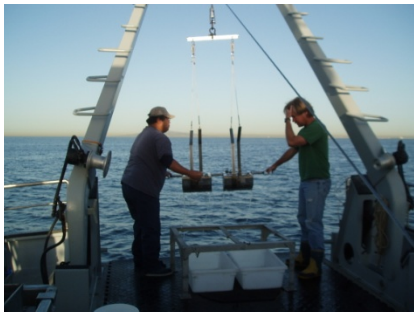
chapter 4

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 below).

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 305 cm (120 in) diameter pipe with associated ballast rock that alters current flow, which can affect sediment characteristics, such as grain size and geochemistry near the structure.

Compliance Criteria Pertaining to Sediment Geochemistry Contained in the District's NPDES Ocean Discharge Permit (Order No. R8-2012-0035, Permit No. CAO110604).

Criteria		Description
V.A.2.d	Inert Solids	The rate of deposition of inert solids and the characteristics of inert solids in ocean sediments shall not be changed such that benthic communities are degraded.
V.A.3.c	Dissolved Sulfides	The dissolved sulfide concentration of waters in and near sediments shall not be significantly increased above that present under natural conditions.
V.A.3.d	COP Table B Substances	The concentrations of substances, set forth in Chapter II, Table B of the California Ocean Plan, in marine sediments shall not be increased to levels which would degrade indigenous biota.
V.A.3.e	Organics in Sediments	The concentration of organic materials in sediments shall not be increased to levels in which would degrade marine life.
V.A.3.g		The concentrations of substances, set forth in Chapter II, Table B of the California Ocean Plan, shall not be exceeded in the area within the waste field where initial dilution is completed.

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.

The District has undertaken three major, multi-year process changes in the last 10 years directly affecting effluent quality and quantity. The first was the initiation of effluent disinfection by chlorination with hypochlorite bleach followed by de-chlorination with sodium bisulfate, in August 2002. The second was the Ground Water Replenishment System (GWRS) wastewater reclamation project that started in January 2008. GWRS has decreased the mean volume of effluent discharged into the ocean by almost 40% from 237 million gallons per day (MGD) in 2006-07 139 MGD in 2011-12. Finally, 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. On July 20, 2012, a new NPDES ocean discharge permit went into effect. It requires single grab samples at 29 stations semi-annually in the summer (July-September) and winter (January-March) and an additional 39 annual stations in summer only (Figure 4-1, Table A-1).

The purpose of the semi-annual surveys was to refine impact assessments near the outfall allowing continued long-term and spatial trend evaluations. Stations are arranged to bracket the outfall diffuser and extend upcoast and downcoast for gradient analysis. Semi-annual stations range in depth from 52 to 65 m. Annual stations provide a larger sampling area that extends farther across and along the shelf; depths range from 40 to 303 m.

The survey data are reported as individual station values and as means for station groups (using the individual station values located within four major zones based on station depth or proximity to the outfall). The depth zones are Inner shelf (0–30 m), Middle shelf (31-120m) and the Outer shelf (121–200 m), and Upper slope (201–500m maximum). Because the Middle shelf is the largest area of concern and extends from a depth of 30 to 120 m, it is divided into three zones: Zone 1 (31-50m), Zone 2 (51-90m), and Zone 3 (91-120m).

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 physical, chemical, and toxicity analyses. All samples were placed in coolers on wet ice and then transported to the District's Environmental Laboratory and Ocean Monitoring Division for analysis.

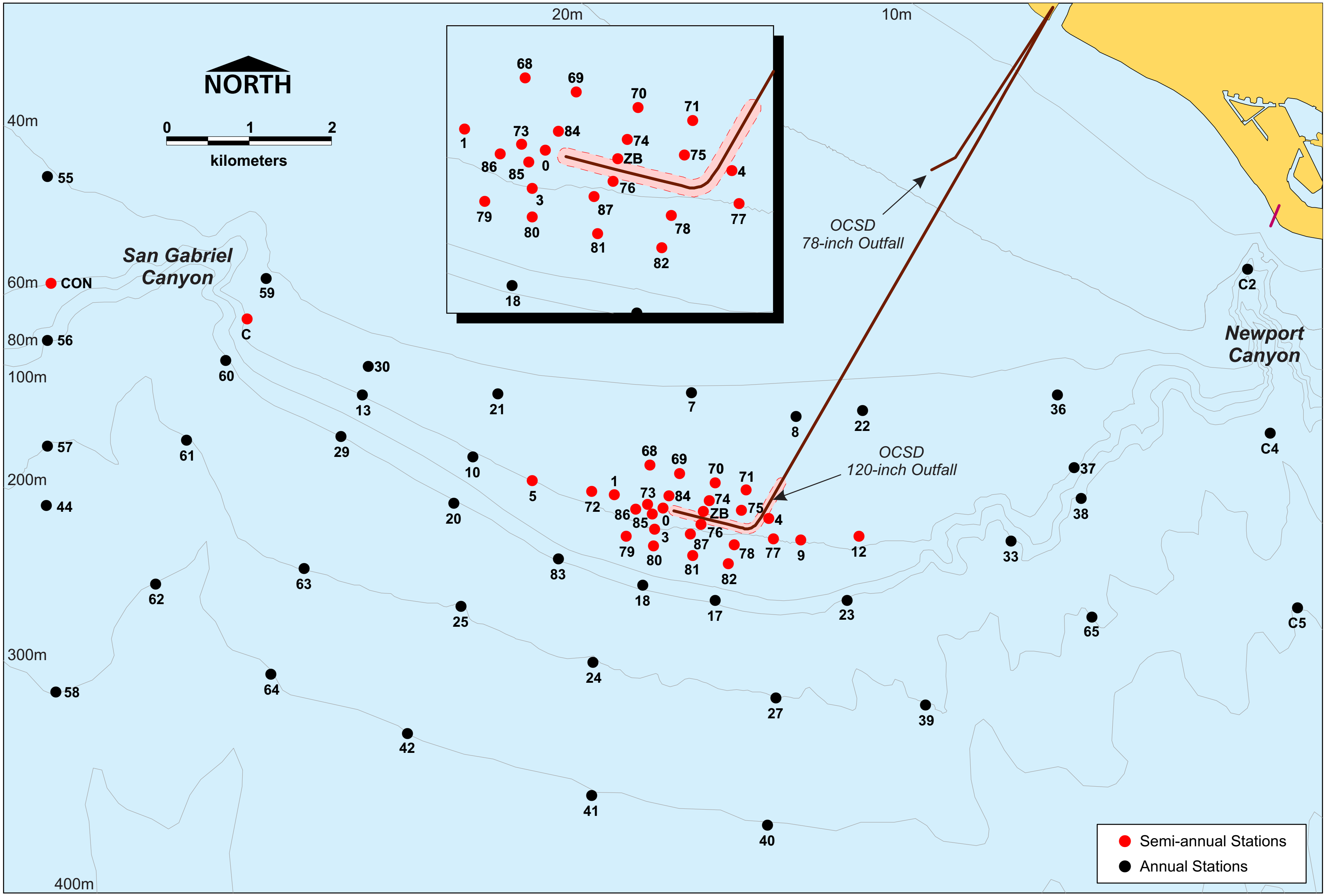


Figure 4-1. **Sediment geochemistry sampling stations for semi-annual and annual surveys, 2012-13.**
Note: ZID boundary indicated by red dashed lines around the outfall terminus.

Orange County Sanitation District, California.

Concentrations of metals, chlorinated pesticides, polychlorinated biphenyls, polycyclic aromatic hydrocarbons, total organic carbon (TOC), total nitrogen, total phosphorus, dissolved sulfides, and grain size were measured in each sediment sample. Grain size analysis included the measurement of phi sizes. Median phi is reported in Tables 4-1 and 4-3, but is not discussed in the text since it is highly correlated with percent fines, which is discussed. Total nitrogen and total phosphorus are new analytes contained in the newly issued 2012 NPDES permit. Linear alkylbenzenes are commonly found in detergents and serve as sewage markers (Eganhouse *et al*. 1983, 1988; Takada and Ishiwatari 1991) and were measured in the July 2012 survey to better identify changes in sediment quality attributable to the wastewater discharge. Total linear alkyl benzenes (tLAB) represent the summed concentrations of 25 individual linear alkyl benzene compounds. Total dichlorodiphenyltrichloroethane (tDDT) represents the summed concentrations of 4-4'-DDMU and 2,4'- and 4,4'-] isomers of DDD, DDE, and DDT; total polychlorinated biphenyls (tPCB) represents the summed concentrations of 45 congeners, and total chlorinated pesticides (tPest) represents the sum of aldrin, dieldrin, cis-chlordane, trans-chlordane, trans-nonachlor, heptachlor, heptachlor epoxide, endosulfan, endrin, hexachlorobenzene, lindane (gamma-BHC), and mirex. The suite of pesticides changed with the new NPDES permit. The previous suite was alpha- and cis-chlordane, cis- and trans-nonachlor, hexachlorobenzene, aldrin, dieldrin, endrin, gamma-BHC, heptachlor, heptachlor epoxide, and mirex. 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), Effects Range-Median (ERM) (Long *et al*. 1995), and 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). While both ERL and ERM are provided for comparison, only an ERM exceedance is considered a significant potential for adverse effects. 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, a 16.5% probability 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, a 6% probability of marginal sediment toxicity, or a 77% likelihood of some degree of sediment toxicity.

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. Toxicity was assessed in sediments from nine stations collected in March 2013 using the 10-day *Eohaustorius estuarius* whole-sediment 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 ($\alpha = 0.05$).

Spatial patterns in sediment character/analytes for the July 2012 and March 2013 semi-annual station data were assessed using correlation-based principal components analysis (PCA) PRIMER v6 (PRIMER 2001) and graphed with MapInfo v11.5 (Mapinfo 2012) . Depth-related gradients and relationships between chemical compounds and physical sediment characteristics were analyzed with Pearson Product Moment Correlation using Minitab 16. Data were transformed where appropriate; the significance level for all statistical tests was set at $\alpha = 0.05$. We also examine temporal trends in constituent annual means from 1999-00 through 2011-12.

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 (OCSD 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.

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 as bar graphs for within-ZID Stations 0, 4, and ZB; downcoast non-ZID Stations 9 and 12; and upcoast non-ZID Stations 1, 5, 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

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 2012 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

In July 2012, station depth and percent fine sediment were significantly correlated (r = 0.80). Therefore, percent fine sediment was used as a surrogate for station depth in further analyses. Historically, certain measures (e.g., mercury) would correlate with tLAB but not grain size, while others (e.g., arsenic) would correlate to grain size, but not to tLAB. Unlike previous years, all sediment physicochemical measures significantly correlated with both tLAB and sediment grain size. This suggests that the deposition of wastewater particles due to bathymetry and sediment grain size is a greater factor than proximity to the outfall. This was corroborated when the upper slope/canyon stations were removed from the analysis. When only shelf stations were analyzed against tLAB an outfall influence was found for cadmium (r = 0.83), copper (r = 0.46), mercury (r = 0.47), and silver (r = 0.49). These results suggest a decreased outfall footprint due to the lower discharge of total suspended solids (TSS) with full secondary wastewater treatment.

Spatial Analysis

Total Linear Alkylbenzenes (tLAB)

In July 2012, the highest rate of effluent particle deposition generally occurred at the outfall terminus and on the outer shelf and slope upcoast from the outfall in the San Gabriel Canyon (Figure 4-2). tLAB concentrations generally followed coastal bathymetry and increased with depth (Table 4-1). Outfall depth stations showed higher concentrations near the outfall and a decreasing gradient moving upcoast and downcoast from the ZID (Figure 4-3)

Similar to most years, the highest middle shelf concentrations of tLAB were seen at middle shelf ZID-stations (mean = 87 µg/kg) compared to a mean of 34 µg/g at non-ZID middle shelf sites (Table 4-1). However, concentrations at all stations were considerably lower than previous years. For example, the highest middle shelf concentration in July 2012 was 217 µg/kg at within-ZID Station 0 which was approximately fourfold lower than the highest concentration in July 2011 of 891 µg/kg at non-ZID Station 5. This suggests that decreased solids discharge is lessening the outfall footprint. In July 2011, half of the middle shelf non-ZID stations had tLAB levels greater than 180 µg/kg. In July 2012, no middle shelf non-ZID station had a tLAB concentration greater than 100 µg/kg. Several upcoast stations in the outer shelf and upper slope/canyon areas and the San Gabriel Canyon exceeded 100 µg/kg. This indicates that upcoast effluent particle transport is occurring with deposition in the San Gabriel Canyon. This pattern is consistent with predominant subtidal currents below 30 m (SAIC 2009).

Percent Fine Sediments

Percent fine sediments generally increased with increasing station depth (Figure 4-4). Mean values ranged from 9% at within-ZID to 63% in upper slope/canyon strata (Table 4-1). Mean percent fines at within-ZID stations was approximately half that of middle shelf non-ZID stations (15%). 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). Mean percent fines at stations downcoast

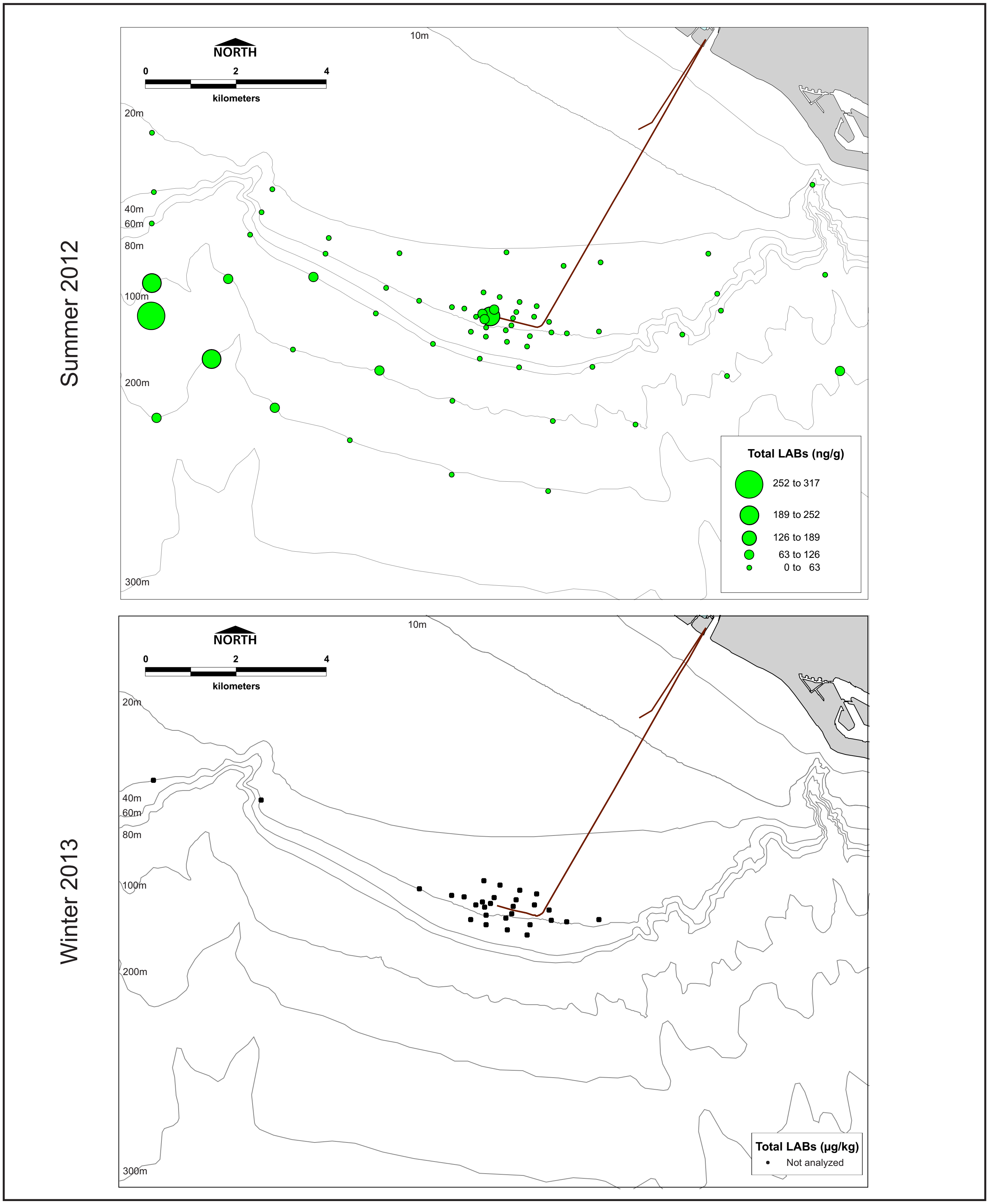


Figure 4-2. **Spatial trend bubble plots of tLABs for Summer 2012 (top) and Winter 2013 (bottom).**

Table 4-1. Concentrations of sediment organic contaminants (µg/kg) at the District's annual and semi-annual stations in Summer 2012 compared to Effects Range–Low (ERL) and Effects Range–Median (ERM) values and regional measurements of sediment physical characteristics.

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Station	Depth (m)	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)
Middle shelf Zone 1 (31-50 meters)										
7	41	19.4	3.63	9.5	0.33	1.10	14.2	NA	NA	NA
8	44	41.3	3.71	19.5	0.36	4.16	25.6	NA	NA	NA
21	44	13.2	3.61	14.1	0.45	1.88	13.4	NA	NA	NA
22	45	9.5	3.75	22.9	0.43	2.89	34.5	NA	NA	NA
30	46	8.4	3.71	19.5	0.36	1.42	32.2	NA	NA	NA
36	45	9.0	3.71	19.0	0.37	2.22	76.4	NA	NA	NA
55	40	4.2	2.88	3.5	0.19	1.17	12.5	NA	NA	NA
59	40	10.1	3.20	7.1	0.30	< 1.03	39.2	NA	NA	NA
	Mean	**14.4**	**3.53**	**14.4**	**0.35**	**2.12**	**31.0**	**NA**	**NA**	**NA**
Middle shelf Zone 2, Non-ZID (51-90 meters)										
1*	56	51.6	3.57	14.4	0.35	3.01	67.2	NA	NA	NA
3*	60	32.6	3.46	8.6	0.36	3.05	30.1	NA	NA	NA
5*	59	42.7	3.66	17.4	0.39	3.12	87.4	NA	NA	NA
9*	59	19.3	3.31	9.9	0.32	2.11	44.3	NA	NA	NA
10	60	31.2	3.71	18.2	0.37	<1.03	16.6	NA	NA	NA
12*	58	15.4	3.20	7.8	0.32	3.59	58.3	NA	NA	NA
13	59	24.4	3.63	18.6	0.38	2.42	16.1	NA	NA	NA
37	56	0.6	2.68	37.1	0.28	1.44	25.7	NA	NA	NA
68*	52	36.4	3.56	11.3	0.32	6.05	54.3	NA	NA	NA
69*	52	20.7	3.61	16.1	0.44	4.17	57.1	NA	NA	NA
70*	52	38.3	3.46	7.7	0.38	2.85	46.5	NA	NA	NA
71*	52	35.6	3.35	7.2	0.25	4.25	28.0	NA	NA	NA
72*	55	54.6	3.55	32.0	0.39	2.31	49.5	NA	NA	NA
73*	55	96.6	3.44	6.4	0.41	6.89	67.0	NA	NA	NA
74*	57	31.1	3.43	23.2	0.36	5.12	44.3	NA	NA	NA
75*	60	42.6	3.37	7.2	0.29	6.29	48.4	NA	NA	NA
77*	60	20.9	3.34	7.5	0.33	3.79	75.4	NA	NA	NA
78*	63	28.2	3.39	9.8	0.29	4.91	167.1	NA	NA	NA
79*	65	34.1	3.52	11.9	0.35	4.24	68.5	NA	NA	NA
80*	65	14.1	3.57	36.7	0.35	1.60	31.0	NA	NA	NA
81*	65	18.3	3.46	7.0	0.32	2.93	43.3	NA	NA	NA
82*	65	20.9	3.38	9.4	0.30	2.70	36.7	NA	NA	NA
84*	54	84.0	3.43	8.4	0.36	1.84	115.4	NA	NA	NA
85*	57	79.1	3.44	7.8	0.38	5.00	43.2	NA	NA	NA
86*	57	33.0	3.46	7.3	0.33	3.02	45.4	NA	NA	NA
87*	60	46.9	3.43	8.4	0.37	3.04	60.2	NA	NA	NA
C*	56	17.2	3.42	13.3	0.39	2.62	59.0	NA	NA	NA
C2	56	8.7	4.04	51.6	1.52	14.70	274.4	NA	NA	NA
CON*	59	7.6	3.48	12.5	0.41	3.95	71.5	NA	NA	NA
	Mean	**34.0**	**3.46**	**15.0**	**0.39**	**3.96**	**63.2**	**NA**	**NA**	**NA**
Middle shelf Zone 2, Within-ZID (51-90 meters)										
0 *	56	216.5	3.37	5.8	0.49	3.85	470.7	NA	NA	NA
4 *	56	27.8	3.40	10.0	0.33	3.17	48.2	NA	NA	NA
76 *	58	52.2	3.39	8.4	0.40	2.22	112.1	NA	NA	NA
ZB *	56	51.0	3.42	12.6	0.33	4.42	77.1	NA	NA	NA
	Mean	**86.9**	**3.40**	**9.2**	**0.39**	**3.42**	**177.0**	**NA**	**NA**	**NA**

Table 4-1 Continues.

Table 4-1 Continued.

Station	Depth (m)	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)
					Middle shelf Zone 3 (91-120 meters)					
17	91	12.1	3.34	10.3	0.38	3.16	47.1	NA	NA	NA
18	91	11.3	3.34	10.3	0.39	2.93	61.2	NA	NA	NA
20	100	29.7	3.85	35.6	0.49	1.08	47.2	NA	NA	NA
23	100	4.8	3.35	10.5	0.37	1.98	31.5	NA	NA	NA
29	100	67.3	3.83	32.3	0.51	2.28	45.4	NA	NA	NA
33	100	2.0	2.60	5.8	0.27	2.52	18.9	NA	NA	NA
38	100	8.7	3.70	19.1	0.64	11.20	131.7	NA	NA	NA
56	100	30.7	3.78	58.3	0.57	5.64	83.8	NA	NA	NA
60	100	42.6	3.72	22.3	0.49	1.95	59.2	NA	NA	NA
83	100	16.5	3.63	12.9	0.41	2.93	70.2	NA	NA	NA
	Mean	**22.6**	**3.51**	**21.7**	**0.45**	**3.57**	**59.6**	**NA**	**NA**	**NA**
					Outer Shelf (121-200 meters)					
24	200	48.5	4.25	56.4	0.89	2.54	72.1	NA	NA	NA
25	200	70.8	4.46	63.2	1.19	11.20	74.5	NA	NA	NA
27	200	19.6	3.98	48.4	0.70	1.87	44.9	NA	NA	NA
39	200	6.0	3.66	60.2	0.56	1.74	58.6	NA	NA	NA
57	200	189.9	4.82	71.1	1.77	8.52	286.1	NA	NA	NA
61	200	124.0	4.13	53.7	1.28	6.97	130.8	NA	NA	NA
63	200	48.3	4.34	62.9	0.97	4.22	64.4	NA	NA	NA
65	200	25.3	3.83	37.6	0.90	3.14	120.5	NA	NA	NA
C4	187	17.1	5.71	84.9	1.74	32.00	179.0	NA	NA	NA
	Mean	**61.1**	**4.35**	**59.8**	**1.11**	**8.02**	**114.5**	**NA**	**NA**	**NA**
					Upper Slope/Canyon (201-500 meters)					
40	303	24.6	4.52	66.7	1.21	1.46	122.7	NA	NA	NA
41	303	20.7	3.95	47.0	1.26	3.24	100.6	NA	NA	NA
42	303	43.6	4.19	55.1	1.63	3.19	64.4	NA	NA	NA
44	241	316.6	4.99	79.0	2.02	12.40	238.6	NA	NA	NA
58	300	109.5	4.95	69.6	2.21	12.30	232.6	NA	NA	NA
62	300	203.2	4.49	70.5	2.15	12.50	336.3	NA	NA	NA
64	300	68.7	3.95	49.0	1.41	10.50	186.1	NA	NA	NA
C5	296	117.3	4.98	67.4	1.76	54.90	214.0	NA	NA	NA
	Mean	**113.0**	**4.50**	**63.0**	**1.71**	**13.81**	**186.9**	**NA**	**NA**	**NA**
					SEDIMENT QUALITY GUIDELINES					
[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 Middle 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)

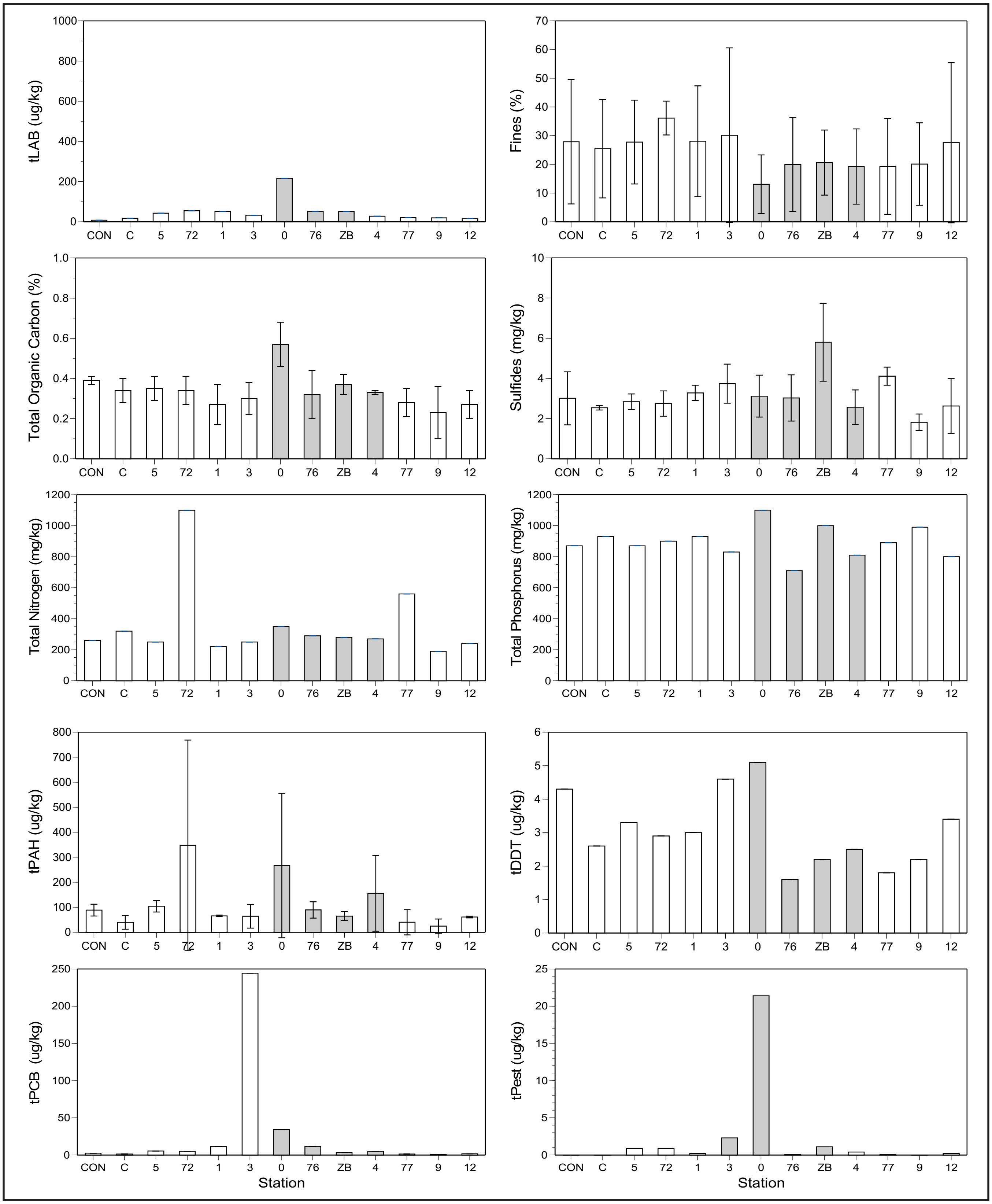

Figure 4-3. Distribution of mean and standard deviation values for total LAB (ųg/kg), fines (%), total organic carbon (%), dissolved sulfides (mg/kg), total nitrogen (mg/kg), total phosphorus (mg/kg), total PAH (ųg/kg), total DDT (ųg/kg), total PCB (ųg/kg), and total chlorinated pesticides in sediments at the 60 m shelf stations during 2012-13.

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

Columns without standard deviation bars indicate that the analysis was conducted only once in the monitoring year, either summer or winter, but not both. See chapter text for when analyses were conducted on individual analytes.

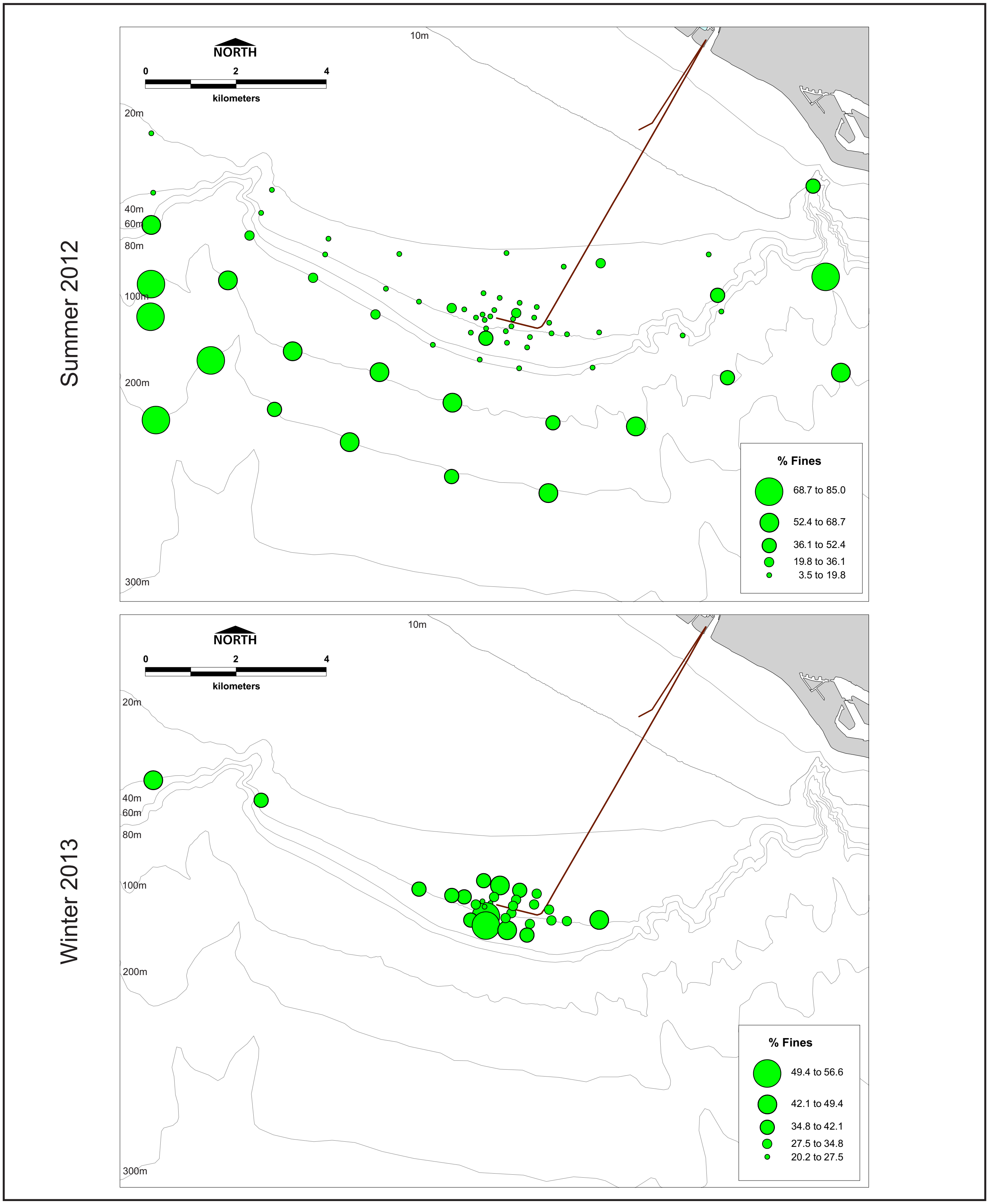

Figure 4-4. **Spatial trend bubble plots of % fines for Summer 2012 (top) and Winter 2013 (bottom).**

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from the outfall were generally comparable to that of within-ZID stations, while upcoast stations were up to three-times that of within-ZID and downcoast sites (Figure 4-3). Consistent with previous years, station group means were comparable to Bight'08 area weighted means (AWM) by depth except for the middle shelf station groups, which were two- to five-times lower. Winter 2013 results showed comparable mean values between Zone 2 within-ZID and non-ZID stations, but means were two to three times higher than in summer 2012. Individual station values were as much as six times higher in winter than summer (Table 4-2). Similar to summer 2012, TOC values were lower near the outfall (Figure 4-4).

Sediment Organic and Nutrient Content

Total Organic Carbon (TOC)
In July 2012, mean percent TOC generally increased with increasing depth and distance from the outfall (Figure 4-5). Mean values ranged from 0.35% at middle shelf Zone 1 stations to 1.71% at upper slope/canyon stations (Table 4-1). Mean percent TOC was comparable at ZONE 2 within-ZID and Zone 2 non-ZID stations indicating minimal outfall influence (Table 4-1; Figure 4-5). Values were generally less than half those of the Bight'08 area weighted means for the middle shelf and comparable to the outer-shelf strata. Winter 2013 results showed a similar distribution (Table 4-2; Figure 4-5). Zone 2 within-ZID Station 0 had a higher TOC percentage than the other outfall-depth stations, but all values were low and not of concern to animal populations (Figure 4-3).

Dissolved Sulfides
Sediment sulfide concentrations generally increased with increased station depth, but were highest in the submarine canyons, in particular the Newport Canyon in summer (Table 4-1; Figure 4-6). Mean concentrations were less than 4 mg/kg in all middle shelf zones with shallow Zone 1 about half that of Zones 2 and 3, which were all comparable. Also, there was no gradient evident at outfall-depth stations (Figure 4-3). These results indicate that the effluent discharge is not a significant influence on the spatial distribution of sulfides. The higher sulfide concentrations in outer shelf and upper slope/canyon strata are consistent with these depositional, deep-water environments. Winter 2013 results showed slightly higher concentrations near the outfall, but all values were low (Table 4-2; Figure 4-6).

Total Nitrogen
As the NPDES permit went into effect after the summer sediment survey was completed there are only results for this newly added measure in winter 2013 and no historical comparison can be made.

Results for middle shelf Zone 2 non-ZID and within-ZID station groups were comparable with means of 325 mg/kg and 298 mg/kg, respectively; station value ranges were also comparable except for non-ZID Station 72 (1,100 mg/kg; located approximately 1 km upcoast from the outfall), which was two to five times more than other non-ZID stations (Table 4-2). The effluent discharge does not appear to be a significant influence on the distribution of nitrogen in sediments near the outfall (Figure 4-7), and there was no gradient evident at outfall-depth stations (Figure 4-3). This sediment constituent was not measured in the regional monitoring programs so no regional comparison can be made.

Table 4-2. Concentrations of sediment organic contaminants (µg/kg) at the District's semi-annual stations in Winter 2013 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 (m)	Total LAB (ųg/kg)	Median Phi	Fines (%)	TOC (%)	Sulfides (mg/kg)	Total P (mg/kg)	Total N (mg/kg)	Total PAH (ųg/kg)	Total DDT (ųg/kg)	Total Pest (ųg/kg)	Total PCB (ug/kg)
Middle shelf Zone 2, Non-ZID (51-90 meters)												
1	56	NA	3.33	20.3	0.65	2.38	930	220	62.0	5.1	0.20	34.2
3	60	NA	3.78	51.6	0.24	4.42	830	250	97.1	4.6	2.30	**244**
5	59	NA	3.59	38.1	0.31	2.57	870	250	120	3.3	0.90	5.4
9	59	NA	3.38	30.3	0.14	1.53	990	190	4.0	2.2	0.00	0.90
12	58	NA	3.73	47.3	0.22	1.67	800	240	63.0	3.4	0.20	1.7
68	52	NA	3.40	39.9	0.30	3.58	870	280	43.0	3.6	0.10	3.3
69	52	NA	3.68	47.7	0.27	2.12	910	290	101	2.4	0.10	3.2
70	52	NA	3.59	37.6	0.23	4.00	770	280	34.0	3.0	0.10	24.3
71	52	NA	3.45	27.8	0.22	3.44	900	200	95.0	2.8	1.70	4.1
72	55	NA	3.66	40.3	0.29	3.20	900	1100	645	2.9	0.90	5.0
73	55	NA	3.48	24.0	0.33	5.86	1100	410	196	3.1	0.80	14.7
74	57	NA	3.49	31.2	0.25	2.81	830	360	57.0	2.4	0.20	3.0
75	60	NA	3.45	30.7	0.23	3.58	780	320	88.5	2.6	1.20	3.9
77	60	NA	3.38	31.1	0.23	4.42	890	560	4.0	1.8	0.10	1.3
78	63	NA	3.43	31.4	0.20	2.48	760	260	52.0	2.2	5.40	3.4
79	65	NA	3.62	38.4	0.35	2.96	870	250	47.0	3.3	1.30	4.9
80	65	NA	3.75	56.5	0.36	3.29	810	310	333	2.5	0.90	2.3
81	65	NA	3.62	43.4	0.26	1.62	850	240	38.0	2.5	0.20	5.7
82	65	NA	3.44	35.5	0.27	1.52	810	390	5.0	1.8	0.10	1.4
84	54	NA	3.55	31.7	0.30	4.94	870	350	177	3.9	0.70	10.5
85	57	NA	3.40	23.6	0.40	4.14	1100	320	256	5.1	1.10	14.7
86	57	NA	3.49	29.3	0.45	3.84	1000	230	42.0	2.9	0.80	10.2
87	60	NA	3.56	33.4	0.27	1.50	880	250	24.0	2.3	0.10	3.6
C	56	NA	3.48	37.6	0.30	2.47	930	320	20.0	2.6	0.00	1.3
CON	59	NA	3.60	43.2	0.38	2.08	870	260	105	4.3	0.00	2.4
	Mean	**NA**	**3.53**	**36.1**	**0.30**	**3.06**	**885**	**325**	**108**	**3.1**	**0.78**	**16.4**
Middle shelf Zone 2, Within-ZID (51-90 meters)												
0	56	NA	3.67	41.7	0.20	3.55	1100	350	63.0	3.0	21.4	11.4
4	56	NA	3.39	28.5	0.32	1.96	810	270	262.5	2.5	0.40	4.9
76	58	NA	3.46	31.6	0.23	3.85	710	290	66.0	1.6	0.10	11.7
ZB	56	NA	3.47	28.6	0.40	7.17	1000	280	51.8	2.2	1.10	3.3
	Mean	**NA**	**3.50**	**32.6**	**0.29**	**4.13**	**905**	**298**	**111**	**2.3**	**5.75**	**7.83**
SEDIMENT QUALITY GUIDELINES												
[1] ERL		NA	NA	NA	NA	NA	NA	NA	4,022	1.58	NA	22.7
[1] ERM		NA	NA	NA	NA	NA	NA	NA	44,792	46.1	NA	180
[2] Bight'08 AWM Mid-shelf		NA	NA	46.8	1.0	NA	NA	NA	179.0	16.0	NA	13.0
[2] Bight '08 AWM Outer-shelf		NA	NA	60.0	1.5	NA	NA	NA	231.0	56.0	NA	19.0
[2] Bight'08 AWM Upper Slope/Basin		NA	NA	81.3	2.6	NA	NA	NA	234.0	238.0	NA	36.0

Bolded station value exceeds the ERM.

AWM = Area Weighted Mean, NS = Not Sampled, NA = Not Applicable, ND = Not Detected. All stations n = 1.

[1] Long *et al*. (1995)

[2] Schiff *et al*. (2011)

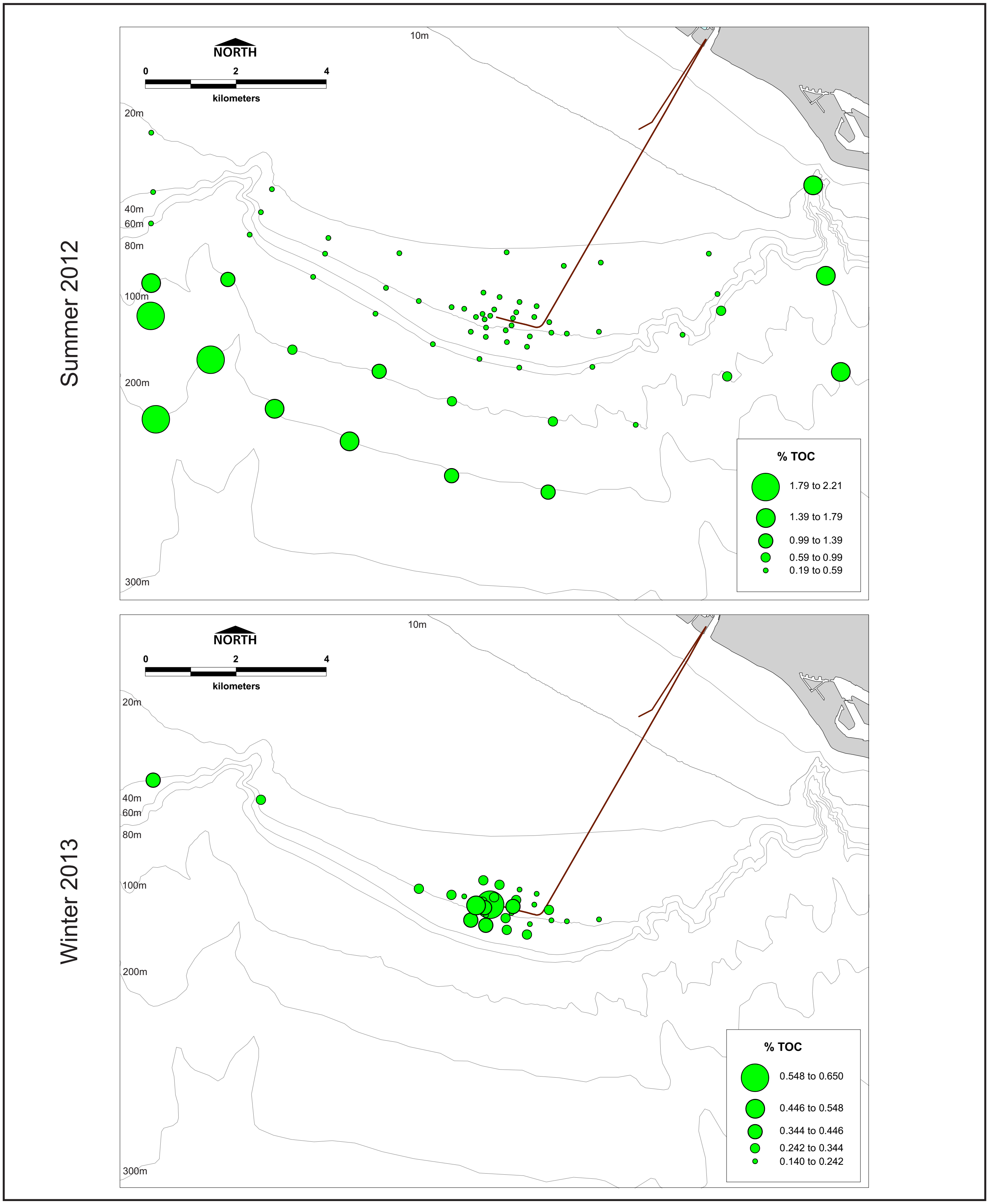

Figure 4-5. **Spatial trend bubble plots of % total organic carbon (TOC) for Summer 2012 (top) and Winter 2013 (bottom).**

Orange County Sanitation District, California.

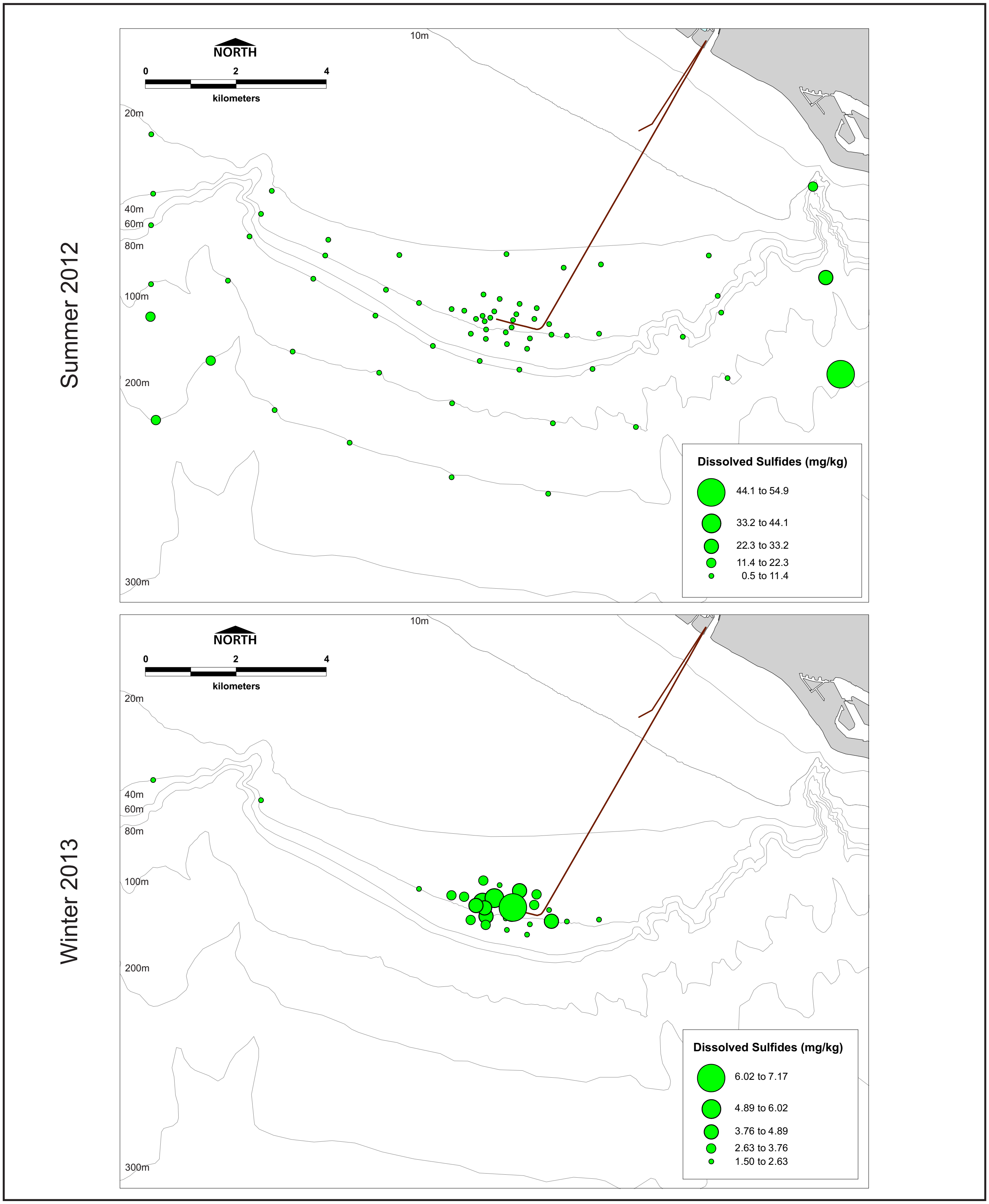

Figure 4-6. **Spatial trend bubble plots of dissolved sulfides for Summer 2012 (top) and Winter 2013 (bottom).**

Orange County Sanitation District, California.

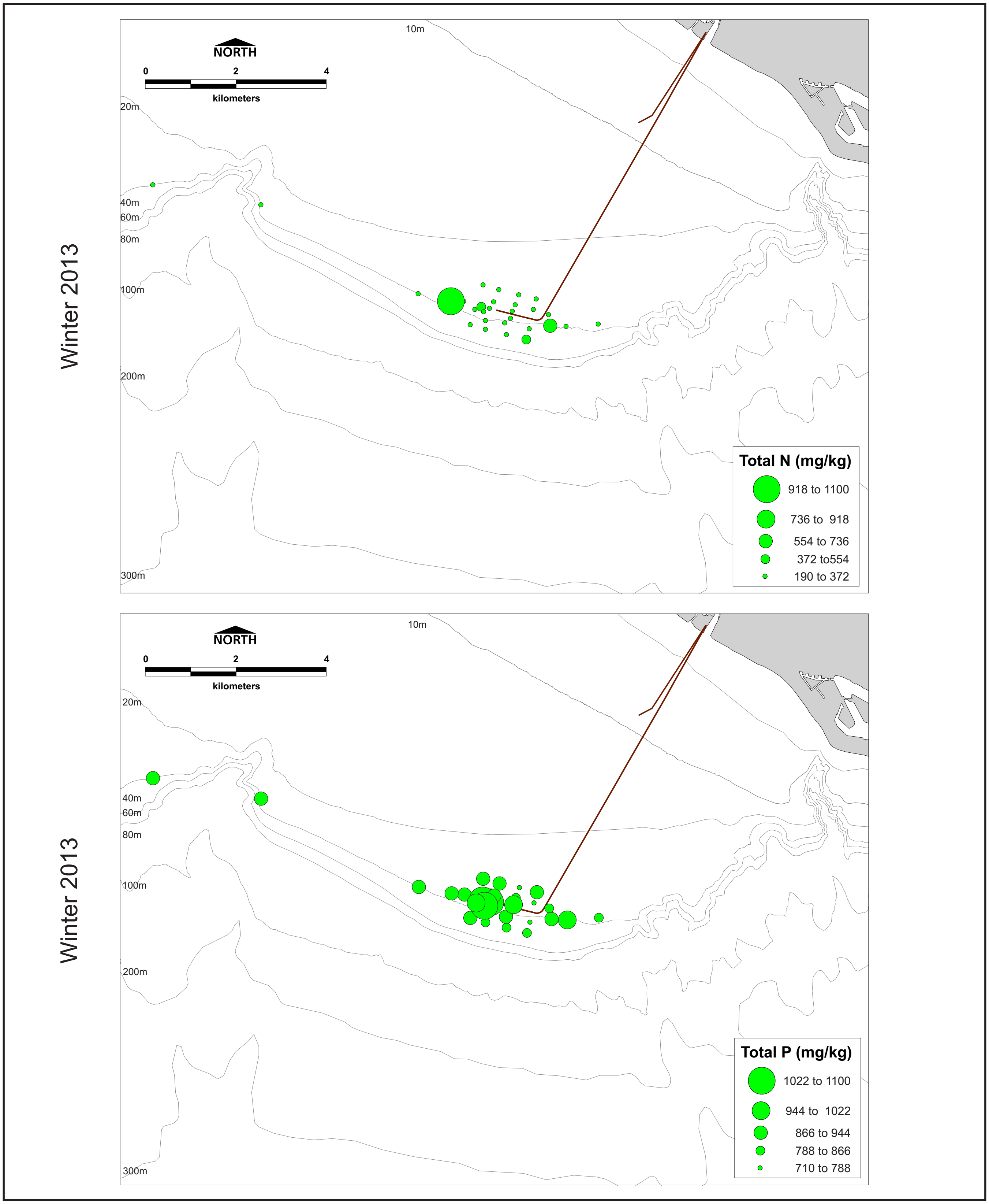

Figure 4-7. Spatial trend bubble plots of total nitrogen (top) and total phosphorus (bottom) for Winter 2013.

Orange County Sanitation District, California.

Total Phosphorus
As with total nitrogen, results for this newly added measure to the NPDES permit were only obtained in winter 2013, and no historical comparison can be made. Means and ranges of sediment phosphorus concentrations were comparable for middle shelf Zone 2 non-ZID and within-ZID station groups with means of 885 mg/kg and 905 mg/kg, respectively (Table 4-2, Figure 4-7). There was no gradient evident at outfall-depth stations (Figure 4-3). Sediment phosphorus was not measured in the regional monitoring programs so no regional comparison can be made.

<u>Organic Contaminants</u>

As a resource reallocation to facilitate the Sediment Mapping strategic process study (see Chapter 7), chlorinated pesticides, tDDT and tPCB were not analyzed in summer 2012; they were only analyzed in winter 2013. tPAH was analyzed in both the Summer 2012 and Winter 2013 surveys.

Total Polycyclic Aromatic Hydrocarbons (tPAH)
In July 2012, sediment tPAH concentrations were low at all stations. Generally, concentrations increased with increasing depth (Table 4-1; Figure 4-8). Mean sediment tPAH concentrations were two to three orders of magnitude lower than the ERM, which is the concentration at which adverse effects on biota are expected. The higher tPAH concentrations in outer shelf and upper slope/canyon strata are consistent with these depositional, deep-water environments. Mean sediment tPAH concentrations were low, but tended to be higher at within-ZID stations though there was no clear gradient relative to the outfall (Figure 4-3). Mean concentrations for all depth strata were comparable to or below the Bight'08 AWM. Winter 2013 results showed a similar distribution (Table 4-2; Figure 4-8).

Total Chlorinated Pesticides Other than DDT (tPest)
The outfall is not a significant source of chlorinated pesticide compounds. Historically, they are generally not detected in most surveys and when detected are in small concentrations.

In winter 2013, unlike the previous year, pesticides were detected at all four within-ZID stations (mean = 5.75 µg/kg) and at 22 of 25 non-ZID stations (mean = 0.78 µg/kg) (Table 4-2; Figure 4-9). All concentrations were low except within-ZID Station 0, which had a concentration of 21.4 µg/kg (of which 20.3 µg/kg was composed of aldrin). The other Zone 2 within-ZID station concentrations were comparable to the Zone 2 non-ZID stations. Concentrations of these pesticides were generally slightly higher at the Zone 2 within-ZID stations than at non-ZID stations suggesting an outfall influence (Figure 4-3). The generally low concentrations at within-ZID stations suggest that the outfall is not a significant source of these compounds. The change in detection is likely due to the change in analytes that were screened per the new discharge permit.

Total dichlorodiphenyltrichloroethanes (tDDT)
In winter 2013, tDDT concentrations were low at all stations and no outfall gradient was evident (Table 4-2; Figure 4-10). All concentrations were well below the ERM and Bight'08 AWMs. 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

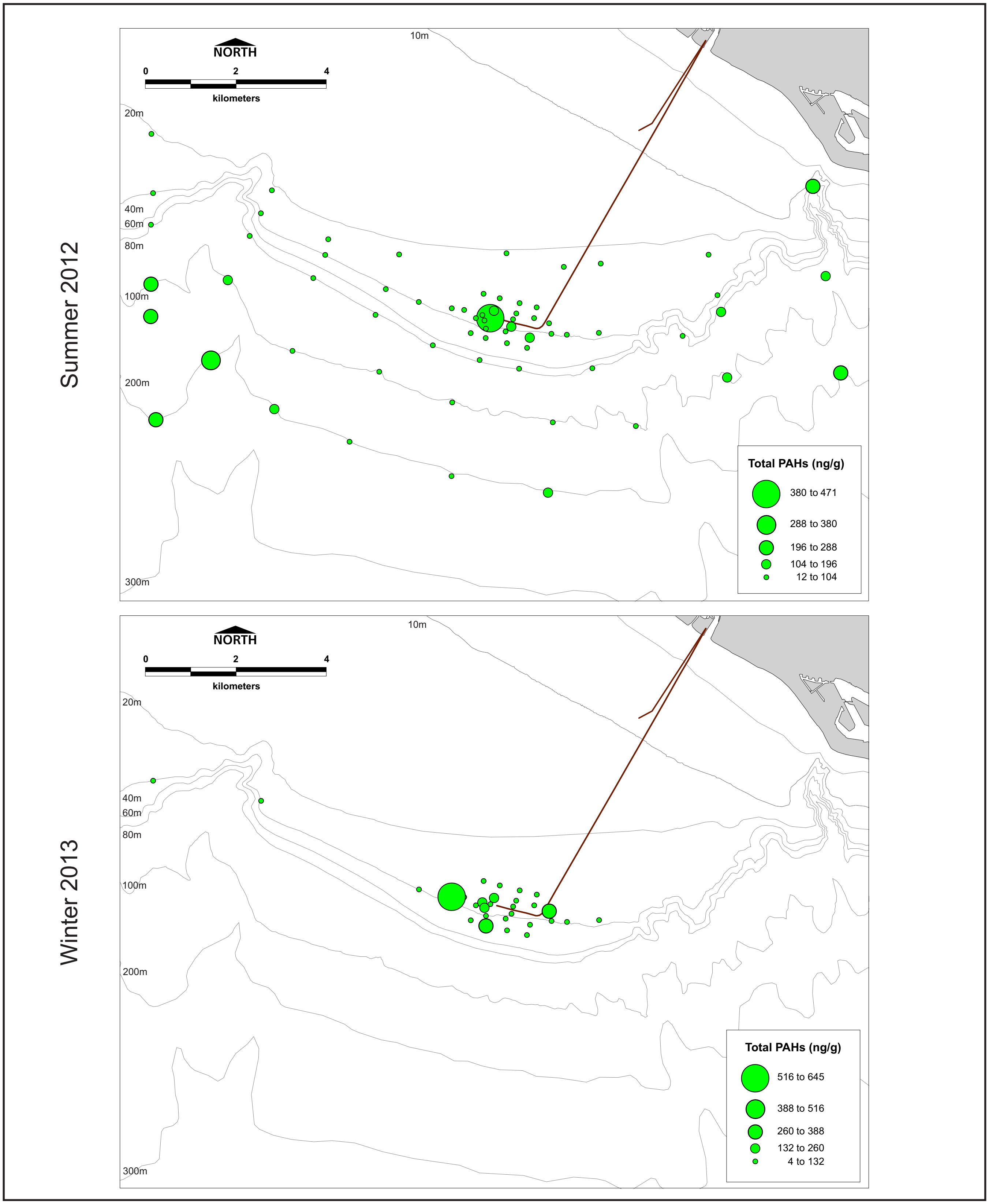

Figure 4-8. **Spatial trend bubble plots of tPAHs for Summer 2012 (top) and Winter 2013 (bottom).**

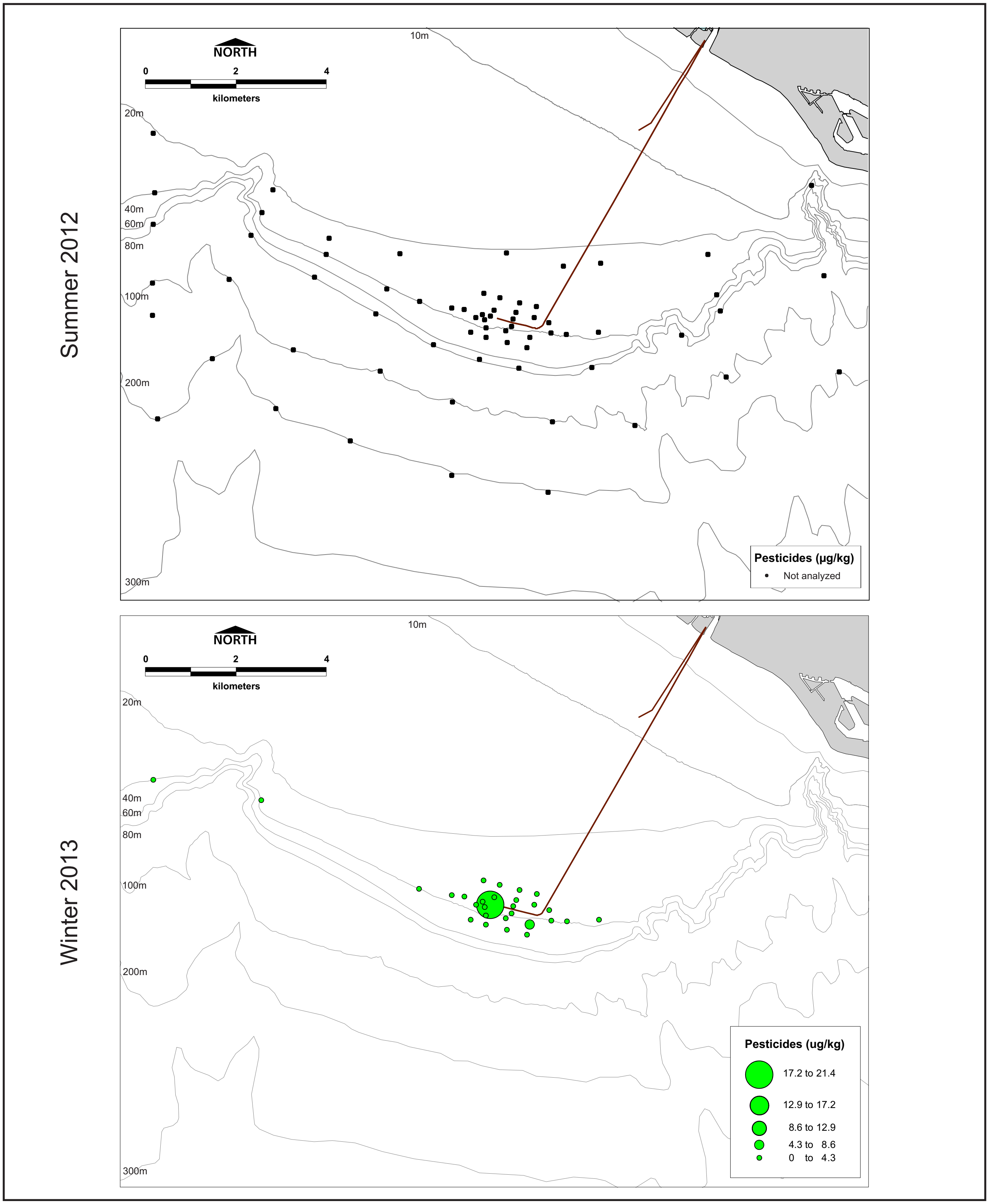

Figure 4-9. **Spatial trend bubble plots of total Other Chlorinated Pesticides for Summer 2012 (top) and Winter 2013 (bottom).**

Orange County Sanitation District, California.

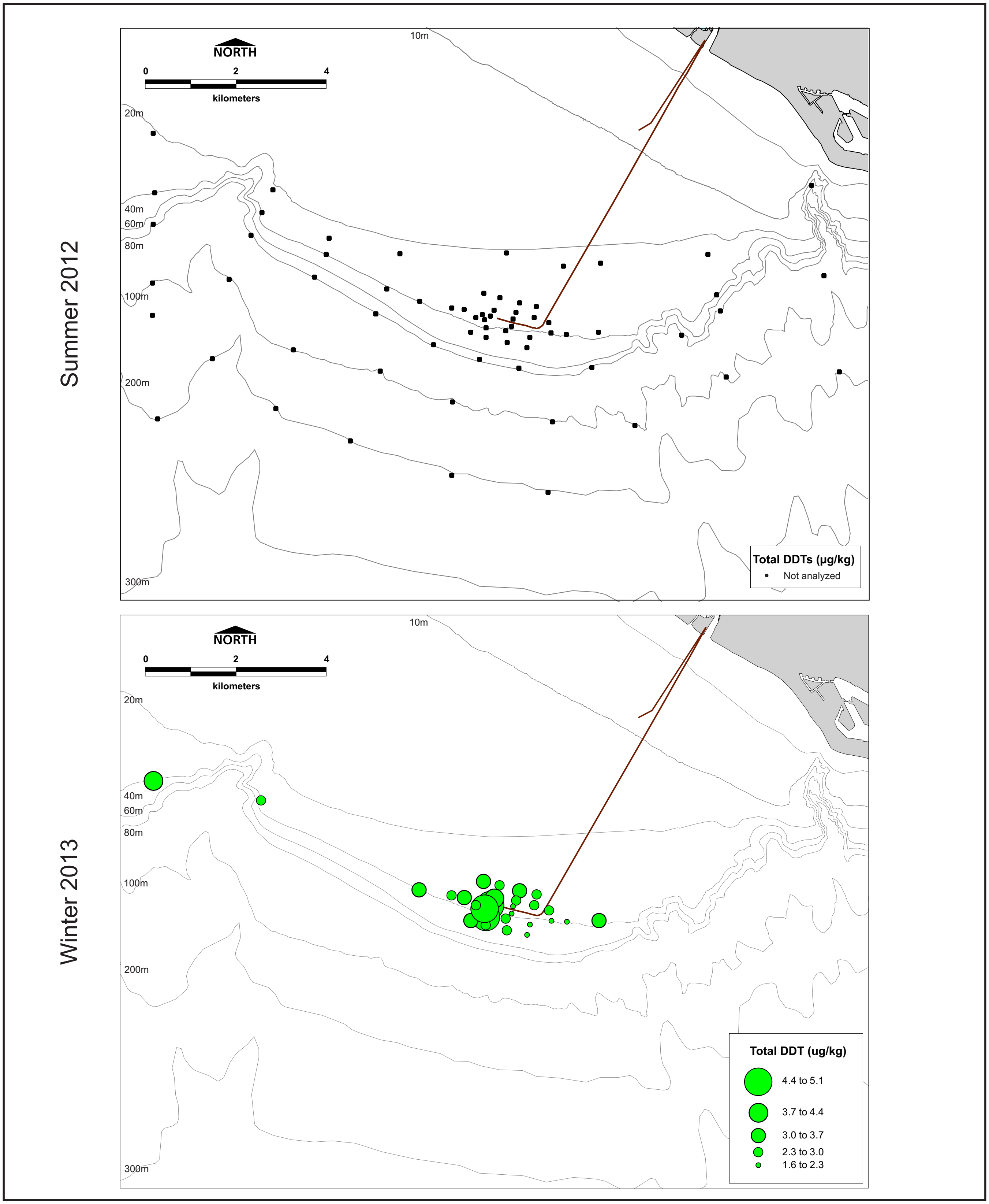

Figure 4-10. Spatial trend bubble plots of tDDTs for Summer 2012 (top) and Winter 2013 (bottom).

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 1970s (Schiff 2000).

Total Polychlorinated Biphenyls (tPCB)
In winter 2013, tPCB concentrations were low throughout the monitoring area with the exception of Station 3 (244 µg/kg) (Figure 4-11). Mean Zone 2 within-ZID and non-ZID station concentrations were 7.83 µg/kg at within-ZID stations and 16.4 µg/kg, respectively (Table 4-2). When Station 3 is removed, the non-ZID station mean is 6.89, which is comparable to the within-ZID station mean. Only Station 3 exceeded the ERM indicating a low possibility of toxicity to marine life. Most station concentrations were below the Bight'08 middle shelf AWM of 13.0 µg/kg. Concentrations were slightly higher near the outfall (Figure 4-4), but were well below levels of concern for marine life. There is no explanation for the high value at Station 3. Historically, Station 3 tPCB concentrations were consistently well below the ERM. Excluding Station 3, tPCB concentrations were slightly higher at Zone 2 within-ZID stations compared to the other outfall-depth stations indicating an outfall influence. This is consistent with previous years.

Metals
Generally, metal concentrations increased with increasing depth (Table 4-3). For both surveys, concentrations at the non-ZID middle shelf stations were comparable to or less than the middle shelf Bight'08 AWMs (Tables 4-3 and 4-4). In Winter 2013, within-ZID Station 4 and non-ZID Station 73 exceeded the ERM for silver. No other analyte in either survey exceeded the ERM which indicates a low probability for adverse effects on biota.

In July 2012, 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 4-12. Group A metals included antimony, arsenic, barium, beryllium, chromium, lead, nickel, selenium, and zinc. Group B consisted of cadmium, copper, mercury, and silver (Appendix B, Figure B-29). Group B metals were significantly correlated with tLAB. The distribution of metals at selected outfall-depth stations generally followed the Group A and B pattern (Figure 4-13).

Principal Components Analysis (PCA)
Principal Components Analysis (PCA) and non-metric multidimensional scaling (MDS) were performed using the July 2012 annual station data, including the 29 semi-annual stations (n = 68 stations) based on two principal components (Figure 4-14). PC1 accounted for 81% of the variability in the data and PC2 for 15% with a cumulative percent variation of approximately 96% (Table 4-5). The MDS analysis showed very low two-dimensional (2d) stress (0.03) and produced similar results to the PCA. 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 (-0.613) and zinc (-0.576). The negative values indicate that metals concentrations increase going from positive (right) to negative (left) along the PC1 axis in Figure 4-14. PC2 is more influenced by the sewage marker tLAB (-0.795), which increases moving from positive (top) to negative (bottom) along the PC2 axis. The 2012-13 tLAB eigenvector values for PC1

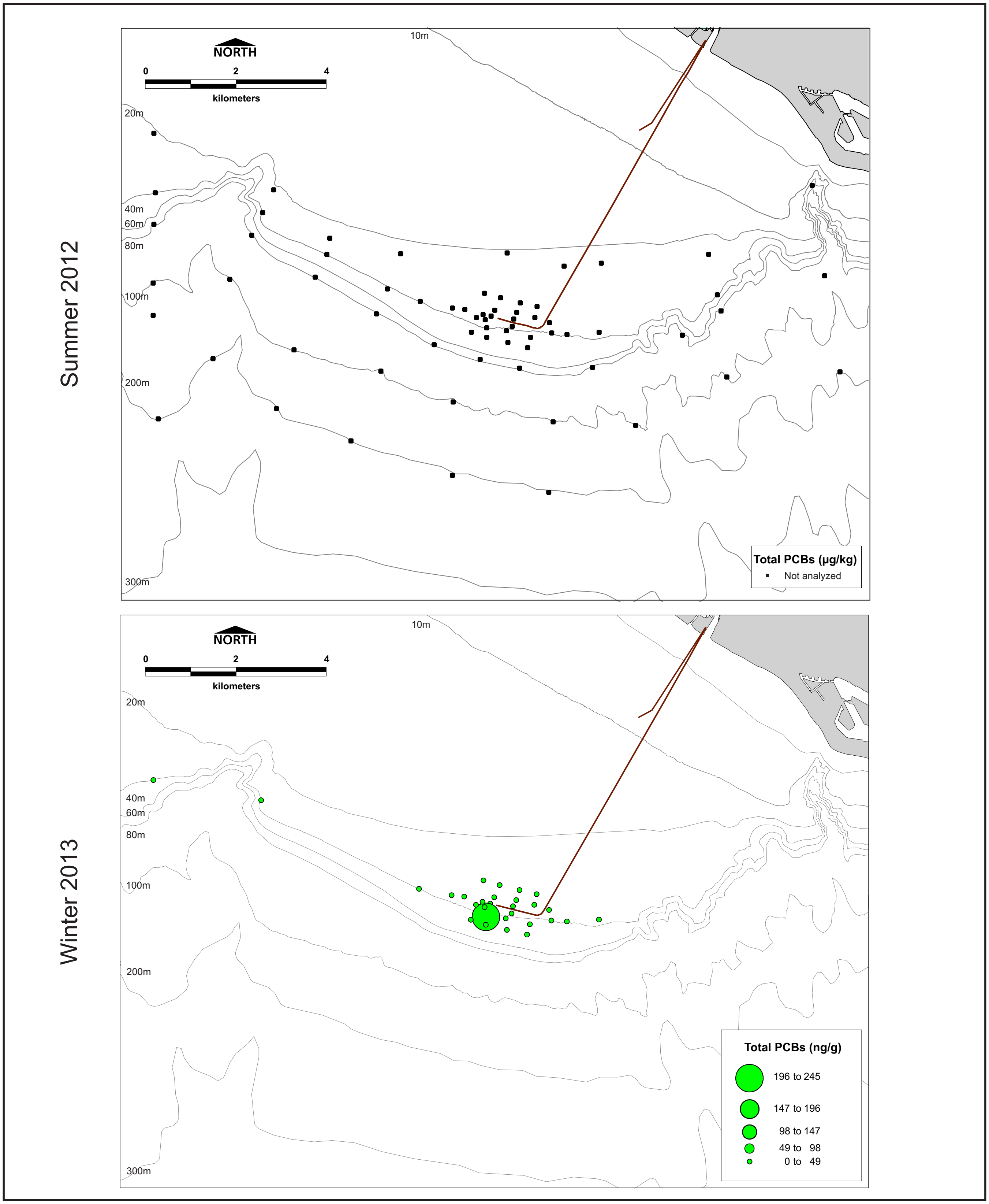

Figure 4-11. Spatial trend bubble plots of tPCBs for Summer 2012 (top) and Winter 2013 (bottom).

Table 4-3. Concentrations of sediment metals (mg/kg) at the District's annual and semi-annual stations in Summer 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)	Sb	As	Ba	Be	Cd	Cr	Cu	Pb	Hg	Ni	Se	Ag	Zn
Middle shelf Zone 1 (31-50 meters)														
7	41	<0.10	3.67	39.2	0.23	0.20	19.6	9.47	6.27	0.025	9.1	0.25	0.52	34.6
8	44	<0.10	3.40	48.9	0.25	0.23	21.1	10.2	6.20	0.021	10.0	0.18	0.15	38.5
21	44	<0.10	3.01	39.2	0.23	0.19	20.0	9.18	5.94	0.020	9.1	0.40	0.15	35.9
22	45	<0.10	3.57	43.0	0.26	0.20	20.4	9.40	6.05	0.021	10.1	<0.15	0.12	39.2
30	46	0.29	2.88	33.4	0.22	0.15	19.0	8.27	5.59	0.015	8.1	0.56	0.13	32.0
36	45	<0.10	3.22	48.8	0.26	0.20	20.3	9.55	6.32	0.019	10.7	0.39	0.08	40.0
55	40	<0.10	2.04	26.8	0.16	0.07	13.5	4.48	3.67	0.009	6.6	0.24	0.03	23.5
59	40	<0.10	2.73	30.3	0.18	0.11	15.6	6.08	4.44	0.013	7.4	0.31	0.07	26.7
	Mean	**0.08**	**3.07**	**38.7**	**0.22**	**0.17**	**18.7**	**8.33**	**5.56**	**0.018**	**8.9**	**0.30**	**0.16**	**33.8**
Middle shelf Zone 2, Non-ZID (51-90 meters)														
1*	56	<0.10	2.67	39.7	0.24	0.30	22.8	12.4	6.42	0.023	9.8	<0.15	0.23	41.8
3*	60	<0.10	2.67	37.2	0.26	0.22	21.2	11.6	4.51	0.025	10.1	0.35	0.17	44.6
5*	59	<0.10	2.72	46.5	0.25	0.25	25.0	12.6	6.35	0.021	11.1	<0.15	0.22	43.5
9*	59	<0.10	2.59	32.2	0.24	0.16	21.0	8.80	4.67	0.021	9.4	<0.15	0.11	38.5
10	60	<0.10	2.99	46.5	0.28	0.28	24.3	12.9	6.00	0.021	11.6	0.37	0.21	45.9
12*	58	<0.10	2.51	25.6	0.22	0.14	16.1	6.42	3.88	0.012	7.6	0.31	0.09	31.1
13	59	<0.10	3.06	45.4	0.24	0.21	23.6	10.8	5.98	0.021	10.6	0.18	0.16	41.6
37	56	<0.10	2.52	26.8	0.20	0.12	14.1	5.37	3.95	0.010	7.3	<0.15	0.05	28.1
68*	52	<0.10	3.46	40.6	0.26	0.29	22.7	11.6	5.65	0.020	10.3	0.44	0.21	41.1
69*	52	<0.10	2.91	39.6	0.25	0.28	22.2	11.2	5.45	0.021	9.9	0.21	0.20	41.1
70*	52	<0.10	2.94	36.3	0.25	0.27	21.9	10.2	5.76	0.018	9.8	<0.15	0.16	40.6
71*	52	<0.10	2.67	34.8	0.24	0.33	19.6	9.11	4.33	0.019	9.0	0.34	0.14	39.8
72*	55	<0.10	2.59	41.5	0.24	0.27	23.2	12.8	5.90	0.021	10.1	<0.15	0.23	41.6
73*	55	<0.10	2.86	32.6	0.23	0.53	22.4	14.6	5.75	0.058	9.2	0.97	0.24	43.8
74*	57	<0.10	3.41	35.4	0.24	0.29	20.2	9.71	4.32	0.015	9.4	0.34	0.13	40.5
75*	60	0.14	2.79	33.1	0.25	0.35	19.0	8.44	4.12	0.020	9.2	0.37	0.11	39.6
77*	60	<0.10	2.36	35.9	0.23	0.18	21.5	9.25	4.55	0.017	9.9	0.16	0.13	39.4
78*	63	<0.10	2.70	33.4	0.24	0.17	21.1	9.05	4.61	0.015	9.5	<0.15	0.12	37.9
79*	65	<0.10	2.88	40.1	0.28	0.20	20.7	11.8	5.00	0.024	9.9	0.38	0.19	41.8
80*	65	<0.10	3.48	45.3	0.36	0.15	23.0	12.6	5.20	0.011	12.8	0.37	0.10	48.1
81*	65	<0.10	2.30	37.3	0.29	0.15	20.3	9.19	4.19	0.012	10.1	0.32	0.12	39.8
82*	65	<0.10	2.41	34.5	0.27	0.13	19.4	8.86	4.05	0.012	9.6	0.34	0.10	38.7
84*	54	0.15	2.89	34.9	0.25	0.50	20.6	12.9	5.59	0.022	9.3	0.35	0.21	43.1
85*	57	<0.10	2.36	35.1	0.25	0.49	26.1	14.1	5.61	0.019	10.5	0.35	0.36	46.4
86*	57	<0.10	2.74	34.3	0.27	0.11	20.4	9.77	4.07	0.014	9.5	0.31	0.20	42.1
87*	60	<0.10	3.09	38.9	0.24	0.28	23.4	12.1	5.99	0.020	10.2	0.18	0.22	41.6
C*	56	<0.10	2.99	44.7	0.25	0.21	21.5	9.78	5.74	0.015	10.5	0.39	0.12	40.5
C2	56	<0.10	5.12	120	0.47	0.51	38.1	23.7	13.40	0.040	22.6	0.58	0.15	94.9
CON*	59	<0.10	2.59	45.3	0.27	0.16	22.7	9.91	6.22	0.016	10.8	0.36	0.12	40.7
	Mean	**0.06**	**2.87**	**40.5**	**0.26**	**0.26**	**22.0**	**11.1**	**5.42**	**0.020**	**10.3**	**0.29**	**0.17**	**42.7**
Middle shelf Zone 2, Within-ZID (51-90 m)														
0 *	56	<0.10	3.26	36.5	0.24	0.89	23.6	16.6	5.33	0.029	9.8	0.36	0.27	49.8
4 *	56	<0.10	2.53	34.9	0.25	0.21	22.6	10.2	4.66	0.015	9.8	<0.15	0.13	42.0
76 *	58	<0.10	2.71	33.9	0.28	0.24	22.3	10.6	3.86	0.044	11.2	0.30	0.17	40.5
ZB *	56	<0.10	3.08	37.3	0.25	0.30	19.6	9.52	3.96	0.046	9.5	0.31	0.13	40.7
	Mean	**<0.10**	**2.90**	**35.7**	**0.26**	**0.41**	**22.0**	**11.7**	**4.45**	**0.034**	**10.1**	**0.26**	**0.17**	**43.3**

Table 4-3 Continues.

Table 4-3 Continued.

Station	Depth (m)	Sb	As	Ba	Be	Cd	Cr	Cu	Pb	Hg	Ni	Se	Ag	Zn
Middle shelf Zone 3 (91-120 meters)														
17	91	<0.10	2.31	38.7	0.28	0.15	20.6	9.71	4.97	0.014	10.8	0.34	0.10	42.6
18	91	<0.10	2.79	44.6	0.29	0.15	24.2	9.94	5.55	0.015	11.7	0.15	0.10	43.3
20	100	<0.10	3.21	54.8	0.29	0.23	25.5	13.0	6.63	0.018	12.4	0.30	0.18	47.7
23	100	<0.10	2.96	36.5	0.26	0.19	21.2	7.92	5.03	0.012	10.5	0.17	0.07	40.0
29	100	0.16	2.68	71.5	0.31	0.32	26.5	14.4	6.94	0.030	13.0	0.52	0.23	48.2
33	100	<0.10	2.37	27.3	0.22	0.16	16.2	5.85	3.88	0.014	8.6	0.32	0.06	33.6
38	100	<0.10	3.59	67.2	0.30	0.41	26.4	12.3	6.84	0.020	13.9	0.26	0.12	50.3
56	100	0.13	3.26	67.9	0.32	0.26	27.6	14.5	7.35	0.019	13.8	0.55	0.19	50.3
60	100	<0.10	3.18	60.7	0.31	0.28	26.6	13.9	6.82	0.025	13.0	0.50	0.20	47.8
83	100	<0.10	2.67	44.9	0.27	0.17	24.1	10.4	5.81	0.012	11.5	0.19	0.12	43.3
	Mean	**0.07**	**2.90**	**51.4**	**0.28**	**0.23**	**23.9**	**11.2**	**5.98**	**0.018**	**11.9**	**0.33**	**0.14**	**44.7**
Outer Shelf (121-200 meters)														
24	200	<0.10	3.16	85.1	0.38	0.41	32.5	16.8	7.94	0.027	16.9	0.41	0.19	58.4
25	200	<0.10	3.66	122	0.42	0.52	41.3	24.3	10.80	0.031	20.3	0.86	0.32	68.6
27	200	<0.10	3.28	71.3	0.36	0.33	28.1	14.1	6.75	0.024	15.1	0.67	0.14	54.1
39	200	0.19	3.08	49.2	0.30	0.25	24.6	10.6	5.62	0.013	12.8	0.75	0.10	44.5
57	200	0.16	5.30	164	0.50	0.75	53.4	39.0	15.20	0.049	24.9	1.04	0.68	80.6
61	200	<0.10	4.67	142	0.44	0.69	47.5	32.3	13.10	0.049	22.4	0.73	0.57	76.1
63	200	<0.10	3.54	177	0.37	0.43	35.0	19.9	9.35	0.025	17.4	0.50	0.26	60.4
65	200	<0.10	4.06	75.0	0.35	0.50	29.1	16.0	7.98	0.022	16.4	0.66	0.17	56.1
C4	187	<0.10	6.28	121	0.55	0.74	43.2	27.1	13.30	0.037	24.4	0.82	0.28	90.1
	Mean	**0.08**	**4.11**	**111.8**	**0.41**	**0.51**	**37.2**	**22.2**	**10.00**	**0.031**	**19.0**	**0.71**	**0.30**	**65.4**
Upper Slope/Canyon (201-500 meters)														
40	303	0.13	3.74	96.9	0.44	0.44	36.5	19.6	8.57	0.017	19.1	0.88	0.18	61.1
41	303	0.13	3.50	93.0	0.44	0.36	36.8	19.8	8.37	0.017	19.2	0.86	0.17	61.2
42	303	0.15	4.24	125	0.50	0.51	44.1	24.9	10.50	0.023	22.5	1.08	0.27	70.5
44	241	0.21	7.30	210	0.59	1.08	61.3	49.6	18.70	0.059	27.6	1.21	0.97	91.6
58	300	0.30	6.62	207	0.57	0.72	58.4	36.3	15.50	0.030	28.1	1.38	0.52	87.1
62	300	0.30	7.22	193	0.57	0.85	58.2	40.5	16.00	0.048	27.4	1.60	0.63	87.1
64	300	0.17	6.66	141	0.50	0.61	42.3	26.8	11.40	0.029	22.9	1.06	0.30	101.0
C5	296	0.19	6.84	134	0.61	0.89	50.8	34.8	15.40	0.043	26.9	1.19	0.46	88.0
	Mean	**0.20**	**5.77**	**150**	**0.52**	**0.68**	**48.6**	**31.5**	**13.06**	**0.033**	**24.2**	**1.16**	**0.44**	**81.0**
SEDIMENT QUALITY GUIDELINES														
[1] ERL		NA	8.20	NA	NA	1.20	81.0	34.0	46.7	0.15	20.9	NA	1.00	150
[1] ERM		NA	70.0	NA	NA	9.60	370	270	218	0.70	51.6	NA	3.70	410
[2] Bight '08 AWM Mid-shelf		NA	6.1	NA	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		NA	6.1	NA	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		NA	8.8	NA	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.

[1] Long *et al*. (1995)

[2] Schiff *et al*. (2011)

Table 4-4. Concentrations of sediment metals (mg/kg) at the District's semi-annual stations in Winter 2013 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)	Sb	As	Ba	Be	Cd	Cr	Cu	Pb	Hg	Ni	Se	Ag	Zn
Middle shelf Zone 2, Non-ZID (51-90 meters)														
0	56	0.14	2.92	31.9	0.29	0.86	29.3	20.7	10.9	0.073	10.2	0.36	0.29	54.2
3	60	<0.10	3.43	36.1	0.30	0.33	20.7	12.3	4.58	0.016	9.9	0.40	0.25	50.2
5	59	<0.10	2.89	39.5	0.31	0.34	19.8	12.1	5.06	0.019	10.7	0.43	0.27	46.5
9	59	<0.10	3.05	31.6	0.27	0.24	19.3	8.07	3.84	0.010	8.7	0.45	0.16	40.7
12	58	<0.10	2.14	33.6	0.26	0.24	18.7	8.89	4.31	0.012	8.8	0.36	0.42	41.4
68	52	<0.10	3.03	38.4	0.27	0.35	19.6	11.8	4.85	0.018	10.0	0.45	0.47	45.7
69	52	<0.10	3.46	40.7	0.27	0.37	20.2	11.1	4.77	0.036	9.6	0.46	0.32	45.8
70	52	<0.10	3.41	36.0	0.27	0.34	18.0	9.61	4.01	0.011	8.7	0.43	0.26	40.2
71	52	<0.10	2.75	32.8	0.31	0.36	18.6	8.82	4.12	0.013	9.4	<0.15	1.00	44.3
72	55	<0.10	2.86	36.1	0.26	0.31	18.0	10.0	4.53	0.017	8.6	0.36	0.29	42.3
73	55	<0.10	3.62	36.2	0.30	0.80	25.7	21.6	5.63	0.021	10.4	<0.15	**5.46**	58.7
74	57	0.12	3.46	37.8	0.28	0.37	19.4	9.88	4.23	0.012	9.5	0.44	0.23	44.3
75	60	<0.10	2.40	29.7	0.26	0.36	17.0	8.83	3.40	0.012	8.5	0.30	1.64	42.4
77	60	0.13	2.44	31.9	0.27	0.23	18.3	8.77	3.97	0.011	9.2	0.34	0.37	42.3
78	63	0.11	2.81	28.3	0.29	0.25	17.3	8.36	3.88	0.011	8.6	0.34	2.28	41.9
79	65	<0.10	2.43	40.4	0.27	0.29	19.2	11.6	4.50	0.013	10.2	0.41	0.33	45.7
80	65	<0.10	3.86	42.0	0.38	0.25	21.0	12.0	4.70	0.010	12.2	0.46	0.22	53.1
81	65	<0.10	2.29	35.5	0.32	0.23	18.6	10.7	4.03	0.010	9.6	0.45	0.85	43.1
82	65	<0.10	2.56	36.8	0.32	0.22	18.4	8.33	3.61	0.008	9.6	0.44	0.25	43.2
84	54	<0.10	3.27	38.2	0.28	0.45	19.9	11.3	4.66	0.016	9.4	0.39	0.30	45.8
85	57	<0.10	3.05	32.4	0.27	0.58	23.5	13.6	5.54	0.034	10.6	0.41	1.00	49.1
86	57	0.10	2.71	42.0	0.28	0.54	21.4	12.5	5.06	0.025	9.4	0.47	0.39	50.3
87	60	<0.10	2.80	35.3	0.30	0.28	18.9	10.7	3.92	0.019	9.4	0.43	0.20	45.3
C	56	<0.10	2.85	38.1	0.24	0.21	17.5	8.57	4.50	0.013	9.4	0.38	0.37	40.0
CON	59	<0.10	2.88	45.2	0.28	0.22	20.1	9.22	4.97	0.012	10.3	0.46	0.17	44.6
	Mean	**0.06**	**2.93**	**36.3**	**0.29**	**0.36**	**19.9**	**11.17**	**4.70**	**0.018**	**9.6**	**0.40**	**0.71**	**45.6**
Middle shelf Zone 2, Within-ZID (51-90 meters)														
0 *	56	<0.10	2.78	37.2	0.27	0.41	19.8	11.3	4.88	0.018	8.9	0.41	0.47	46.7
4 *	56	<0.10	3.45	30.8	0.28	0.22	20.1	10.0	4.50	0.011	9.4	<0.15	**7.00**	45.6
76 *	58	<0.10	2.77	36.3	0.30	0.26	19.6	9.88	4.00	0.011	9.3	0.44	0.18	45.7
ZB *	56	<0.10	3.16	34.4	0.27	0.42	19.2	10.1	3.74	0.014	9.9	0.43	0.21	45.6
	Mean	**<0.10**	**3.04**	**34.7**	**0.28**	**0.33**	**19.7**	**10.32**	**4.28**	**0.014**	**9.4**	**0.34**	**1.96**	**45.9**
SEDIMENT QUALITY GUIDELINES														
[1] ERL		NA	8.20	NA	NA	1.20	81.0	34.0	46.7	0.15	20.9	NA	1.00	150
[1] ERM		NA	70.0	NA	NA	9.60	370	270	218	0.70	51.6	NA	3.70	410
[2] Bight '08 AWM Mid-shelf		NA	6.1	NA	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		NA	6.1	NA	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		NA	8.8	NA	0.29	1.4	68.0	22.8	15.0	0.09	29.0	1.60	1.60	79.0

Bolded station values exceed the ERM.

NA = Not applicable. All stations n=1.

[1] Long *et al*. (1995)

[2] Schiff *et al*. (2011)

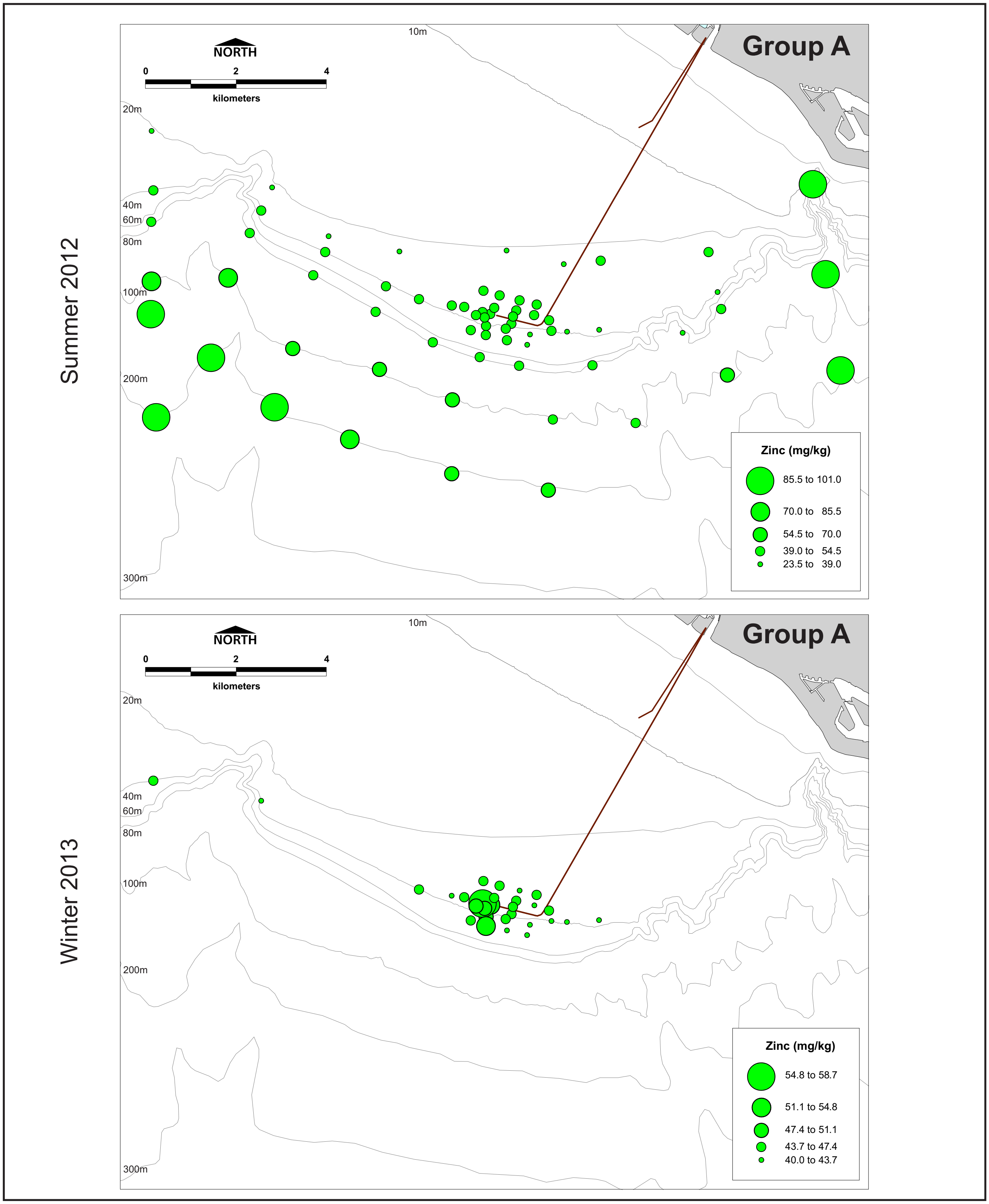

Figure 4-12. **Spatial trend bubble plots of representative Group A metals (zinc) and Group B metals (cadmium) for Summer 2012 (top) and Winter 2013 (bottom).**

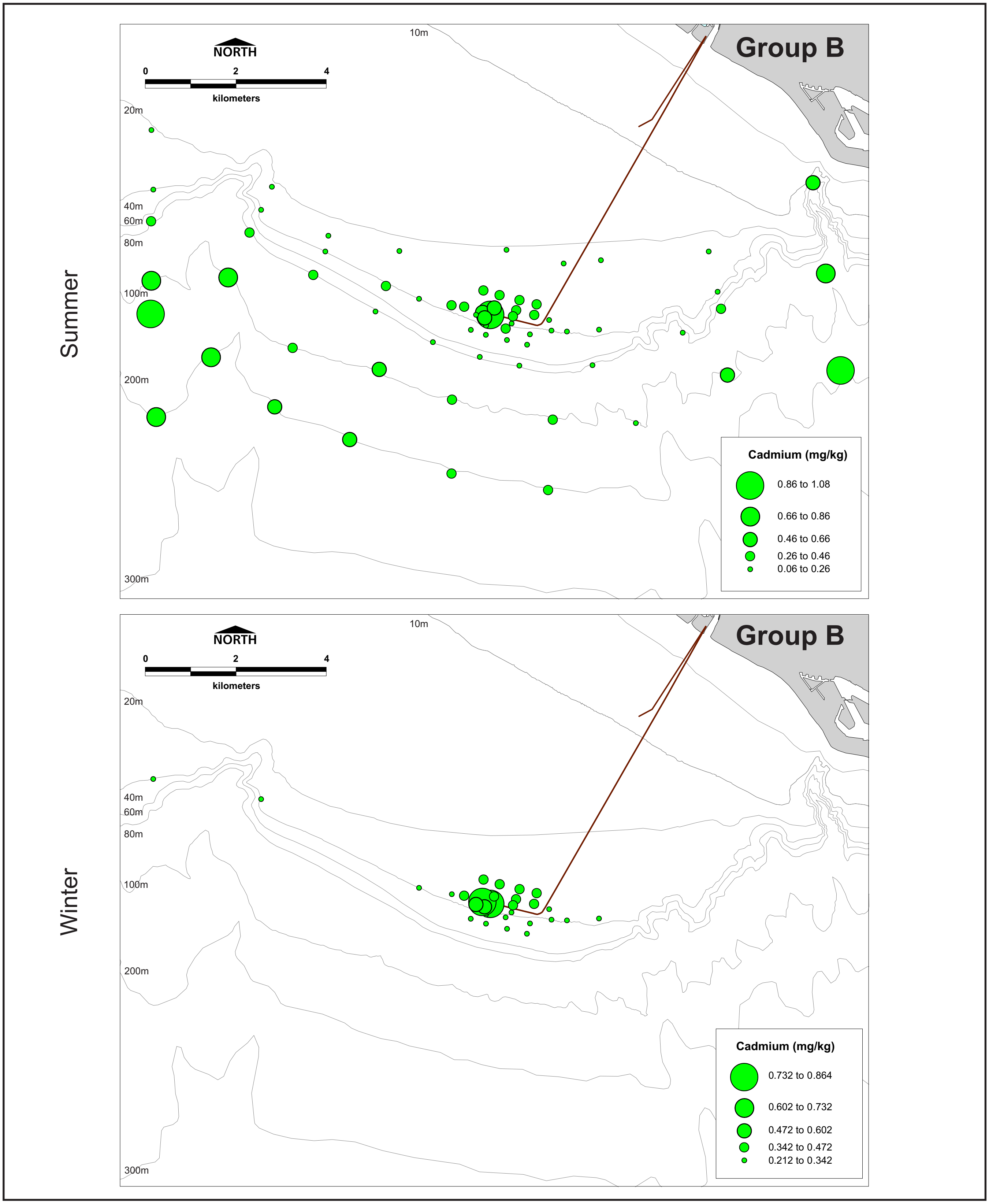

Figure 4-12 continued.

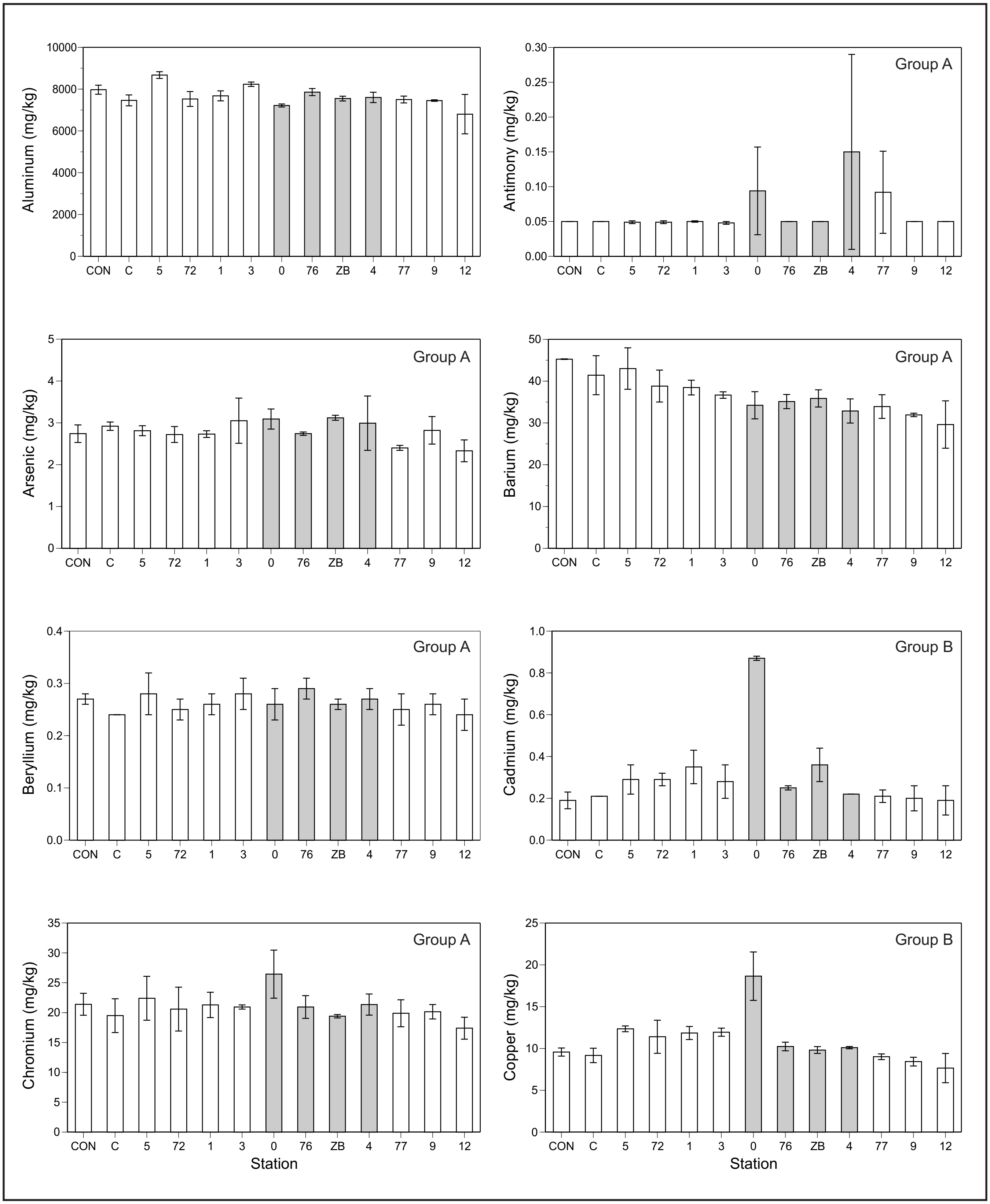

Figure 4-13. Distribution of mean and standard deviation values (mg/kg) for aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, copper, iron, lead, mercury, nickel, selenium, silver, and zinc in sediments at the 60 m shelf stations during 2012-13.
Stations plotted from north to south (left to right). ZID stations indicated in gray.

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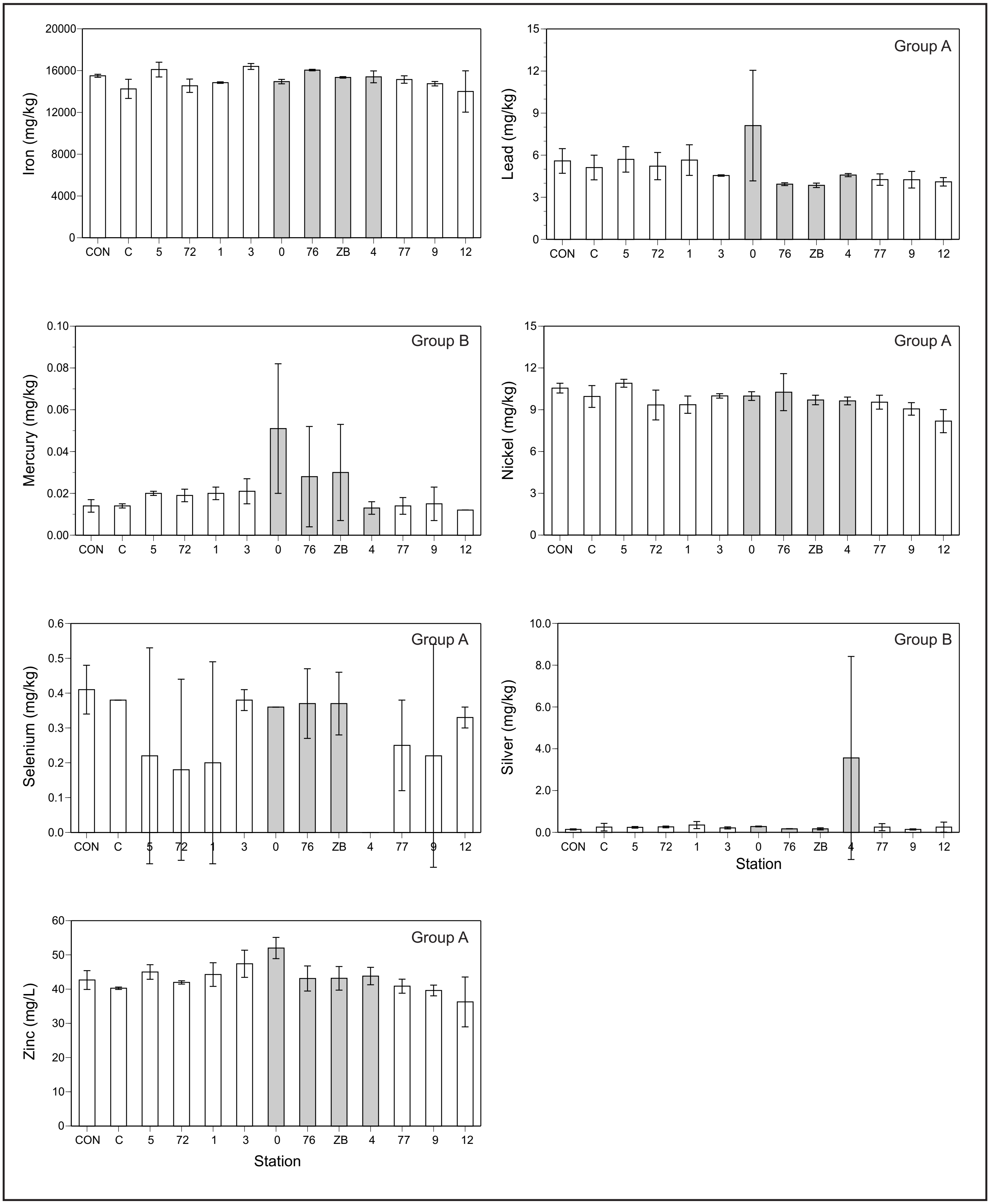

Figure 4-13 continued.

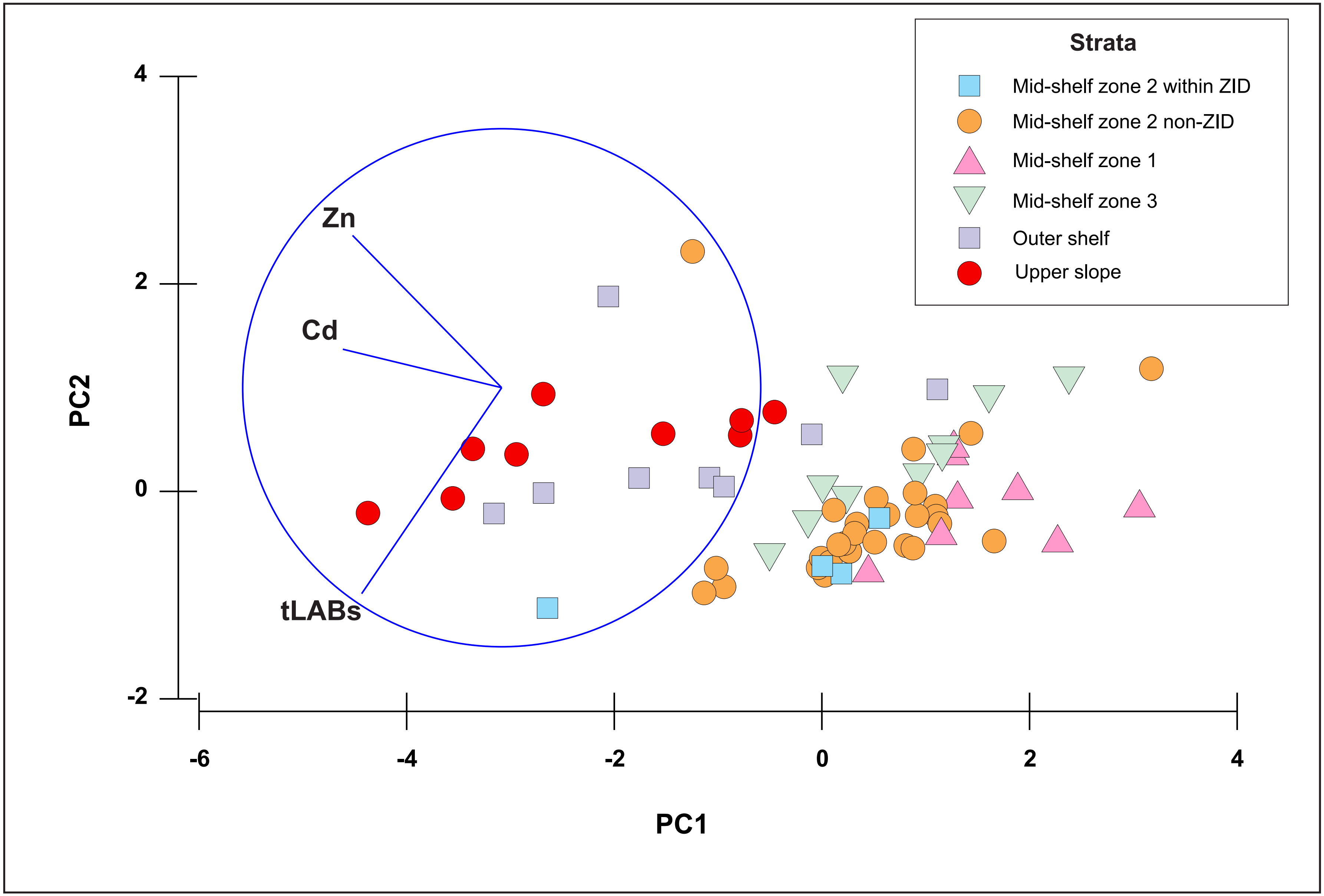

Figure 4-14. **Station plot of principal components analysis (PCA) for sediment geochemistry in July 2012. Station symbols correspond to depth strata groupings.**

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and PC2 are more similar to each other than in 2011-12. This indicates that tLAB is less of a factor in determining sediment geochemistry distributions than it was last year.

Table 4-5. Eigenvalues and Eigenvectors from the principal components analysis performed on the July 2012 annual survey data.

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Eigenvalues			
Principal Component	**Eigen Value**	**Percent Variation**	**Cumulative Percent Variation**
1	2.44	81.2	81.2
2	0.44	14.7	95.9
Eigenvectors			
Factor	**Principal Component 1**	**Principal Component 2**	
tLAB	-0.540	-0.795	
Cadmium	-0.613	0.149	
Zinc	-0.576	0.588	

The stations at the positive end of PC1 tend to be shallower and have lower concentrations of the two metals than at the negative end, which has deeper stations with higher percent fine sediments and higher metals concentrations. The stations towards the bottom of Figure 4-14 have higher tLAB levels than those towards the top. Therefore, the location of stations along PC1 is more influenced by the depositional nature of the sediments, whereas the location of stations along PC2 is more influenced by the outfall discharge. These results indicate that station depth, most likely percent fine sediment, is a greater factor than the outfall discharge in determining the pattern of deposition of sediment geochemistry analytes in the monitoring area.

Long-term (Temporal) Trend Analysis

Most patterns for selected 60 m depth stations for all sediment measures showed there were no noteworthy differences from historical station variability (OCSD 2013) and within non-ZID station groups were at concentrations that are not of biological concern (i.e., below ERM values). Most measures showed either no significant change or a decrease over time since 1999 at most 60 m stations (Figure 4-15). Since 1999, beryllium and nickel have increased slightly, but at a comparable rate at all stations indicating an area-wide influence.

Sediment Toxicity

Whole-sediment toxicity testing was conducted on sediments collected from nine stations in March 2013. No toxicity was indicated in any of the samples (Table 4-6). This is in contrast to the previous years (2009–11) 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 in 2005 and continued through 2011. See Chapters 5 and 7 for additional information on the decline and subsequent recovery of invertebrate communities in the monitoring area.

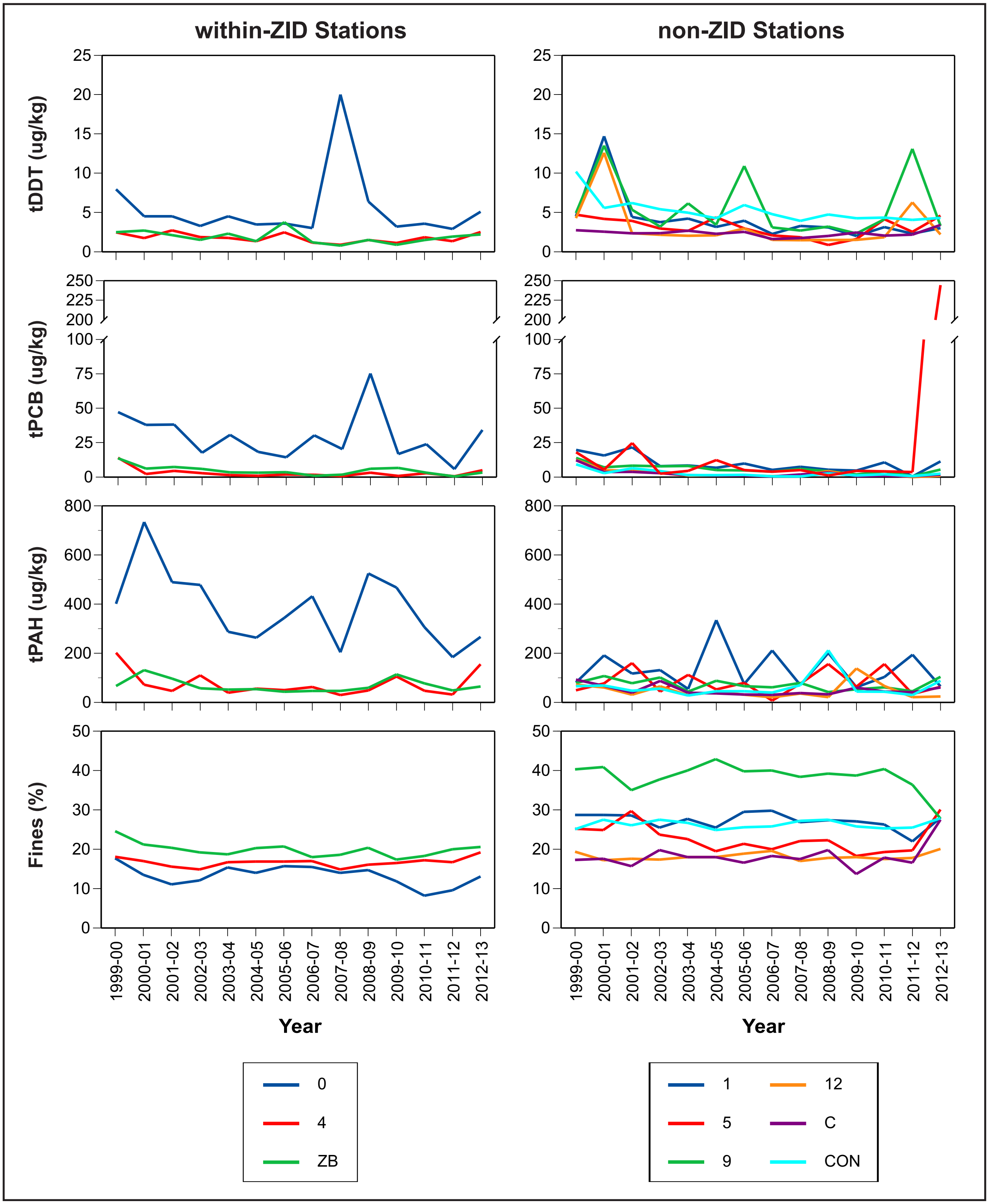

Figure 4-15. **Changes over time for total DDT, total PCB, total PAH, % fines, sulfides[1], total organic carbon, arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, and zinc in sediments at the 60 m shelf station groups during 1999–2013.**

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

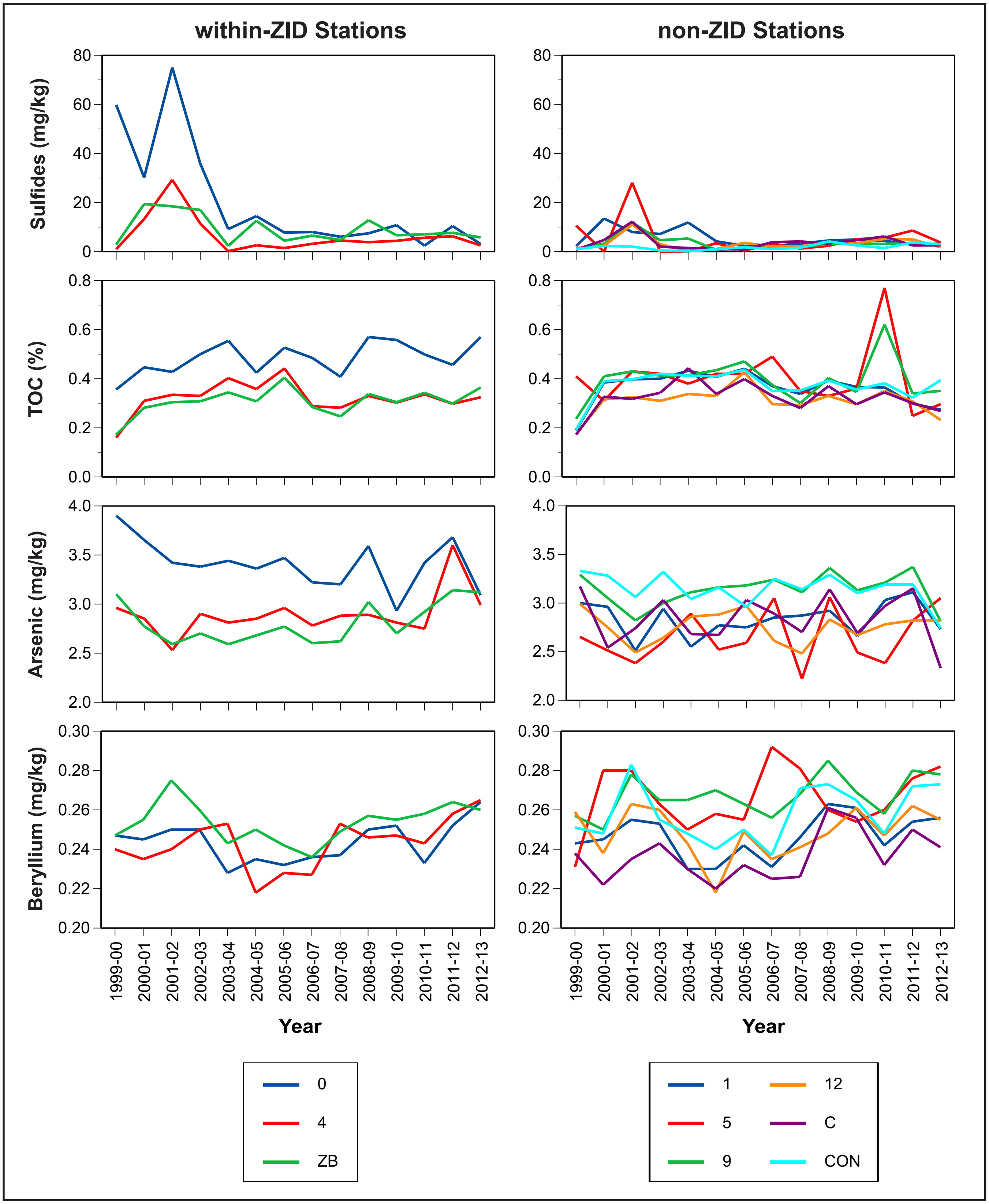

Figure 4-15 continued.

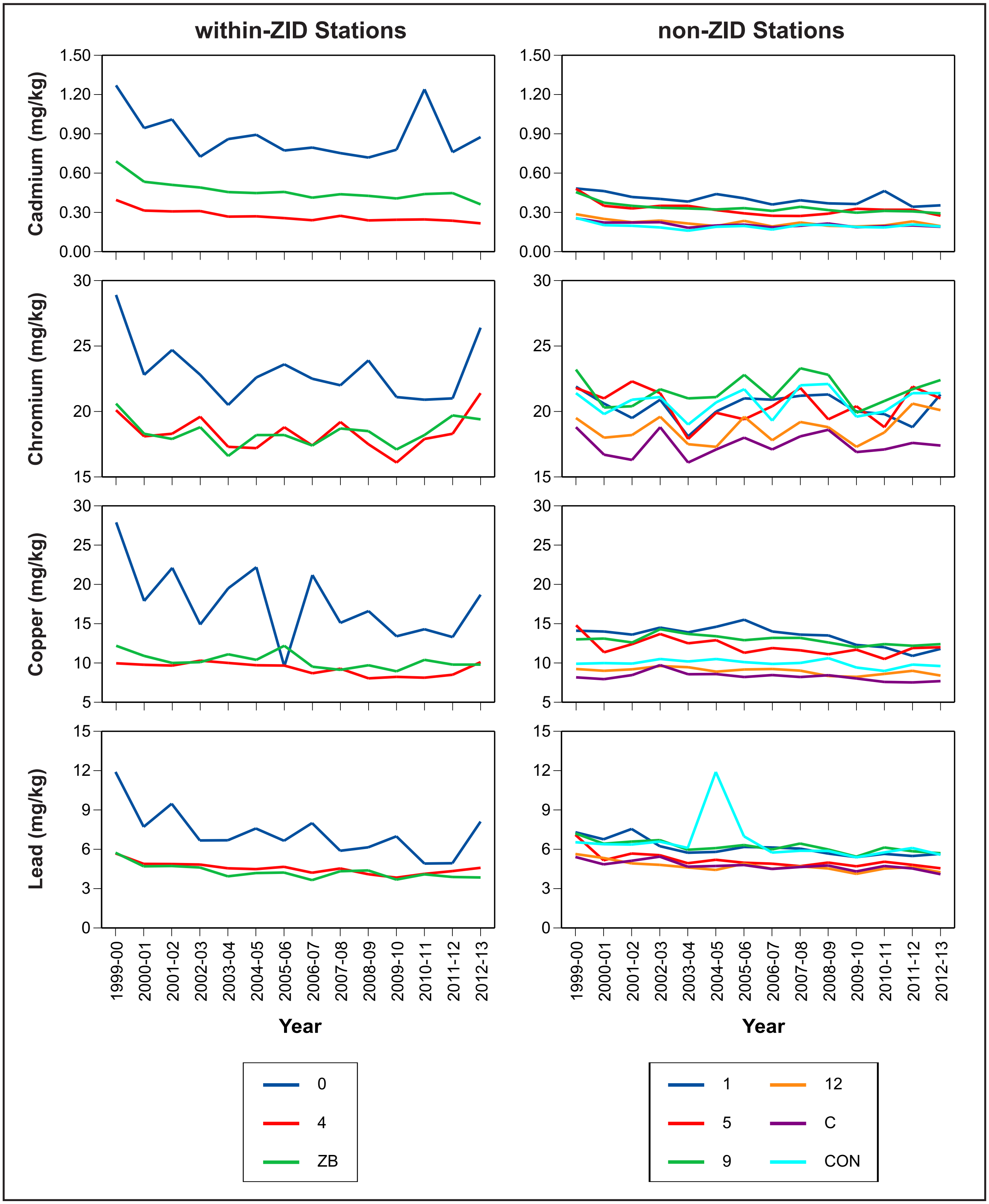

Figure 4-15 continued.

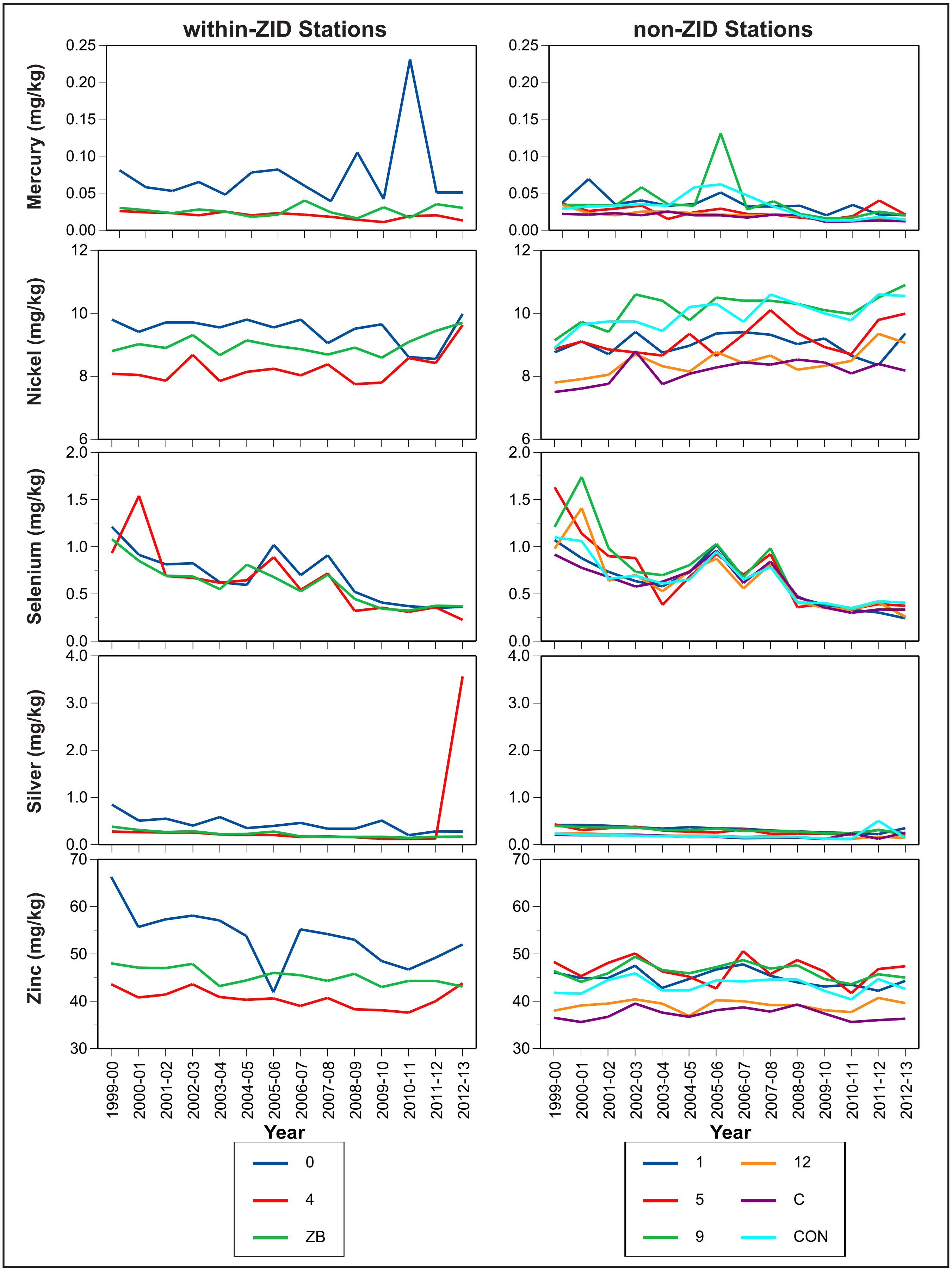

Figure 4-15 continued.

Table 4-6. Whole-sediment *Eohaustorius estuarius* (amphipod) sediment toxicity test results for March 2013. Test results given as the difference between test sediment percent survival vs. home sediment percent survival.

Orange County Sanitation District, California.

Date	Station								
	CON	**72**	**1**	**73**	**0**	**76**	**ZB**	**4**	**77**
March 2013	2.1	0	3.1	-2.1	3.1	1.0	4.1	1.0	1.0
Historical Results									
2011-12	0.7	NS	0.7	-3.1	0	0.5	1.1	0.3	0.5
2010-11	1.0	NS	3.5	NS	**10.6**	NS	4.0	3.5	NS
2009-10	2.6	NS	2.5	NS	**22.7**	NS	1.0	1.0	NS

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).

NS = Not Sampled

.

Table 4-7. Mean Effects Range-Medium Quotient (mERMq) values for sediment contaminant concentrations at sediment toxicity stations in March 2013.

Orange County Sanitation District, California.

Date	Station								
	CON	**72**	**1**	**73**	**0**	**76**	**ZB**	**4**	**77**
March 2013	0.03	0.04	0.05	**0.22**	0.08	0.04	0.03	**0.24**	0.03
Historical Results									
2011-12 Mean	0.04	0.06	0.03	0.06	0.05	0.14	0.03	0.02	0.04
2010-11 Mean	0.03	NS	0.04	NS	0.06	NS	0.03	0.02	NS
2009-10 Mean	0.03	NS	0.03	NS	0.06	NS	0.03	0.03	NS

For 2012-13 results: n = 2; historical results: n = 4, historical results excluding Station 3: 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.

In 2012-13, seven of nine samples tested for whole-sediment toxicity were below the mERMq threshold (i.e., mERMq > 0.11) indicating low potential for toxicity (Table 4-7). Stations 4 (mERMq = 0.24) and 73 (mERMq = 022) were above the threshold, which indicates a moderate potential for high toxicity. The high values at both stations were driven by a high concentration in the winter survey of silver (Station 4, 7.00 mg/kg; Station 73, 5.46 mg/kg), which exceeded the ERM. In contrast, the silver concentration in July 2012 was 0.24 mg/kg at Station 73 and 0.13 mg/kg at Station 4. However, since testing indicated no measurable toxicity in the sediments from these stations, the silver may not have been in a bioavailable form.

CONCLUSIONS

Sediment geochemistry results from the 2012-13 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 over time in organic chemical constituents, with nearly all concentrations below the ERM thresholds. Metal constituents outside the ZID are generally at concentrations below that of biological concern with no clear outfall-related temporal trends. This was corroborated by the absence of measurable sediment toxicity. Principal Components Analysis indicated that the influence of the wastewater discharge was less than the year before. This suggests that the decrease in the discharge of effluent solids due to increased wastewater treatment may be having a positive effect on the receiving environment.

Overall, these results suggested that there were some minor effects to sediment quality, but they are mainly localized very near the outfall or in depositional areas, such as the outer shelf and upper slope/submarine canyons, but these effects are not of a magnitude that should cause adverse effects on marine communities.

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