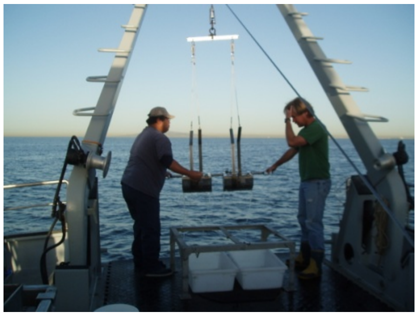
chapter 4

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 update).

Both natural and anthropogenic processes affect the physical and chemical properties of sediments. Large-scale, regional, and local currents, combined with naturally occurring inputs (e.g., atmospheric, terrestrial, biogenic) provide and distribute organic and inorganic constituents to sediments. These patterns are then influenced by anthropogenic alterations to the system, for example the wastewater outfall. The outfall is a 10 ft. diameter pipe with associated ballast rock that alters current flow, which can affect sediment characteristics, such as grain size and geochemistry near the structure. Discharged effluent contains a variety of organic and inorganic contaminants that can affect sediment quality (Anderson et al. 1993; OCSD 1985, 2003). Also, changes in effluent characteristics (e.g., flow, concentrations, particle size) may be reflected in sediments near to as well as some distance from the outfall. Therefore, periodic measurements of the physical, chemical, and toxicological characteristics of sediments are used to assess these changes and can identify temporal and spatial trends due to natural and anthropogenic sources.

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.

The District has undertaken three projects in the last 9 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) wastewater reclamation project that was initiated in January 2008. This has decreased the mean volume of effluent discharged into the ocean by almost 40% from 237 million gallons per day (MGD) in 2006-07 to 212 MGD in 2007-08 and to 139 MGD in 2011-12. Third, since 2002 the District has increased the amount of flow receiving secondary treatment standards from 50% in 2002 to 100% in June 2012. While the effluent volume has decreased due to GWRS, the annual mass balance of contaminants being discharged has decreased as a result of increasing secondary treatment. What effects, if any, these treatment changes have had and will have in the future on sediment characteristics and biota are currently being assessed.

METHODS

The District collects sediment samples for physical, chemical, and toxicity analyses. The District's 2004 NPDES ocean discharge permit required that single samples be 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 (see OCSD 2012 Figure 4-1). However, for 2011-12, the District received regulatory approval to conduct modified semiannual (summer and winter) benthic sampling at 9 semi-annual stations, 39 annual stations and 21 additional new stations (Figure 4-1). District scientists are currently conducting special studies to investigate changes to the infaunal invertebrate and demersal fish communities near the discharge site. The modified sampling scheme allowed for increased focus near the outfall to facilitate this investigation. See Chapters 5 (Macrobenthic Invertebrate Communities) for more information on the investigation.

The purpose of the semiannual surveys was to refine impact assessments near the outfall diffuser and along the 60 m (outfall depth) contour, while still allowing continued long-term and spatial trend evaluations. The survey data are reported as individual station values and as means for station groups (using the individual station values located within six zones based on station depth or proximity to the outfall). The depth zones are Shallow-shelf (40–46 m), Mid-shelf within-ZID (56 m), Mid-shelf non-ZID (52–65 m), Outer-shelf (91–100 m), Slope (187–241 m), and Basin (296–303 m).

Single samples were collected at all stations using paired, stainless steel, 0.1 m^2 Van Veen grab samplers. The top 2 cm of the sediment was collected with a stainless steel scoop and placed into specific containers for chemical and toxicity analyses. All 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 dichlorodipheynltrichloroethane (tDDT) represents the summed concentrations of o,p'- and p,p'- [2,4- and 4,4'-] isomers of DDD, DDE, and DDT, and p,p'-DDMU, total polychlorinated biphenyls (tPCB) represents the

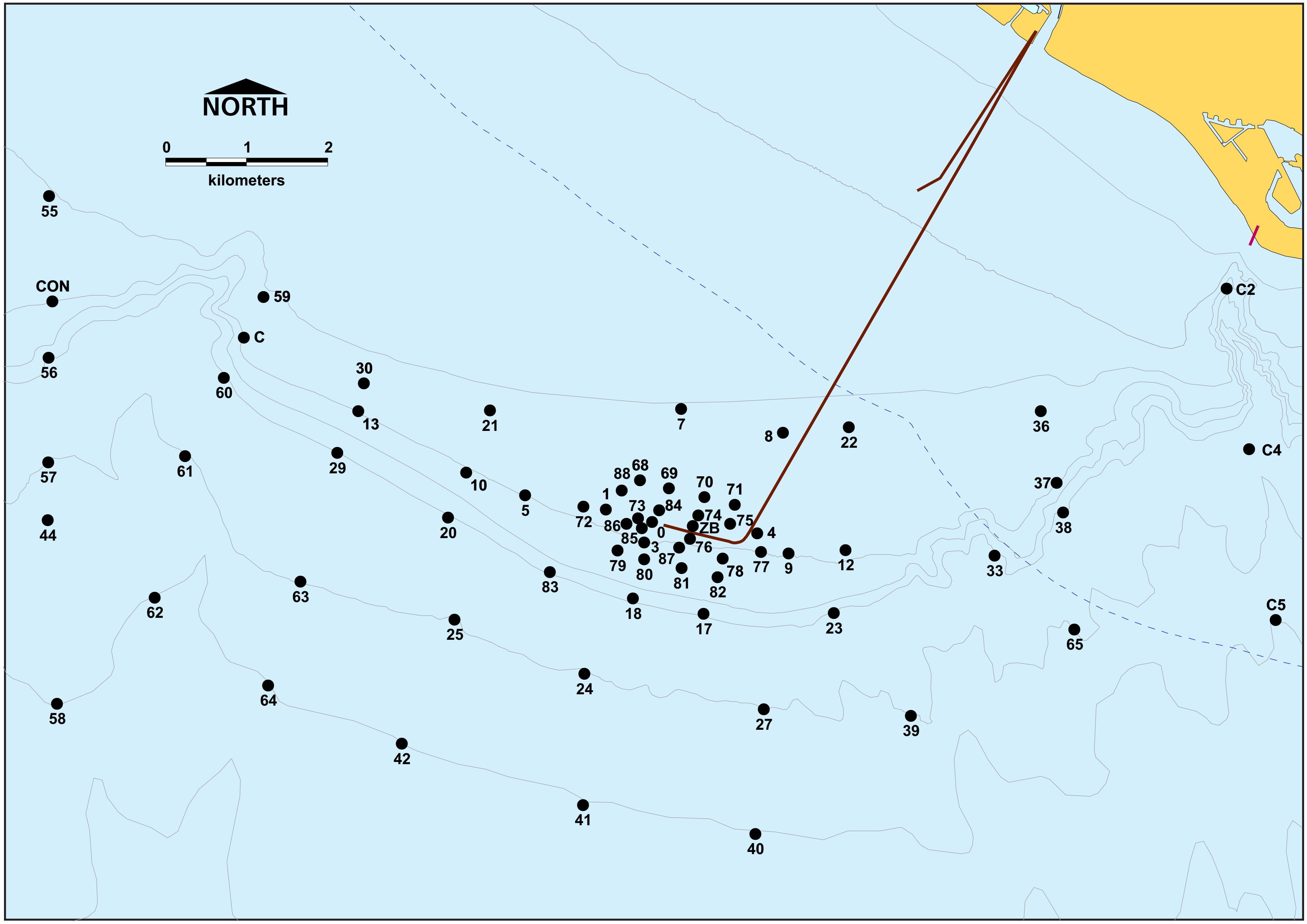


Figure 4-1. **Sediment geochemistry sampling stations for semi-annual surveys, 2011-12.**

Orange County Sanitation District, California.

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) are commonly found in detergents and serve as sewage markers (Eganhouse et al. 1983, 1988; Takada and Ishiwatari 1991). LABs were measured in the July 2011 survey to better identify changes in sediment quality attributable to the wastewater discharge. For summed concentrations, such as tDDT, any 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 considered to be zero. Single analytes (e.g., metals) not detected during 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 complement toxicity, bioaccumulation, and benthic community assessments (Long and MacDonald 1998). The ERL is defined as the 10th percentile sediment concentration of a chemical below which a toxic effect is unlikely. The ERM is the 50th percentile sediment 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 whole sediment toxicity tests as a measure of sediment quality. Sediment toxicity was tested in August/September 2011 (ten stations) and January 2012 (nine stations) using samples of whole sediments in a 10-day *Eohaustorius estuarius* amphipod survival test. Amphipods were exposed to test and control sediments and the percent survival in each were determined. The data are presented as differences in percent survival between test and control stations. Toxicity threshold criteria were selected to be consistent with the State of California Sediment Quality Objectives (SQO) for bays and estuaries (State of California 2009). The SQO categorizes toxicity into four categories: 1) non-toxic, 2) low toxicity, 3) moderate toxicity, and 4) high toxicity. Classification is based on the percent difference from a control and whether or not the difference is statistically significant based on a t-test ($p \leq 0.05$). These methods are discussed in more detail in Appendix A.

The mERMq was also employed as an assessment benchmark in this analysis. 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 combined 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.

Spatial patterns for the July 2011 and January 2012 annual station data were assessed graphically by sediment character or analyte using geographic data maps created using MapInfo v11.5 (Mapinfo 2012) and statistically by correlation-based principal components analysis (PCA) using the PRIMER v6 statistical software package (PRIMER 2001). Depth related gradients and relationships between chemical compounds and physical sediment characteristics were assessed using Pearson Product Moment Correlation using the Minitab® Statistical Software package. Data were transformed where appropriate. Statistical significance was set at $p \leq 0.05$. Temporal trends were assessed graphically using constituent annual means from monitoring years 1999-00 through 2011-12.

A subset of the outfall-depth stations were used for a qualitative spatial assessment. Means were calculated for the summer and winter surveys (n=2) and plotted using bar graphs. The stations used were within-ZID Stations 0, 4, 76, and ZB; downcoast non-ZID Stations 9, 12, and 77; and upcoast non-ZID Stations 1, 3, 5, 72, C, and CON.

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 Summer 2011 and Winter 2012 surveys. Total linear alkylbenzene (tLAB) analysis was not performed on the Winter 2012 samples, so assessments of potential outfall influence cannot be made with this data. Therefore, the primary focus of this chapter is on the Summer 2011 survey data. The Winter 2012 data is presented in Tables 4-2 (sediment organics) and 4-4 (sediment metals), but is not discussed in detail.

Correlation Analysis

The analysis of relationships between sediment physicochemical characteristics and tLAB sediment concentration was performed 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 outfall discharge of treated wastewater. When there is a significant correlation of a sediment measure to tLAB but not station depth, there is likely a discharge-related influence. A correlation with station depth but not tLAB indicates a depositional influence likely associated with sediment grain size.

In July 2011, similar to previous years, station depth was highly correlated with percent fines (R = 0.82) due to the depositional pattern associated with sediment grain size.

Spatial Analysis

Total Linear Alkylbenzenes (tLAB)
In July 2011, the highest rate of effluent particle deposition generally occurred on the shelf near to and upcoast from the outfall (Table 4-1; Figure 4-2). Elevated concentrations were also found at several slope and basin stations indicating effluent particle transport several kilometers upcoast and offshore from the outfall. Total LAB concentrations were not correlated with percent fines suggesting that tLAB concentrations are indicative of effluent transport and particle deposition to specific areas.

Unlike previous years, the highest concentrations of tLAB were seen at mid-shelf non-ZID stations (mean=190 µg/kg) not at within-ZID sites (mean=100 µg/kg) (Figure 4-3). This is likely partially due to the increased number of stations near, but outside the ZID. The highest tLAB concentration was at non-ZID Station 5 (891µg/kg), which was over two-times that of the highest within-ZID station (Station 76=346 µg/kg). Half of the mid-shelf non-ZID stations had tLAB levels greater than 180 µg/kg, while the remaining stations ranged from <1.0 to 27.8 µg/kg. Concentrations of tLAB >100 µg/kg were also found in upcoast slope and San Gabriel Canyon Stations 44 (165 ug/kg) and 57 (157 µg/kg), and basin Stations 58 (110 µg/kg) and 62 (150 µg/kg). This suggests upcoast effluent particle transport is occurring with deposition in the San Gabriel Canyon, which has the potential for measurable discharge impacts away from the outfall nearfield area. This pattern is consistent with predominant subtidal currents below 30 m (SAIC, 2009).

Percent Fine Sediments
Percent fine sediment generally increased with increasing station depth, particularly at out-shelf, slope, and basin stations. Values ranged from 32.9% in shallow-shelf to 90.1% in basin strata (Table 4-1; Figure 4-4). Mean percent fines at within-ZID stations (15.8%) was approximately two-thirds that of mid-shelf non-ZID stations (24.9%). The lower percentage of fines found near the outfall is due in part to scouring by ocean currents and contributions from coarse-grained shell hash (i.e., the calcareous tubes of worms and mollusk shells). However, percent fine sediments at stations outside the ZID, but <1 km away from the outfall were generally comparable to within-ZID stations being two to three times lower than mid-shelf stations >1 km away. This indicates an outfall influence on grain size that extends beyond the ZID. Station group means were comparable to Bight'08 area weighted means (AWM) by depth except for the two mid-shelf station groups, which were two- to three-times lower.

Total LAB concentrations were not significantly correlated with percent fines. Prior to July 2009, tLAB concentrations generally correlated with grain size measures, but this has decreased over the last few years. One potential cause of this change may be that increased wastewater reclamation through GWRS, which began in 2008, is altering particle sizes and decreasing effluent discharge velocity from the outfall diffuser affecting grain size distributions in the monitoring area. This hypothesis is being examined as part of the special investigation into changes in the benthos near the outfall.

Mean percent fines at stations downcoast from the outfall were generally comparable to within-ZID stations, while upcoast stations were up to twice that of the downcoast sites (Figure 4-3).

Table 4-1. Concentrations of sediment organic contaminants (µg/kg) at the District's annual stations in Summer 2011 compared to Effects Range–Low (ERL) and Effects Range–Median (ERM) values and regional measurements of sediment physical characteristics.

Orange County Sanitation District, California

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)
Shallow Shelf (40 – 46 meters)										
7	41	15.2	3.87	39.5	0.35	1.97	28.4	2.20	ND	0.26
8	44	28.1	3.90	41.6	0.35	1.58	27.4	1.89	ND	1.18
21	44	20.6	3.82	36.3	0.31	3.65	20.5	2.50	ND	0.93
22	45	10.6	4.00	49.9	0.36	3.78	46.2	2.00	ND	0.59
30	46	14.7	3.64	29.0	0.95	3.18	29.6	1.90	ND	ND
36	45	4.5	3.89	43.2	ND	4.79	36.1	2.16	ND	0.70
55	40	4.6	2.91	6.0	0.16	1.48	7.9	0.76	ND	ND
59	40	12.7	3.35	17.9	0.27	2.24	8.9	1.50	ND	0.41
	Mean	13.9	3.67	32.9	0.38	2.83	25.6	1.86	ND	0.51
Mid-Shelf Within-ZID (56 – 58 meters)										
0**	56	21.0	3.43	7.9	0.48	8.72	216.9	4.05	ND	1.91
4**	56	1.3	3.47	18.2	0.31	3.94	30.4	1.56	ND	ND
76**	58	346.1	3.47	16.0	0.27	5.31	334.1	1.12	ND	1.89
ZB**	56	32.0	3.57	21.1	0.31	6.64	34.0	2.44	ND	ND
	Mean	100.1	3.49	15.8	0.34	6.15	153.9	2.29	ND	1.00
Mid-Shelf Non-ZID (52 – 65 meters)										
1**	56	2.9	3.62	21.6	0.29	4.18	188.1	2.16	ND	ND
3**	60	2.8	3.58	19.2	0.25	7.95	46.4	3.14	ND	1.33
5**	59	891.4	3.84	37.0	0.33	3.67	38.5	6.27	ND	1.06
9**	59	0.3	3.46	16.9	0.29	5.55	16.5	3.03	ND	ND
10	60	22.5	4.19	44.9	0.36	3.24	34.1	3.00	ND	0.29
12**	58	0.5	3.53	16.0	0.33	2.26	45.5	3.39	ND	0.45
13	59	19.3	3.87	41.5	0.37	3.72	36.7	2.60	ND	ND
37	56	6.9	2.68	14.6	0.28	4.11	27.1	1.48	ND	0.10
68**	52	336.2	3.75	31.2	0.33	3.19	49.2	2.08	ND	1.37
69**	52	0.7	3.71	28.9	0.32	1.95	60.4	3.46	ND	ND
70**	52	323.8	3.64	25.4	0.33	4.78	59.7	1.61	ND	0.85
71**	52	0.7	3.49	18.1	0.26	1.98	27.6	1.75	ND	ND
72**	55	335.6	3.69	27.5	0.34	3.91	75.7	3.74	ND	2.47
73**	55	7.3	3.51	15.8	0.70	3.34	52.8	3.09	ND	2.11
74**	57	27.8	3.50	17.5	0.26	1.70	16.5	2.25	ND	0.51
75**	60	325.7	3.44	14.7	0.24	6.68	18.4	1.73	ND	0.75
77**	60	349.2	3.45	17.6	0.27	4.25	32.0	1.35	ND	0.15
78**	63	25.1	3.52	15.6	0.26	5.38	7.7	2.54	ND	ND
79**	65	308.9	3.65	23.4	0.35	6.50	99.1	3.73	ND	0.94
80**	65	304.8	3.70	29.5	0.31	3.87	83.7	1.56	ND	0.69
81**	65	298.2	3.55	19.5	0.24	3.10	45.0	1.26	ND	0.53
82**	65	297.5	3.46	18.1	0.28	2.62	27.3	1.08	ND	0.80
84**	54	436.6	3.48	14.1	0.31	8.35	115.5	1.82	ND	2.88
85**	57	463.1	3.41	11.0	0.43	56.0	150.8	2.11	ND	3.35
86**	57	181.5	3.53	17.1	0.34	8.40	56.6	2.64	ND	ND
87**	60	314.2	3.52	18.4	0.46	4.14	26.6	1.41	ND	6.47
88**	57	338.7	3.74	31.2	0.40	17.7	60.4	2.09	ND	3.20
C **	56	24.9	3.49	23.5	0.39	3.49	28.4	4.53	ND	0.20

Table 4-1 Continues.

Table 4-1 Continued.

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)
Mid-Shelf Non-ZID (52 – 65 meters)										
C2	56	26.5	5.68	90.6	1.65	17.2	406.7	14.57	ND	ND
CON **	59	25.9	3.65	25.7	0.33	3.22	46.7	5.39	ND	ND
	Mean	190.0	3.64	24.9	0.38	6.90	66.0	5.39	ND	1.00
Outer Shelf (91–-100 meters)										
17	91	12.9	3.46	19.8	0.36	1.26	14.0	2.32	ND	ND
18	91	10.9	3.74	30.6	0.34	13.1	18.3	1.55	ND	0.15
20	100	23.6	4.19	58.6	0.90	3.08	32.7	69.12	ND	1.38
23	100	8.0	3.50	20.6	0.29	2.04	13.6	1.70	ND	ND
29	100	29.8	4.32	66.1	0.48	3.34	50.9	4.30	ND	0.51
33	100	24.2	3.64	34.2	0.41	4.84	47.3	2.60	ND	ND
38	100	10.2	3.46	37.2	0.49	4.88	47.8	1.53	ND	0.13
56	100	39.6	4.15	55.9	0.51	4.99	79.7	6.02	ND	2.35
60	100	24.5	4.29	63.4	0.54	8.72	41.4	3.80	ND	0.75
83	100	312.8	3.80	32.7	0.43	18.60	51.2	2.97	ND	1.10
	Mean	49.7	3.86	41.9	0.47	6.49	39.7	9.59	ND	0.64
Slope (187 – 241 meters)										
24	200	34.8	4.71	80.4	0.78	5.53	129.3	11.11	ND	ND
25	200	43.6	4.88	89.0	1.15	8.50	160.0	13.27	ND	ND
27	200	18.4	4.40	67.7	0.64	2.16	37.7	5.30	ND	ND
39	200	9.6	3.73	34.8	0.45	2.38	19.4	3.00	ND	0.33
44	241	165.2	6.50	96.5	1.91	17.80	253.4	12.77	ND	7.49
57	200	157.1	5.83	92.9	1.57	14.40	208.4	18.21	ND	10.09
61	200	78.5	4.94	35.3	1.13	10.10	146.4	8.02	ND	5.13
63	200	31.2	4.85	85.8	1.03	5.55	69.4	13.44	ND	ND
65	200	24.1	4.50	66.5	0.74	9.23	86.3	5.79	ND	1.73
C4	187	1.1	5.91	89.5	1.47	58.60	277.1	11.65	ND	1.50
	Mean	56.4	5.03	73.8	1.09	13.43	139.0	10.26	ND	2.63
Basin (296 – 303 meters)										
40	303	28.6	4.80	84.7	1.07	4.09	76.9	7.02	ND	2.22
41	303	40.1	4.94	81.2	1.15	3.87	70.5	9.70	ND	2.50
42	303	38.9	5.21	86.8	1.30	4.09	85.0	8.62	ND	2.24
58	300	107.9	6.24	97.8	1.90	10.20	198.9	24.78	ND	6.65
62	300	149.9	6.05	97.0	1.76	12.40	255.6	19.68	ND	8.43
64	300	29.3	5.25	87.5	1.30	4.01	65.7	7.27	ND	ND
C5	296	30.4	6.19	95.9	1.89	33.60	218.2	16.42	ND	ND
	Mean	60.7	5.53	90.1	1.48	10.32	138.7	13.36	ND	3.15
[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’08 AWM Mid-shelf		NA	NA	46.8	1.0	NA	179.0	16.0	NA	13.0
[2] Bight’08 AWM Outer-shelf		NA	NA	60.0	1.5	NA	231.0	56.0	NA	19.0
[2] Bight’08 AWM Upper Slope/Basin		NA	NA	81.3	2.6	NA	234.0	238.0	NA	36.0

AWM = Area Weighted Mean, NS = Not Sampled, NA = Not Applicable, ND = Not Detected. All stations n=1. ** Semi-annual Station

[1] Long et al. 1995

[2] Schiff et al. (2011)

Table 4-2. Concentrations of sediment organic contaminants (µg/kg) at the District's annual stations in Winter 2012 compared to Effects Range–Low (ERL) and Effects Range–Median (ERM) values and regional measurements of sediment physical characteristics.

Orange County Sanitation District, California

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)
Shallow Shelf (40 – 46 meters)										
7	41	NA	3.84	37.2	0.35	0.52	17.60	2.51	0.00	2.36
8	44	NA	3.91	42.7	0.32	4.42	22.70	3.27	0.00	3.28
21	44	NA	3.82	36.7	0.31	1.91	13.10	2.68	1.48	3.53
22	45	NA	3.98	48.4	0.34	4.07	19.80	2.17	1.30	0.70
30	46	NA	3.70	31.8	0.27	0.52	136.10	1.76	0.72	0.33
36	45	NA	4.04	51.2	0.30	1.80	49.60	2.70	0.00	0.95
55	40	NA	2.91	5.9	0.17	1.03	4.60	1.28	0.97	0.00
59	40	NA	3.39	19.6	0.27	2.11	13.30	2.25	0.44	0.65
	Mean	**NA**	**3.70**	**34.2**	**0.29**	**2.05**	**34.60**	**2.33**	**0.61**	**1.48**
Mid-Shelf Within-ZID (56 – 58 meters)										
0**	56	NA	3.39	11.3	0.43	12.00	150.30	1.76	0.00	9.75
4**	56	NA	3.43	15.1	0.29	8.61	32.60	1.11	0.00	1.14
76**	58	NA	3.54	18.0	0.27	2.60	49.70	3.51	0.00	2.21
ZB**	56	NA	3.55	18.8	0.28	8.73	63.30	1.41	0.00	0.74
	Mean	**NA**	**3.48**	**15.8**	**0.32**	**7.99**	**73.98**	**1.95**	**0.00**	**3.46**
Mid-Shelf Non-ZID (52 – 65 meters)										
1**	56	NA	3.62	22.4	0.31	1.77	199.00	2.46	0.00	0.77
3**	60	NA	3.62	20.1	0.25	9.32	21.60	1.92	0.00	5.82
5**	59	NA	3.82	35.7	0.35	3.51	50.70	19.90	0.00	0.35
9**	59	NA	3.42	18.6	0.33	4.47	26.10	9.54	0.00	0.00
10	60	NA	3.99	49.0	0.36	1.55	63.30	2.62	0.00	1.79
12**	58	NA	3.37	17.1	0.28	2.79	35.80	0.96	0.00	0.63
13	59	NA	3.85	39.7	0.36	2.02	36.00	2.17	0.00	1.98
37	56	NA	2.76	14.7	0.27	4.92	42.30	5.29	0.00	0.00
68**	52	NA	3.77	33.0	0.32	2.57	71.80	2.11	0.00	0.57
69**	52	NA	3.71	29.3	0.33	5.27	31.40	3.42	0.00	0.56
70**	52	NA	3.65	26.3	0.35	0.52	20.10	1.85	0.00	1.38
71**	52	NA	3.46	16.9	0.30	1.28	27.30	1.43	0.00	0.49
72**	55	NA	3.70	28.4	0.33	12.40	21.20	17.77	0.00	0.00
73**	55	NA	3.46	12.4	0.42	6.64	188.30	3.07	0.00	4.31
74**	57	NA	3.51	17.8	0.95	8.98	12.90	2.22	0.00	0.21
75**	60	NA	3.47	15.6	0.32	1.68	17.90	2.28	0.00	0.79
77**	60	NA	3.44	17.3	0.32	4.07	13.60	28.88	0.00	0.00
78**	63	NA	3.49	18.1	0.29	6.65	22.90	2.89	0.00	0.34
79**	65	NA	3.65	22.7	0.33	6.11	37.40	26.56	0.00	0.00
80**	65	NA	3.77	33.9	0.37	4.17	12.40	11.30	0.00	0.00
81**	65	NA	3.62	22.3	0.27	4.71	28.00	18.86	0.00	0.00
82**	65	NA	3.54	20.3	0.25	4.04	15.40	10.76	0.00	0.00
84**	54	NA	3.60	20.6	0.38	12.80	244.50	3.18	0.00	27.11
85**	57	NA	3.51	14.6	0.37	15.00	36.40	2.85	0.00	2.77
86**	57	NA	3.62	21.8	0.36	12.90	10.60	2.19	0.00	1.74
87**	60	NA	3.56	20.5	0.35	12.60	156.60	2.42	0.00	0.89
88**	57	NA	3.72	29.2	0.32	17.80	68.50	11.57	0.00	0.98
C **	56	NA	3.52	22.6	0.40	2.14	19.80	4.11	0.00	0.87

Table 4-2 Continues.

Table 4-2 Continued.

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)
Mid-Shelf Non-ZID (52 – 65 meters)										
C2	56	NA	5.65	92.9	1.63	49.10	484.60	10.82	0.00	1.57
CON **	59	NA	3.65	25.2	0.31	4.32	13.90	2.70	0.00	1.33
	Mean	**NA**	**3.65**	**26.0**	**0.39**	**7.54**	**67.68**	**7.27**	**0.00**	**1.91**
Outer Shelf (91–-100 meters)										
17	91	NA	3.66	33.0	0.36	2.11	13.50	2.96	0.00	2.82
18	91	NA	3.76	30.9	0.29	0.52	25.80	1.77	0.00	0.34
20	100	NA	4.24	60.4	0.47	0.52	46.50	3.09	0.00	1.03
23	100	NA	3.31	20.3	0.29	1.42	15.00	0.90	0.00	0.15
29	100	NA	4.41	71.6	0.51	1.33	36.80	7.91	0.83	4.39
33	100	NA	3.03	22.3	0.41	7.09	43.00	3.52	0.56	0.00
38	100	NA	4.18	56.1	0.47	5.43	18.70	5.93	0.00	0.00
56	100	NA	3.88	41.1	0.41	5.52	78.40	11.29	0.00	1.10
60	100	NA	4.12	54.4	0.37	1.74	15.80	3.86	0.00	0.00
83	100	NA	3.83	35.3	0.31	3.05	23.40	11.80	0.00	1.09
	Mean	**NA**	**3.84**	**42.5**	**0.39**	**2.87**	**31.69**	**5.30**	**0.14**	**1.09**
Slope (187 – 241 meters)										
24	200	NA	4.76	86.6	0.87	8.49	40.30	12.52	0.00	4.51
25	200	NA	5.17	92.2	1.14	5.71	37.00	12.05	0.00	1.61
27	200	NA	4.43	66.7	0.66	2.62	50.40	5.77	0.97	2.96
39	200	NA	3.74	35.9	0.46	2.10	13.10	7.68	0.00	0.00
44	241	NA	6.13	94.8	1.91	22.30	62.20	15.23	0.00	0.00
57	200	NA	5.89	92.4	1.69	19.90	51.00	19.65	0.00	0.00
61	200	NA	5.13	87.1	1.12	7.92	107.10	25.72	0.00	0.00
63	200	NA	4.94	87.7	1.04	10.90	149.80	17.00	0.00	2.14
65	200	NA	4.30	58.5	0.66	4.19	19.20	5.58	0.00	0.00
C4	187	NA	5.93	86.3	1.48	31.90	136.60	5.88	0.00	0.00
	Mean	**NA**	**5.18**	**80.5**	**1.13**	**11.11**	**73.95**	**12.03**	**0.09**	**1.02**
Basin (296 – 303 meters)										
40	303	NA	5.03	86.7	1.24	3.76	51.70	12.30	0.00	0.00
41	303	NA	4.83	80.2	1.19	2.94	20.00	19.19	0.00	0.00
42	303	NA	5.56	92.1	1.51	4.65	209.30	26.54	0.00	3.44
58	300	NA	6.29	98.1	1.96	14.20	173.80	28.80	0.00	0.00
62	300	NA	6.29	97.5	1.91	21.20	285.70	22.25	0.00	3.60
64	300	NA	6.13	95.2	1.76	7.01	140.60	17.02	1.68	2.35
C5	296	NA	5.03	86.7	1.24	3.76	51.70	12.30	0.00	0.00
	Mean	**NA**	**5.69**	**91.6**	**1.60**	**8.96**	**146.85**	**21.02**	**0.28**	**1.57**
[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'08 AWM Mid-shelf		NA	NA	46.8	1.0	NA	179.0	16.0	NA	13.0
[2] Bight'08 AWM Outer-shelf		NA	NA	60.0	1.5	NA	231.0	56.0	NA	19.0
[2] Bight'08 AWM Upper Slope/Basin		NA	NA	81.3	2.6	NA	234.0	238.0	NA	36.0

AWM = Area Weighted Mean, NS = Not Sampled, NA = Not Applicable, ND = Not Detected. All stations n=1. ** Semi-annual Station

[1] Long et al. 1995

[2] Schiff et al. (2011)

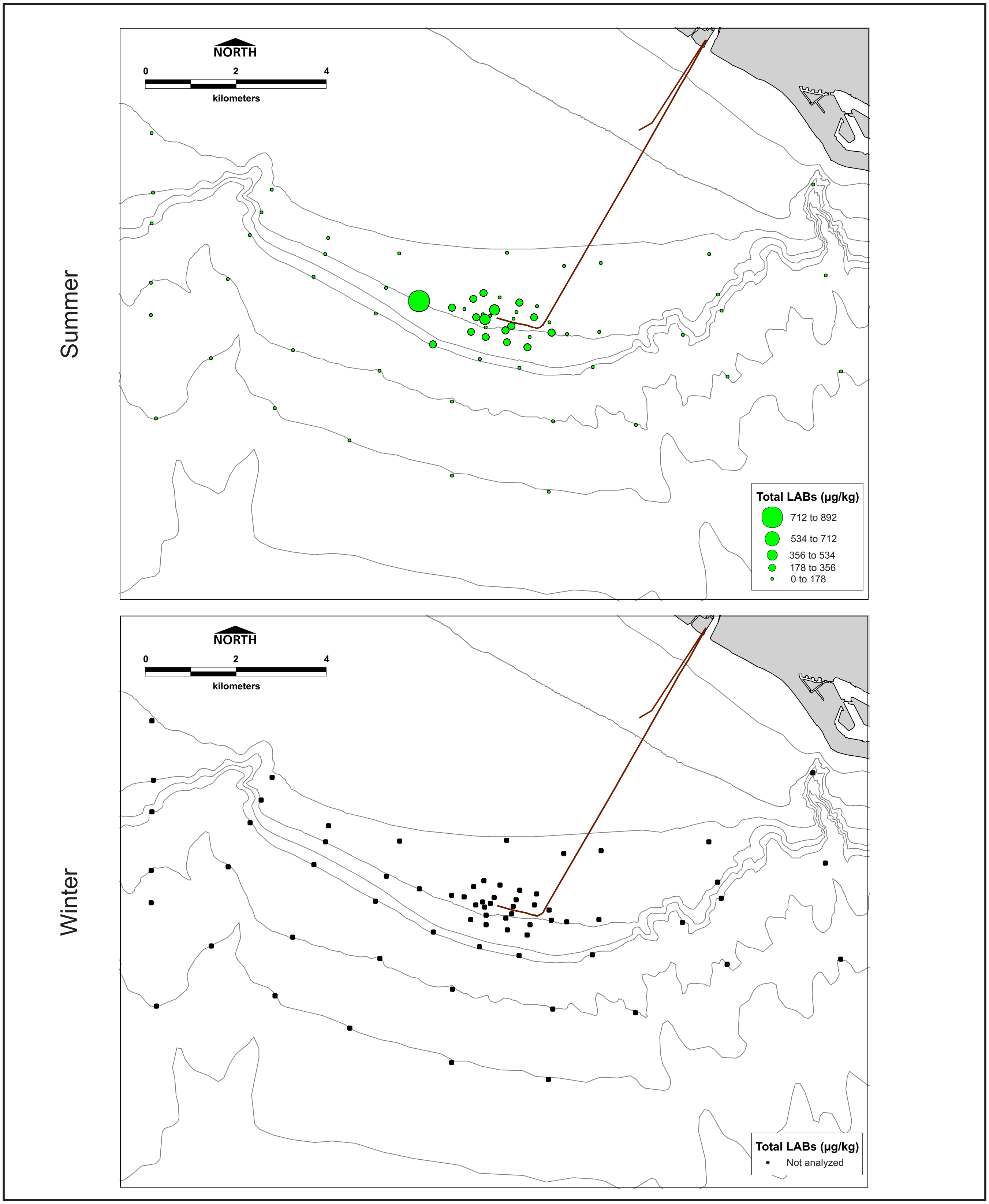


Figure 4-2. **Spatial trend bubble plots of tLABs for summer 2011 (top) and winter 2012 (bottom).**

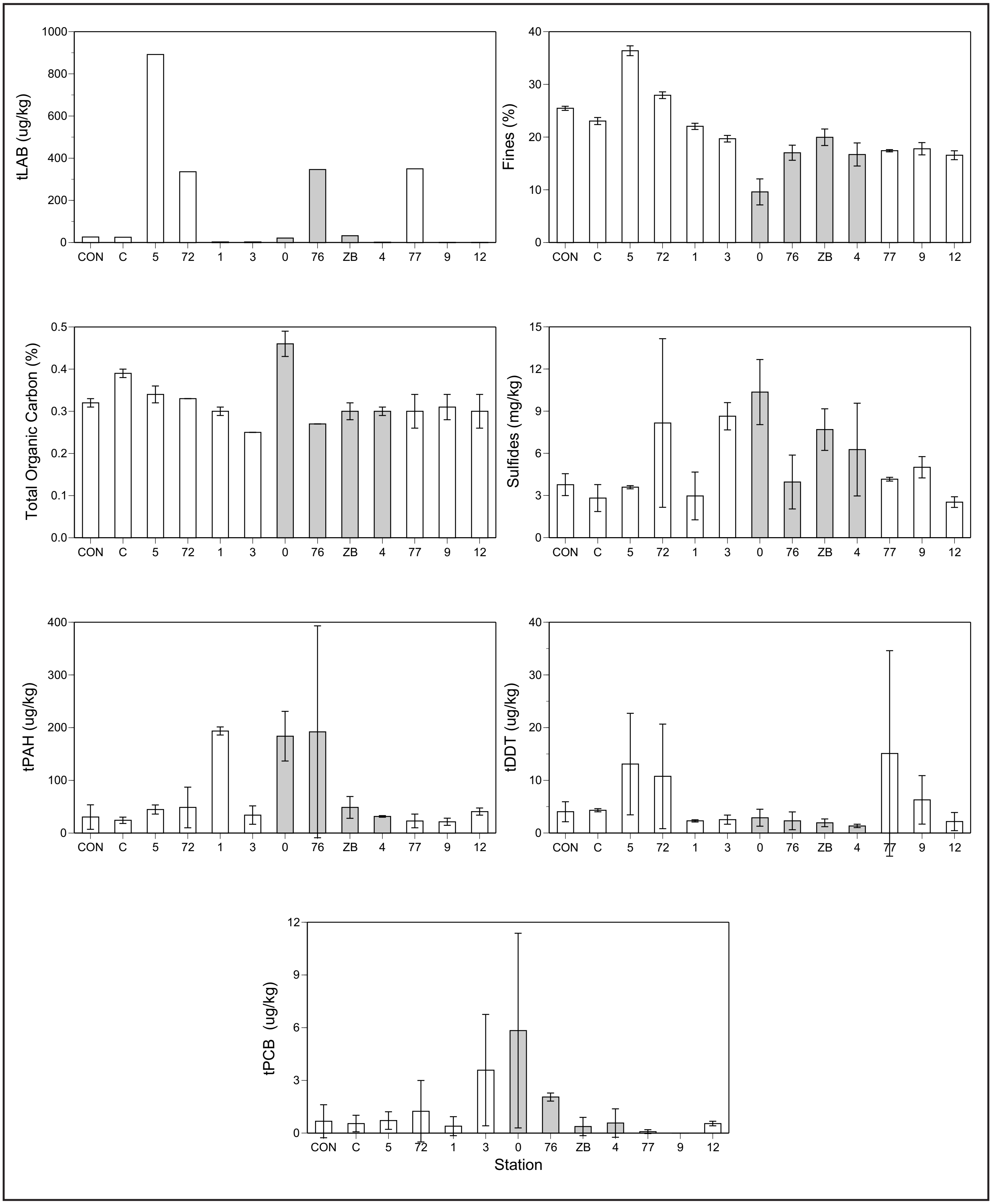


Figure 4-3. **Distribution of mean and standard deviation values for total LAB (ųg/kg), fines (%), total organic carbon (%), dissolved sulfides (mg/kg), total PAH (ųg/kg), total DDT (ųg/kg), and total PCB (ųg/kg) in sediments at the 60 m shelf stations during 2011-12.**
Stations plotted from north to south (left to right). ZID stations indicated in grey.

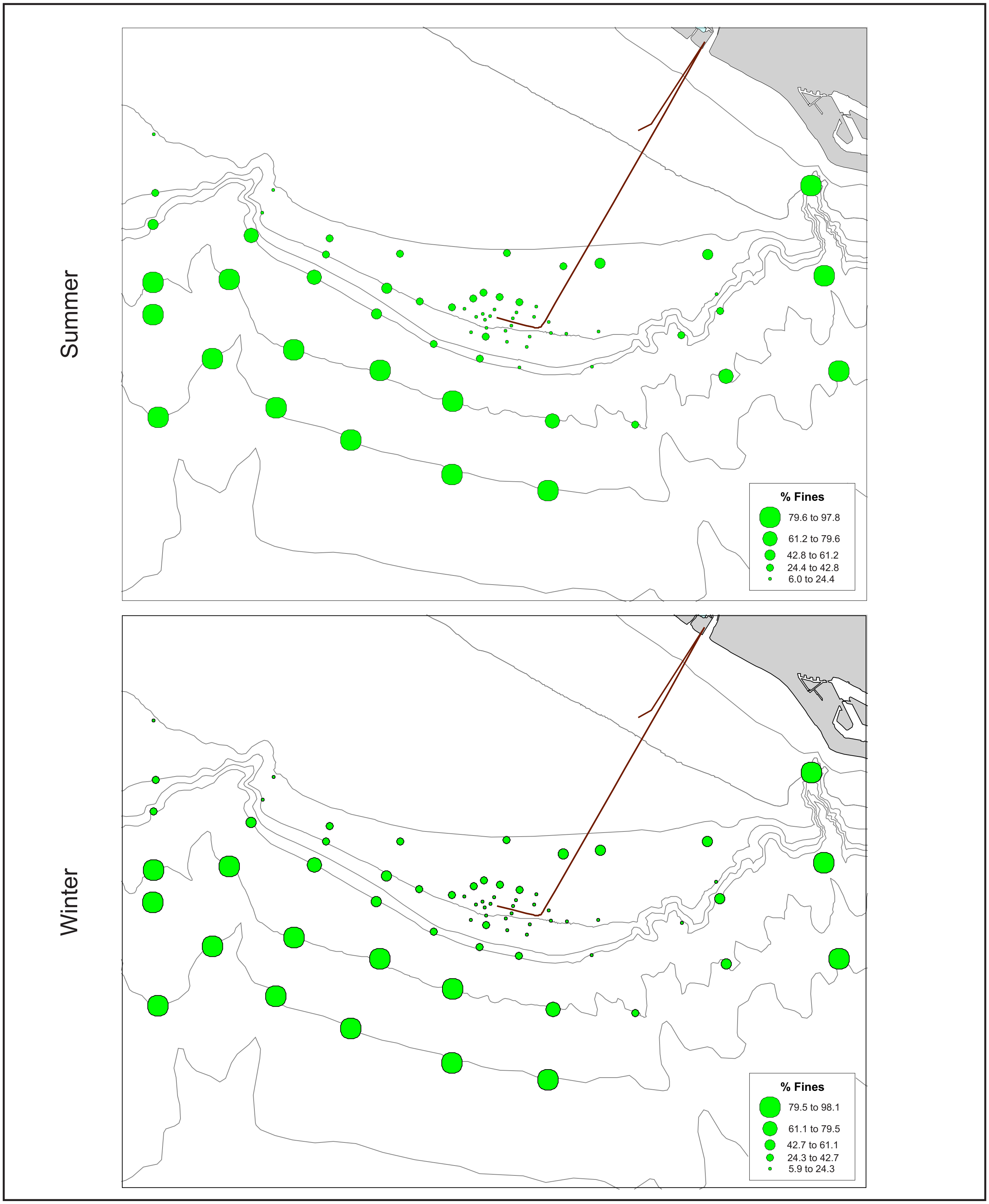


Figure 4-4. **Spatial trend bubble plots of % fines for summer 2011 (top) and winter 2012 (bottom).**

Sediment Organic Content

Total Organic Carbon (TOC)

In July 2011, mean percent TOC generally increased with increasing depth and distance upcoast and ranged from 0.34% at mid-shelf within-ZID stations to 1.48% at basin stations (Table 4-1; Figure 4-5). TOC was not correlated with tLAB, but was strongly correlated with percent fine sediment (R=0.88) indicating that the outfall discharge was not a significant factor in TOC spatial distribution. Values were generally less than half those of the Bight'08 area weighted means for the mid-shelf and outer-shelf strata.

Mean percent sediment TOC was highest at within-ZID stations, while values were comparable at upcoast and downcoast stations (Figure 4-3) indicating no significant outfall influence.

Dissolved Sulfides

In the annual survey, sediment sulfide concentrations remained low ranging from 2.83 mg/kg at shallow-shelf stations to 13.4 mg/kg at slope stations (Table 4-1; Figure 4-6). Mean concentrations at within-ZID stations (6.15 mg/kg) were comparable to mid-shelf non-ZID and outer shelf sites (6.90 and 6.49 mg/kg, respectively). The higher sulfide concentrations in slope, basin, and submarine canyon stations are consistent with these depositional, deep-water environments. Consistent with previous years (OCSD 2010, 2011), correlation analysis showed a weak, but significant relationship of dissolved sulfides to percent fines (R=0.27), but not to tLAB concentrations indicating that the effluent discharge is not a significant influence on the spatial distribution of sulfides.

Mean dissolved sulfide concentrations are extremely variable at the outfall-depth stations (Figure 4-3). The variability can occur between surveys (high standard deviation at stations) and the magnitude of differences between stations. Generally, inter-survey variability and concentrations are higher at within- and near-ZID stations and less so with increased distance from the outfall both upcoast and downcoast. While still low, within-ZID station concentrations were up to three times that of the farfield control station (CON).

Sediment sulfide toxicity thresholds have not been determined for marine benthic organisms due to the lack of a dose-response relationship. However, increased sediment sulfide concentrations often co-occur with lower dissolved oxygen levels, which can negatively impact biota (Lapota *et al*. 2000).

Organic Contaminants

Total Polycyclic Aromatic Hydrocarbons (tPAH)

In July 2011, sediment tPAH concentrations at all stations were low. Mean sediment tPAH concentrations at the annual stations ranged from 25.6 ug/kg at shallow-shelf stations to 153.9 at within-ZID stations (Table 4-1; Figure 4-7). Generally, concentrations increased with increasing depth. tPAH levels were moderately correlated with percent fines (R=0.50), but not with tLABs, though several stations near the ZID (Stations 1, 73, 84, 85, and 87) had tPAH concentrations comparable to the ZID stations suggesting an outfall influence. Concentrations at all shelf stations were comparable to or below the Bight'08 AWM. The higher tPAH levels were seen in slope, basin, and submarine canyon stations, which is consistent with a depositional environment and previous monitoring results. The sediment

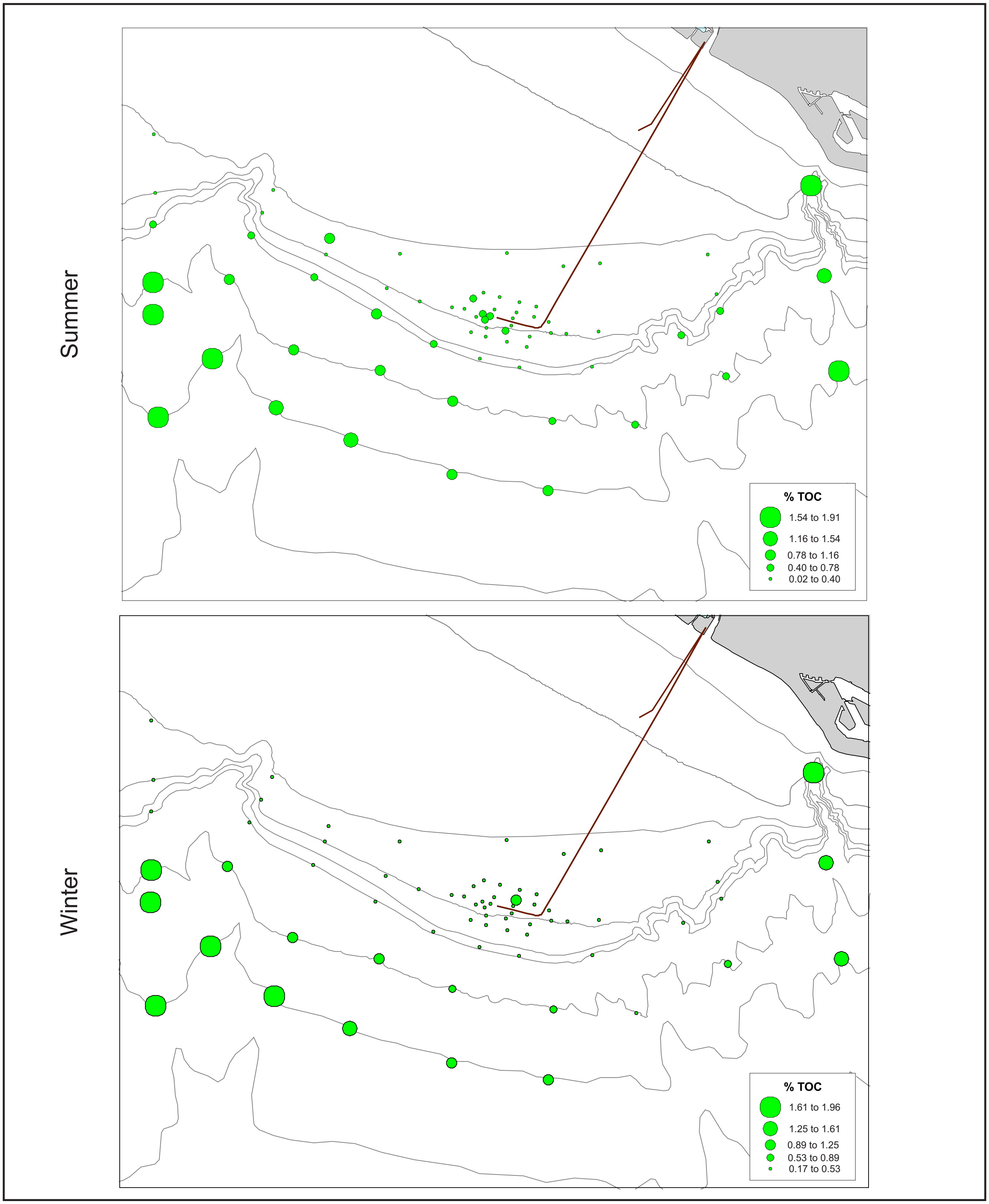


Figure 4-5. **Spatial trend bubble plots of % total organic carbon (TOC) for summer 2011 (top) and winter 2012 (bottom).**

Orange County Sanitation District, California.

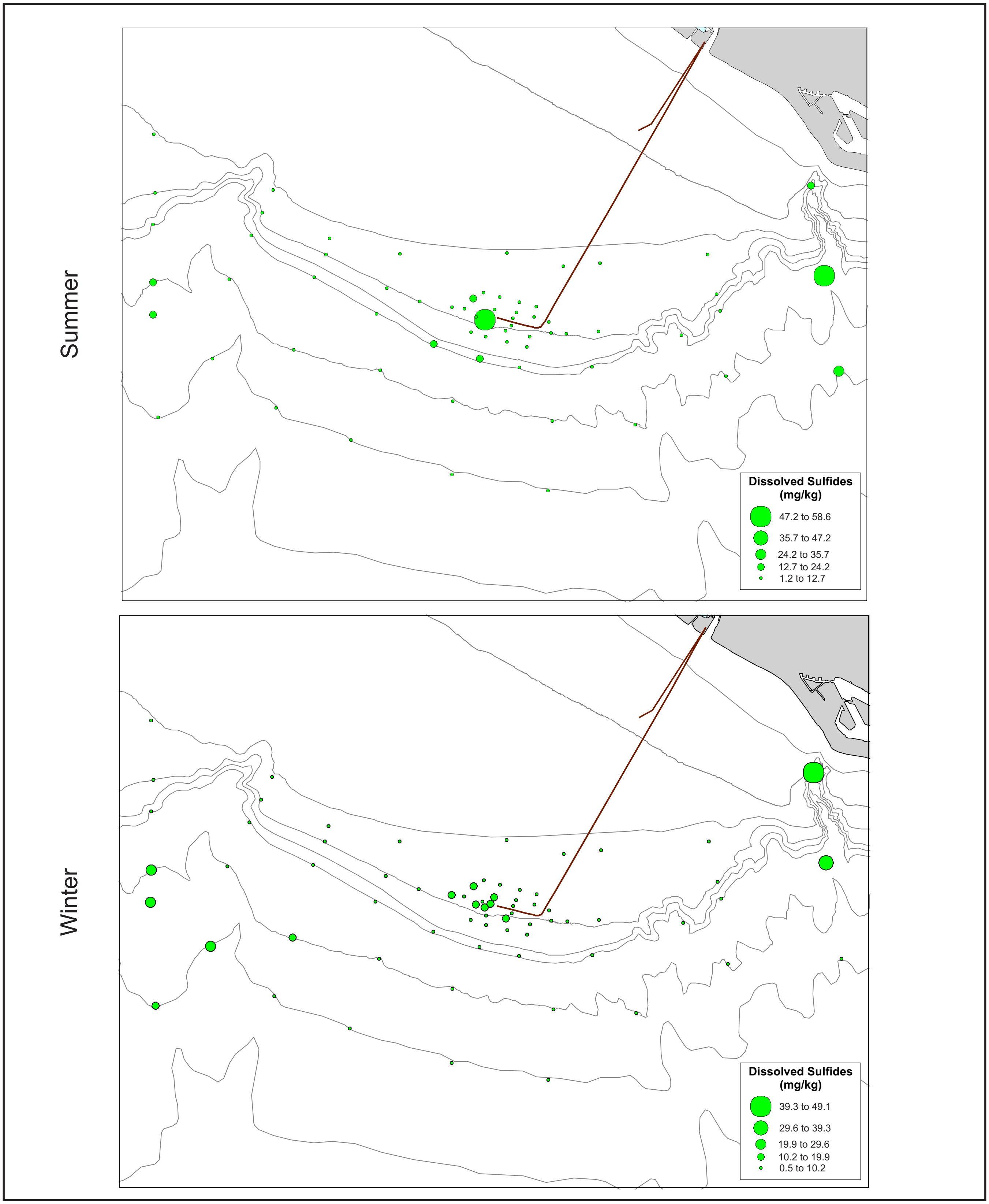


Figure 4-6. **Spatial trend bubble plots of dissolved sulfides for summer 2011 (top) and winter 2012 (bottom).**

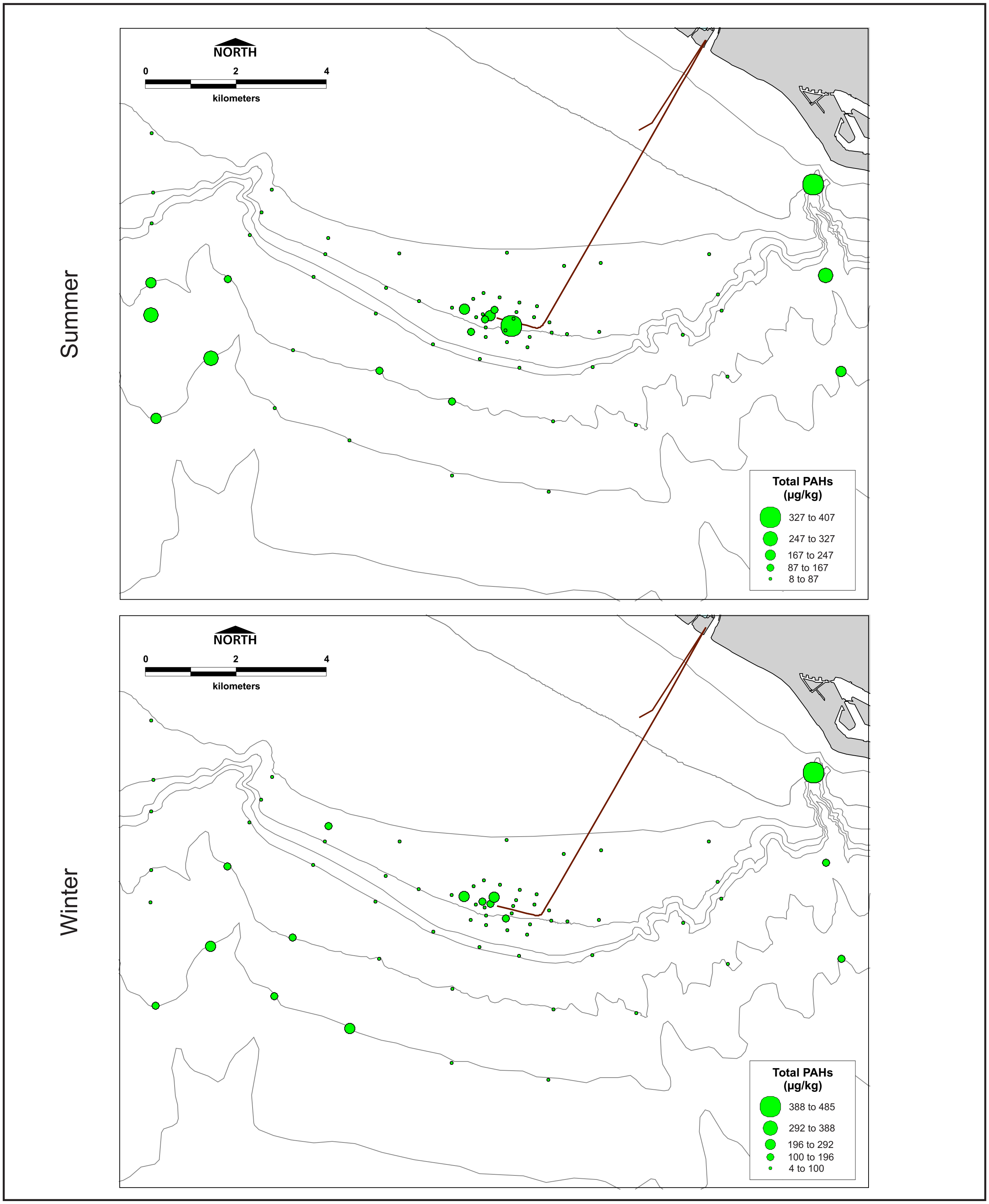


Figure 4-7. Spatial trend bubble plots of tPAHs for summer 2011 (top) and winter 2012 (bottom).

levels at all sites were well below the ERL indicating a very low probability of adverse effects on biota.

Mean sediment tPAH concentrations at non-ZID stations were low (<50 ug/kg) except for Station 1 (~200 ug/kg) which was comparable to within-ZID sites (Figure 4-3). However, these values were comparable or below the Bight'08 mid-shelf AWM of 179 ug/kg and the ERL of 4,022 ug/kg.

Total Chlorinated Pesticides Other than DDT (tPest)
The outfall is not a significant source of chlorinated pesticide compounds. They were not detected at any station in the Summer 2011 survey and at only 9 of 68 stations, none of which were near the outfall, in Winter 2012 (Tables 4-1 and 4-2).

Total dichlorodipheynltrichloroethanes (tDDT)
Mean tDDT concentrations at annual stations ranged from 1.86 ug/kg at shallow shelf to 13.4 at basin stations (Table 4-1). Fifty-five of the 68 stations had tDDT concentrations that exceeded the ERL. Only outer-shelf Station 20 (69.1 ug/kg) exceeded the ERM of 46.1 ug/kg. All other shelf stations were below the Bight'08 AWMs. Generally, sediment tDDT levels increased with increasing depth and into depositional environments (Figure 4-8). tDDT was moderately correlated with percent fine sediment, but not with tLAB indicating no outfall influence. Sediment tDDT concentrations tended to be higher upcoast and offshore in the monitoring area (Figure 4-3). This pattern likely reflects the influence of the high tDDT concentrations in Palos Verdes Shelf sediments and the redistribution of tDDT-laden sediments in the SCB. Historically, tDDT has been found to be highly variable between years and stations (OCSD 2003). The lack of outfall influence is consistent with results from previous years and the legacy contaminant properties of DDT. DDT is found ubiquitously in the Southern California Bight and its occurrence in sediments is due to historical discharges that ceased in the early 1970's.

Unlike previous years, mean sediment tDDT concentrations at outfall-depth stations were higher at non-ZID stations than within the ZID (Figure 4-3). All station means, except within-ZID Station 4 (1.34 ug/kg), exceeded the ERL (1.58 ug/kg), but not the ERM, still indicating a low probability of sediment toxicity. All station means were below the Bight'08 AWM.

Total Polychlorinated Biphenyls (tPCB)
In July 2011, mean tPCB concentrations were low throughout the monitoring area. Concentrations ranged from 0.51 ug/kg at shallow-shelf stations to 3.15 ug/kg at basin stations (Table 4-1). Concentrations generally increased with increasing station depth (Figure 4-9). tPCB levels were weakly correlated with tLAB (R=0.26) and slightly more with percent fine sediment (R=0.36). This is consistent with both the historical discharge of PCBs from the outfall and with effluent particle settling in depositional areas (e.g., slope, basin, and submarine canyons). All stations were below the ERL (22.7 ug/kg) indicating a low possibility of toxicity to marine life.

Mean tPCB concentrations were generally low and well below the ERL. Within-ZID Stations 0 and 76, and nearfield Station 3 had higher concentrations than other outfall-depth stations, but were still low (Figure 4-3) and below the Bight'08 AWM of 13.0 ug/kg.

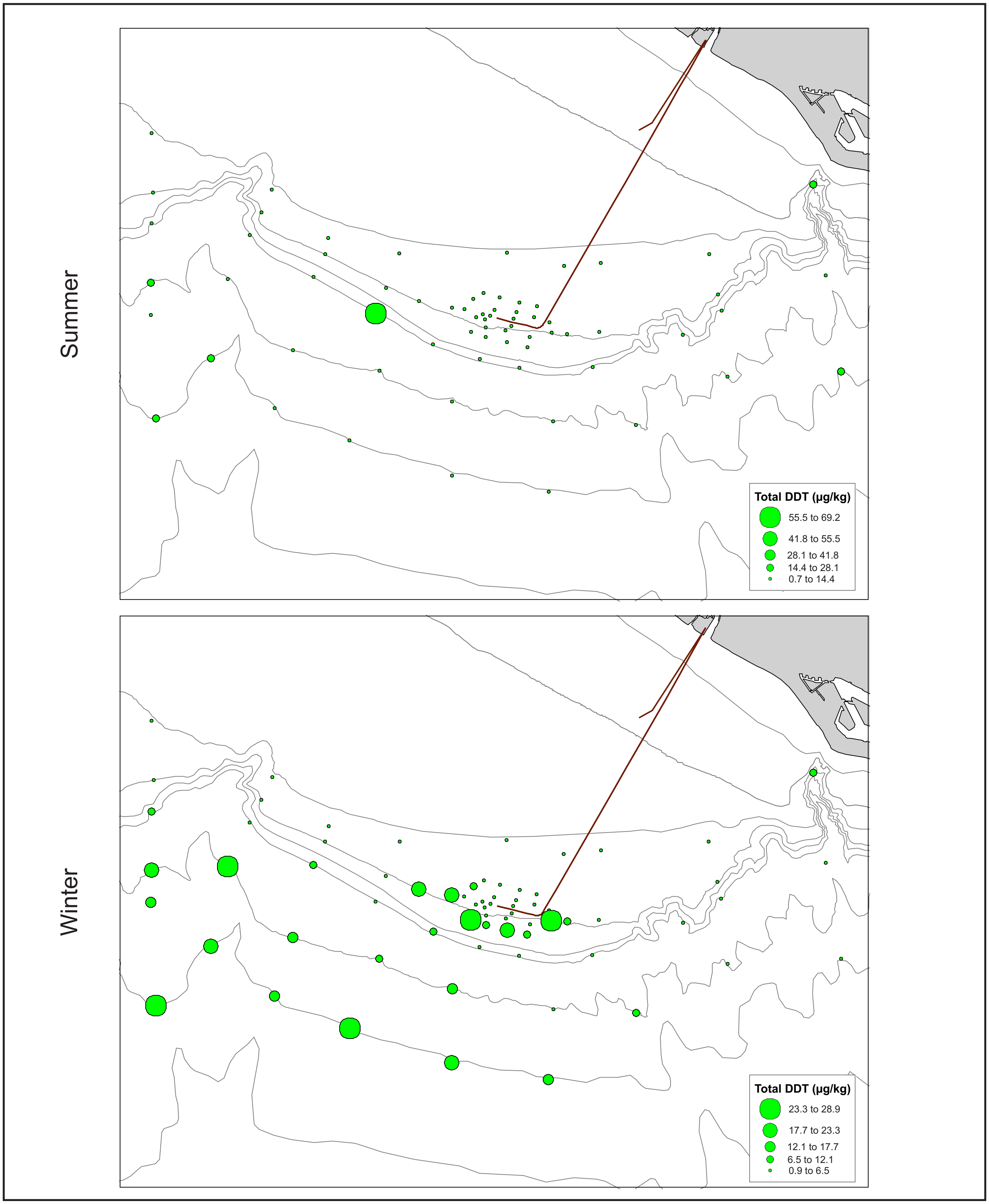


Figure 4-8. **Spatial trend bubble plots of tDDTs for summer 2011 (top) and winter 2012 (bottom).**

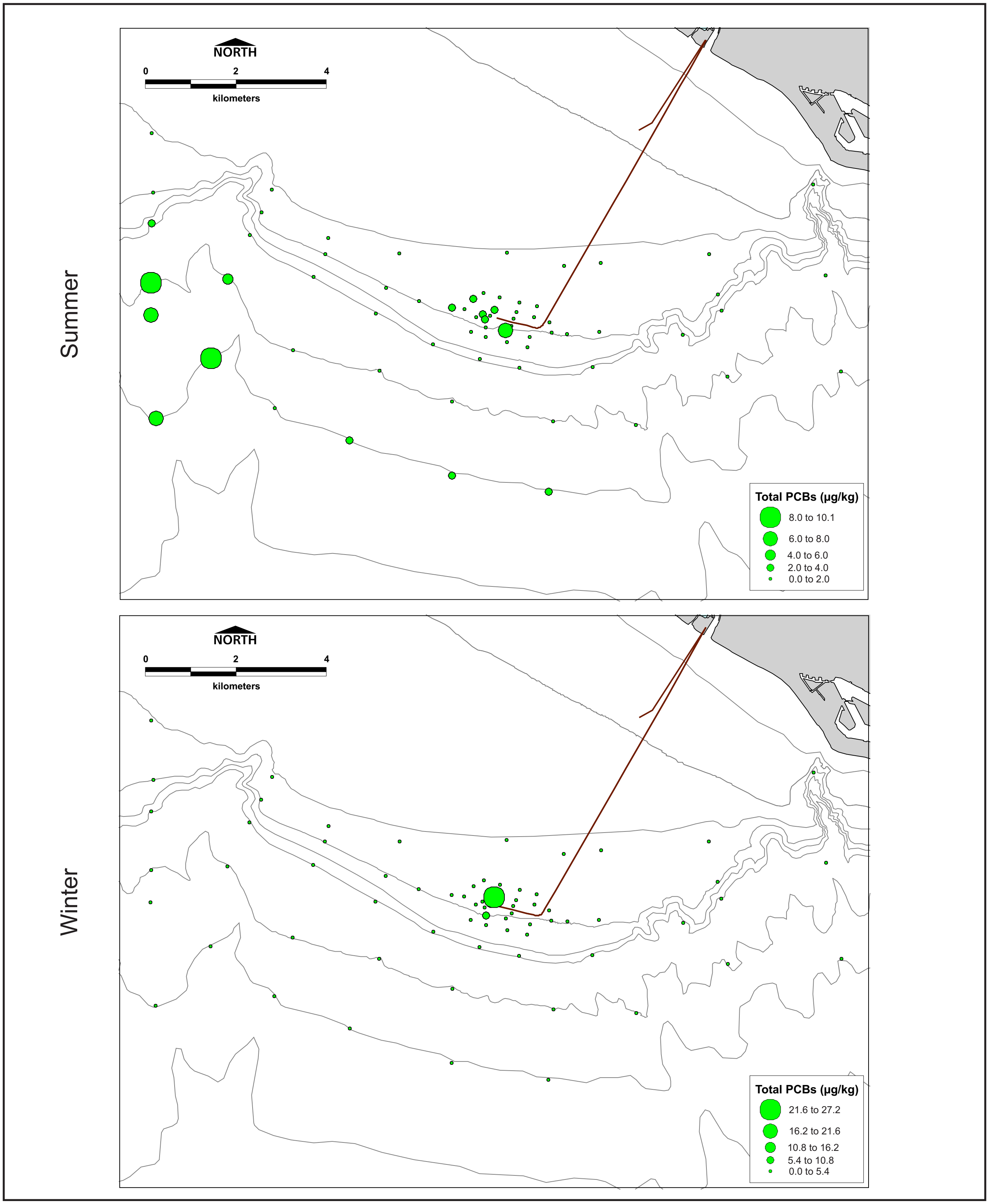


Figure 4-9. **Spatial trend bubble plots of tPCBs for summer 2011 (top) and winter 2012 (bottom).**

Metals

In July 2011, as in previous years, metals were grouped according to two basic sediment concentration patterns: 1) Group A metals show grain size/depth-related patterns with no clear outfall effect and 2) Group B metals are those with some degree of outfall influence (Figure 4-10). Unchanged from last year, Group A metals included arsenic, beryllium, chromium, lead, nickel, and selenium. Group B consisted of cadmium, copper, mercury, silver, and zinc. Unlike previous years, no metals were significantly correlated with tLABs. This may be the result of decreased solids emissions due to increased secondary treatment, lower effluent flows due to GWRS affecting particle settling, or both. All metals except mercury were strongly correlated (R-values ranged from 0.61 to 0.91) with percent fine sediments. The spatial distributions of all metals are presented in Appendix B, Figure B-36.

Of the 748 sediment metal analyses conducted (11 metals x 68 stations) only 13 (<2%) exceeded ERL values and none exceeded ERMs indicating a low possibility of toxicity to biota. Only copper and nickel exceeded their ERLs, predominately at slope and basin stations (Table 4-3). Generally, metal concentrations at the shallow-, mid-, and outer-shelf stations were comparable to or less than the mid- and outer-shelf Bight'08 AWMs except cadmium and zinc, mostly near the outfall, and beryllium on the outer-shelf.

The distribution of metals at selected outfall-depth stations generally followed the Group A and B pattern (Figure 4-11), though that pattern is more evident when the entire 68 station grid is examined. Mean sediment concentrations for most metals at the subset of outfall-depth stations were comparable to or below Bight'08 mid-shelf AWMs and ERL values (Table 4-3). No significant risk to biota from any metal was indicated by the data.

Principal Components Analysis (PCA)

Principal Components Analysis (PCA) and non-metric multidimensional scaling (MDS) were performed using the July 2011 annual station data, including the 29 semiannual stations (n=68 stations) based on two principal components (Figure 4-12). PC1 accounted for 65% of the variability in the data and PC2 for 31% with a cumulative percent variation of approximately 96% (Table 4-5). The MDS analysis showed very low two-dimensional (2d) stress (0.04) and produced similar results to the PCA (Figure 4-13; Table 4-6). This demonstrates that PCA provides a good two-dimensional representation of the multidimensional space.

Eigenvector values show that PC1 is influenced approximately equally by cadmium (-0.683) and copper (-0.677). The negative values indicate that metals concentrations increase going from positive (right) to negative (left) along the PC1 axis in Figure 4-12. PC2 is almost exclusively influenced by the sewage marker tLAB (0.961), which increases moving from negative (bottom) to positive (top) along the PC2 axis.

Cadmium (R=0.67, P<0.001) and copper (0.83, P<0.001) correlate strongly with percent fine sediment, which tend to increase with increasing station depth. The stations at the positive end of PC1 tend to be shallower and have lower concentrations of the metals than at the negative end, which has deeper stations with higher percent fine sediments and higher metals concentrations. The stations towards the top of Figure 4-12 have higher tLAB levels than those towards the bottom. Therefore, the location of stations along PC1 is more influenced by the depositional nature of the sediments, whereas the location of

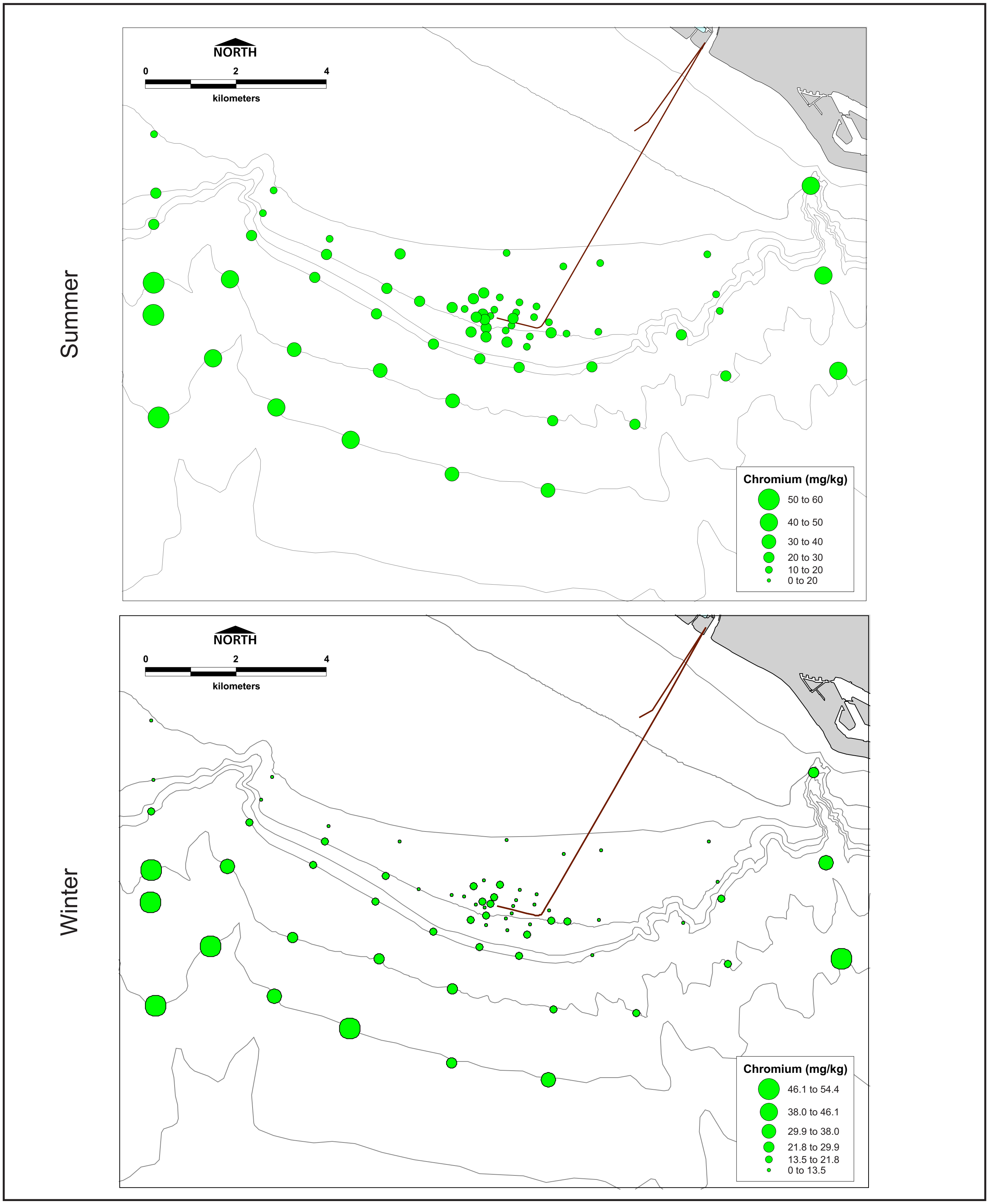


Figure 4-10. **Spatial trend bubble plots of representative Group A metals (chromium) and Group B metals (copper) for summer 2011 (top) and winter 2012 (bottom).**

Orange County Sanitation District, California.

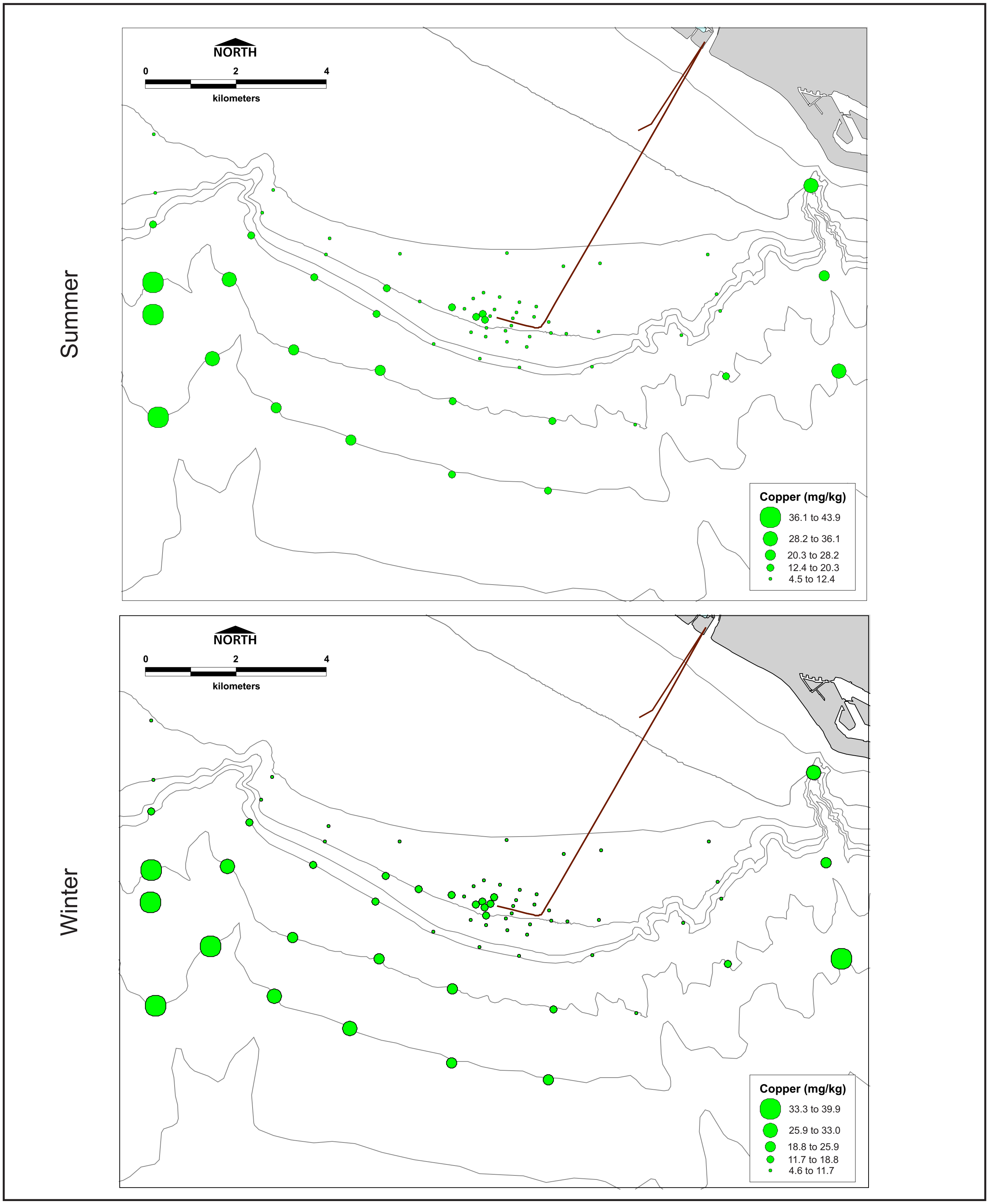


Figure 4-10 continued.

Table 4-3. Concentrations of sediment metals (mg/kg) at the District's annual stations in Summer 2011 compared with Effects Range–Low (ERL) and Effects Range–Median (ERM) values and regional measurements of sediment physical characteristics.

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	3.99	0.24	0.26	19.4	9.40	6.35	0.02	9.13	0.43	0.18	38.0
8	44	3.42	0.25	0.28	18.2	9.37	6.01	0.02	8.98	0.44	0.16	38.3
21	44	3.82	0.26	0.24	20.4	9.97	6.33	0.04	9.35	0.43	0.18	40.6
22	45	3.53	0.28	0.27	18.9	9.42	6.45	0.02	9.65	0.26	0.13	41.6
30	46	3.09	0.25	0.22	19.1	8.64	5.78	0.08	8.58	0.38	0.29	37.0
36	45	3.14	0.27	0.23	15.8	7.47	5.60	0.01	8.73	0.22	0.07	36.3
55	40	2.29	0.17	0.12	13.2	4.59	3.72	0.01	6.56	0.27	0.03	25.7
59	40	2.15	0.21	0.15	14.2	5.74	4.31	0.01	6.90	0.21	0.09	28.2
	Mean	3.18	0.24	0.22	17.4	8.08	5.57	0.03	8.49	0.33	0.14	35.7
Mid-Shelf Within-ZID (56 – 58 meters)												
0 **	56	3.44	0.25	0.66	18.5	11.90	4.41	0.04	7.89	0.32	0.30	49.1
4 **	56	3.66	0.26	0.24	18.7	8.66	4.36	0.01	8.54	0.39	0.13	40.4
76 **	56	2.30	0.28	0.26	18.6	9.11	3.95	0.02	8.86	0.34	0.14	42.7
ZB **	56	3.62	0.28	0.48	21.0	10.60	4.24	0.02	10.00	0.42	0.17	44.1
	Mean	3.26	0.27	0.41	19.2	10.07	4.24	0.02	8.82	0.37	0.18	44.1
Mid-Shelf Non-ZID (52 – 65 meters)												
1**	56	2.60	0.25	0.37	17.8	10.1	5.06	0.02	7.93	0.21	0.21	39.9
3**	60	2.52	0.26	0.32	21.3	11.8	4.86	0.04	9.79	0.44	0.21	47.6
5**	59	3.29	0.27	0.31	22.1	12.2	5.94	0.03	10.6	0.45	0.24	45.9
9**	59	2.69	0.25	0.23	18.7	8.69	4.59	0.02	8.95	0.41	0.13	39.4
10	60	3.00	0.31	0.36	20.9	12.4	6.41	0.02	10.3	0.27	0.25	46.7
12**	58	3.24	0.25	0.20	17.1	7.34	4.47	0.02	8.19	0.37	0.12	35.3
13	59	3.34	0.30	0.29	23.1	11.4	6.25	0.02	10.9	0.44	0.19	47.9
37	56	2.17	0.25	0.21	13.9	6.96	4.51	0.01	8.22	0.21	0.07	36.7
68**	52	3.41	0.27	0.35	20.4	11.1	5.48	0.07	10.1	0.40	0.23	43.0
69**	52	3.10	0.26	0.33	19.4	10.0	5.09	0.05	9.28	0.43	0.21	41.4
70**	52	3.39	0.27	0.35	19.3	10.0	5.15	0.02	9.35	0.36	0.19	42.3
71**	52	2.81	0.24	0.35	17.1	8.47	4.00	0.02	8.56	0.38	0.14	40.6
72**	55	2.98	0.26	0.33	21.1	13.1	5.70	0.03	9.91	0.43	0.28	45.2
73**	55	2.92	0.25	0.65	20.8	12.6	5.30	0.04	9.23	0.41	0.25	47.5
74**	57	2.73	0.26	0.42	18.2	8.60	4.13	0.02	8.60	0.34	0.15	41.5
75**	60	3.15	0.24	0.41	17.2	8.69	3.35	0.02	9.32	0.35	0.11	42.1
77**	60	3.05	0.26	0.28	20.9	9.54	4.64	0.02	9.35	0.38	0.15	42.3
78**	63	2.44	0.30	0.25	18.9	8.57	4.18	0.02	8.95	0.36	0.14	42.0
79**	65	3.02	0.27	0.29	20.8	11.8	5.12	0.03	9.67	0.41	0.22	44.5
80**	65	2.81	0.35	0.42	21.3	11.5	5.18	0.02	11.3	0.41	0.14	49.1
81**	65	2.93	0.30	0.21	20.3	9.03	4.46	0.02	10.3	0.41	0.13	44.3
82**	65	2.26	0.30	0.20	19.7	8.41	4.20	0.01	9.36	0.40	0.13	42.5
84**	54	3.16	0.24	0.59	19.4	10.5	4.39	0.03	8.15	0.41	0.19	44.6
85**	57	2.94	0.25	0.65	21.0	13.2	4.61	0.11	8.64	0.45	0.23	45.6
86**	57	2.74	0.25	0.56	21.1	12.9	5.00	0.04	9.07	0.41	0.26	48.8
87**	60	2.48	0.27	0.28	18.5	9.11	4.01	0.03	8.83	0.38	0.26	42.6
88**	57	3.18	0.25	0.36	20.2	10.6	5.99	0.02	9.13	0.42	0.21	41.7
C **	56	2.81	0.27	0.20	19.2	8.32	5.89	0.01	9.08	0.25	0.11	39.3
C2	56	8.01	0.65	0.91	40.3	30.0	16.9	0.04	**25.0**	1.17	0.23	121.0

Table 4-3 Continues.

Table 4-3 Continued.

Station	Depth (m)	As	Be	Cd	Cr	Cu	Pb	Hg	Ni	Se	Ag	Zn
Mid-Shelf Non-ZID (52 – 65 meters)												
CON **	59	3.53	0.27	0.20	21.4	10.0	5.97	0.02	11.0	0.45	0.20	45.6
	Mean	3.09	0.28	0.36	20.4	10.9	5.37	0.03	10.0	0.41	0.18	46.0
Outer Shelf (91–-100 meters)												
17	91	3.20	0.29	0.20	20.6	9.07	5.14	0.01	10.7	0.46	0.10	43.9
18	91	3.30	0.31	0.21	20.9	9.48	5.06	0.01	11.4	0.46	0.11	46.3
20	100	3.40	0.32	0.31	25.1	14.0	6.60	0.02	12.8	0.47	0.23	51.9
23	100	3.42	0.28	0.21	20.3	8.27	4.93	0.02	10.8	0.38	0.09	44.2
29	100	3.31	0.31	0.34	26.2	14.8	7.31	0.03	13.2	0.53	0.27	52.9
33	100	3.82	0.31	0.36	20.9	9.64	5.61	0.02	11.5	0.49	0.12	46.8
38	100	3.67	0.29	0.37	19.6	10.2	5.47	0.02	11.8	0.60	0.10	46.1
56	100	3.18	0.33	0.37	27.0	14.7	7.36	0.03	13.9	0.63	0.25	55.2
60	100	3.32	0.31	0.36	27.7	15.2	7.24	0.03	14.1	0.53	0.25	53.2
83	100	3.08	0.32	0.22	21.8	10.2	5.68	0.02	11.6	0.43	0.14	48.6
	Mean	3.37	0.31	0.29	23.0	11.6	6.04	0.02	12.2	0.50	0.17	48.9
Slope (187 – 241 meters)												
24	200	3.41	0.42	0.49	30.0	17.3	8.37	0.02	16.4	0.75	0.23	60.5
25	200	3.70	0.44	0.59	37.0	22.5	10.40	0.03	19.9	0.92	0.36	71.0
27	200	3.41	0.37	0.41	28.7	14.3	7.03	0.02	15.4	0.74	0.16	57.4
39	200	3.71	0.34	0.31	23.4	10.4	5.52	0.02	12.7	0.57	0.10	49.1
44	241	6.67	0.56	1.01	57.9	43.9	18.10	0.06	27.7	1.47	0.88	103.0
57	200	5.80	0.54	0.87	50.0	39.2	16.70	0.06	25.0	1.21	0.81	92.1
61	200	4.48	0.44	0.75	46.8	30.2	12.00	0.05	21.5	1.04	0.59	82.0
63	200	4.55	0.44	0.59	38.1	21.4	9.29	0.04	19.2	0.91	0.34	68.2
65	200	4.50	0.38	0.60	27.1	15.9	7.37	0.02	17.0	0.81	0.42	62.3
C4	187	7.51	0.56	0.79	41.3	26.4	13.30	0.04	23.0	1.17	0.26	95.4
	Mean	4.77	0.45	0.64	38.0	24.2	10.81	0.04	19.8	0.96	0.41	74.1
Basin (296 – 303 meters)												
40	303	3.68	0.47	0.50	31.2	17.9	8.89	0.01	16.8	0.80	0.19	63.6
41	303	4.16	0.45	0.52	39.6	19.7	8.22	0.02	19.5	1.02	0.21	69.7
42	303	4.43	0.46	0.59	42.7	23.3	9.82	0.02	21.6	1.16	0.28	77.6
58	300	7.16	0.59	0.83	57.6	37.7	17.7	0.04	28.9	1.45	0.62	100.0
62	300	6.20	0.56	0.87	49.8	32.9	14.4	0.04	24.8	1.56	0.54	93.3
64	300	4.87	0.50	0.56	43.4	24.0	9.70	0.02	21.9	1.19	0.24	74.2
C5	296	6.24	0.67	0.88	42.8	28.6	14.3	0.02	23.5	1.28	0.38	91.5
	Mean	5.25	0.53	0.68	43.9	26.3	11.9	0.03	22.4	1.21	0.35	81.4
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'08 AWM Mid-shelf		6.1	0.3	0.32	31.0	10.7	7.8	0.05	12.0	0.72	0.24	46.0
[2] Bight'08 AWM Outer-shelf		6.1	0.19	0.47	36.0	12.3	9.1	0.05	17.0	0.54	0.25	52.0
[2] Bight'08 AWM Upper Slope/Basin		8.8	0.29	1.4	68.0	22.8	15.0	0.09	29.0	1.60	1.60	79.0

NA = Not applicable. All stations n=1. ****** Quarterly Stations

[1] Long et al. (1995)

[2] Schiff et al. (2006)

Table 4-4. Concentrations of sediment metals (mg/kg) at the District's annual stations in Winter 2012 compared with Effects Range–Low (ERL) and Effects Range–Median (ERM) values and regional measurements of sediment physical characteristics.

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	3.41	0.25	0.25	20.6	9.60	6.07	0.023	9.4	0.42	1.36	37.7
8	44	4.02	0.26	0.27	21.3	10.00	6.26	0.037	10.2	0.42	0.26	42.0
21	44	4.10	0.26	0.21	21.7	9.30	6.08	0.019	9.1	0.38	0.28	39.6
22	45	3.40	0.26	0.27	20.7	10.30	6.25	0.018	10.3	0.35	0.15	42.2
30	46	3.43	0.22	0.21	18.3	8.43	5.68	0.024	7.9	0.35	1.21	35.2
36	45	3.94	0.26	0.26	18.9	9.13	6.40	0.023	9.9	0.43	0.19	41.9
55	40	2.51	0.16	0.11	13.7	4.67	3.50	0.019	6.7	0.27	0.27	25.9
59	40	2.84	0.19	0.16	16.1	6.28	4.53	0.024	7.6	0.35	0.34	29.6
	Mean	**3.46**	**0.23**	**0.22**	**18.9**	**8.46**	**5.60**	**0.023**	**8.9**	**0.37**	**0.51**	**36.8**
Mid-Shelf Within-ZID (56 – 58 meters)												
0 **	56	3.91	0.25	0.86	23.4	14.70	5.45	0.060	9.2	0.39	0.27	49.2
4 **	56	3.54	0.26	0.24	17.9	8.34	4.30	0.027	8.3	0.33	0.14	39.5
76 **	56	2.71	0.26	0.25	21.5	10.10	4.15	0.014	9.7	0.35	0.25	43.4
ZB **	56	2.65	0.25	0.42	18.4	8.94	3.51	0.052	8.9	0.33	0.17	44.4
	Mean	**3.20**	**0.25**	**0.44**	**20.3**	**10.52**	**4.35**	**0.038**	**9.0**	**0.35**	**0.21**	**44.1**
Mid-Shelf Non-ZID (52 – 65 meters)												
1**	56	3.61	0.25	0.32	19.8	11.60	5.92	0.020	8.8	0.40	0.24	44.5
3**	60	3.12	0.29	0.32	22.4	11.90	4.76	0.023	9.8	0.35	0.42	45.9
5**	59	3.44	0.29	0.30	21.3	12.10	5.75	0.023	10.4	0.38	0.37	45.5
9**	59	2.95	0.27	0.23	22.5	9.31	4.66	0.015	9.7	0.41	0.21	42.0
10	60	3.09	0.28	0.31	22.2	12.10	6.20	0.022	11.2	0.35	0.24	45.4
12**	58	3.06	0.25	0.20	18.1	7.69	4.61	0.011	8.6	0.31	0.13	36.6
13	59	3.51	0.28	0.26	22.3	11.30	6.09	0.017	10.7	0.34	0.20	45.4
37	56	2.94	0.22	0.29	14.0	6.06	4.09	0.017	7.5	0.30	0.15	31.3
68**	52	3.34	0.25	0.34	20.4	11.30	5.41	0.033	9.4	0.39	1.28	41.7
69**	52	3.46	0.27	0.34	23.1	11.50	5.43	0.029	10.3	0.37	0.33	44.7
70**	52	3.37	0.25	0.34	18.9	9.86	5.06	0.022	9.4	0.34	0.20	41.5
71**	52	3.49	0.27	0.35	17.8	8.37	4.23	0.022	8.4	0.37	0.18	40.7
72**	55	3.29	0.27	0.31	20.6	12.00	5.52	0.030	9.4	0.42	0.36	44.6
73**	55	3.02	0.26	0.80	23.9	15.00	5.84	0.034	9.2	0.39	0.44	51.0
74**	57	3.27	0.24	0.39	18.5	8.96	4.82	0.018	8.8	0.32	0.16	43.6
75**	60	3.60	0.26	0.45	21.6	10.40	4.69	0.019	9.6	0.41	0.59	46.1
77**	60	2.73	0.27	0.23	22.2	9.44	4.48	0.016	9.3	0.35	0.36	42.0
78**	63	2.48	0.26	0.22	18.9	8.96	4.45	0.013	8.8	0.31	0.16	40.2
79**	65	2.59	0.28	0.27	22.0	11.60	5.13	0.020	10.3	0.41	0.25	45.1
80**	65	3.84	0.33	0.20	21.3	11.00	5.22	0.013	11.2	0.36	0.18	49.1
81**	65	3.37	0.28	0.20	17.7	8.02	4.01	0.013	8.7	0.33	0.14	37.6
82**	65	2.79	0.27	0.17	21.9	8.83	3.99	0.012	9.9	0.35	0.22	42.0
84**	54	3.64	0.27	0.59	25.0	14.90	6.75	0.027	9.9	0.43	0.41	50.8
85**	57	3.25	0.24	0.55	20.5	11.80	5.06	0.028	9.0	0.38	0.29	44.0
86**	57	3.27	0.27	0.50	21.4	13.10	5.43	0.056	10.1	0.40	0.42	46.2
87**	60	2.46	0.28	0.26	20.4	9.83	4.19	0.018	9.6	0.35	0.22	44.6
88**	57	3.59	0.26	0.30	22.0	11.20	5.90	0.047	9.7	0.38	0.38	45.4
C **	56	3.04	0.26	0.26	21.4	9.43	5.82	0.028	10.0	0.38	3.54	42.7
C2	56	7.70	0.62	0.87	36.3	29.70	15.10	0.047	24.9	0.97	0.94	123.0

Table 4-4 Continues.

Table 4-4 Continued.

Station	Depth (m)	As	Be	Cd	Cr	Cu	Pb	Hg	Ni	Se	Ag	Zn
Mid-Shelf Non-ZID (52 – 65 meters)												
CON **	59	2.84	0.27	0.21	21.4	9.60	6.23	0.018	10.2	0.39	0.81	43.7
	Mean	**3.34**	**0.28**	**0.35**	**21.3**	**11.23**	**5.49**	**0.024**	**10.1**	**0.39**	**0.46**	**46.2**
Outer Shelf (91–-100 meters)												
17	91	3.39	0.36	0.20	22.6	11.40	5.96	0.014	11.8	0.42	0.15	49.4
18	91	2.88	0.32	0.21	23.2	11.10	5.53	0.015	12.3	0.42	0.14	49.9
20	100	3.30	0.30	0.29	24.8	14.30	6.46	0.026	12.9	0.39	0.42	51.6
23	100	3.28	0.30	0.21	16.6	7.49	4.28	0.009	9.5	0.38	0.15	42.5
29	100	3.49	0.31	0.32	25.6	14.10	6.78	0.037	12.9	0.41	0.24	51.9
33	100	3.01	0.25	0.27	18.2	7.86	4.31	0.013	10.2	0.38	0.16	41.1
38	100	3.79	0.31	0.40	23.8	10.30	6.16	0.018	11.9	0.45	0.27	46.4
56	100	3.21	0.31	0.37	24.1	12.10	6.47	0.020	12.0	0.48	0.20	49.4
60	100	3.47	0.33	0.34	24.1	13.20	6.58	0.020	12.1	0.54	0.24	51.0
83	100	3.31	0.28	0.22	22.6	10.60	5.41	0.014	11.9	0.43	0.21	47.4
	Mean	**3.31**	**0.31**	**0.28**	**22.6**	**11.25**	**5.79**	**0.019**	**11.7**	**0.43**	**0.22**	**48.1**
Slope (187 – 241 meters)												
24	200	3.41	0.42	0.52	32.4	19.50	8.64	0.028	17.9	0.66	0.41	64.5
25	200	3.87	0.42	0.63	37.8	23.30	10.40	0.033	19.2	0.81	1.00	72.2
27	200	3.14	0.34	0.42	28.5	15.00	6.76	0.021	16.4	0.60	0.19	57.9
39	200	3.70	0.36	0.30	22.2	10.70	5.25	0.014	12.3	0.54	0.13	51.2
44	241	6.32	0.62	0.99	51.1	38.00	14.90	0.040	24.9	1.40	0.72	98.8
57	200	5.94	0.59	0.96	49.8	38.80	15.60	0.048	22.9	1.17	0.88	94.8
61	200	4.25	0.43	0.69	41.8	26.90	10.40	0.039	21.0	0.89	0.44	74.4
63	200	3.73	0.39	0.60	35.9	22.80	9.90	0.032	19.2	0.71	0.37	69.1
65	200	3.98	0.41	0.45	26.2	14.30	6.71	0.021	15.1	0.66	0.18	60.0
C4	187	7.45	0.60	0.82	38.3	25.40	11.30	0.035	22.1	1.06	0.28	90.4
	Mean	**4.76**	**0.47**	**0.67**	**37.4**	**24.45**	**10.37**	**0.032**	**19.9**	**0.89**	**0.48**	**76.3**
Basin (296 – 303 meters)												
40	303	3.81	0.44	0.55	38.9	21.20	9.36	0.018	20.6	1.01	0.23	70.2
41	303	3.85	0.44	0.52	37.2	19.90	8.46	0.016	19.8	0.96	0.33	65.9
42	303	4.94	0.65	0.65	47.9	28.30	11.30	0.021	24.3	1.25	0.37	82.7
58	300	6.01	0.56	0.79	54.4	37.90	15.50	0.033	28.9	1.48	0.57	96.1
62	300	6.83	0.56	1.03	52.1	39.90	15.70	0.043	26.8	1.27	0.76	97.3
64	300	6.91	0.51	0.86	44.0	32.00	12.30	0.034	26.7	1.36	0.49	87.0
C5	296	3.81	0.44	0.55	38.9	21.20	9.36	0.018	20.6	1.01	0.23	70.2
	Mean	**5.39**	**0.53**	**0.73**	**45.8**	**29.87**	**12.10**	**0.028**	**24.5**	**1.22**	**0.46**	**83.2**
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'08 AWM Mid-shelf		6.1	0.3	0.32	31.0	10.7	7.8	0.05	12.0	0.72	0.24	46.0
[2] Bight'08 AWM Outer-shelf		6.1	0.19	0.47	36.0	12.3	9.1	0.05	17.0	0.54	0.25	52.0
[2] Bight'08 AWM Upper Slope/Basin		8.8	0.29	1.4	68.0	22.8	15.0	0.09	29.0	1.60	1.60	79.0

NA = Not applicable. All stations n=1. ****** Quarterly Stations

[1] Long et al. (1995)

[2] Schiff et al. (2006)

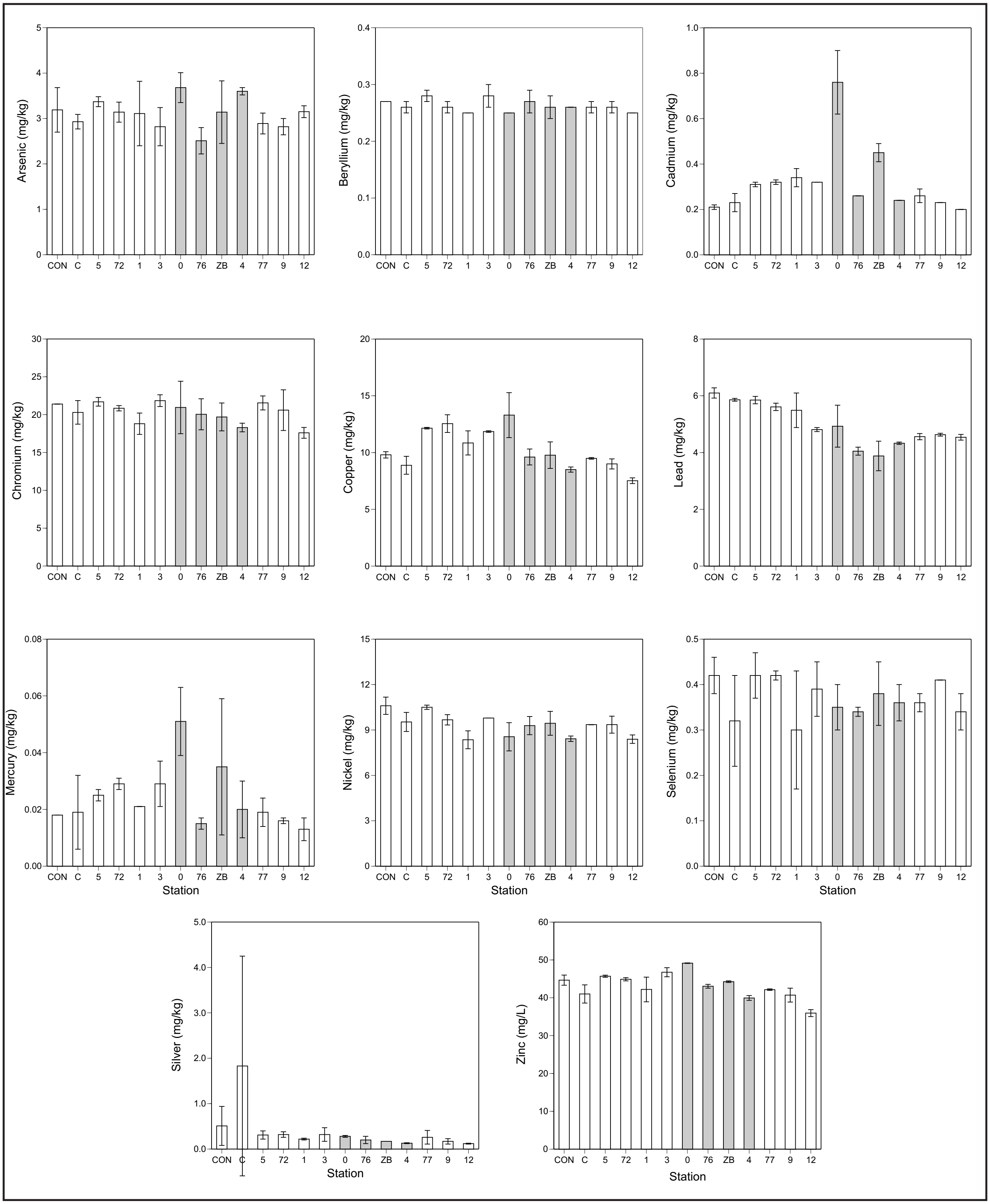


Figure 4-11. Distribution of mean and standard deviation values (mg/kg) for arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, and zinc in sediments at the 60 m shelf stations during 2011-12.

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

Orange County Sanitation District, California.

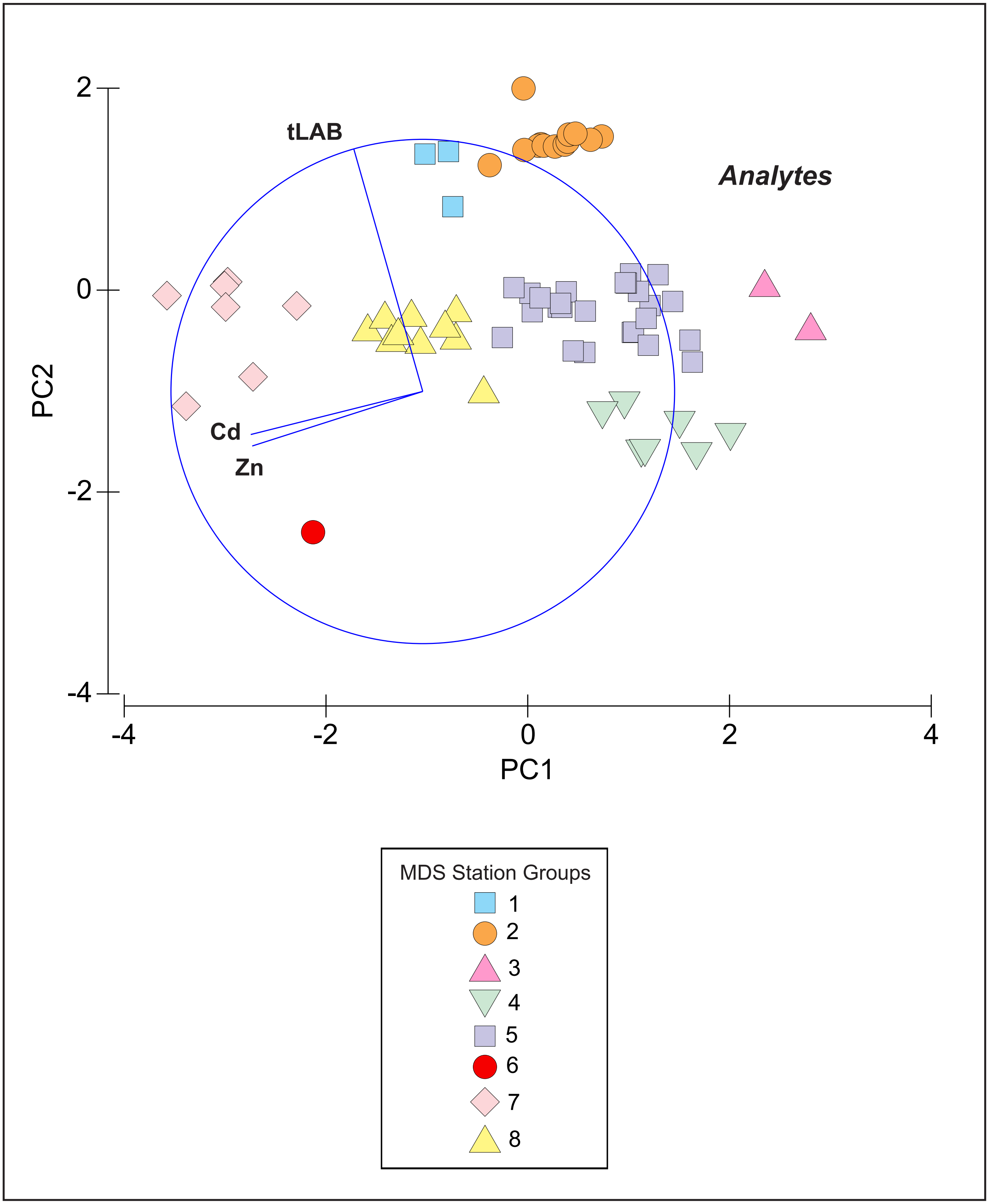


Figure 4-12. **Station plot of principal components analysis (PCA) for July 2011. Station symbols correspond to PCA station groupings (group numbers).**

Table 4-5. Eigen values and Eigen vectors from the principal components analysis performed on the July 2011 annual survey data.

Orange County Sanitation District, California.

Eigen Values			
Principal Component	**Eigen Value**	**Percent Variation**	**Cumulative Percent Variation**
1	1.94	64.8	64.8
2	0.92	30.8	95.6
Eigen Vectors			
Factor	**Principal Component 1**	**Principal Component 2**	
tLAB	-0.274	0.961	
Cadmium	-0.683	-0.171	
Zinc	-0.677	-0.216	

Table 4-6. Station groups identified by non-metric multidimensional Scaling (MDS) of cadmium, zinc, and total linear alkylbenzenes (tLAB) data from July 2011 (n=68).

Orange County Sanitation District, CA

Station Group	Stations	Station Location Relative to Outfall Diffuser
1	84, 85, 86	Near outfall terminus, upcoast
2	5, 68, 70, 72, 75, 76, 77, 79, 80, 81, 82, 83, 87, 88	Within-ZID (Sta. 76) to within 2 km upcoast of outfall diffuser
3	55, 59	Farfield upcoast and inshore
4	1, 3, 4, 9, 12, 69, 71	Nearfield up- and downcoast of outfall diffuser
5	7, 8, 10, 13, 17, 18, 20, 21, 22, 23, 27, 29, 30, 33, 36, 37, 38, 39, 56, 60, 74, 78, C, CON, ZB	Mid-shelf area, non-ZID
6	C4	Newport Canyon
7	44, 57, 58, 61, 62, C2, C5	San Gabriel and Newport Canyons
8	0, 24, 25, 40, 41, 42, 63, 64, 65, 73	Within-ZID (Sta. 0), slope and basin

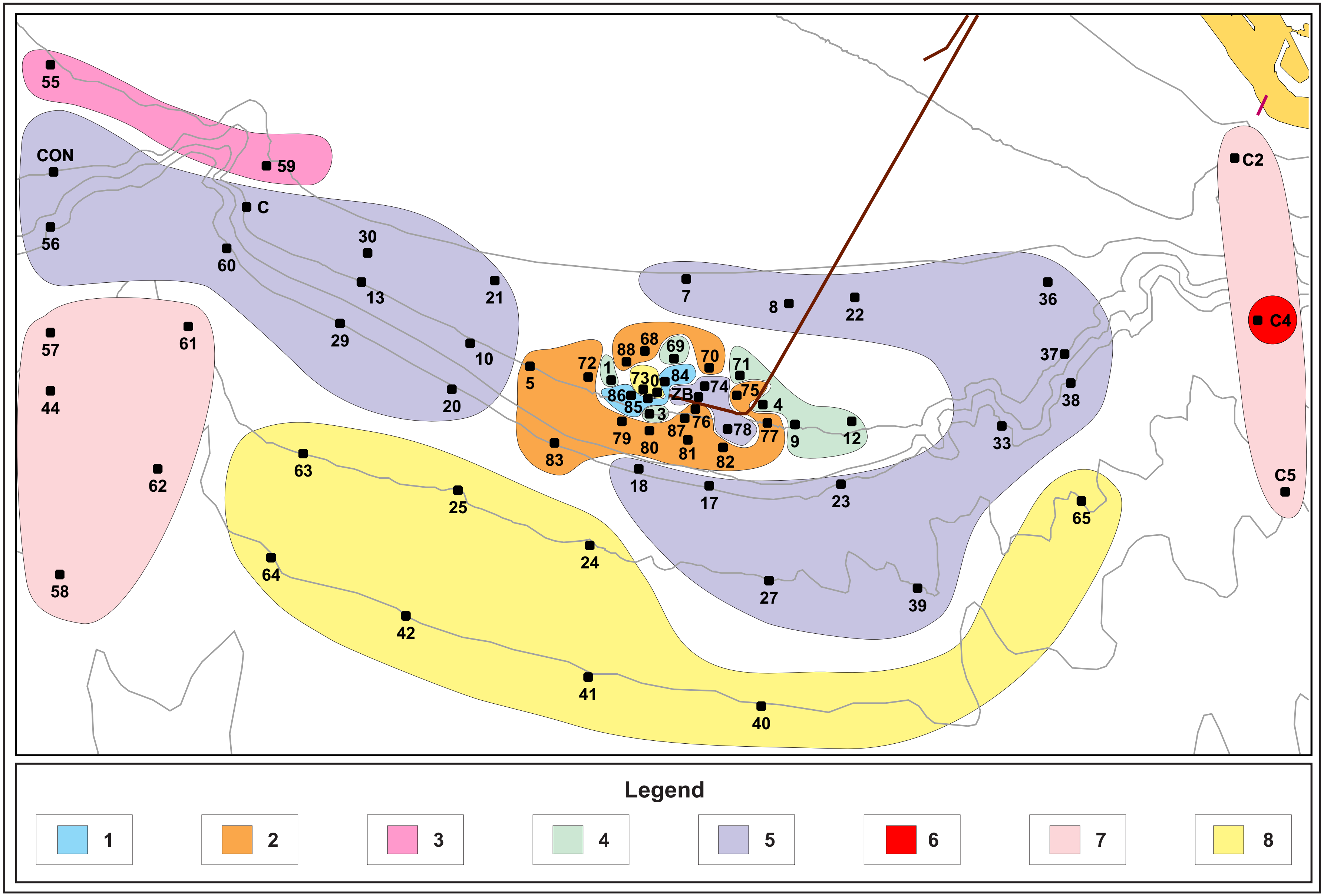


Figure 4-13. **Map of station groups from principal components analysis for July 2011.**

Orange County Sanitation District, California.

stations along PC2 is more strongly influenced by the outfall discharge. This indicates that the wastewater influence is predominantly upcoast and offshore of the outfall diffuser.

Long-term (Temporal) Trend Analysis

Most patterns at selected 60 m depth semiannual stations for all sediment measures showed no noteworthy differences from historical station variability (OCSD 2011) and are at concentrations that are not of biological concern (i.e., below ERL values) in non-ZID station groups. An exception is the legacy contaminant tDDT (Figure 4-14). In addition, arsenic at Station 4, mercury at Station 3 (previously unreported), and silver at Station CON all exceeded their historic ranges in 2011-12, though concentrations were still low.

Most measures showed either no significant change or a decrease over time at most 60 m stations. These include percent fines, dissolved sulfide, tDDT, tPCB, tPAH, arsenic, beryllium, cadmium, chromium, copper, lead, nickel, selenium, silver, and zinc. Since 1999-2000, percent TOC is increasing slightly at a comparable rate at all stations indicating an area-wide influence. Mercury concentrations are higher and more variable over time at within-ZID Station 0 than all other 60-m stations with concentrations two- to four-times higher than at the other stations.

Sediment Toxicity

Whole-sediment toxicity testing was conducted on sediments collected from 10 stations in summer 2011 and from 9 stations in winter 2012. No toxicity was indicated in any of the samples (Table 4-7). This is in contrast to the previous two years when significant toxicity was detected at within-ZID Station 0. Station 0 is the site of the highest degree of impact on infaunal communities that began occurring in 2005.

In 2011-12, all samples were below the mERMq threshold indicating low potential for toxicity (i.e., mERMq>0.11) except farfield upcoast Station C in January (mERMq=0.13; Table 4-8), which indicates a moderate potential. The high value at Station C was driven by a high concentration of silver (0.96 mg/kg), which is approximately equal to the ERL (1.00 mg/kg). In contrast, the July 2011 concentration was 0.03 mg/kg. Sediment toxicity was not tested at this station.

The general lack of whole-sediment toxicity and low mERMq scores is inconsistent with the observed decline in invertebrate communities that has been occurring near the outfall over the last few years. These results suggest that whatever factor(s) is causing invertebrate communities to decline near the outfall it is not acutely toxic, as measured by these test endpoints, or it is not measured in the permit-required suite of chemicals monitored by the District. See Chapter 5 for a complete discussion of the decline in invertebrate communities in the monitoring area.

CONCLUSIONS

Sediment geochemistry results from the 2011-12 monitoring year were generally consistent with those of previous years suggesting generally good sediment quality in the monitoring area as measured by core monitoring parameters. There are mostly decreasing trends

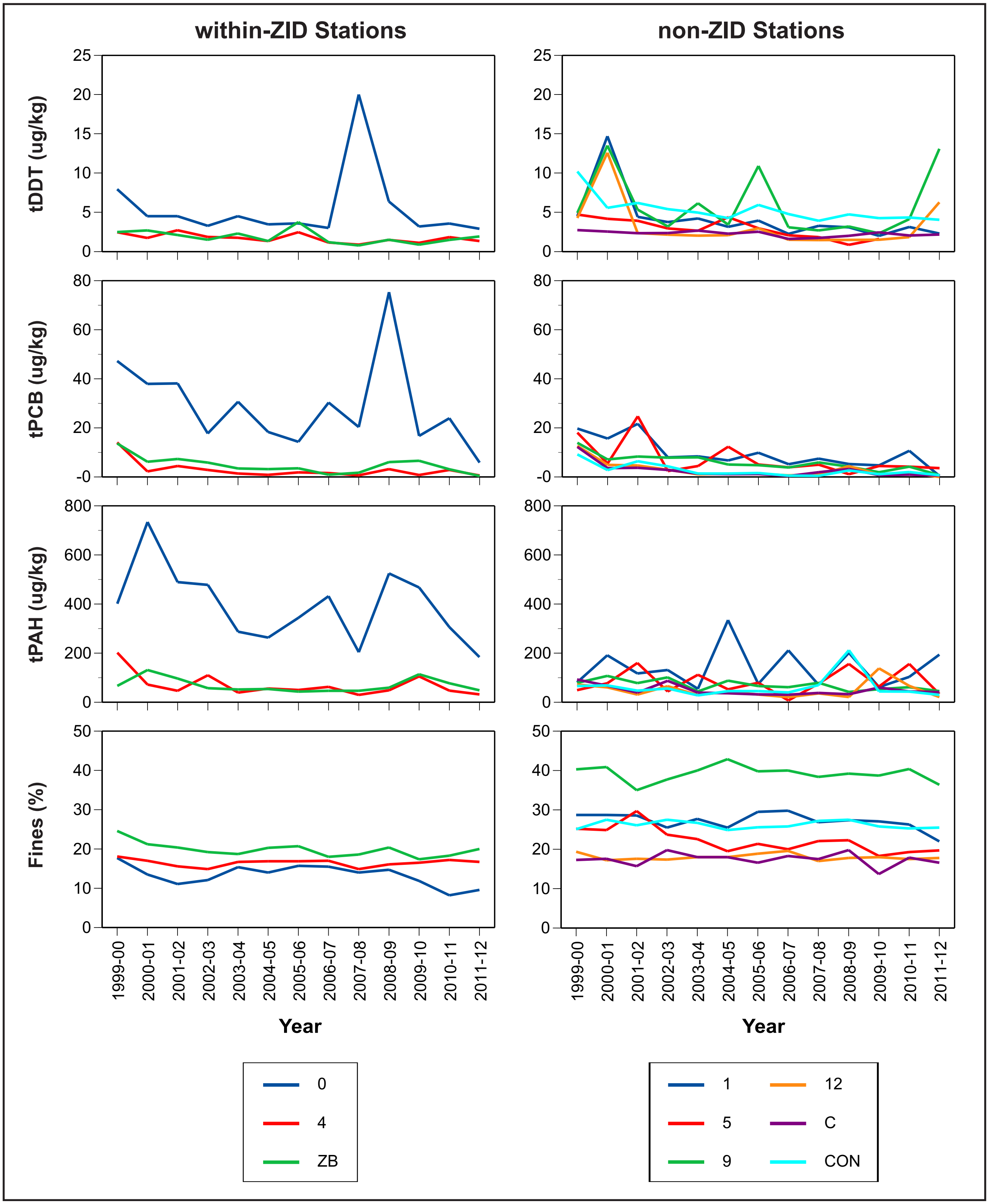


Figure 4-14. **Changes over time for total DDT, total PCB, total PAH, % fines, sulfides[1], total organic carbon, arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, and zinc in sediments at the 60 m shelf station groups during 1997–2012.**

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

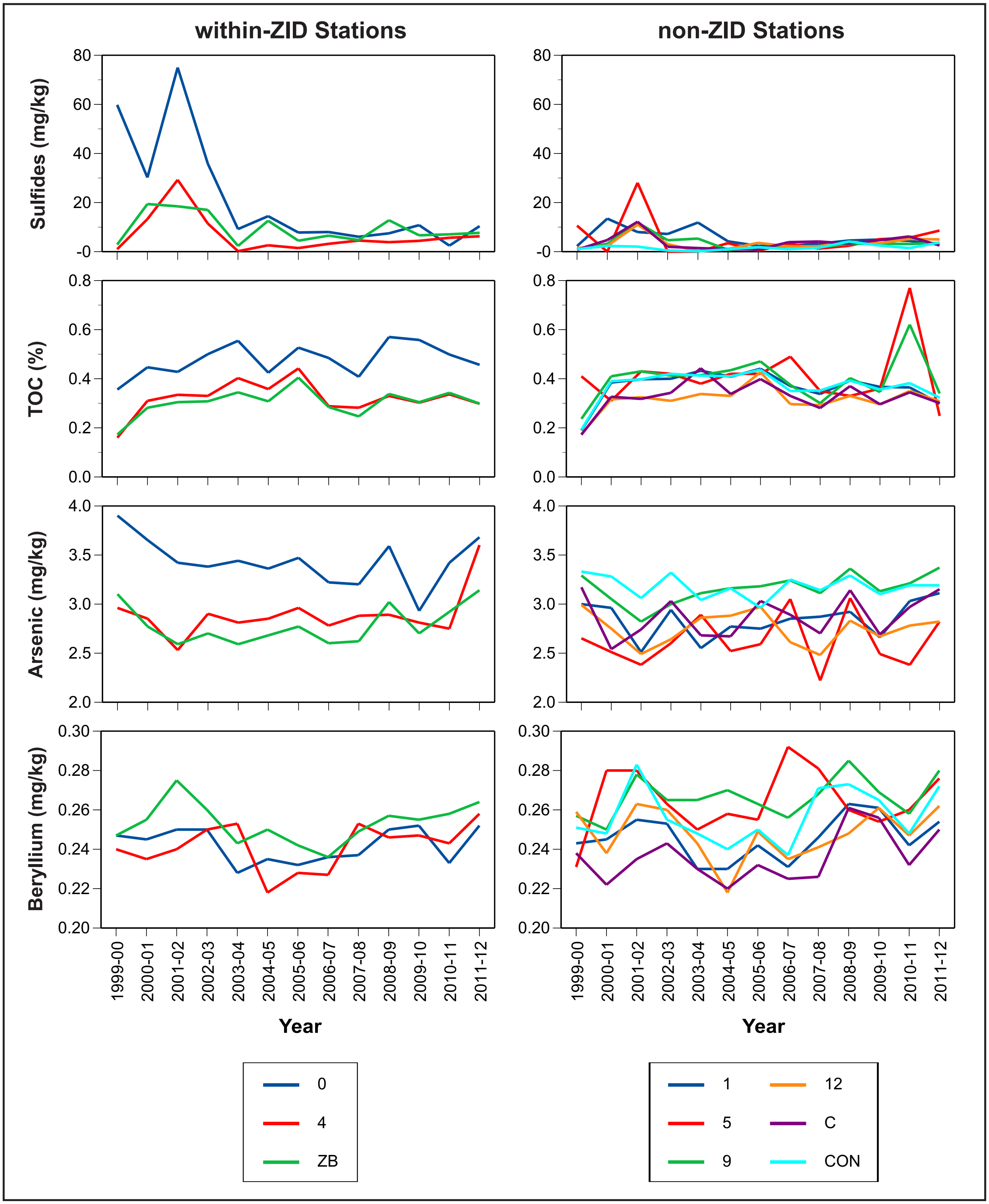


Figure 4-14 continued.

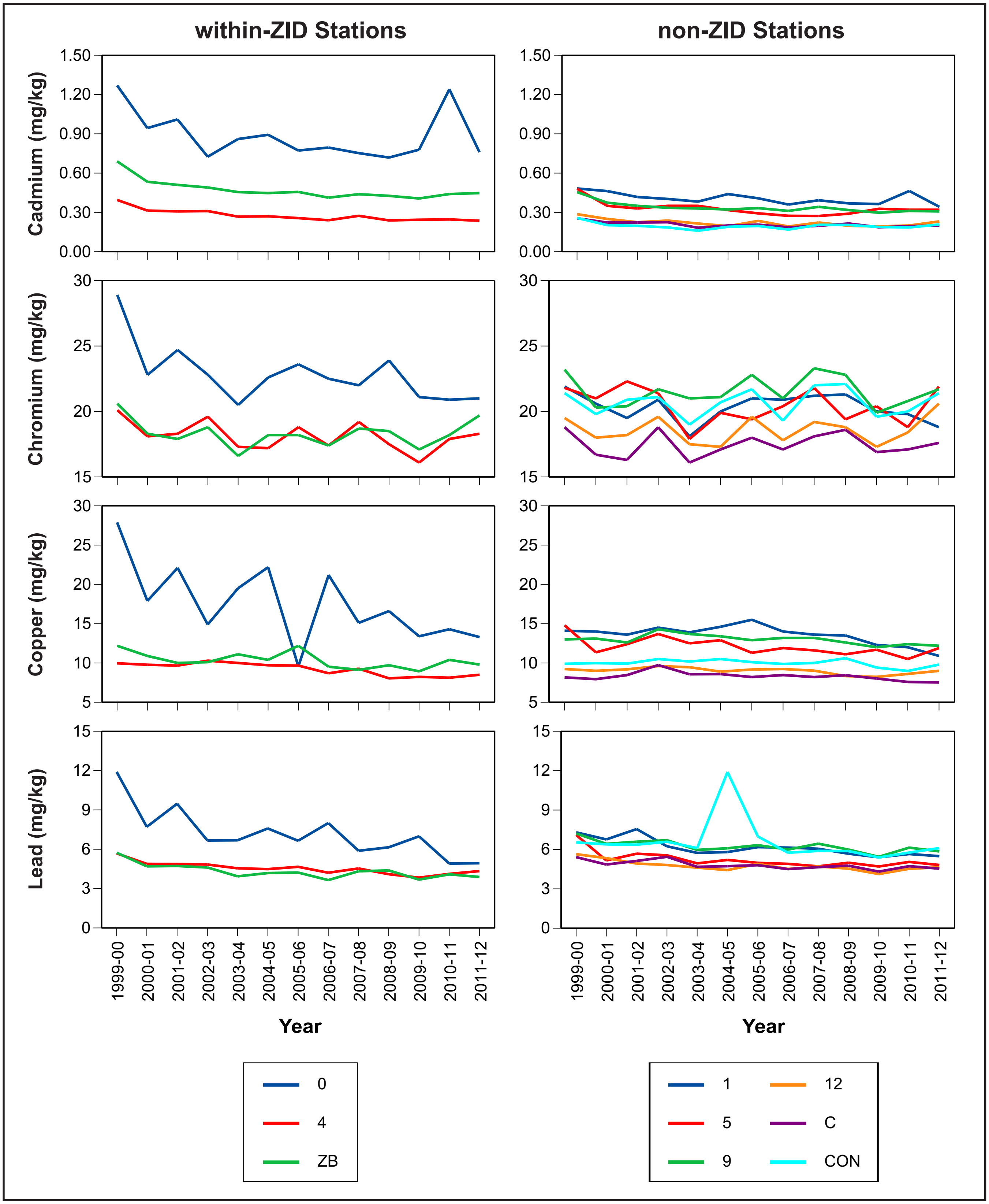


Figure 4-14 continued.

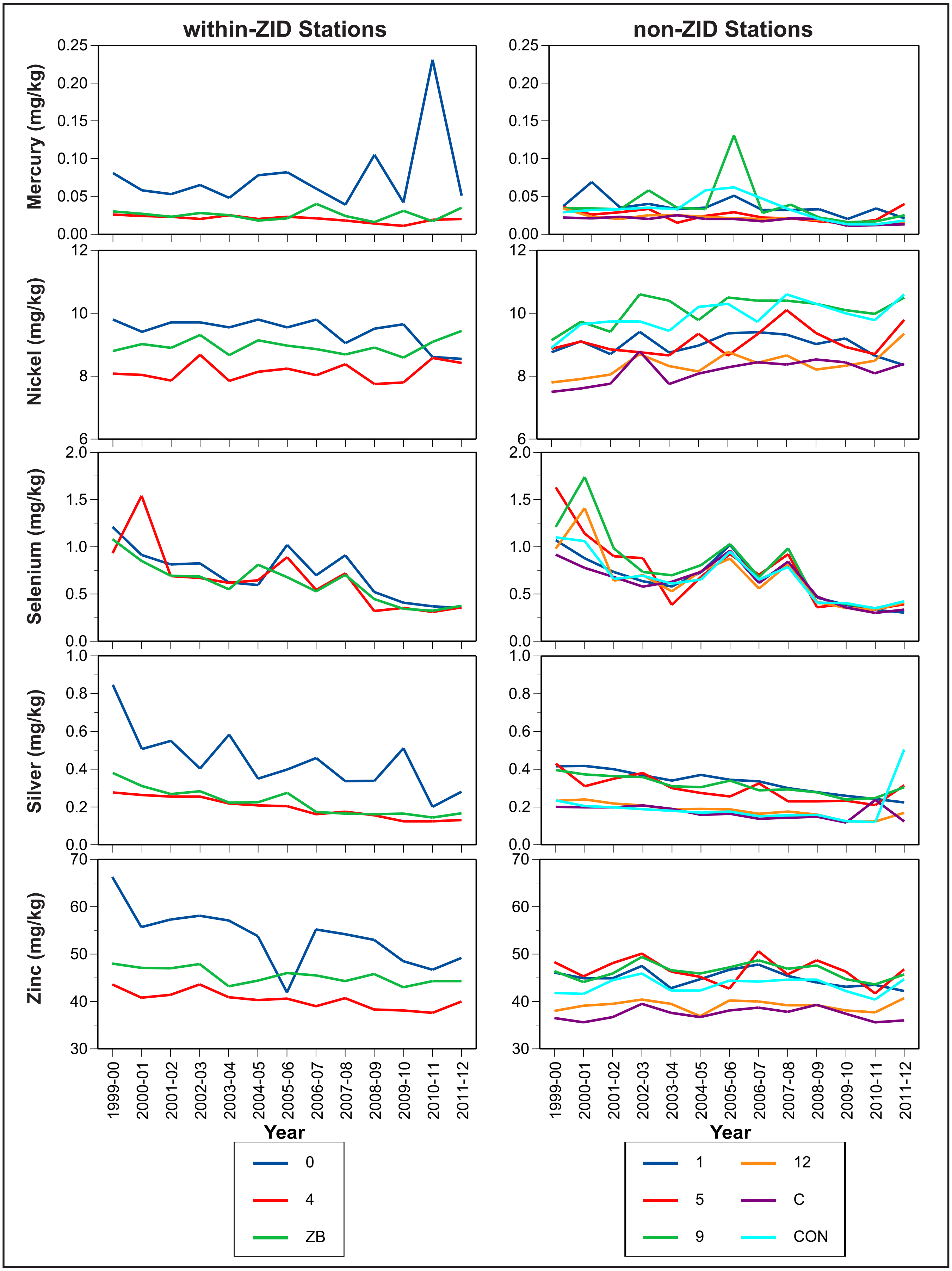


Figure 4-14 continued.

Table 4-7. **Whole-sediment *Eohaustorius estuarius* (amphipod) sediment toxicity test results for August 2011 and January 2012. Test results given as the difference between test sediment percent survival vs. home sediment percent survival.**

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Date	Station											
	CON	**5**	**1**	**85**	**84**	**3**	**0**	**ZB**	**76**	**4**	**77**	**9**
July 2011	-2.1	NS	1.1	-2.1	4.3	-3.2	0	1.1	1.1	-1.1	-1.1	NS
January 2012	-3.1	2.0	-1.0	NS	NS	-2.0	0	NS	0	-2.0	-2.0	0
Historical Results												
2010-11	1.0	0.5	3.5	NS	NS	NS	**10.6**	3.5	NS	3.5	NS	1.5
2009-10	2.6	-2.1	2.6	NS	NS		**22.7**	1.1	NS	1.0	NS	1.0

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

Bolded values represent significant toxicity.

Shaded stations are located within the zone of initial dilution (ZID).

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

Table 4-8. **Mean Effects-Range-Medium Quotient (mERMq) values for sediment contaminant concentrations during 2011-12.**

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Survey	Station									
	CON	**C**	**5**	**1**	**3**	**0**	**ZB**	**4**	**9**	**12**
July 2011	0.03	0.02	0.03	0.03	0.03	0.04	0.03	0.02	0.02	0.02
January 2012	0.05	**0.13**	0.04	0.03	0.04	0.05	0.03	0.02	0.03	0.02
2011-12 Mean	0.04	0.08	0.04	0.03	0.04	0.05	0.03	0.02	0.03	0.02
Historical Results										
2010-11 Mean	0.03	0.03	0.03	0.04	0.05	0.06	0.03	0.02	0.02	0.03
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	0.03	0.03	0.02

For 2011-12 results: n=2; historical results: n=4, except Station 3 historical results: n=1.

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.

over time in organic chemical constituents, with most concentrations below the ERL 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 the predominant influence of the wastewater discharge is upcoast and offshore of the outfall diffuser. Mean ERMq analysis indicated a low probability of sediment toxicity in the monitoring area, including inside the ZID, which was consistent with whole-sediment toxicity test results. Overall, results suggested that there were some minor effects to sediment quality, but they are mainly localized near the outfall or in depositional areas, such as the slope, basin, and submarine canyons, but not of a magnitude that should cause adverse effects on marine communities. However, these results were in contrast to the depressed invertebrate communities near the outfall suggesting that the causative factor(s) are not measured in the core monitoring program.

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