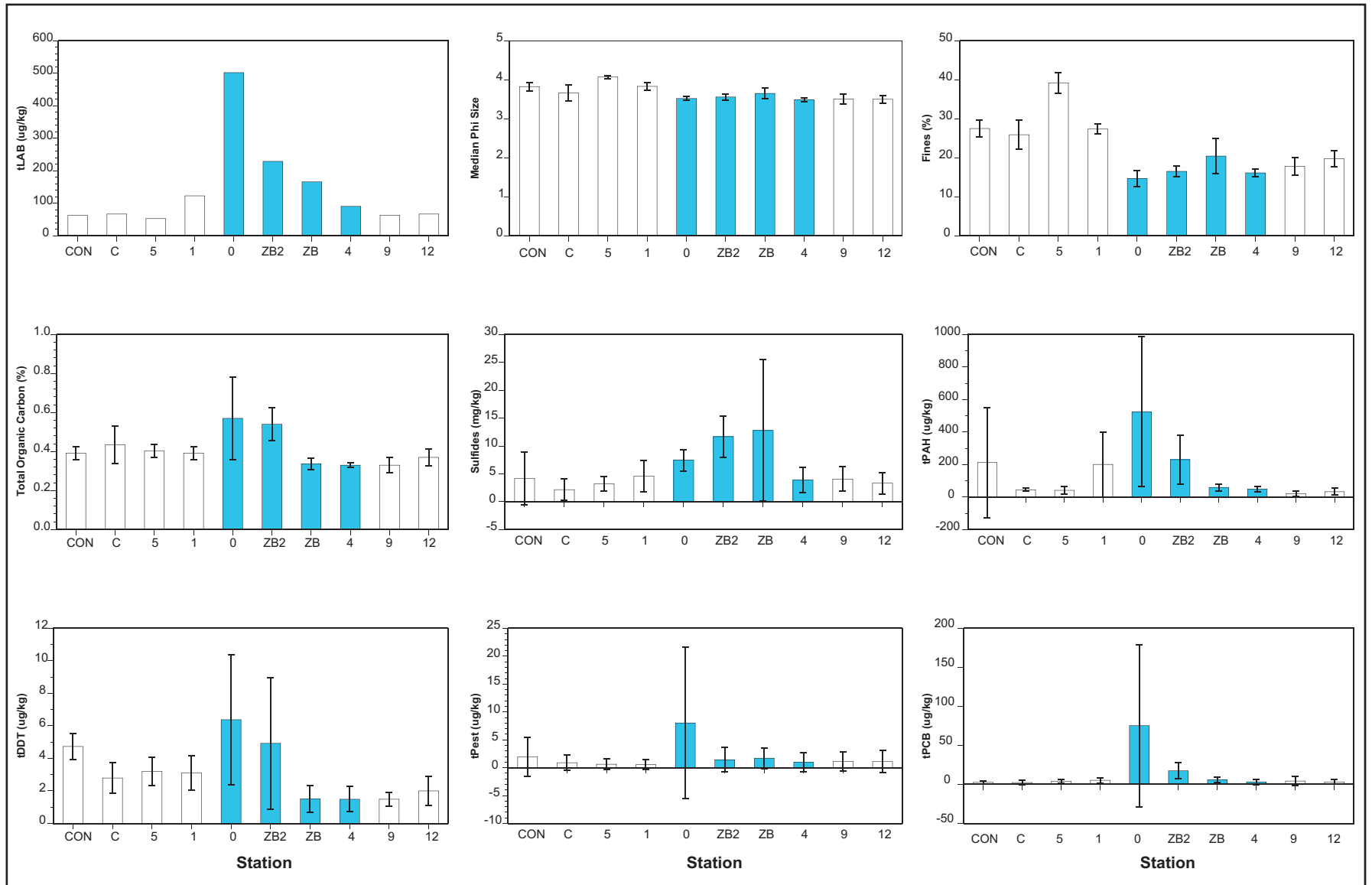


Figure 4-3. Distribution of mean and standard deviation values for total LAB (ug/kg), median phi, fines (%), total organic carbon (%), dissolved sulfides (mg/kg), total PAH (ug/kg), total DDT (ug/kg), total pesticides (ug/kg), and total PCB (ug/kg) in sediments at the 60 m shelf stations during 2008-09.

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

relationships for station depth to median phi ($R = 0.88$) and percent fines ($R = 0.84$). There was no significant relationship between sediment grain size and tLAB sediment concentrations indicating that the wastewater discharge did not significantly affect grain size distributions in the monitoring area.

Non-ZID quarterly station means for median phi ranged from 3.50 at Station 12 to 4.07 at Station 5, while proportions of percent fines (silt and clay) ranged from 17.8% at Station 9 to 39.2% 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 mean (Table 4-1). Median phi and percent fines were higher upcoast from the outfall (Figure 4-3).

Sediment Organic Content

Total Organic Carbon (TOC)

In July 2008, sediment TOC concentrations ranged from 0.28% at northern Station 55 to 2.21% at Station C5 in the Newport Canyon. 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 ($R = 0.83$) and tLAB ($R = 0.50$).

At the non-ZID quarterly stations, sediment TOC ranged from 0.33% at Station 9 to 0.44% at Station C (Table 4-1; Figure 4-3). Each of the 10 quarterly and 26 of the 39 annual stations showed increases in TOC compared to 2007-08 (OCSD 2008), suggesting an area-wide influence on sediment TOC concentrations. All quarterly station means were below the Bight'03 mid-depth and POTW means (Table 4-1).

Dissolved Sulfides

In the annual survey, sediment sulfide concentrations remained low and ranged from not detected at Stations 7, 18, 21, 22, 30, and 37 to 31 mg/kg at Station C2. Compared to shelf stations, sulfide concentrations were elevated in the Newport Canyon and some slope 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 no significant relationships of dissolved sulfides to either station depth or tLAB concentrations which suggest non-discharge sources.

Sediment sulfide concentrations at non-ZID quarterly stations ranged from 2.16 mg/kg at Station C to 4.58 mg/kg at Station 1 (Table 4-1; Figure 4-3). In 2008-09 Station CON sediment sulfide concentration was 4.17 mg/kg, a substantial increase from the 2007-08 mean concentration of 1.97 mg/kg (OCSD 2008). The reason for this increase at Station CON is not known, but since no discharge-related pattern was seen in the July 2008 survey, this suggests the causative factor is not related to the outfall discharge.

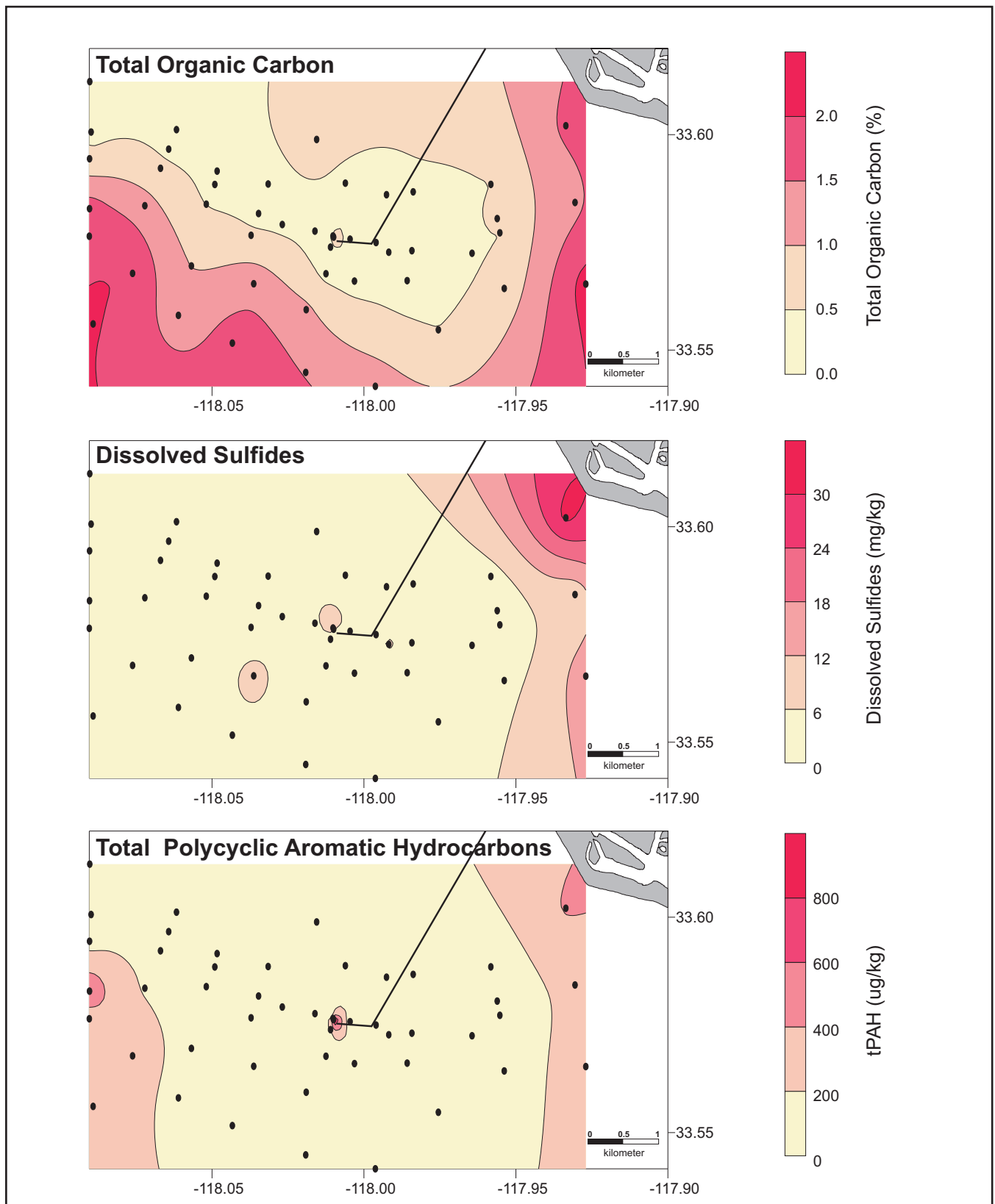


Figure 4-4. Spatial distributions of total organic carbon (TOC), dissolved sulfides (mg/kg), and total polycyclic aromatic hydrocarbons (ug/kg) during July 2008.

Orange County Sanitation District, California.

Organic Contaminants

Polycyclic Aromatic Hydrocarbons (PAH)

In July 2008, sediment total PAH (tPAH) concentrations were highest at stations within the ZID and nearest the diffuser terminus, followed by Newport and San Gabriel Submarine Canyons, and slope areas (Figure 4-4). Concentrations ranged from 9 µg/kg at Station 9 to 992 µg/kg at Station 0. Correlation analysis showed a significant relationship of tPAH with tLAB ($R = 0.87$), but not with station depth, suggesting an outfall influence. All tPAH concentrations in the monitoring area were well below the ERL value, indicating a low probability of sediment toxicity due to PAHs.

Mean tPAH concentrations at non-ZID quarterly stations ranged from 21 µg/kg at Station 9 to 212 µg/kg at Station CON (Table 4-1; Figure 4-3). The concentrations increased from 2007-08 at Stations 1, C, and CON. The largest change occurred at Station CON, which increased from 59 to 212 µg/kg from 2007-08 (OCSD 2008). Non-ZID station means, except Stations 1 and CON, were below the Bight'03 mid-depth and large POTW 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 2008, tDDT concentrations ranged from 0.48 µg/kg at Station ZB to 24.8 µg/kg at Station 58. 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). Thirty-nine of the 49 stations sampled in July 2008 exceeded the ERL of 1.56 µg/kg. All concentrations were below the ERM, as well as the Bight'03 mid-depth and large POTW means (Table B-13). 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 relationship of tDDT with station depth ($R = 0.70$) and a small, but significant relationship with tLAB ($R = 0.36$).

Non-ZID quarterly station means for tDDT ranged from 1.49 µg/kg at Station 9 to 4.74 µg/kg at Station CON (Table 4-1) with no outfall pattern was 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 2008, unlike previous years, the distribution of the summed constituents of the other chlorinated pesticides (tPest) showed an outfall influence (Figure 4-5). Detectable concentrations occurred at only 3 stations (Stations C5, 0 and ZB; Table B-13). Correlation analysis showed a significant relationship of tPest with tLAB ($R = 0.45$), but not with station depth suggesting an outfall influence.

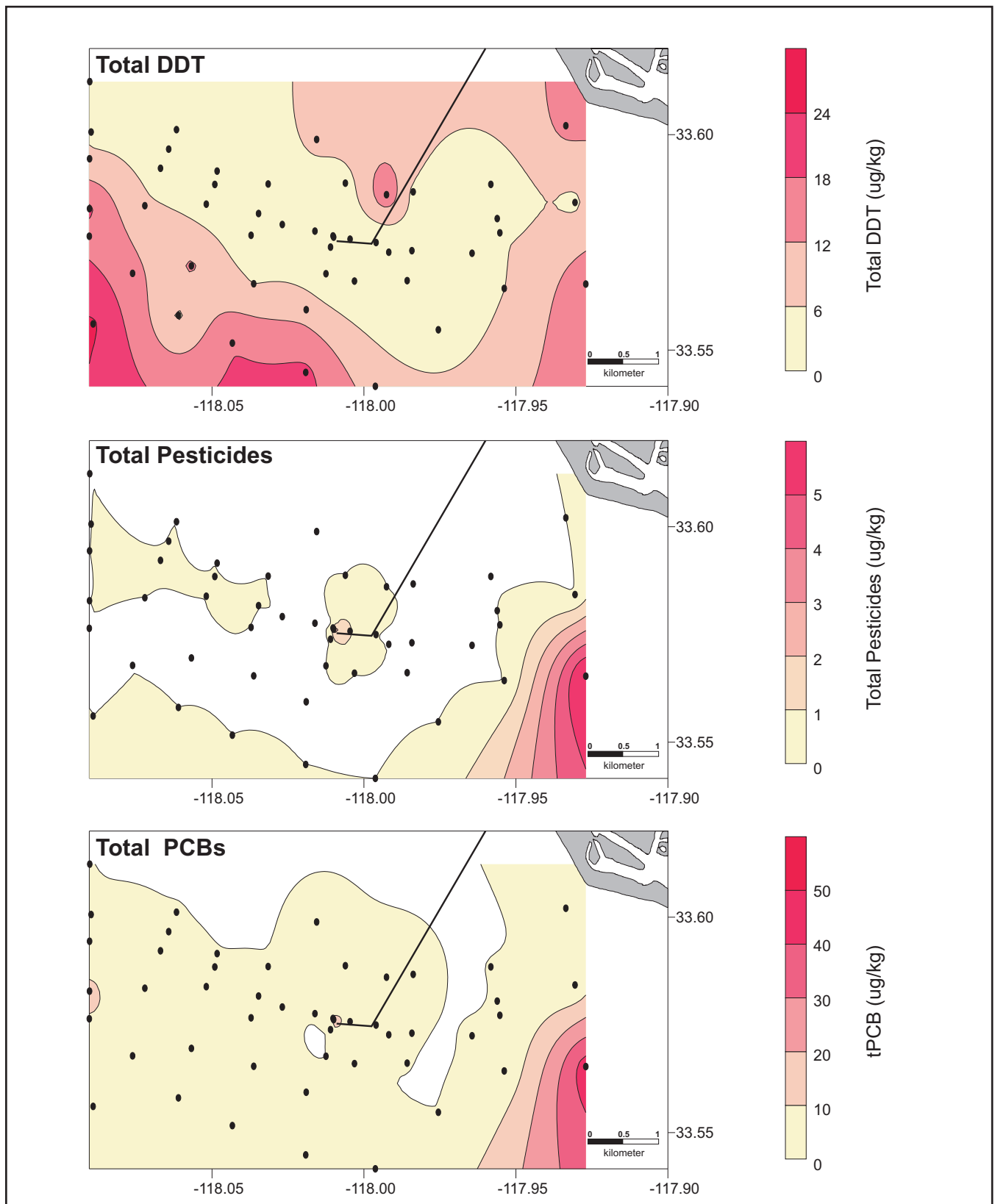


Figure 4-5. Spatial distributions of total DDT (tDDT), total pesticides, and total PCB (tPCB) concentrations (ug/kg) during July 2008.

Orange County Sanitation District, California.

Non-ZID quarterly station means for tPest ranged from 0.55 µg/kg at Station 1 to 1.95 µg/kg at Station CON (Table 4-1; Figure 4-3). Historically, pesticides other than DDT are generally not detected at all stations and when they are detected it is very near the detection limit. This year pesticides were measureable at all 60 m stations, primarily in October 2008 and January 2009. In July 2008, pesticides were measured at Stations 0 and ZB only, while none were detected at any station in April 2009. The reason for the increase in chlorinated pesticides this year is not known. Fish tissue contaminant analysis conducted in July 2008 showed measureable concentrations of tPest in fish tissues, which are normally not detected (see Chapter 6).

Polychlorinated Biphenyls (PCB)

In July 2008, sediment concentrations of total PCB (tPCB) ranged from not detected at Station 18 to 45.9 µg/kg at Station C5 (Figure 4-5). This pattern is consistent with previous monitoring years (OCSO 2007). The tPCB concentration at Station C5 exceeded the ERL and the SCBPP outfall average. Most station concentrations were below the SCBPP non-outfall average and Bight'98 area weighted mean (Table B-13). Correlation analysis showed small, but significant relationships of tPCB to depth ($R = 0.38$) and tLAB ($R = 0.35$).

Quarterly non-ZID station mean tPCB concentrations ranged from 2.4 µg/kg at Station C to 5.25 µg/kg at Station 1 (Table 4-1). Mean concentrations were highest at ZID Stations 0, ZB, and ZB2 and decreased outside the ZID (Figure 4-3). All non-ZID stations had tPCB concentrations well below the ERL.

Metals

In July 2008, 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). All metals showed significant correlations to tLABs and all but mercury were also significantly correlated with station depth. The stronger correlations to tLAB and lesser to station depth were found in Group B metals. Some metals may switch groups from year-to-year (e.g., copper), possible 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 (zinc and mercury, respectively). Group A metals included arsenic, beryllium, chromium, lead, nickel, and zinc. Group B included cadmium, copper, mercury, selenium, and silver. Arsenic, copper, mercury, and nickel concentrations exceeded their respective ERLs at several stations, generally those located within the canyons and slope areas. The exception was mercury which exceeded the ERL (0.15 mg/kg) only at Station ZB2 (0.25 mg/kg). Contour plots for metals not presented in Figure 4-5 can be found in Appendix B (Figures B-22 and B-23).

Quarterly station mean sediment concentrations for metals were below ERL values for all analytes at all non-ZID stations (Table 4-2; Figure 4-7).

Principal Components Analysis (PCA)

Principal Components Analysis (PCA) was performed using the July 2008 annual station data, including the 10 quarterly stations ($n = 49$ stations). PCA identified 7 station groups that generally followed depth gradients, the influences of the Newport and San Gabriel Canyons, and the outfall diffuser terminus (Figure 4-8). Four of the groups were single station groups consisting of 2 ZID stations (0 and ZB2) and 2 Newport Canyon Stations (C2

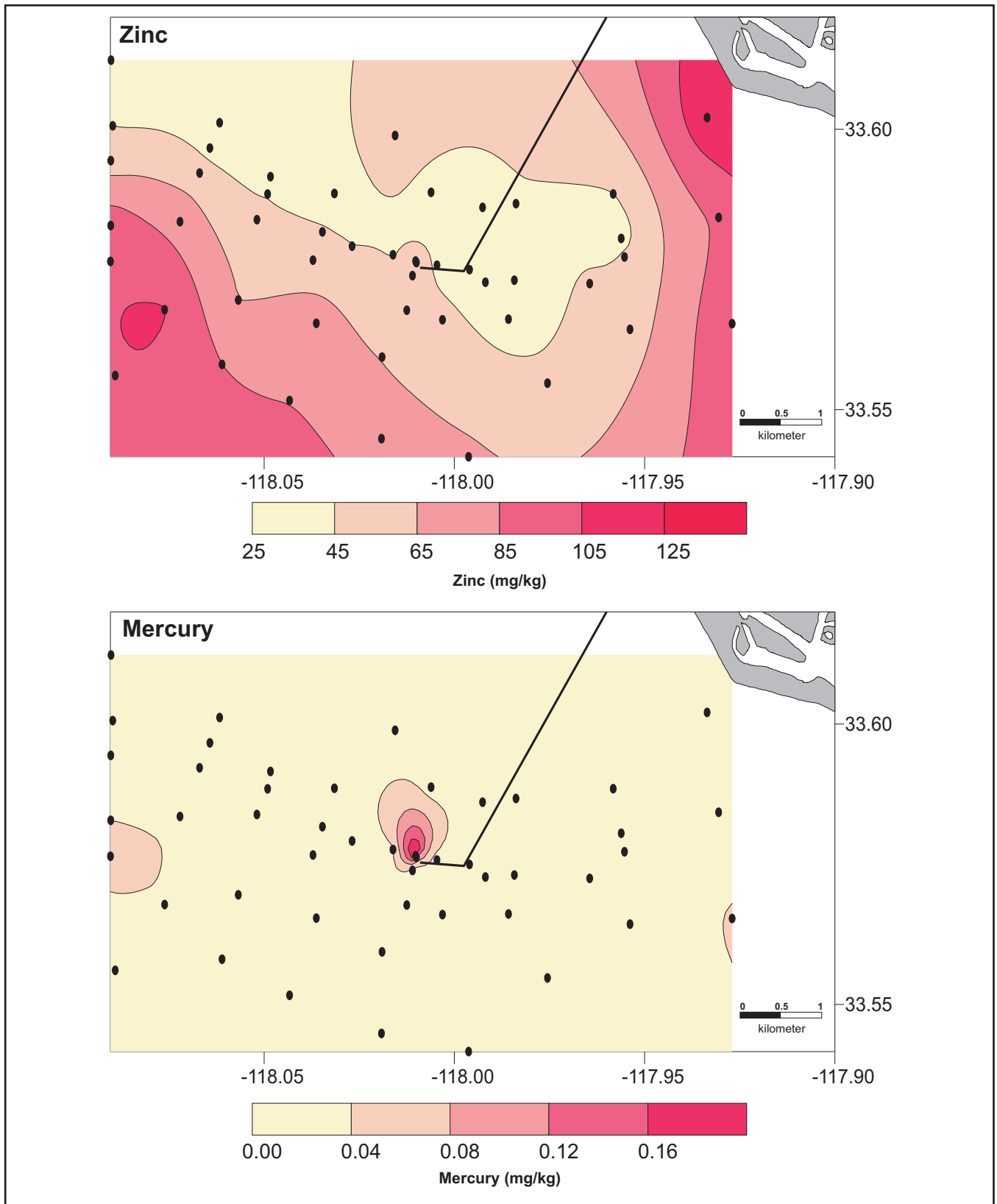


Figure 4-6. Spatial distributions of zinc (mg/kg) and mercury (mg/kg) during July 2008.

Orange County Sanitation District, California.

Table 4-2. Average concentrations of sediment metals (mg/kg) at the District's quarterly stations in 2008-09.

Values greater than the ERL are bolded. Quarterly stations n = 4.

Orange County Sanitation District, California.

Station	As	Be	Cd	Cr	Cu	Pb	Hg	Ni	Se	Ag	Zn
Within-ZID Stations											
0	3.59	0.250	0.719	23.9	16.6	6.15	0.105	9.51	0.522	0.338	53.0
4	2.89	0.246	0.239	17.5	8.04	4.10	0.014	7.75	0.321	0.166	38.3
ZB	3.02	0.257	0.426	18.5	9.72	4.38	0.016	8.91	0.447	0.162	45.8
ZB2	3.43	0.261	0.766	23.6	18.1	6.33	0.205	9.26	0.524	0.306	53.3
Average	3.23	0.254	0.538	20.9	13.1	5.24	0.085	8.96	0.454	0.243	47.6
Non-ZID Stations											
1	2.92	0.263	0.369	21.3	13.5	5.67	0.033	9.02	0.462	0.278	44.0
5	3.36	0.285	0.317	22.8	12.6	5.98	0.022	10.3	0.406	0.277	47.6
9	2.83	0.248	0.197	18.8	8.33	4.53	0.019	8.21	0.417	0.160	39.2
12	3.14	0.261	0.215	18.6	8.45	4.76	0.020	8.53	0.474	0.148	39.3
C	3.33	0.239	0.203	18.9	8.58	5.69	0.017	8.55	0.382	0.154	38.6
CON	3.29	0.273	0.204	22.1	10.6	5.87	0.020	10.3	0.408	0.158	44.6
Average	3.15	0.262	0.251	20.4	10.3	5.42	0.022	9.15	0.425	0.196	42.2
Sediment Quality Guidelines											
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
N/A = Not Applicable, ND = Not Detected, AWM = Area Weighted Mean											
¹ Long et al. (1995)											
² Schiff et al. (2006)											

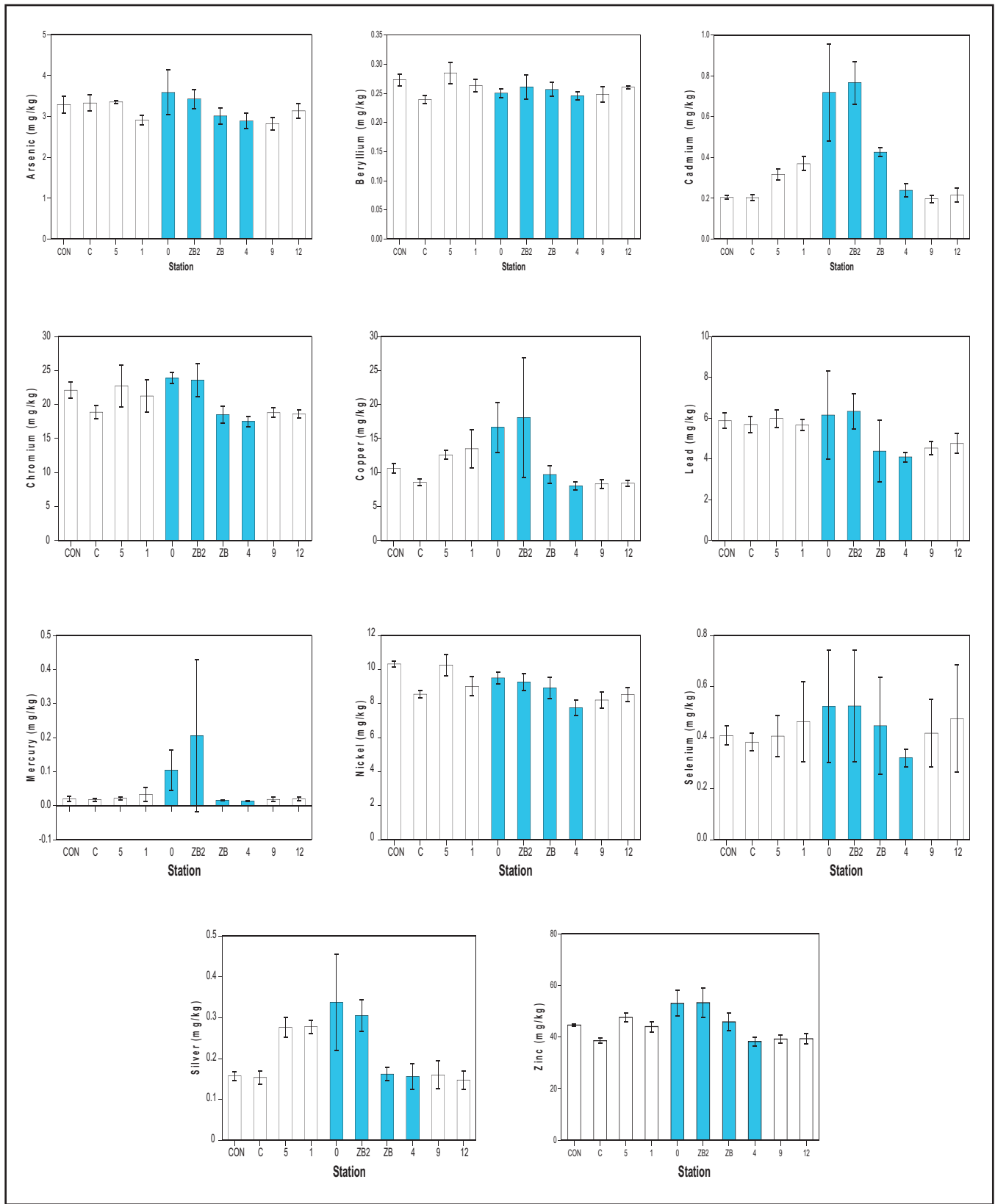


Figure 4-7. Distribution of mean and standard deviation values (mg/kg) for arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, and zinc in sediments at the 60 m shelf stations during 2008-09.
 Stations plotted from north to south (left to right). ZID stations indicated in blue.
 Orange County Sanitation District, California.

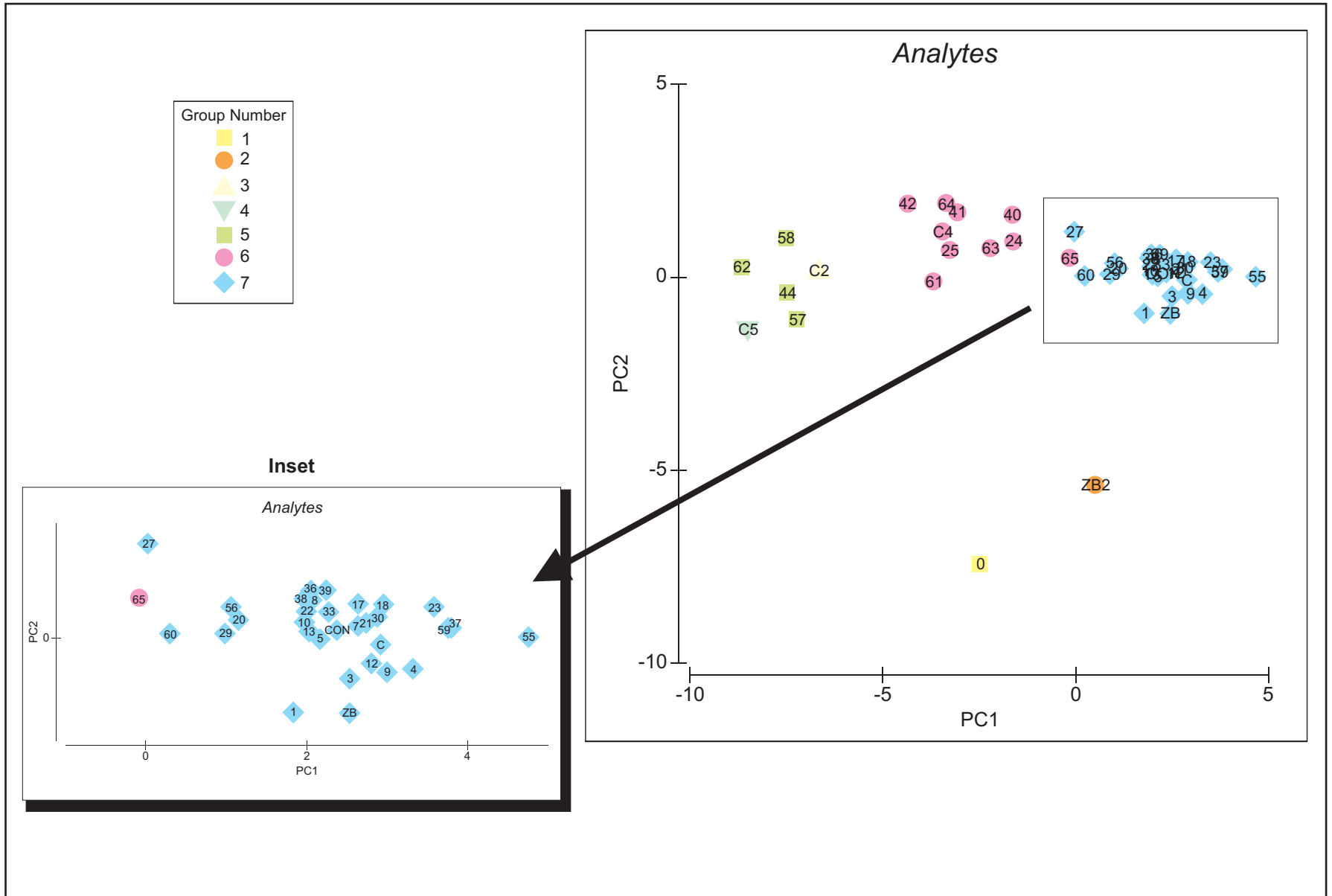


Figure 4-8. Principal components analysis (PCA) station plot. Station symbols correspond to PCA station groupings (group numbers).

and C5). The remaining stations groups included a San Gabriel Canyon group (Stations 44, 57, 58, and 62), a slope group (Stations 24, 25, 40, 41, 42, 61, 63, 64, and C4), and a San Pedro Shelf group consisting of the remaining 32 stations (Figure 4-9). The station group pattern is similar to that seen for infaunal abundances (see Chapter 5, Figure 5-10). Station 0 had the greatest concentrations of tPAH, tLAB, and cadmium. The high concentration of mercury (6x > the mean of 0.04 mg/kg) set Station ZB2 apart. Station C2 had the highest dissolved sulfide concentration, while Station C5 separated due to high levels of tPCB, percent fines, TOC, and selenium. The San Gabriel Canyon group had the highest levels of tDDT, chromium, copper, nickel and silver, and the second highest mean tLAB sediment concentrations behind Station 0. The elevated tLAB concentration and the fact that copper and silver correlated significantly with tLAB suggests an outfall influence in the San Gabriel Canyon is consistent with predominant upcoast-flowing sub-tidal currents below 30 m (SAIC, 2009). The lowest and second lowest sediment concentrations for all analytes were found in the San Pedro Shelf and slope station groups, respectively.

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 2008-09 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, 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 2008-09 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 decrease 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 no change over time. All groups follow a similar inter-annual pattern except the non-ZID stations closest to the outfall terminus (NFU) which has the greatest rate of increase and variability. Mercury concentrations at WZU in 2008-09 are the highest for the ten-year period examined here and comparable to 2005-06. 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). However, the current results were obtained using the new method and the reason for the increase in sediment mercury concentrations cannot be attributed to the analysis. 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.

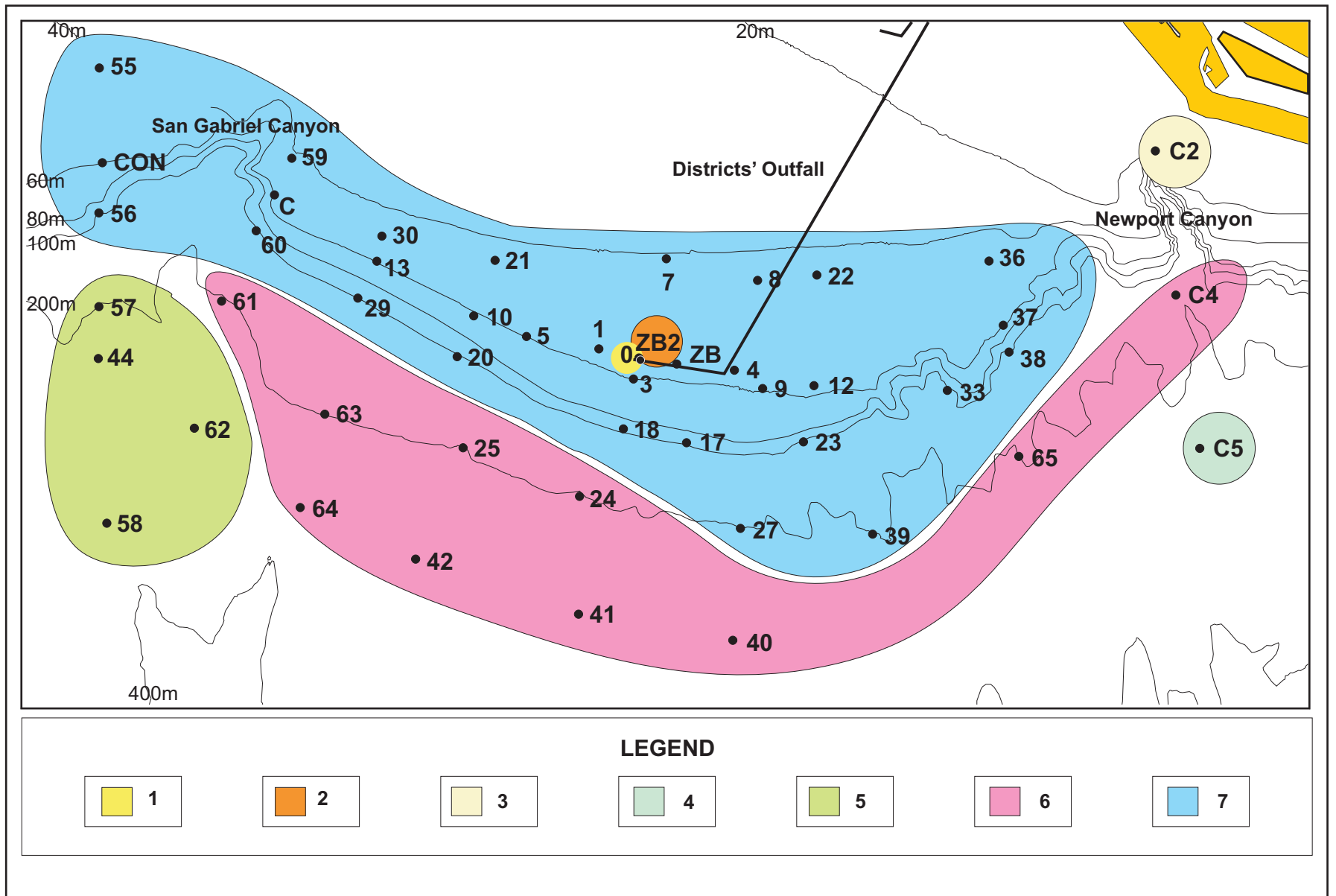


Figure 4-9. Map of station groups from principal components analysis for July 2008.

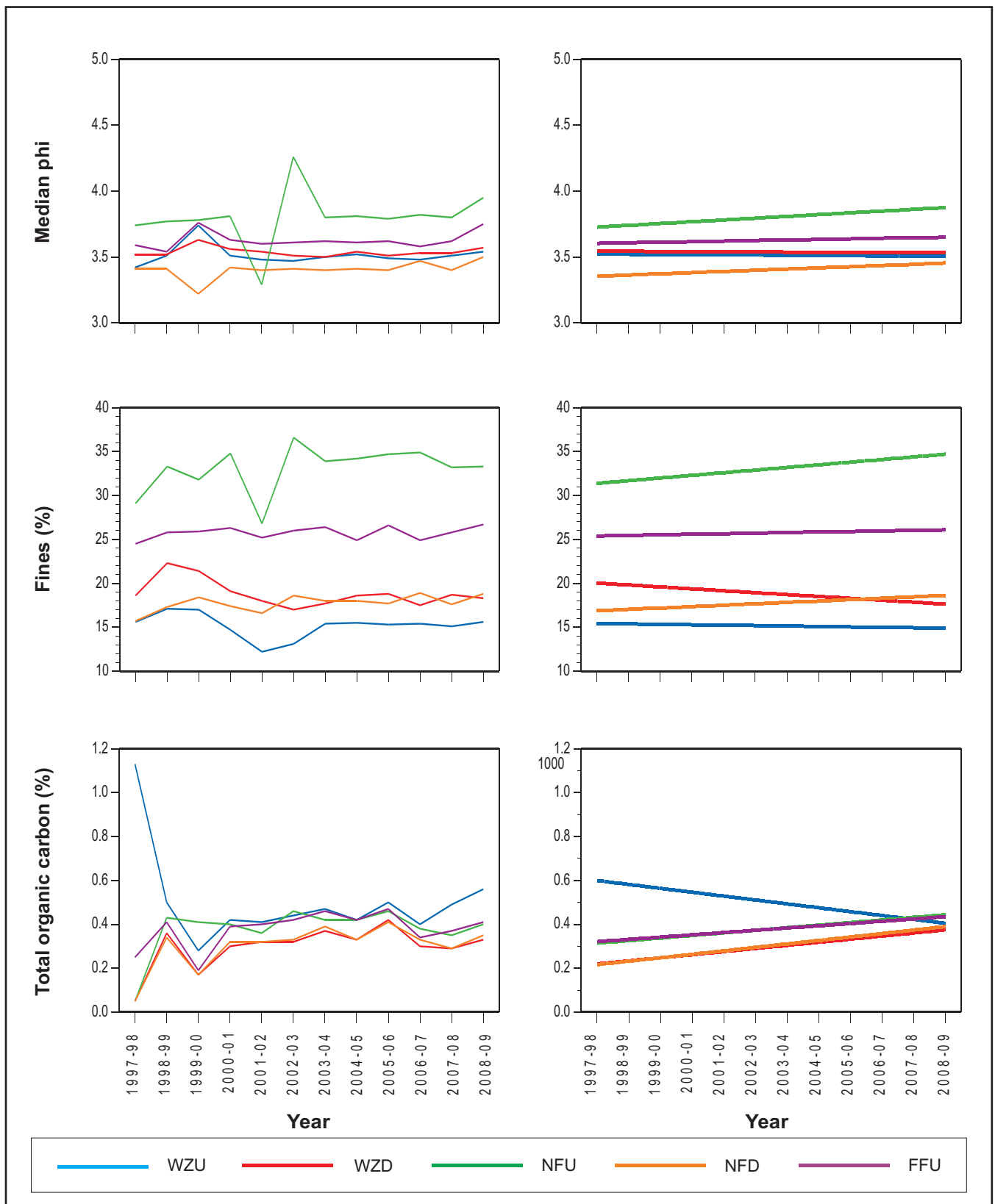


Figure 4-10. Changes over time for total DDT, total PCB, total PAH, median phi, % fines, sulfides¹, total organic carbon, arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, and zinc in sediments at the 60 m shelf station groups during 1997–2009.

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

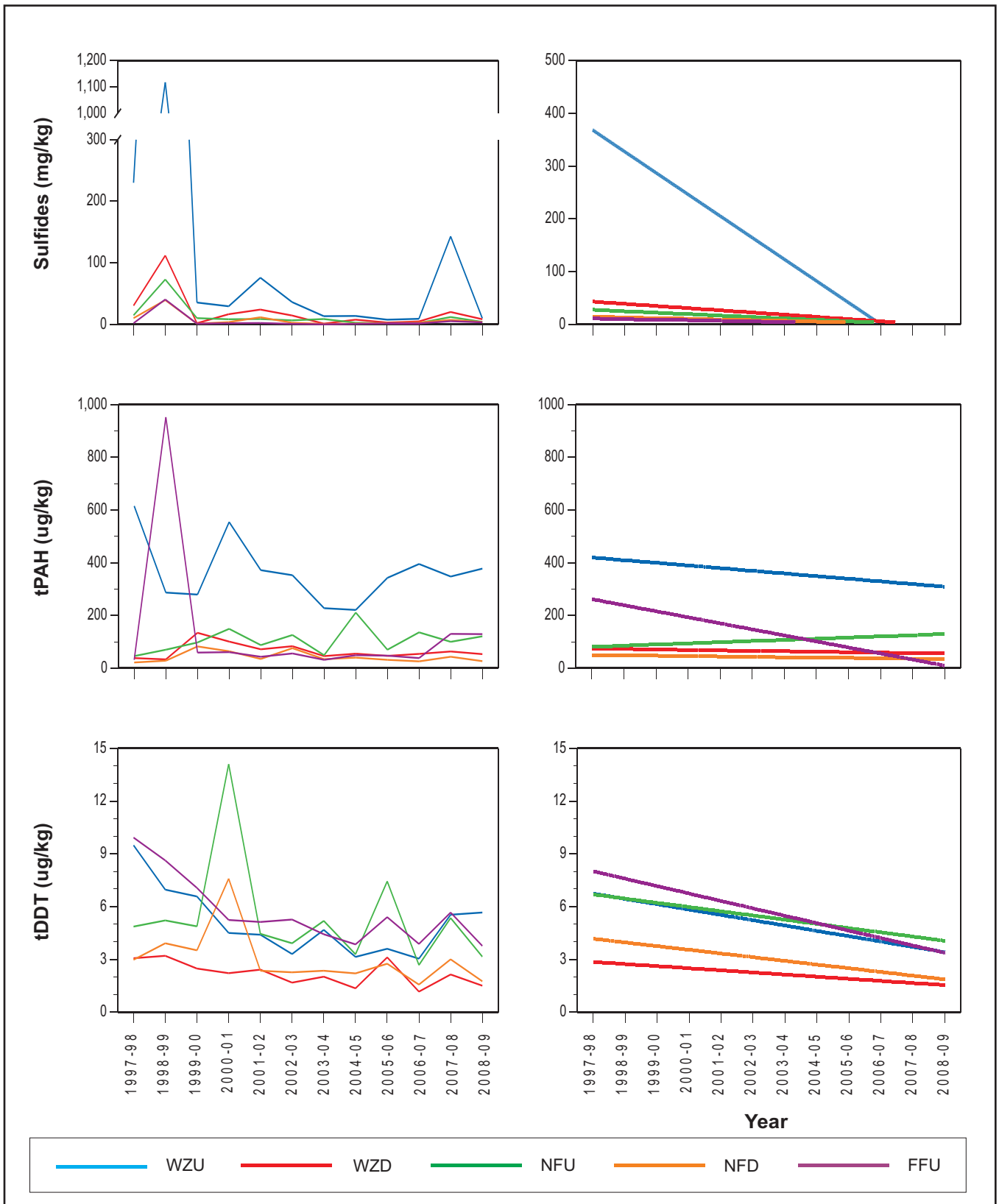


Figure 4-10 Continued.

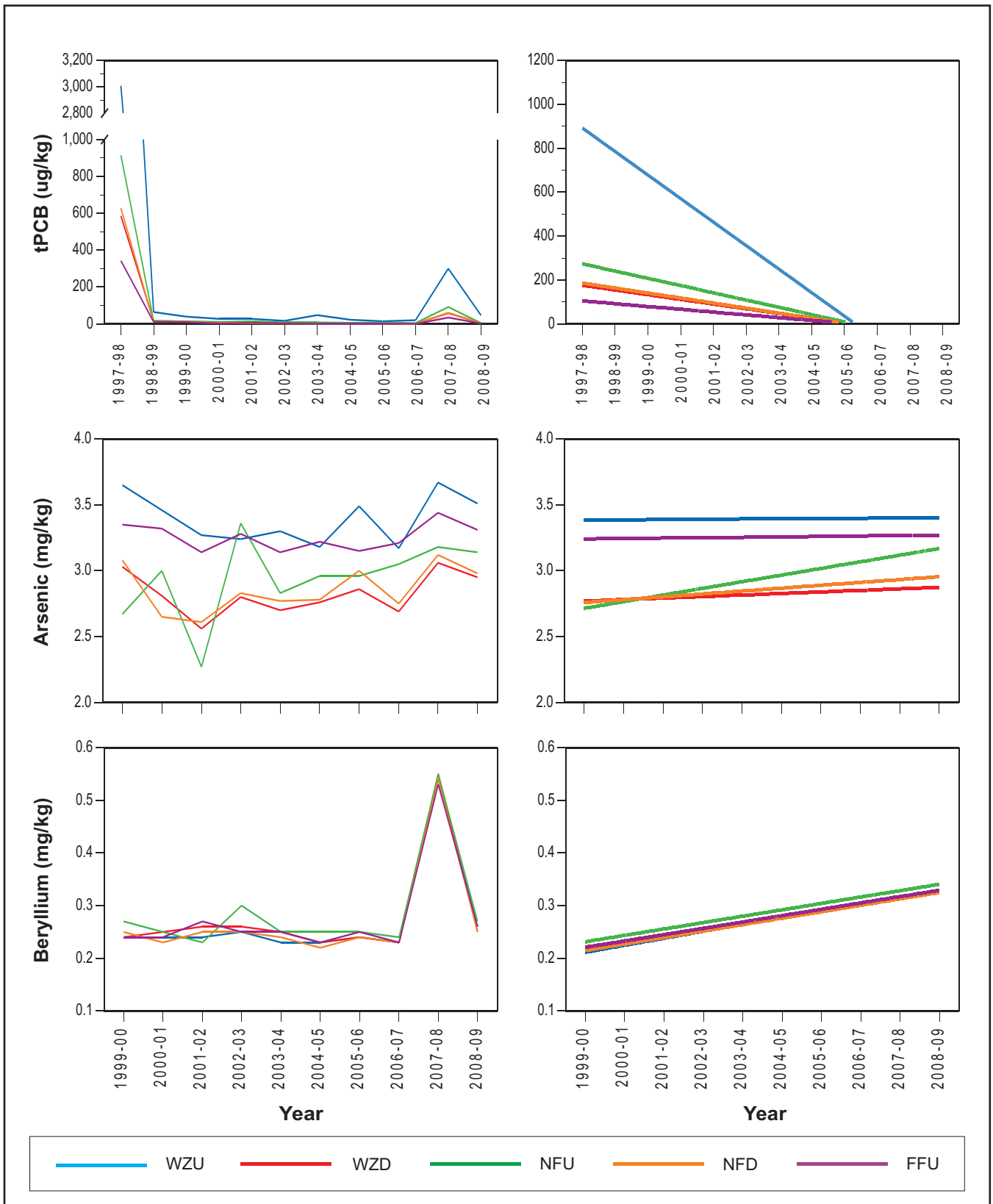


Figure 4-10 Continued.

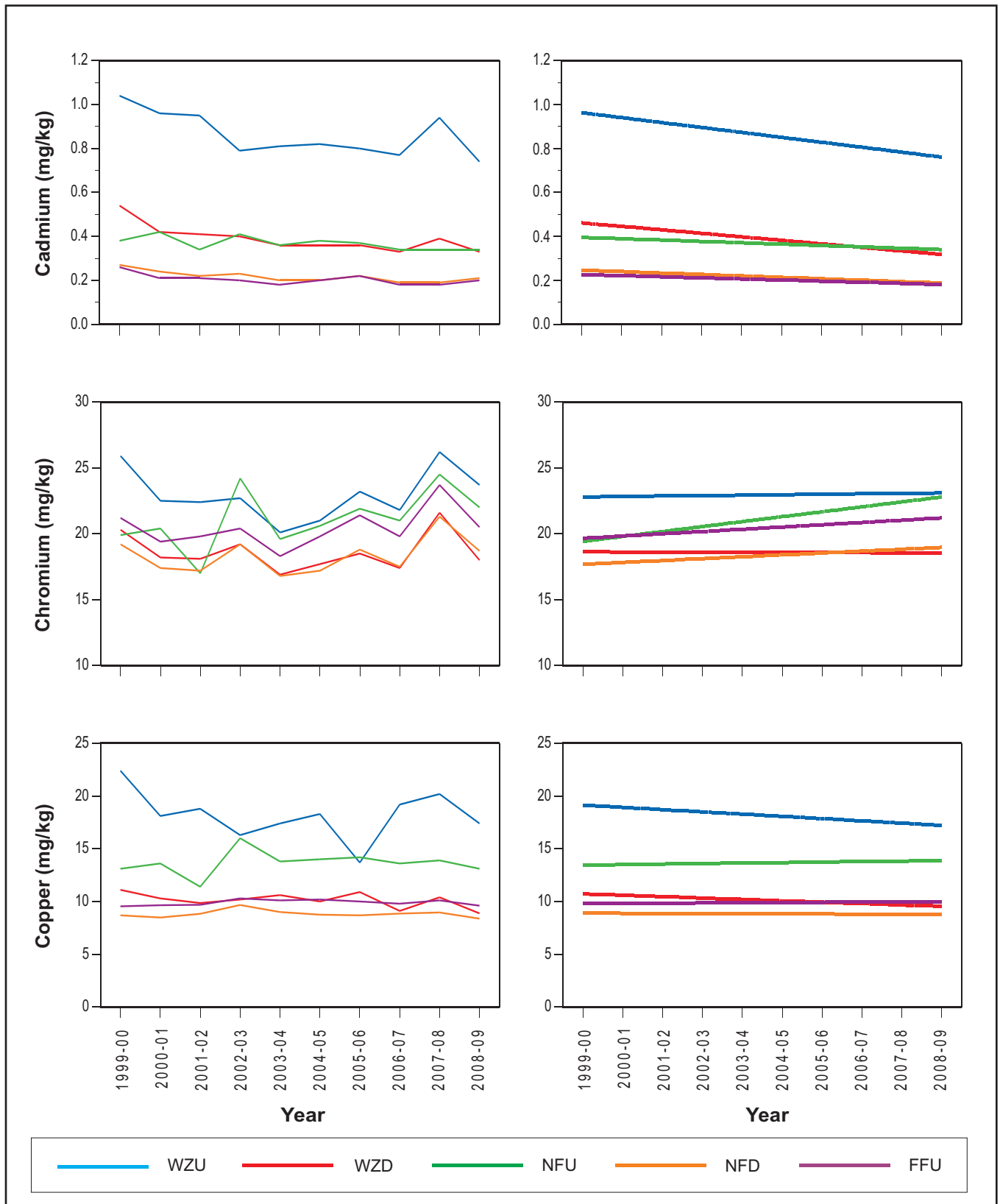


Figure 4-10 Continued.

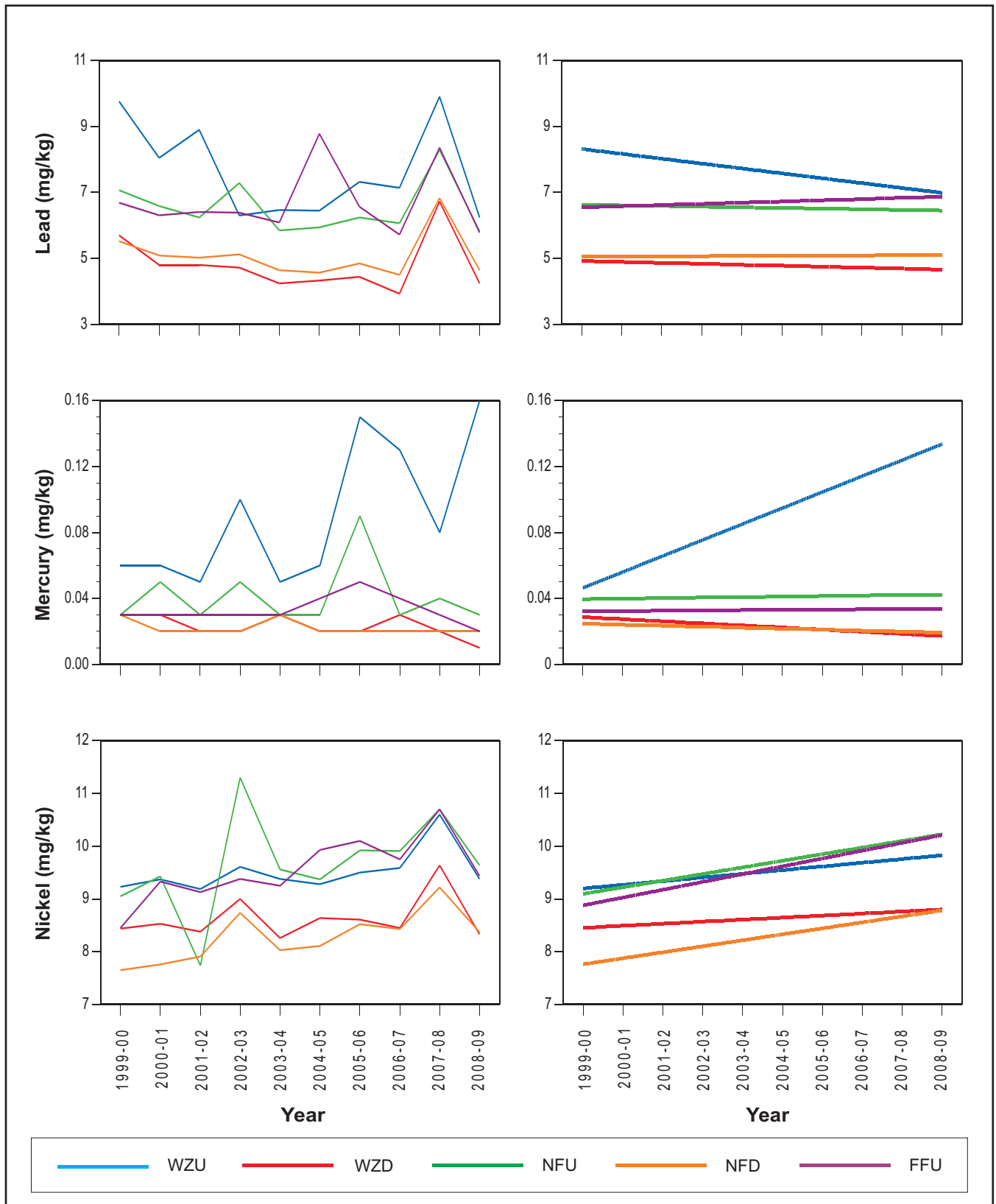


Figure 4-10 Continued.

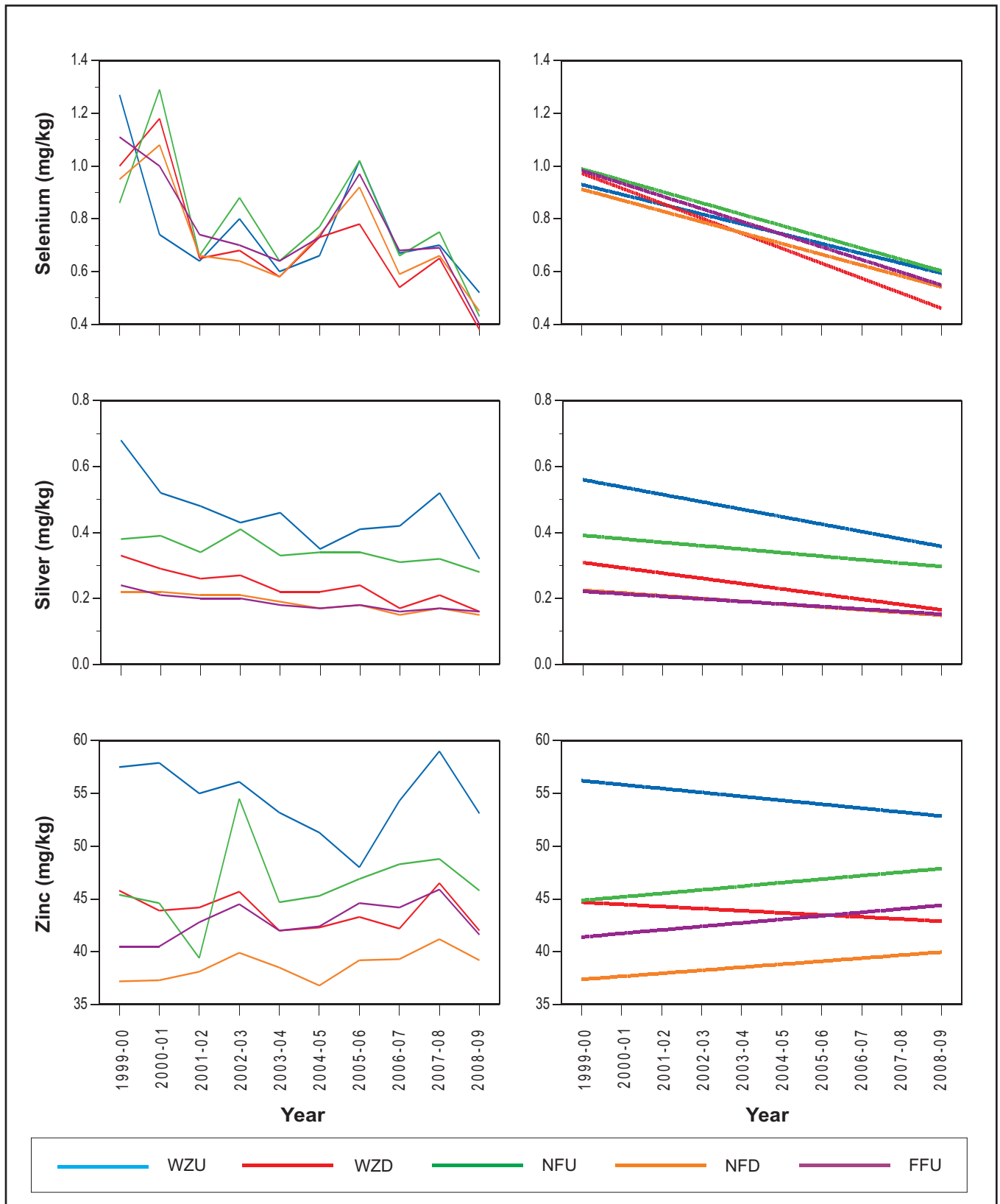


Figure 4-10 Continued.

Sediment Toxicity

Whole-sediment toxicity testing was conducted on sediments collected during the January 2009 survey. No significant toxicity was found with the 10-day amphipod survival test. The percent difference in amphipod survival between station and control sediment was less than 7% for all stations, indicating very low acute toxicity (Table 4-3).

Four samples showed the potential for moderate toxicity (i.e., mERMq>0.11; Table 4-4). Three of these occurred within the ZID at Stations 0 (October 2008 and April 2009) and ZB2 (October 2008), and one occurred at farfield Station CON (October 2008). Measurable levels of chlorinated pesticides were found at all 3 stations in October 2008, but only Stations 0 and ZB2 showed concomitant changes in community health measures (i.e., BRI and ITI; see Chapter 5). Similar results occurred at ZID Station 0 in April 2009.

CONCLUSIONS

The results from the 2008-09 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 are generally at concentrations outside the ZID below that of biological concern with no clear outfall-related temporal trends. Principal Components Analysis indicated that stations grouped by station depth and proximity to the Newport and San Gabriel Submarine Canyons, with outfall-related increases in some constituents indicated in the San Gabriel Canyon and 2 within-ZID stations. Mean ERMq analysis indicated a low probability of sediment toxicity in the monitoring area outside the ZID. There was one instance when mERMq analysis predicted moderate toxicity at farfield Station CON, but no toxicity was evident either in laboratory tests or infaunal communities. Overall, results suggested that there were some minor impacts to sediment quality, but they are mainly localized near the outfall. As discussed in Chapter 5 (Invertebrate Communities) and Chapter 6 (Trawl Communities), biological communities were not degraded outside the ZID. Therefore, while some wastewater discharge effects are indicated, the magnitude of these effects was not sufficient to adversely affect biological communities in the District's monitoring area and all permit compliance criteria were met (see Chapter 2).

Table 4-3. Sediment toxicity test results for January 2009. Whole-sediment (amphipod) test results given as test sediment percent difference from home sediment.

Negative values represent values greater than 100% of home sediment.

Orange County Sanitation District, California.

Date	Station									
	CON	C	5	1	ZB2	0	ZB	4	9	12
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

Amphipod test results that are >20% different and p<0.05 from the control = toxic response (Bay et al. 2000)

Home Sediment = Control

*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.

Table 4-4. Mean ERMq values for sediment contaminant concentrations, 2008-09.

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

Orange County Sanitation District, California.

Survey	Station									
	CON	C	5	1	ZB2	0	ZB	4	9	12
July 2008	0.03	0.02	0.03	0.03	0.04	0.07	0.03	0.02	0.03	0.03
October 2008	0.11	0.05	0.05	0.06	0.13	0.11	0.09	0.05	0.08	0.06
January 2009	0.04	0.04	0.04	0.04	0.09	0.08	0.06	0.03	0.03	0.04
April 2009	0.03	0.03	0.03	0.04	0.05	0.18	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

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