Chapter 4. Sediment Characteristics

INTRODUCTION

Ocean sediment samples are collected and analyzed as part of the South Bay Ocean Outfall (SBOO) monitoring program to characterize the surrounding physical environment and assess general sediment conditions. These conditions define the primary habitat for benthic invertebrates that live within or on the surface of sediments and can influence their presence and distribution. In addition, many species of demersal fish are associated with specific sediment types that reflect the habitats of their preferred prey (Cross and Allen 1993). Both natural and anthropogenic factors affect the composition, distribution, and stability of seafloor sediments.

Natural factors that affect sediment conditions on the continental shelf include the strength and direction of bottom currents, exposure to wave action, seafloor topography, inputs associated with outflows from rivers and bays, beach erosion, runoff from other terrestrial sources, and decomposition of calcareous organisms (e.g., Emery 1960). The analysis of parameters such as sediment grain size and the relative percentages of different sediment fractions (e.g., sand, silt, and clay) can provide useful information about current velocity, amount of wave action, and overall habitat stability in an area. Further, understanding sediment particle size distributions facilitates interpretation of the interactions between benthic organisms and the environment. For example, differences in sediment composition (e.g., fine vs. coarse particles) and associated levels of organic loading at a site can affect the burrowing, tube building, and feeding abilities of infaunal invertebrates, thus affecting benthic community structure (Gray 1981, Snelgrove and Butman 1994). Geological history can also affect the chemical composition of local sediments. For example, erosion from coastal cliffs and shores, and flushing of terrestrial sediments and debris from bays, rivers, and streams can contribute to the deposition and accumulation of metals or other contaminants and also affect the overall organic content of sediments. Additionally, primary productivity by phytoplankton is a major source of organics to these sediments (Mann 1982, Parsons et al. 1990). Finally, particle size composition can affect concentrations of chemical constituents within sediments. For example, levels of organic compounds and trace metals within ocean sediments generally rise with increasing amounts of fine particles (Emery 1960, Eganhouse and Venkatesan 1993).

Municipal wastewater outfalls are one of many anthropogenic factors that can directly influence the composition and distribution of sediments through the discharge of treated effluent and the subsequent deposition of a wide variety of organic and inorganic compounds. Some of the most commonly detected compounds discharged via ocean outfalls are trace metals, pesticides, and various organic compounds such as organic carbon, nitrogen, and sulfides (Anderson et al. 1993). Moreover, the presence of large outfall pipes and associated ballast materials (e.g., rock, sand) may alter the hydrodynamic regime in surrounding areas.

This chapter presents summaries and analyses of sediment particle size and chemistry data collected during 2008 at monitoring sites surrounding the SBOO. The primary goals are to: (1) assess possible effects of wastewater discharge on benthic habitats by analyzing spatial and temporal variability of various sediment parameters, (2) determine the presence or absence of sedimentary and chemical footprints near the discharge site, and (3) evaluate overall sediment quality in the region.

MATERIALS AND METHODS

Field Sampling

Sediment samples were collected at 27 benthic stations in the SBOO region during January and July 2008 (Figure 4.1). These stations range in depth from 18 to 60 m distributed along or adjacent

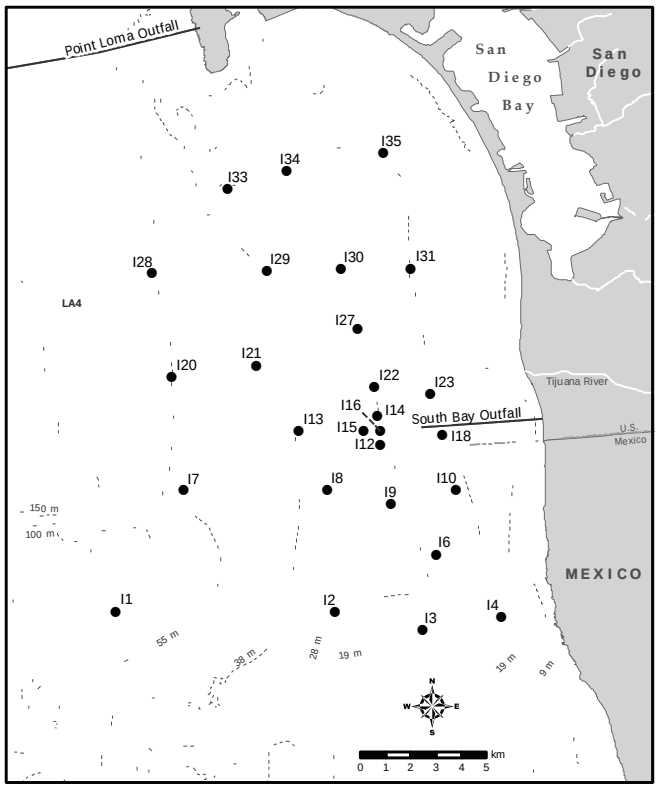

Figure 4.1
Benthic station locations where sediments are sampled for the South Bay Ocean Outfall Monitoring Program.

to four main depth contours. Each sediment sample was collected from one side of a chain-rigged double Van Veen grab with a 0.1-m^2 surface area; the other grab sample from the cast was used for macrofaunal community analysis and visual observations of sediment composition (see Chapter 5). Sub-samples for various analyses were taken from the top 2 cm of the sediment surface and handled according to EPA guidelines (USEPA 1987).

Laboratory Analyses

All sediment chemistry and particle size analyses were performed at the City of San Diego's Wastewater Chemistry Services Laboratory. Particle size analysis was performed using a Horiba LA-920 laser scattering particle analyzer, which measures particles ranging in size from 0.00049 to 2.0 mm (i.e., 11 to -1 phi). Coarser sediments (e.g., coarse sand, gravel, shell hash) were removed prior to analysis by screening the samples through a 2.0-mm mesh sieve. These data were expressed as "% coarse" of the total sample sieved. Output from the Horiba particle size analyzer was categorized into sand, silt, and clay fractions as follows: sand was defined as particles ranging between 2.0 and >0.0625 mm in diameter, silt as particles between 0.0625 and 0.0039 mm, and clay as particles <0.0039 mm. These data were standardized and combined with any sieved coarse fraction (i.e., particles >2.0 mm) to obtain a distribution of coarse, sand, silt, and clay fractions totaling 100%. The coarse fraction was included with the 2.0 mm fraction in the calculation of various particle size parameters, which were determined using a normal probability scale (see Folk 1968). These parameters were summarized and expressed as overall mean particle size (mm), phi size (mean, median, skewness, kurtosis), and the proportion of coarse, sand, silt, and clay. The proportion of fine particles (% fines) was calculated as the sum of all silt and clay fractions.

Sediment samples were analyzed on a dry weight basis for total organic carbon (TOC), total nitrogen (TN), total sulfides, trace metals, chlorinated pesticides (e.g., DDT), polychlorinated biphenyl compounds (PCBs), and polycyclic aromatic hydrocarbons (PAHs) (Appendix C.1). TOC and TN were measured as percent weight (% wt) of the sediment sample; sulfides and metals were measured in units of mg/kg and are expressed in this report as parts per million (ppm); pesticides and PCBs were measured in units of ng/kg and expressed as parts per trillion (ppt); PAHs were measured in units of µg/kg and expressed as parts per billion (ppb). The data reported herein were generally limited to values above the method detection limit (MDL). However, concentrations below MDLs were included as estimated values if the presence of the specific constituent was verified by mass-spectrometry (i.e., spectral peaks confirmed). A detailed description of the analytical protocols is available in City of San Diego (2009).

Data Analyses

Values for total PAH, total DDT, and total PCB were calculated for each sample as the sum of all constituents with reported values. Values for each individual constituent are listed in Appendix C.2. Zeroes were substituted for all non-detects (i.e., null values) when calculating means and medians.

Summaries of parameters included detection rates (i.e., number of reported values/number of samples), annual means by station, annual means for all stations combined (areal mean), and maximum value during the year. Statistical analyses included correlation analyses of all sediment chemistry parameters with percent fine materials, transformed to meet assumptions of the test. Residuals were also inspected for normality after analysis.

Historical analyses included comparisons between annual mean and maximum values for 2008 to those from the pre-discharge period (1995–1998). In addition, data from stations closest to the outfall (nearfield) were compared to all other stations (farfield) over the pre- and post-discharge periods. Stations considered "nearfield" (I12, I14, I15, I16) are located within 1000 m of the outfall wye. Levels of contamination were further evaluated by comparing data for this study to the Effects Range Low (ERL) and Effects Range Median (ERM) sediment quality guidelines of Long et al. (1995) when available. The National Status and Trends Program of the National Oceanic and Atmospheric Administration (NOAA) originally calculated the ERLs and ERMs to provide a means for interpreting monitoring data. The ERLs are considered to represent chemical concentrations below which adverse biological effects are rarely observed. Values above the ERL but below the ERM represent values at which effects occasionally occur. Concentrations above the ERM indicate likely biological effects, though these are not always validated by toxicity testing (Schiff and Gossett 1998).

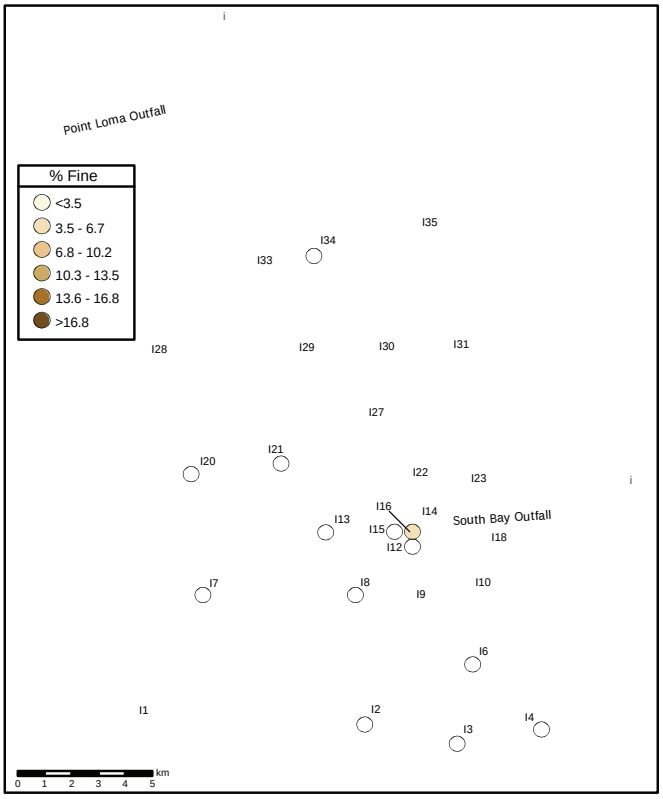

Figure 4.2
Particle size distribution for SBOO benthic stations sampled in 2008. Data are annual means per station (n=2).

Results and Discussion

Particle Size Distribution

Sediment particle composition was diverse at benthic sites sampled around the SBOO in 2008. Mean particle sizes ranged from about 0.06 to 0.98 mm (Appendix C.3). With few exceptions, there was little difference in intra-station particle size composition between the winter and summer surveys (Appendix C.3), and there was no clear relationship with proximity to the outfall during the year (Figure 4.2). Overall, sediment composition has been highly variable throughout the region since sampling began in 1995, with no significant changes being apparent since wastewater discharge began in early 1999 (Figure 4.3). Instead, intra-station variability near the outfall and at other monitoring sites was most likely attributable to the different sediment types that occur throughout the region. For example, the average percent fines component (i.e., silt and clay combined) ranged from 0 to 43% across all stations in 2008 alone (Table 4.1), with higher values tending to occur in sediments at stations north of the outfall (Figure 4.3). Many sites in the region were also characterized by the presence of different types of coarse sediments, including red relict sands (e.g., stations I6, I7, I20, I21), black sands (e.g., station I28), and shell hash (e.g., stations I4, I13, I23, I33, I34) (see Appendix C.3).

The sorting coefficient reflects the range of particle sizes comprising sediments and is calculated as the standard deviation (SD) in phi size units. In general, areas composed of particles

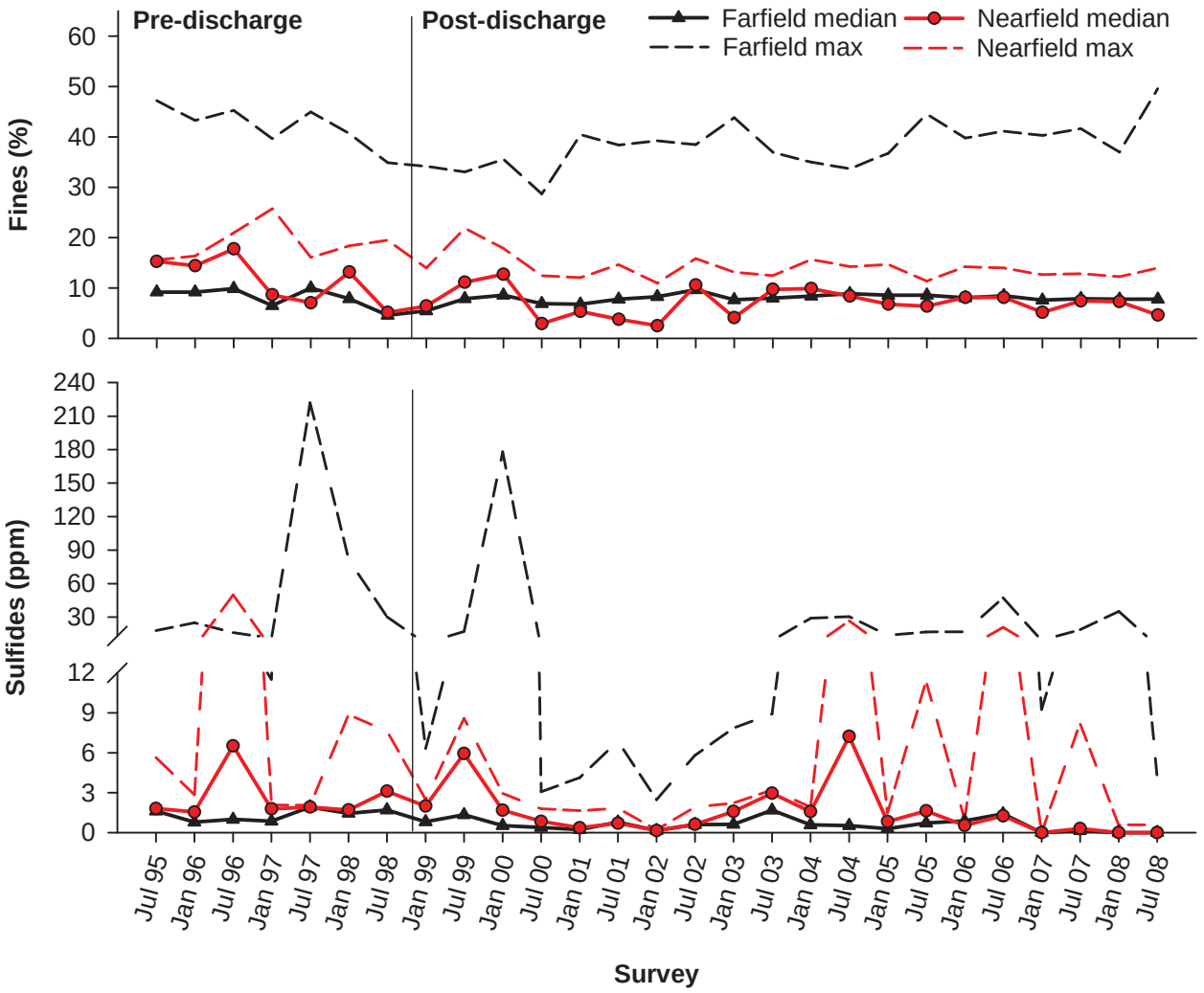

Figure 4.3
Summary of particle size and organic indicator data surrounding the SBOO from between 1995–2008: Percent fines (Fines); Sulfides; Total Nitrogen (TN); Total Organic Carbon (TOC). Data are expressed as median and maximum values pooled over all farfield (n≤23) and nearfield (n≤4) stations; % wt=percent weight. Reference line represents onset of discharge from the SBOO. Note that the y-axis scale differs across a break.

of similar size are considered to have well-sorted sediments (i.e., SD≤0.5 phi) and are indicative of areas subject to fast moving currents or large disturbances (e.g., storm surge, rapid suspension/deposition of materials) (Folk 1968). In contrast, samples with particles of varied sizes are characteristic of poorly sorted sediments (i.e., SD≥1.0 phi). Sediments collected throughout the South Bay region, including at stations near the outfall, tended to be moderately well to poorly sorted, with sorting coefficients ranging from 0.6 to 1.7 on average (Table 4.1). Poorly sorted sediments (i.e., SD≥1.0 phi on average) were present at stations I7, I8, I12, I15, I22, I23, I28, I33, and I35. Of these, station I28 located along the 55-m depth contour, and stations I23 and I35 located along the 19-m depth contour, had the highest mean sorting coefficients of 1.2–1.7 phi. The sorting coefficients for these stations have been >1.0 off and on over the years (e.g., City of San Diego 2006, 2007, 2008).

Indicators of Organic Loading

Sulfides, total organic carbon (TOC) and total nitrogen (TN) are quantified in sediments as measures of potential organic loading in the region from the SBOO discharge. Organic materials may become deposited in marine sediments also via natural sources, including the result of primary productivity,

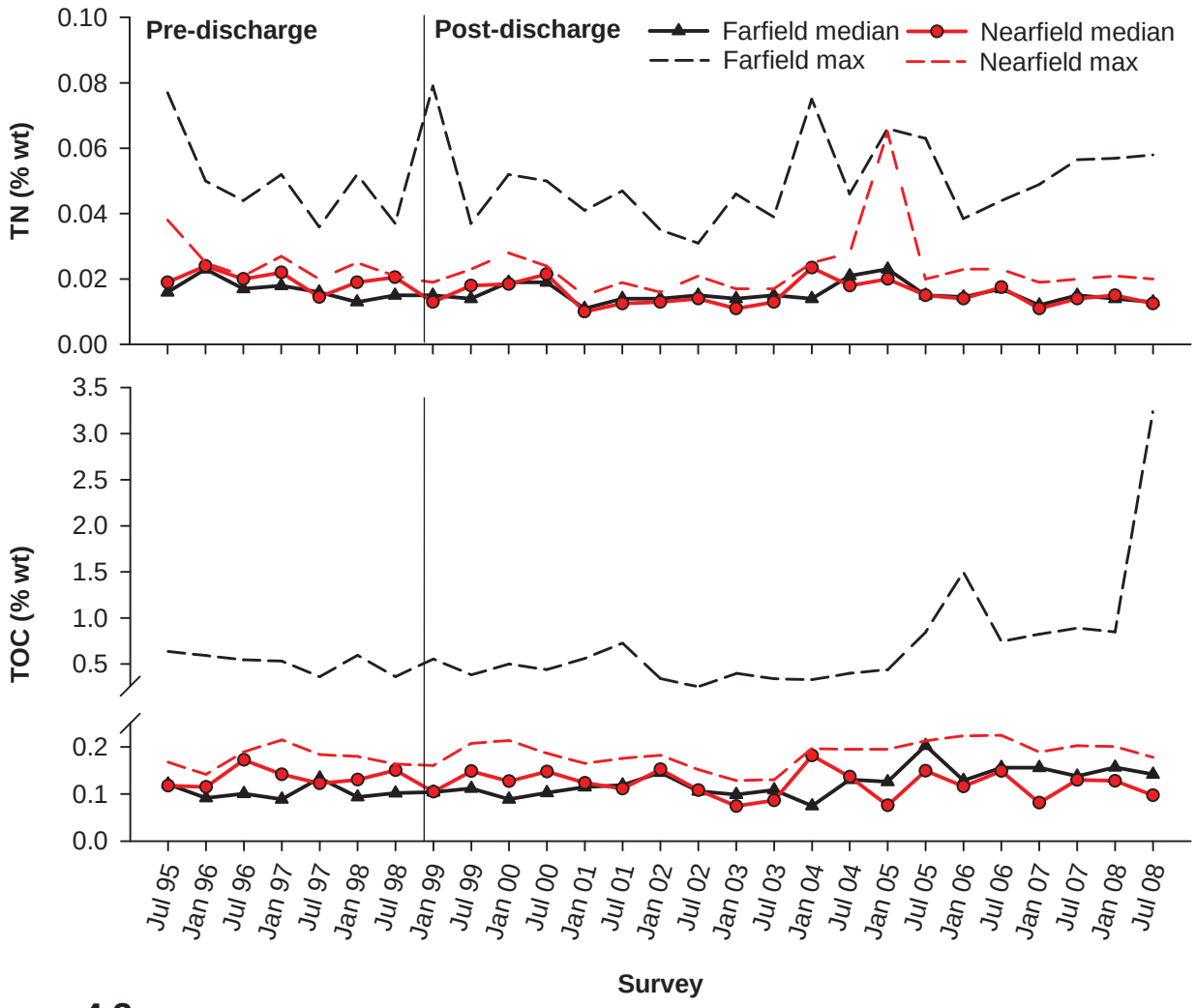

Figure 4.3 *continued*

breakdown of detrital materials, and outflows from rivers (Eganhouse and Venkatesan 1993). Organic enrichment is of concern because it may disrupt ecological processes and impair habitat quality for macrobenthic marine organisms. For example, sulfides, which are the byproducts of anaerobic bacterial breakdown of organic matter, may be toxic to benthic marine organisms if the sediments become excessively enriched (Gray 1981). Nitrogen is typically limiting in marine systems, and when enriched can lead to sudden phytoplankton "blooms" in coastal waters. After such blooms occur, a flux of organic material is again deposited in the sediment as the phytoplankton die and settle to the seafloor.

Generally, the distribution of organic indicators in SBOO sediments during 2008 was similar to that found prior to discharge (City of San Diego 2000) and did not appear to be influenced by wastewater discharge in the region. Detection rates were relatively high for TOC and TN (≥80%) and relatively low for sulfides (35%), with highly variable concentrations (Table 4.1, Appendix C.4). TOC ranged from 0.044 to 1.7 % wt per station on average, whereas TN ranged from 0.004 to 0.057 % wt and sulfides ranged from 0.04 to 18.54 ppm. Concentrations of all three indicators at stations nearest the discharge site (e.g., stations I12, I14, I15, I16) were within the range of values reported elsewhere in the region. For example, the highest concentrations of sulfides occurred in sediments from some of the stations to the north of the SBOO (i.e., I30, I33, I35). None of these indicators demonstrated noticeable changes near the outfall that appear to be coincident with

Table 4.1

Summary of particle size parameters and organic loading indicators at SBOO benthic stations during 2008. Data are annual means per station (n=2); nearfield stations are in bold; nd=not detected; SD=standard deviation; Pre-discharge period=1995–1998.

	Particle Size					Organic Indicators		
	Mean (phi)	SD (phi)	Coarse (%)	Sand (%)	Fines (%)	Sulfides (ppm)	TN (% wt)	TOC (% wt)
19 m stations								
I35	3.7	1.2	0.0	66.5	33.5	18.54	0.032	0.249
I34	1.0	0.9	26.6	73.2	0.2	0.28	0.004	0.161
I31	3.1	0.7	0.0	92.3	7.6	0.72	0.012	0.096
I23	2.2	1.3	15.4	71.7	13.0	0.50	0.025	1.698
I18	3.1	0.6	0.0	91.1	8.9	0.60	0.014	0.118
I10	3.1	0.7	0.3	90.0	9.6	0.24	0.013	0.122
I4	0.8	0.7	9.2	90.8	0.0	nd	nd	0.063
28 m stations								
I33	3.1	1.0	0.0	85.4	14.5	1.04	0.023	0.440
I30	3.4	0.8	0.0	83.4	16.6	2.24	0.022	0.201
I27	3.3	0.7	0.0	86.2	13.8	nd	0.016	0.155
I22	2.8	1.0	0.0	89.3	10.7	nd	0.021	0.173
I16	**2.3**	**0.9**	**1.0**	**94.1**	**4.9**	**0.29**	**0.007**	**0.094**
I15	**2.0**	**1.0**	**2.4**	**91.3**	**6.3**	**nd**	**0.006**	**0.099**
I14	**3.2**	**0.8**	**0.0**	**86.8**	**13.2**	**0.30**	**0.020**	**0.189**
I12	**2.2**	**1.0**	**2.0**	**92.8**	**5.1**	**nd**	**0.014**	**0.120**
I9	3.4	0.8	0.0	82.9	17.1	0.09	0.019	0.197
I6	0.9	0.8	10.5	88.4	1.1	nd	0.012	0.089
I3	1.0	0.7	10.2	89.8	0.0	nd	0.005	0.044
I2	1.5	0.9	4.7	94.3	1.0	nd	nd	0.048
38 m stations								
I29	2.0	0.8	11.2	75.0	13.8	0.16	0.021	0.302
I21	1.1	0.9	7.2	89.5	3.3	nd	0.015	0.177
I13	1.0	0.8	7.6	91.3	1.1	nd	0.005	0.140
I8	1.5	1.0	4.9	91.9	3.2	nd	0.015	0.118
55 m stations								
I28	3.2	1.7	7.2	49.5	43.3	nd	0.057	0.852
I20	0.7	0.7	15.3	83.0	1.6	nd	nd	0.053
I7	0.7	1.0	12.6	83.7	3.6	nd	0.016	0.139
I1	2.9	0.9	0.0	90.9	9.1	0.04	0.020	0.266
Detection rate (%)						35	80	100
2008 area mean	2.2	0.9	5.5	85.0	9.5	0.9	0.015	0.24
2008 area max	4.0	2.1	53.1	99.8	49.6	35.3	0.058	3.24
Pre-discharge mean	2.3	0.8	1.4	87.7	10.2	4.59	0.019	0.143
Pre-discharge max	4.2	2.5	52.5	100.0	47.2	222.00	0.077	0.638

wastewater discharge (see Figure 4.3). TN was positively correlated with percent fines (Table 4.2, Figure 4.4A), indicating that it varied with sediment type. TOC was also positively correlated with percent fines, though an outlier was removed prior to analysis; i.e., the TOC value detected in sediments collected in July from station I23 (3.24 % wt) was the highest ever reported since monitoring began in 1995. In contrast, values for sulfides and TN in this sample were within normal ranges.

Trace Metals

Aluminum, barium, chromium, iron, manganese, nickel, tin, and zinc were detected in 100% of sediment samples collected in the SBOO

Table 4.2

Results of correlation analyses on percent fine material and all other sediment chemistry parameters from samples collected in the SBOO region in 2008. Shown are analytes which had correlation coefficients (R^2 values)≥0.60. Percent fines were square-root transformed and all other analytes were transformed as necessary to meet the assumption of normality for this analysis. Residuals were also inspected for normality.

Analyte	R^2	p-value
Organic indicators (% wt)		
Total Nitrogen	0.84	<0.001
Total Organic Carbon*	0.73	<0.001
Trace metals (ppm)		
Aluminum	0.85	<0.001
Barium	0.80	<0.001
Copper	0.68	<0.001
Manganese	0.78	<0.001
Nickel	0.89	<0.001
Zinc	0.79	<0.001

*Outlier removed (see text)

region during 2008 (Table 4.3, Appendix C.5). Antimony, arsenic, cadmium, copper, lead, mercury, silver, and thallium were also detected, but less frequently (i.e., detection rates of 15–98%), while beryllium and selenium were not detected at all. Concentrations of each metal were highly variable, with no discernable patterns relative to the outfall. None of the highest concentrations occurred in sediments closest to the SBOO. Instead, concentrations for some metals (i.e., aluminum, barium, copper, manganese, nickel, zinc) were correlated with proportions of fine particles (Table 4.2). Nickel was found to be correlated tightest with percent fines (Figure 4.4B), followed by aluminum. Although chromium, iron, and lead were not correlated with percent fines, the highest concentrations of these metals occurred at the two stations with the highest proportion of fine sediments in the region (see Table 4.1); these stations included I35 located near the mouth of San Diego Bay and I28 near the now defunct LA-4 dumpsite. Overall, most metals had mean and maximum concentrations in 2008 that were less than pre-discharge values (Table 4.3). Exceptions were cadmium, antimony, lead, mercury, nickel, thallium, and zinc, which exceeded their pre-discharge areal means, though their maximum values were below those recorded prior to discharge. Only two metals exceeded environmental threshold values during the year (see Appendix C.5). First, the ERL for arsenic was exceeded in sediments from a single sample at station I21 located northwest of the SBOO discharge site. Second, both the ERL and ERM for silver were exceeded in sediments from stations located throughout the monitoring area.

Pesticides

Chlorinated pesticides were detected in up to 41% of the South Bay sediment samples collected in 2008 (Table 4.4, Appendix C.6). Hexachlorobenzene (HCB) was the most prevalent pesticide, occurring in sediments from 17 of 27 stations at concentrations averaging between 19–750 ppt (Table 4.4). Total DDT (primarily p,p-DDE) was detected in 35% of the samples at a total of 13 different stations, with concentrations averaging 43–1050 ppt. With the exception of a single sample collected at station I29 in January, total DDT concentrations were lower than its ERL of 1580 ppt (Appendix C.6), and all concentrations of this pesticide were lower than pre-discharge levels (Table 4.4). One other pesticide, BHC (beta isomer), was also detected, but only in a single sample collected at station I27 in January. As with the various trace metals, pesticide values showed no patterns relative to wastewater discharge.

PCBs and PAHs

PCBs were detected in sediments from only five SBOO stations (I9, I14, I18, I23, I28) during 2008 (Table 4.4). Overall, only 9% of the samples collected had detectable levels of PCBs, with average concentrations ranging from 90 to 696 ppt. Total PCB concentrations at stations I12, I14, I15, and I16 located nearest the discharge site were similar to values reported elsewhere in the region. The highest PCBs were found in sediments collected at station I28 during both the January and July surveys (i.e., 696 and 1392 ppt, respectively) (Appendix C.6).

PAHs were also detected relatively infrequently in sediment samples collected during 2008. Additionally, all concentrations of total PAH were below both the pre-discharge maximum value and

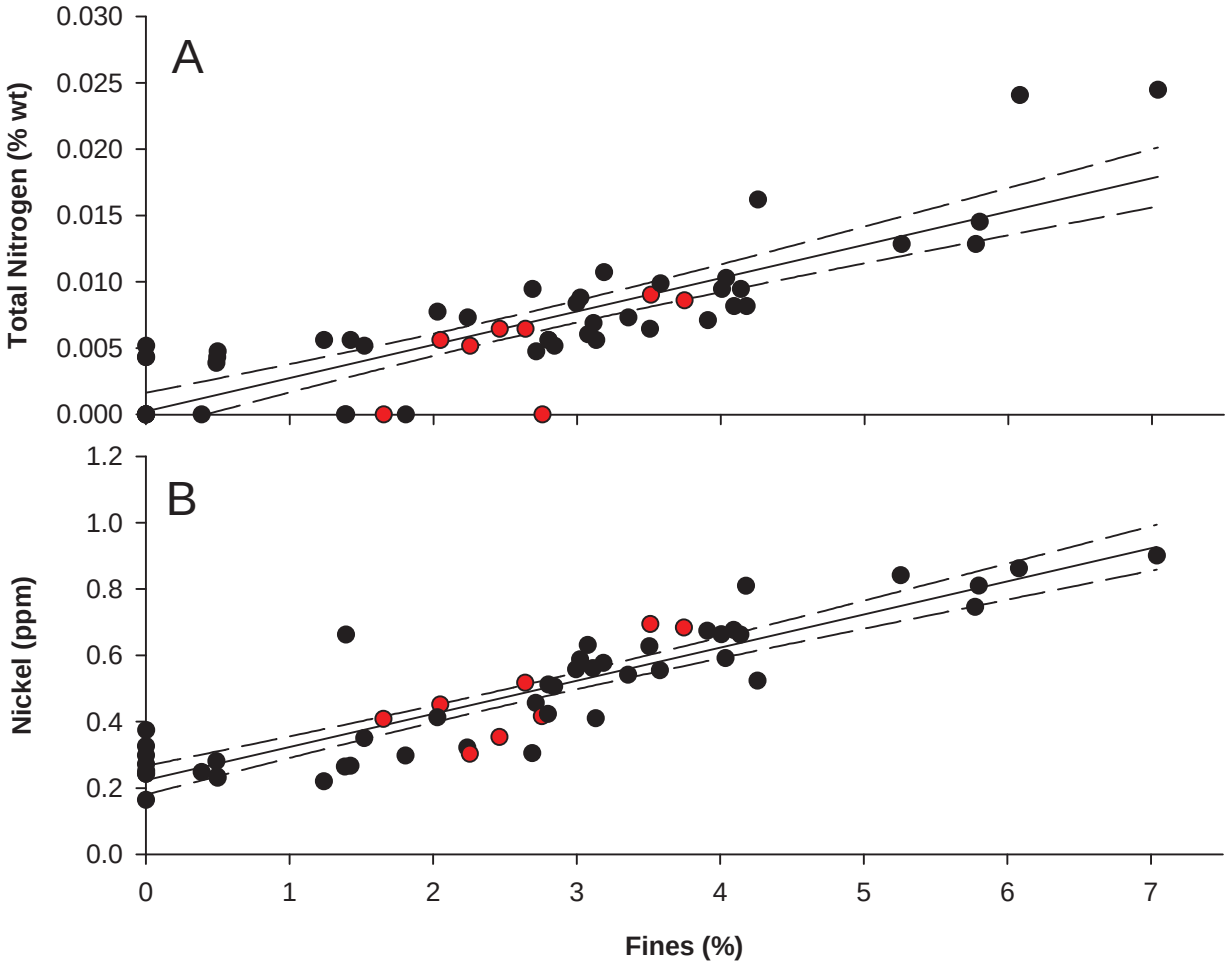

Figure 4.4
(A) Total nitrogen and (B) nickel correlated with percent fine material at SBOO stations in 2008. Data are transformed (fines=square-root; TN and Ni=log(x+1)) to meet normality assumptions for the test. The solid line represents the best fit regression line; dashed lines represent 95% confidence intervals; samples collected from nearfield stations are indicated in red.

ERL of 4022 ppt for this parameter (Table 4.4). Relatively low levels of these compounds were detected in 22% of the samples from 11 different stations, primarily during the January survey (Appendix C.6). The most common PAH detected was naphthalene, which was detected in about 19% of the sediment samples (Appendix C.2). There was no apparent relationship between PAH concentrations and proximity to the outfall discharge site.

Summary and Conclusions

Sediment composition in the South Bay outfall region was diverse in 2008, with grain size distributions ranging from very fine to very coarse particles. The diversity of sediment types may be partially attributed to the multiple geological origins of relict red sands, shell hash, coarse sands, and other detrital materials that occur in the offshore area surrounding the SBOO (Emery 1960). In addition, sediment deposition associated with the transport of materials originating from the Tijuana River, and to a lesser extent from San Diego Bay, may contribute to the higher silt content at some stations located near the outfall, as well as to the north (see City of San Diego 1988). There was no evident relationship between sediment grain size composition and proximity to the outfall discharge site.

Various trace metals, indicators of organic loading (sulfides, TN, TOC), chlorinated pesticides (DDT, BHC, HCB), PCBs, and PAHs were detected in

Table 4.3

Concentrations of trace metals (ppm) detected at SBOO benthic stations during 2008. Data are annual means (n=2); nearfield stations are in bold. ERL=effects range low threshold value; ERM=effects range median threshold value; na=not available; nd=not detected; Pre-discharge period=1995–1998. See Appendix C.1 for MDLs and metals defined by periodic table symbols.

		Al	Sb	As	Ba	Be	Cd	Cr	Cu	Fe	Pb	Mn	Hg	Ni	Se	Ag	Tl	Sn	Zn
	ERL:	na	na	8.2	na	na	1.2	81	34	na	46.7	na	0.15	20.9	na	1	na	na	150
	ERM:	na	na	70	na	na	9.6	370	270	na	218	na	0.71	51.6	na	3.7	na	na	410
19-m stations	I35	8795	0.2	2.25	46.75	nd	0.07	14.2	4.3	10355	2.26	104.4	0.009	5.0	nd	3.25	0.42	0.9	29.5
	I34	1510	nd	1.20	5.50	nd	0.05	4.0	0.8	3350	1.54	40.5	0.014	0.8	nd	0.03	nd	1.0	6.6
	I31	4030	nd	1.04	19.20	nd	0.03	7.8	1.4	4020	0.49	54.1	nd	1.8	nd	0.97	nd	0.8	10.6
	I23	4685	0.2	1.74	27.70	nd	0.04	8.4	1.7	5415	0.62	58.0	nd	2.3	nd	0.69	0.26	1.3	12.2
	I18	5410	nd	1.26	44.10	nd	nd	11.3	2.2	7025	nd	77.7	nd	2.4	nd	0.26	nd	1.4	12.8
	I10	4815	0.3	1.38	19.63	nd	0.03	10.9	1.1	6145	0.55	60.9	0.001	2.4	nd	1.88	0.45	1.1	12.5
	I4	956	0.2	1.24	2.86	nd	0.04	4.7	0.5	1990	1.06	18.6	nd	0.7	nd	0.79	nd	0.6	4.8
28-m stations	I33	5165	0.2	1.68	24.25	nd	0.07	8.8	2.6	6365	2.04	74.3	0.016	2.7	nd	0.99	nd	0.9	17.0
	I30	6835	0.2	1.94	34.40	nd	nd	11.2	2.7	6865	0.66	67.5	0.005	3.6	nd	1.85	nd	1.1	18.3
	I27	7200	0.2	1.40	33.15	nd	0.04	11.2	2.7	7035	0.41	73.5	nd	3.5	nd	1.18	0.27	1.7	17.5
	I22	4650	nd	1.39	21.70	nd	0.03	8.8	2.3	5070	0.55	49.6	0.003	2.6	nd	0.74	nd	1.2	11.6
	I16	**4470**	**nd**	**1.48**	**23.10**	**nd**	**nd**	**7.5**	**2.0**	**5555**	**nd**	**56.2**	**nd**	**1.9**	**nd**	**0.66**	**nd**	**1.4**	**12.8**
	I15	**2755**	**nd**	**2.48**	**8.75**	**nd**	**nd**	**9.1**	**0.9**	**4965**	**1.17**	**30.3**	**nd**	**1.3**	**nd**	**0.44**	**nd**	**1.1**	**10.1**
	I14	**8185**	**nd**	**1.69**	**43.10**	**nd**	**nd**	**11.6**	**3.2**	**8200**	**nd**	**82.7**	**nd**	**3.9**	**nd**	**0.28**	**0.32**	**1.3**	**20.5**
	I12	**3235**	**nd**	**1.88**	**16.55**	**nd**	**nd**	**5.9**	**1.0**	**3990**	**nd**	**37.8**	**nd**	**1.5**	**nd**	**0.51**	**nd**	**0.7**	**9.1**
	I9	7975	0.2	1.54	39.25	nd	nd	12.4	3.0	8065	nd	86.0	0.002	4.6	nd	2.29	0.41	1.2	19.9
	I6	1145	0.2	4.69	3.40	nd	0.03	8.4	0.4	4195	1.35	12.8	nd	0.8	nd	0.05	nd	1.3	13.7
	I3	862	0.2	1.18	2.04	nd	nd	6.5	0.6	2060	0.46	9.1	nd	0.9	nd	nd	nd	0.5	3.3
	I2	1195	nd	0.32	2.97	nd	0.09	5.9	1.0	1315	nd	10.8	nd	0.9	nd	0.14	nd	1.3	3.6
38-m stations	I29	5118	0.2	4.74	24.13	nd	nd	10.3	2.4	8420	1.70	53.8	0.008	3.4	nd	1.67	0.40	1.2	15.3
	I21	1345	0.2	7.47	3.18	nd	nd	8.7	0.6	6400	1.70	16.7	nd	0.9	nd	nd	nd	1.5	6.7
	I13	4000	0.3	6.68	22.40	nd	0.02	10.4	1.9	7050	0.96	51.1	nd	2.2	nd	nd	nd	1.1	12.7
	I8	2190	0.2	2.45	6.39	nd	0.04	10.1	0.8	4685	1.02	27.3	0.002	1.4	nd	0.18	nd	1.2	9.1
55-m stations	I28	8055	0.2	2.50	34.75	nd	0.05	12.8	5.1	9375	2.73	78.6	0.023	6.6	nd	1.86	0.28	1.5	24.4
	I20	1925	0.2	3.17	4.08	nd	0.08	11.9	1.2	8930	2.60	23.8	nd	1.2	nd	nd	nd	1.7	9.9
	I7	1285	0.2	5.32	3.16	nd	nd	9.3	0.4	7110	1.81	21.6	nd	0.9	nd	nd	nd	0.5	6.5
	I1	2965	0.4	0.92	10.30	nd	0.07	7.4	1.4	3855	0.86	50.7	0.006	2.7	nd	1.35	nd	1.3	9.0
Detection rate (%)		100	37	98	100	0	35	100	89	100	63	100	30	100	0	50	15	100	100
2008 area mean		4102	0.4	2.42	19.51	—	0.08	9.2	2.0	5845	1.49	49.2	0.011	2.3	—	1.60	0.70	1.1	12.6
2008 area max		10400	0.7	9.00	49.20	—	0.17	17.7	6.3	12500	4.03	118.0	0.029	7.0	—	4.61	0.90	2.0	31.3
Pre-discharge mean		5164	0.08	2.47	21.82	0.13	0.002	10.2	2.6	6568	0.09	55.4	0.002	1.9	0.07	nd	0.2	nd	12.5
Pre-discharge max		15800	5.6	10.9	54.3	2.14	0.4	33.8	11.1	17100	6.8	162	0.078	13.6	0.62	nd	17	nd	46.9

Table 4.4

Concentrations of total DDT, BHC, hexachlorobenzene (HCB), total PCB, and total PAH at SBOO benthic stations in 2008. Data are annual means (n=2); nearfield stations are in bold. ERL=effects range low threshold value; ERM=effects range median threshold value; na=not available; nd=not detected; Pre-discharge period=1995–1998.

		tDDT (ppt)	BHC (ppt)	HCB (ppt)	tPCB (ppt)	tPAH (ppb)
	ERL:	1580	na	na	na	4022
	ERM:	46100	na	na	na	44792
19-m stations	I35	nd	nd	nd	nd	7.3
	I34	nd	nd	nd	nd	8.9
	I31	nd	nd	658	nd	6.6
	I23	190	nd	19	305	nd
	I18	60	nd	34	90	nd
	I10	nd	nd	26	nd	nd
	I4	nd	nd	nd	nd	6.6
28-m stations	I33	55	nd	750	nd	nd
	I30	195	nd	nd	nd	13.2
	I27	130	95	100	nd	7.5
	I22	75	nd	103	nd	nd
	I16	**nd**	**nd**	**nd**	**nd**	**nd**
	I15	**55**	**nd**	**215**	**nd**	**nd**
	I14	**310**	**nd**	**nd**	**102**	**15.2**
	I12	**nd**	**nd**	**33**	**nd**	**nd**
	I9	nd	nd	80	159	nd
	I6	nd	nd	nd	nd	nd
	I3	105	nd	90	nd	nd
	I2	nd	nd	nd	nd	nd
38-m stations	I29	1050	nd	415	nd	26.4
	I21	nd	nd	43	nd	8.3
	I13	43	nd	155	nd	43.2
	I8	65	nd	180	nd	nd
55-m stations	I28	750	nd	340	696	nd
	I20	nd	nd	nd	nd	nd
	I7	nd	nd	113	nd	11.8
	I1	nd	nd	nd	nd	nd
Detection rate (%)		35	2	41	9	22
2008 area mean		114.2	3.5	124.2	50.1	5.7
2008 area max		1690	190	1500	1392	86.4
Pre-discharge mean		568.1	nd	nd	na	3.39
Pre-discharge max		23380	nd	nd	na	636.5

sediment samples collected from SBOO benthic stations during 2008. Concentrations of the various contaminants remained relatively low in the region compared to many other coastal areas off southern California (see Schiff and Gossett 1998, Noblet et al. 2003, Schiff et al. 2006). Only two metals (silver and arsenic) and DDT exceeded ERL values for southern California. For example, relatively high concentrations of silver occurred in sediments throughout the region, while a single sample with elevated arsenic and another sample with elevated DDT were found in sediments from stations quite distant from the outfall.

Overall, sediments in the South Bay region were similar in 2008 to years past (see City of San Diego 2006, 2007, 2008) and there was no evidence of contamination by the discharge of wastewater from the SBOO. Although there were several samples where concentrations exceeded pre-discharge maximums for some metals or DDT, concentrations of most contaminants were not substantially different from those detected before discharge began in early 1999 (see City of San Diego 2000). In addition, the samples that did exceed pre-discharge values were collected from stations widely distributed throughout the region and showed no patterns that could be attributed to wastewater discharge. Instead, concentrations of TN, TOC, as well as for several metals, tended to be higher at sites characterized by finer sediments. This pattern is consistent with that found in other studies, in which the accumulation of fine particles has been shown to influence the organic and metal content of sediments (e.g., Eganhouse and Venkatesan 1993).

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