Appendix A:

ESTIMATES OF
MASS EMISSIONS TO THE
SOUTHERN CALIFORNIA BIGHT
REGION

ACKNOWLEDGEMENTS

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APPENDIX A1: Stormwater Mass Emissions Modeling

I. INTRODUCTION

The ocean environment of southern California represents an important ecological resource (Dailey *et al.* 1993). The Southern California Bight (SCB), whose coastal waters extend from Point Conception, north of Santa Barbara, to the south beyond the U.S.-Mexico International Border, is home to over 500 species of fish and more than 1,500 species of invertebrates. The coastal waters support unique habitats, such as kelp forests, and serve as an important migratory route for birds and marine mammals.

The SCB is also an important economic resource. An estimated $9 billion is spent annually on ocean-related activities (NRC 1990). For example, recreational fisherman land over 14 million fish each year and sandy beaches in the SCB attract more than 146 million beachgoers annually (Helvey *et al.* 1987, Schiff *et al.* 1999). Moreover, the Los Angeles/Long Beach Harbor Complex is the largest commercial port on the west coast of the United States while San Diego Bay supports one of the largest Naval facilities in the Pacific Rim.

Numerous potential risks pose threats to the ecosystem of the SCB. Over 17 million people inhabit the coastal communities of the SCB and represent a variety of mounting stressors and impacts to the coastal zone. For example, 75% of the bays and estuaries have been dredged and filled for coastal development such as ports and marinas (Cross and Allen 1993). In addition, numerous sources of pollutants are discharged from both land-based and sea-based activities. These activities include the discharge of treated sewage and industrial effluents, surface runoff from urban and agricultural activities, boating and shipping activities, spills, and atmospheric fallout, among others. Many of these discharges commingle after being discharged and can accumulate for a greater effect than any single discharge alone.

One tool used by environmental managers to evaluate potential ecosystem risk is mass emissions. Mass emissions measure the total pounds of materials discharged to the ocean. Mass emission estimates help ecosystem managers make decisions about stewarding coastal resources in at least two ways. First, mass emissions assist environmental managers by comparing the mass of a specific pollutant discharged among two or more sources. Managers may wish to compare two types of sources or two sources of the same type. For example, managers may wish to assess if more pollutants are discharged from a publicly owned treatment works (POTW) facility that discharges treated sewage effluents, or from a creek that receives stormwater runoff from an urbanized watershed. Alternatively, the manager may wish to assess whether more pollutants are originating from one watershed than another watershed. In either scenario, the manager is using mass emissions to evaluate potential risk.

The second application that environmental managers use in evaluating mass emissions data is decision-making for assessing trends. If the decision is made that one source needs to be controlled, then mass emission measurements over time can be used to determine whether the management actions taken were effective in reducing pollutant contributions.

The goal of this report is to estimate mass emissions of potential pollutants from a variety of sources to the coastal waters of the SCB. The objective is to compare which sources contribute the highest proportion of potential pollutants. A secondary objective is to assess trends in mass emissions for the purpose of determining whether individual sources have been effectively controlled, or whether they are increasing their contributions to the SCB. The sources to be examined include large and small POTWs, industrial facilities, power generating stations, dredged materials, and urban/non-urban stormwater runoff.

This report is divided into 13 sections. Sections two through eight address the seven sources that were selected for study. Within each of these sections, we describe the type(s) of discharge(s), explain our methods for calculating mass emissions, present results, and illustrate any observed trends. The ninth section is a summary that collates all of the sources to assess which sources appear to be larger than others. Finally, in the last two sections, we present conclusions and recommendations for improving mass emission estimates to suit management needs.

II. STORMWATER RUNOFF

Description of Source

Stormwater is perceived by regulatory agencies and the scientific community to be a large source of pollutant loading, creating multiple impacts to the coastal waters of southern California. Urban runoff has been identified as one of the primary sources of pollutant impacts in inland and estuarine waters around the nation (U.S. EPA 1995). Stormwater runoff has also been shown to impact the water quality of coastal waters in the SCB by demonstrating toxicity to marine organisms (Bay *et al*. 1998) and degrading SCB beaches (Noble *et al*. 2000). Numerous sources of potential pollutants in stormwater runoff have been identified including the contributions from urban activities such as industry, transportation, and residential development or from non-urban activities (agricultural uses and undeveloped open areas). The quantification of the impact of urban runoff over a large area has not been addressed to date in California as a whole, although a few studies have been conducted in the SCB (Bay *et al*. 1998).

The county agencies in southern California monitor the water quality of stormwater discharges in their respective regions as a part of their stormwater National Pollutant Discharge Elimination System (NPDES) permit monitoring programs. However, their monitoring programs were designed independently from one another, are isolated in their scope and methodology, and lack the integration required to make large-scale stormwater assessments. For example, only 5% of the SCB watershed area and 2% of the annual runoff volume were representatively monitored in 1994 (Schiff 1997).

The goal of the present study was to make a large-scale assessment of runoff mass emissions to the coastal waters of the SCB. The SCB is one of the most urbanized areas in the United States; thus, the quantity of mass emissions to coastal waters has the potential to be large compared to undeveloped regions. This potential is exacerbated in the SCB because of the infrequent, but intense, rainfall that may accumulate pollutants over longer periods.

Methods

The large spatial scale of this project and the lack of previous monitoring effort dictated the need for a modeling approach for estimating mass emissions from runoff (Appendix A). A simple modeling approach was designed to address the variety of watersheds that exist throughout the region. The modeling approach decided upon was the Rational Method to address our relatively simple needs. The Rational Method's governing equation is:

$$Q = A * i * c \qquad\qquad \text{Equation (1)}$$

where:

Q	=	Runoff volume
A	=	Drainage area
i	=	Rainfall
c	=	Runoff coefficient.

Although this equation simplifies the runoff process, it is adequate for satisfying the underlying question of coastal loading from stormwater runoff on an annual scale.

The first step in determining the mass of constituent inputs to the California coast from stormwater runoff was to define the spatial extent of the watersheds contributing to the loading. Watershed delineations for the state were obtained from a data set created by the Interagency California Watershed Mapping Committee (CALWATER). In defining the spatial extent, the general guideline of using coastal Hydraulic Unit Code (HUC) areas was followed (California Department of Fish and Game 1998). Dams greater than 20 mi^2 were overlaid on the watersheds within each of the coastal HUCs. The drainage areas above the dams were removed to reduce the amount of constituent transformation and runoff retention to produce a more accurate representation of runoff reaching the coastal ocean (Appendix A). Table II-1 presents the drainage areas modeled within each county and land use category.

Stormwater loads to the coastal California oceans were estimated for a "typical" water year. The difficulty with the definition of a "typical" year arises in the spatial and temporal variability of precipitation. A model that estimated the spatially variable average annual rainfall was used to drive the stormwater runoff model. To estimate the rainfall across the state, the rainfall model PRISM, or Parameter-elevation Regressions on Independent Slopes Model, was utilized (Daly and Taylor 1998). This model used rainfall data from 1961 to 1990 in conjunction with elevation information to estimate rainfall across the area. The rainfall value at the center of each watershed was assigned to that watershed.

Stream and rainfall data were used to calibrate and validate volumes from the stormwater runoff model. Stream data were obtained from local monitoring programs, USGS-gaged sites, and United States Army Corps of Engineers (USACOE) sites. Rain data, at times, were collected at the same site as the stream data; but for the majority of the sites, rain gages from within the watershed were used to assign a rainfall amount to a gage for a specific storm.

Runoff coefficients were optimized for each land use type in the SCB with minimal subjectivity. The optimization technique entailed comparing the measured volumes to the modeled volumes by minimizing their difference (termed residual difference). The estimated runoff coefficients were iteratively changed to produce a sum of residuals equal to zero, thus minimizing the bias in the stormwater volume estimation (Appendix A). Table II-2 presents the optimized runoff coefficients for the modeled area. The model was verified with independent data and reproduced the measured volumes within 22 – 58%.

Two types of water quality data are collected from SCB stormwater monitoring programs. The first type of water quality data is collected from mass emission sites that capture water quality at the end of a creek or river; these data characterize the variety of land uses within that watershed. The second type of water quality data is collected from land use sites, which are small sub-watersheds of homogeneous land uses (i.e., residential commercial, industrial, etc.). Land use water quality data from monitoring programs in San Diego, Los Angeles, and Ventura counties were used to generate characteristic land use concentrations to drive the stormwater runoff-loading model (Regional Water Quality Control Boards [RWQCB] data files). The mass emission data from monitoring programs in San Diego, Orange, and Los Angeles counties were used for model verification.

Results and Discussion

Stormwater runoff from coastal watersheds in the SCB produced large volumes and significant quantities of several constituents (Table II-3). Nutrient and trace metal constituents were routinely measured in SCB monitoring programs and loads are estimated in metric tons (MT) for these constituents for an average water year. In contrast, several organic constituents were not regularly monitored or were measured at levels consistently below analytical reporting levels. Several organic constituents were not measurable (i.e., chlordane, dieldrin, total PCBs) or were discharged in very small quantities (i.e., chlorpyrifos, diazinon, total DDT).

To assess the uncertainty in load estimates due to differences in water quality, mass emissions were calculated based upon the 10th and 90th percentile for each constituent concentration (Appendix A). Mass emissions varied between one and three orders of magnitude depending upon the constituent (Table II-3). The bracketing of load estimates is based upon water quality data collected from all SCB stormwater monitoring programs. Water quality data are intrinsically variable among storm events as many measured and unmeasured factors affect water quality including rainfall quantity, rainfall intensity, cumulative seasonal rainfall, and antecedent dry period, as well as sources within the watershed. The extent that any individual factor controls the variability in water quality of storm runoff is unknown.

To assess the uncertainty in load estimates due to differences in annual rainfall, we recalculated mass emissions for TSS, zinc, and nitrate based upon the 10th and 90th percentiles of annual rainfall quantities in the historical records between 1961 and 1990 (Table II-4). Mass emissions for each of these three constituents varied between <9 and >320% of the mean load estimate based upon variability in rainfall and water quality. It appears that water quality played a stronger role than precipitation in this sensitivity analysis. This result may be a reflection of the model and the limits of our data. The model is linear; hence, changes in rainfall are expressed in a linear format when this may not always be true. We only used the 10th and 90th percentiles for this sensitivity analysis. Minima and maxima represent the extremes of our data set and introduce even greater variability.

The effect of non-detectable constituents for water quality measurements significantly impacted mass emission estimates (Table II-5). Samples with the highest number of non-detectable measurements were, as expected, most affected by the averaging scheme. Chloropyrifos had loads that varied by two orders of magnitude for the different schemes. Some constituents that were 100% non-detectable varied from zero to nearly one MT (e.g., dieldrin). Constituents with a smaller proportion of non-detectable measurements were less affected (e.g., suspended solids). Non-detectable quantities always hinder mass emission estimates because the true load is unknown. We found that laboratory reporting levels in the regional water quality database often varied by an order of magnitude among programs. These differences in reporting levels were frequently accompanied by an increase in non-detectable measurements (Appendix A).

The majority of stormwater runoff mass emissions were generated from highly to moderately urbanized watersheds (Table II-6, Appendix A). Highly urbanized (>25% imperviousness) and moderately urbanized (10 – 25% imperviousness) watersheds represented approximately two-thirds of the watershed area and contributed the majority of mass emissions for 16 of 18 constituents. Except for TSS and mercury, highly to moderately urbanized watersheds generated between 57 and 89% of the total stormwater runoff loads to the coastal oceans of the SCB. Highly urbanized watersheds, in particular, generated a disproportionate amount of load relative to their 6% of total watershed area. Between 30 and 50% of the total stormwater load for nutrients (i.e., ammonia, nitrate, nitrite, and phosphorous), trace metals (i.e., copper and zinc) or pesticides (i.e., diazinon) were generated from highly urbanized land uses.

Part of the reason we observed differences among watershed types is because stormwater runoff mass emissions were not generated evenly across land use types (Table II-7). Commercial and industrial land uses had the greatest pollutant fluxes for 11 of 17 constituents including most trace metals, BOD/COD, and TSS. Agricultural land uses had the greatest fluxes for pesticides such as total DDT and chlorpyrifos. In contrast, open land uses had the lowest fluxes for all but one constituent (mercury).

Mass emissions of fecal indicator bacteria (total coliform, fecal coliform, and enterococcus) were not estimated for this report, but comparisons of geometric mean densities were calculated (Table II-8). The mean densities of all three indicators were high, often exceeding 10^3 organisms/100 mL. The densities of fecal indicator bacteria for each sample were compared to water quality thresholds established by the State for AB411. These thresholds include total coliforms (10,000 organisms/100 mL), fecal coliforms (400 organisms/100 mL), and enterococcus (104 organisms/100 mL). The frequency of exceedence ranged from 52 to 100%, depending upon indicator and land use type. Enterococcus exceeded the AB411 thresholds most frequently while total coliforms exceeded these thresholds the least. However, open land uses, where anthropogenic activities are limited, had large densities and frequently exceeded AB411 thresholds. The preponderance of fecal indicator bacteria is not a new phenomenon in stormwater discharges and has been observed regionally in southern California (Schiff 1997) and nationally (U.S. EPA 1983). Epidemiological studies in Santa Monica Bay during the summer demonstrated that swimming-related illnesses increase next to storm drains compared to swimmers at distances of 400 yds (Haile *et al*. 1999). However, the health risk of swimming due to wet weather discharges is unknown.

TABLE II-1. Land use distribution by land use and county for the modeled area (in square miles).

	Residential	Commercial	Industrial	Open	Agriculture	Other	Total
Los Angeles	479	118	154	694	14	7.7	1,467
Orange	218	71	58	308	31	0.56	687
Riverside	137	26	0	176	0	0.36	339
San Bernardino	3.7	0.40	0	25	0	0	29.1
San Diego	322	90	67	937	194	0	1,610
Santa Barbara	31	36	0	297	1.2	0	365
Ventura	76	21	40	848	175	0	1,160
SCB	1,267	363	319	3,286	415	8.6	5,659

TABLE II-2. Optimized model runoffcoefficients.

Land Use	Runoff Coefficient
Agriculture	0.10
Commercial	0.57
Industrial	0.58
Open	0.08
Residential	0.23
Other Urban	0.38

TABLE II-3. Comparison of estimated runoff loads to the Southern California Bight using the 90th percentile, 10th percentile, and arithmetic mean water quality concentrations.

	Tenth Percentile	Average	Ninetieth Percentile
Ammonia (MT)	4.8	427	906
BOD (MT)	4,427	20,558	40,144
Cadmium (kg)	106	598	1,246
Chlordane (kg)	-	-	-
Chlorpyrifos (kg)	-	15.1	50.7
Chromium (kg)	1,676	11,088	20,749
COD (MT)	4,117	61,467	138,629
Copper (MT)	7.10	35.7	75.9
DDT (kg)	5.90	21.3	27.5
Diazinon (kg)	-	13.9	-
Dieldrin (kg)	-	-	-
Lead (MT)	0.67	12.3	32.1
Mercury (kg)	-	819	13.5
MTBE (kg)	-	-	-
Nickel (MT)	2.07	11.5	26.2
Nitrate (MT)	226	2,720	6,227
Nitrite (MT)	-	68.0	137
PCB (kg)	-	-	-
Phosphate (MT)	233	508	795
Selenium (kg)	37.5	458	548
Suspended Solids (MT)	42,583	264,668	564,683
Zinc (MT)	28.7	161	313

TABLE II-4. Model load response to 90th and 10th percentiles of rain and water quality concentrations.

Water Quality	Precipitation		
	10%	Average	90%
SUSPENDED SOLIDS			
10%	100.3%	213%	352%
Average	47.0%	100%	165%
90%	7.56%	16.1%	26.5%
NITRATE			
10%	108%	229%	378%
Average	47.0%	100%	165%
90%	3.91%	8.3%	13.7%
ZINC			
10%	91.5%	195%	321%
Average	47.0%	100%	165%
90%	8.40%	17.9%	29.5%

TABLE II-5. The effects of different methods of averaging non-detects (ND) on the estimated stormwater load.

	Total Number of Samples	Number Non-Detects	ND = 0	ND = ½ D.L.	ND = D.L.
Ammonia (MT)	2525	586	427	443	458
BOD (MT)	852	42	20,558	20,712	20,867
Cadmium (kg)	2132	1659	598	951	1,303
Chlordane (kg)	637	636	-	108	216
Chlorpyrifos (kg)	459	454	15.1	770	1,526
Chromium (kg)	2143	1354	11,088	12,575	14,062
COD (MT)	951	217	61,467	62,192	62,916
Copper (MT)	2177	279	35.7	36.1	36.5
DDT (kg)	636	615	21.3	64.4	107
Diazinon (kg)	465	435	13.9	398	783
Dieldrin (kg)	601	599	-	45.82	91.6
Lead (MT)	2139	684	12.3	13.7	15.1
Mercury (kg)	963	918	819	1,242	1,665
MTBE (kg)	8	8	-	467	934
Nickel (MT)	2133	1033	11.5	13.1	14.6
Nitrate (MT)	2493	95	2,720	2,724	2,728
Nitrite (MT)	797	292	68.0	124	181
PCB (kg)	599	599	-	313	626
Phosphate (MT)	1063	28	508	509	510
Selenium (kg)	997	858	458	2,793	5,128
Suspended Solids (MT)	1869	67	264,668	264,736	264,805
Zinc (MT)	2124	205	161	166	172

TABLE II-6. Total percent of stormwater loads by relative amount of urbanization.

	Highly Urbanized	Moderately Urbanized	Less Urbanized
Ammonia	39%	40%	21%
BOD	34%	35%	31%
Cadmium	26%	36%	38%
Chlordane	-	-	-
Chlorpyrifos	5.1%	43%	52%
Chromium	19%	38%	43%
COD	41%	40%	19%
Copper	31%	37%	33%
DDT	7.1%	43%	50%
Diazinon	49%	41%	11%
Dieldrin	-	-	-
Lead	36%	38%	26%
Mercury	14%	26%	60%
MTBE	-	-	-
Nickel	24%	37%	39%
Nitrate	30%	36%	34%
Nitrite	44%	40%	15%
PCB	-	-	-
Phosphate	33%	35%	32%
Selenium	33%	36%	31%
Suspended Solids	18%	33%	48%
Zinc	43%	37%	20%

TABLE II-7. Flux of constituents in stormwater runoff from various land use types in the Southern California Bight.

	Agriculture	Commercial	Industrial	Open	Residential	Other Urban
Ammonia (kg/km^2)	66.6	137.0	77.2	3.0	41.2	81.3
BOD (kg/km^2)	1,576	5,055	4,182	651	1,538	3,366
Cadmium (kg/km^2)	0.17	0.08	0.14	0.02	0.02	0.07
Chlordane (kg/km^2)	-	-	-	-	-	-
Chlorpyrifos (kg/km^2)	0.01	-	-	-	-	-
Chromium (kg/km^2)	5.24	1.47	1.29	0.24	0.29	0.88
COD (kg/km^2)	6,561	15,926	14,844	427	7,095	12,728
Copper (kg/km^2)	8.37	6.42	9.28	0.76	1.98	5.30
DDT (kg/km^2)	0.0190	-	0.0009	-	0.00004	0.0002
Diazinon (kg/km^2)	-	0.003	0.004	-	0.002	0.004
Dieldrin (kg/km^2)	-	-	-	-	-	-
Lead (kg/km^2)	2.25	2.40	3.49	0.16	1.01	2.20
Mercury (kg/km^2)	0.005	0.008	0.056	0.075	0.036	0.044
MTBE (kg/km^2)	-	-	-	-	-	-
Nickel (kg/km^2)	4.05	1.75	2.01	0.28	0.46	1.25
Nitrate (kg/km^2)	372	405	379	90.71	258	379
Nitrite (kg/km^2)	0.74	21.0	13.3	0.66	9.27	15.0
PCB (kg/km^2)	-	-	-	-	-	-
Phosphate (kg/km^2)	21.1	107.65	82.1	18.8	46.9	79.4
Selenium (kg/km^2)	0.07	0.07	0.12	0.01	0.04	0.07
Suspended Solids (kg/km^2)	76,839	23,158	35,017	12,316	7,994	20,401
Zinc (kg/km^2)	12.8	45.8	65.5	1.49	11.1	35.3

TABLE II-8. Density of fecal indicator bacteria and frequency of water quality threshold exceedences in stormwater discharges by land use type. Single sample water quality thresholds were established by AB411.

	Log Mean Density (per 100mL)			Frequency of Exceedence (%)			
	Total Coliform	Fecal Coliform	Enterococcus	Total Coliform	Fecal Coliform	Enterococcus	Any Indicator
Agriculture	220,000	15,700	-	100	100	-	100
Commercial	117,000	9,500	36,000	100	92	100	96
Industrial	60,000	4,500	60,000	88	81	100	86
Open	9,800	900	1,400	52	58	80	63
Residential	103,000	23,000	93,000	97	98	100	98

III. LARGE PUBLICLY OWNED TREATMENT WORKS

Description of Source

Publicly owned treatment works (POTWs) are facilities that receive and treat sanitary waste from the surrounding municipalities. The sources of sanitary waste include inputs from domestic and industrial sewerage systems. In southern California, POTWs are divided into large and small categories based largely upon flow; large POTWs range from 200 to 370 million gallons per day (MGD), while small POTWs range from < 1 to 30 MGD. This section addresses the large POTWs.

Four large POTWs in the SCB discharge directly to the coastal oceans (Figure III-1). These include the City of Los Angeles Hyperion Treatment Plant (Hyperion), the County Sanitation District of Los Angeles Joint Water Pollution Control Plant (JWPCP), the Orange County Sanitation District Plant Nos. 1 and 2 (OCSD), and the City of San Diego Pt. Loma Wastewater Treatment Plant (Pt. Loma). Each of these POTWs provides advanced primary and/or secondary treatment prior to discharge (Table III-1). All facilities discharge their treated effluents through large effluent outfalls located on the seabed at depths of 60 to 100 m.

Methods

The effluent from large POTWs has been routinely monitored for over three decades for a variety of general constituents, nutrients, trace metals, and organic constituents, in accordance with their NPDES permits. Data from the 1995 compliance monitoring period were used to estimate mass emissions for the present study. Final effluent samples were collected just prior to discharge and, depending upon the constituent, were measured at intervals ranging from daily to annually. The effluent monitoring data were obtained from the discharger's monitoring reports and/or its reports of waste discharge to the RWQCBs (RWQCB data files).

Mass emissions were calculated according to Equation 2:

$$ME = \sum_{i=1}^{n} (C_i * Q_i * T_i) \qquad \text{Equation (2)}$$

where:

ME = Annual mass emissions
C = Mean constituent concentration for month i
Q = Mean daily effluent flow for month i
T = Number of days in month i
n = Months of the year.

The main limitation to this approach is the occurrence of non-detectable quantities (ND) below the analytical laboratory reporting level. All NDs were assigned a value of zero for this study. Since we calculated concentrations and mass emissions on a monthly

basis, months with unreported data were assigned the annual mean concentration, even if the annual mean concentration was below the reporting level.

Results and Discussion

The four large POTWs in the SCB cumulatively discharged over 1.5 x 10^{12} L (1,103 MGD) in 1995 (Table III-2, 3-3). Any single large POTW discharges more treated municipal wastewater than all the small POTWs in the SCB combined.

No single large POTW had the highest concentrations for all constituents (Table III-2). Over half of the 33 constituent concentration comparisons were adversely impacted by either varying reporting levels (9 constituents) or because they were not measured in common among all facilities (9 constituents). The JWPCP had the highest effluent concentration for eight of the 15 remaining constituents, but also had the lowest concentration for three constituents.

Only 13 of the 25 constituents examined for mass emissions could be compared among facilities (Table III-3). The JWPCP had the highest mass emissions for 10 of the 12 remaining constituents, but also had the highest volume discharged. The OCSD and Pt. Loma plants consistently had the least volume and, subsequently, the least mass emissions.

Although the mass emissions from large POTWs appear to be large, the loadings have been decreasing over time (Table III-4). The combined mass emissions from the large POTWs have decreased for all constituents including suspended solids (76%), oil and grease (71%), BOD (55%), trace metals (average 95% for all metals), and chlorinated hydrocarbons such as total DDT (>99.9%), and total PCBs (>99.9%). Wastewater flows increased by an average of 19% during this same time period as the result of a population increase of over four million people. The significant reduction in mass emissions from large POTWs was equally attributable to increased treatment and reclamation, source control, pretreatment programs, and biosolids disposal practices. For example, Hyperion used to discharge biosolids to Santa Monica Bay, but the discharge was terminated in 1987. Hyperion, as well as JWPCP, are increasing treatment and plan to have full secondary treatment of their effluent in the near future.
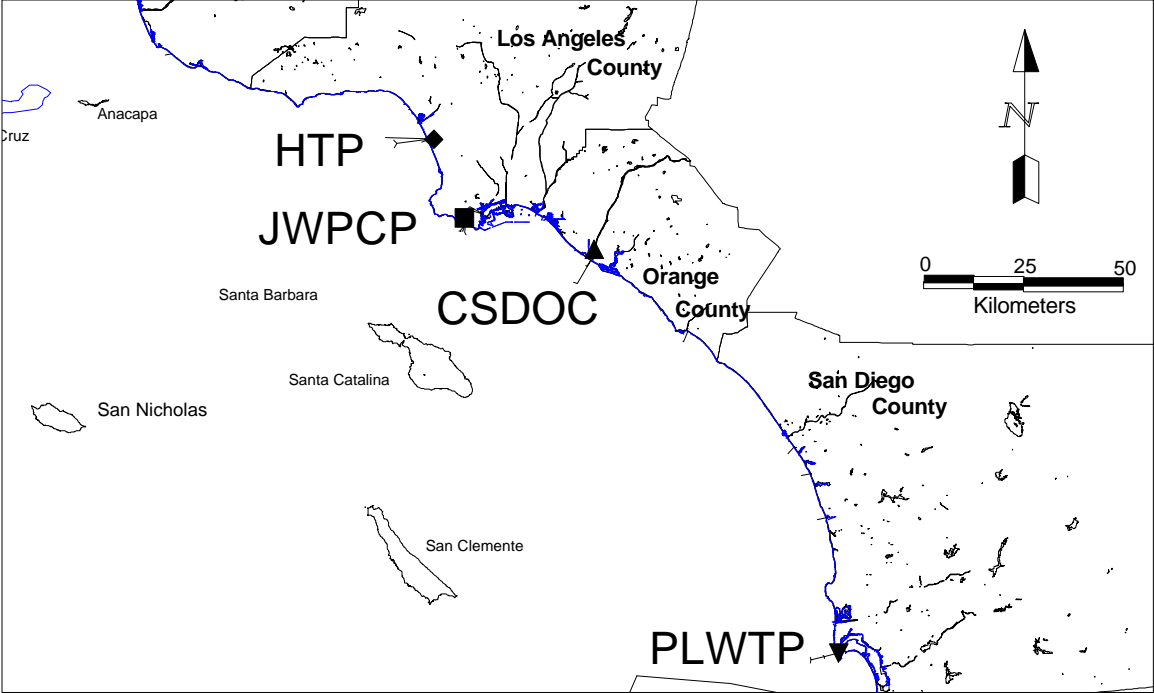
FIGURE III-1. Location of large publicly owned treatment works in the Southern California Bight including City of Los Angeles (HTP), Los Angeles County Sanitation Districts (JWPCP), Orange County Sanitation Districts (CSDOC), and City of San Diego (PLWTP).

TABLE III-1. Flow rate of municipal wastewater discharged into the ocean by the largest municipal wastewater treatment facilities in southern California in 1996.

Treatment Plant	Length of Outfall from Shore (m)	Depth of Discharge (m)	1996 Advanced Primary (mgd)	Secondary (mgd)	Total Flow (mgd)
HTP	8,300	57	161	196	357
JWPCP	2,800/3,600	60	137	194	331
CSDOC	7,250	60	120	116	236
PLWTP	7,285	93	179	0	179
Total			597	506	1,103

mgd = millions gallons per day (1mgd = 3,785,000 L/day)

TABLE III-2. Means and coefficients of variation (CVs) of annual constituent concentrations in effluents from the largest municipal wastewater treatment facilities in southern California in 1997.

Constituent	HTP Mean[a]	CV (%)	JWPCP Mean[a]	CV (%)	CSDOC Mean[a]	CV (%)	PLWTP Mean[a]	CV (%)
Flow (mgd)	358	3	346	4	244	2	189	2
Flow (million L/day)	1,355	3	1,310	4	924	2	715	2
Suspended Solids (mg/L)	30	7	69	8	51	5	39	9
Settleable Solids (mL/L)	0.01	183	0.1	36	0.4	20	0.3	45
BOD (mg/L)	69	8	102	5	78	5	105	7
Oil and Grease (mg/L)	11	19	13	6	17.0	7	9.9	17
Nitrate-N (mg/L)	0.198	151	0.07	45	NA	-[b]	0.08[c]	121
Nitrite-N (mg/L)	NR	-	0.14	41	NA	-	NA	-
Ammonia-N (mg/L)	26.0	14	30.0	3	24	5	26.4	10
Organic-N (mg/L)	5.0	14	6.34	10	NA	-	NA	-
Phosphate (mg/L)	NA	-	3.35	10	NA	-	0.5[c]	69
Total Phosphorus (mg/L)	3.94	12	NA	-	NA	-	NA	-
Cyanide (µg/L)	7	70	8	17.997	2	183	8.0	80
Turbidity (NTU)	22	7	51	7	39	2	37	10
Acute Toxicity (TUa)								
Pimephales promelas	0.71	97	0.79	80	0.81	22	1.3	11
Chronic Toxicity (TUc)								
Haliotis rufescens	34	30	NA	-	NA	-	50	57
Macrocystis pyrifera								
Germ Tube Length	NR	-	9	190	NA	-	95	64
Germination	NR	-	<16.7	-	NA	-	76	46
Arsenic (µg/L)	3	58	2	21	1	92	1.50	23
Cadmium (µg/L)	<2	-	0.5	135	0.4	51	0.2	203
Chromium (µg/L)	1	195	4	154	5	18	0.3	234
Copper (µg/L)	34	27	23	16	35	10	74	49
Lead (µg/L)	0.5	346	0.7	346	0.5	160	<18	-
Mercury (µg/L)	<0.3	-	<0.5	-	0.06	236	0.037	204
Nickel (µg/L)	8	70	49	17	22	20	3	142
Selenium (µg/L)	<1	-	16	13	2	78	1.37	18
Silver (µg/L)	5.1	54	5	63	2	49	0.15	346
Zinc (µg/L)	40	23	66	54	41	9	64	68
Phenols (µg/L)[d]	NA	-	254	38	38	34	NA	-
Chlorinated[e]	<7[f]	-	7	86	0.83	249	<6.1	-
Nonchlorinated[e]	1.9	116	88	74	5.4	43	12.9	23
Total DDT (µg/L)	<0.013[f]	-	0.004	216	<0.04[f]	-	<0.04[f]	-
Total PCB (µg/L)	<0.065[f]	-	<0.9[f]	-	<0.3	-	<0.6[f]	-
PAHs (µg/L)	<1	-	0.6	149	0.31	346	<7.8[f]	-

[a]The number of significant figures are those reported by the agencies.
[b]Dash = Not applicable.
[c]Only soluble forms of phosphate and nitrate were analyzed.
[d]Colorimetric method.
[e]Gas chromatography/mass spectrometry method.
[f]Maximum reporting limit.
NA = Not analyzed.
NR = Not reported.

TABLE III-3. Estimated constituent mass emissions from the largest municipal wastewater treatment facilities in southern California in 1997.

Constituent	HTP	JWPCP	CSDOC	PLWTP	Total
Flow[a] (L x 10^9)	495	478	338	261	1,572
Suspended Solids (mt)	14,628	32,898	17,306	10,273	75,105
BOD (mt)	34,257	48,597	26,228	27,429	136,511
Oil and Grease (mt)	5,310	6,170	5,731	2,582	19,793
Nitrate-N (mt)	98	35	NA	21	154
Nitrite-N (mt)	NR	68	NA	NA	68
Ammonia-N (mt)	12,848	14,308	7,985	6,875	42,016
Organic-N (mt)	2,456	3,028	NA	NA	5,484
Phosphate (mt)	NA	1,607	NA	126	1,733
Total Phosphorus (mt)	1,950	NA	NA	NA	1,950
Cyanide (mt)	3.2	3.9	0.58	2.1	9.8
Arsenic (mt)	1.2	1.1	0.45	0.39	3.1
Cadmium (mt)	nd	0.24	0.12	0.05	0.4
Chromium (mt)	0.65	2	1.5	0.09	4.2
Copper (mt)	17	11	12	19	59
Lead (mt)	0.26	0.33	0.17	nd	0.8
Mercury (mt)	nd	nd	0.02	0.01	0.03
Nickel (mt)	4.1	23	7.3	0.72	35
Selenium (mt)	nd	7.5	0.51	0.36	8.4
Silver (mt)	2.5	2.3	0.79	0.04	5.6
Zinc (mt)	20	31	14	17	82
Phenols[b] (mt)	NA	121	13	NA	134
Chlorinated[c]	nd	3.1	0.28	nd	3.4
Nonchlorinated[c]	0.9	41.2	1.8	3.4	47
Total DDT (kg)	nd	2.1	nd	nd	2.1
Total PCB (kg)	nd	nd	nd	nd	0.0
PAHs (kg)	nd	290	104	nd	394

[a]Annual flow volumes were the sum of mean daily flow per month times the number of days in each month.
[b]Colorimetric method.
[c]Gas chromatography/mass spectrometry method.
mt = Metric tons.
NA = Not analyzed.
NR = Not reported.
nd = Not detected.

TABLE III-4. Estimated combined constituent mass emissions for HTP, JWPCP, CSDOC, and PLWTP from 1971 through 1997.

Constituent	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
Flow (L x 10^9)	1,284	1,278	1,319	1,336	1,346	1,406	1,319	1,382	1,438	1,493	1,492	1,511	1,549
Flow (mgd)	930	922	954	967	975	1,015	955	1,001	1,041	1,078	1,080	1,094	1,122
Suspended Solids[a] (mt x 10^3)	294	287	292	271	285	286	242	254	244	232	225	227	245
BOD[b] (mt x 10^3)	283	250	227	234	234	256	242	234	242	255	261	266	252
Oil and Grease (mt x 10^3)	62	61	61	55	57	59	49	49	45	38	37	37	36
NH_3-N (mt x 10^3)	55	40	46	39	36	37	40	39	41	41	41	42	40
Total P[c] (mt x 10^3)	34	36	39	38	11	23	11	10	10	10	9.5	9.0	9.0
MBAS (mt x 10^3)	0.3	6.3	5.9	6.8	6.3	6.1	5.4	5.8	6.3	6.4	5.6	5.7	5.2
Cyanide (mt)	188	238	244	303	251	401	213	176	145	116	98	77	46
Arsenic (mt)	31	18	16	18	12	11	12	15	15	11	12	8.0	10
Cadmium (mt)	52	34	49	55	51	44	41	44	43	39	32	21	23
Chromium (mt)	667	675	694	690	579	592	368	279	239	275	187	203	163
Copper (mt)	535	486	508	576	510	506	402	416	361	335	337	284	272
Lead (mt)	226	252	180	199	198	189	150	216	224	175	130	122	98
Mercury (mt)	2.9	2.6	3.1	1.8	2.2	2.5	2.6	1.9	2.6	1.8	1.8	1.2	1.1
Nickel (mt)	326	262	318	315	282	302	262	318	256	224	167	168	163
Selenium (mt)	12	11	16	18	11	22	22	23	7.9	11	15	6.4	6.5
Silver (mt)	15	22	29	22	25	20	34	32	43	30	28	25	26
Zinc (mt)	1,834	1,201	1,189	1,324	1,087	1,061	834	833	7,287	729	538	545	497
DDT[f] (kg)	21,527	6,558	3,818	1,562	1,158	1,633	855	1,121	839	671	480	290	223
PCB[f] (kg)	8,730	9,830	3,389	5,421	3,065	3,492	2,183	2,540	1,170	1,127	1,252	785	628
PAHs (kg)	_h	_h	_h	_h	_h	_h	_h	_h	_h	_h	_h	_h	_h

[a]Solids from HTP's 7-mile outfall are total solids.
[b]Hyperion's 7-mile outfall is not included.
[c]Sum of soluble phosphate (PLTWP) and total phosphorus (HTP and JWPCP).
[d]Analyses discontinued.
[e]Only HTP data were available.
[f]Estimates for 1973 through 1975 were based on Southern California Coastal Water Research Project, Bodega Bay Marine Laboratories, and University of Washington analyses, except for DDT estimates for JWPCP were based on JWPCP's own analyses.   Estimates for remaining years are based on discharger data.
[g]Concentrations were below method detection limits.
[h]PAH results were not tracked by SCCWRP until 1996.

1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
1,565	1,579	1,623	1,629	1,632	1,656	1,627	1,455	1,440	1,485	1,474	1,529	1,527	1,572
1,129	1,143	1,175	1,179	1,178	1,199	1,178	1,053	1,039	1,075	1,069	1,106	1,103	1,137
198	205	185	149	97	83	80	79	79	75	68	73	70	75
230	254	182	167	169	161	159	139	135	136	132	138	127	137
30	34	29	26	25	23	22	19	19	18	19	19	18	20
40	43	45	44	44	45	46	44	42	41	41	41	41	42
9.2	8.5	11	9.0	7.1	6.9	7.1	6.7	5.9	4.3	3.7	3.6	3.5	3.7
4.6	4.3	4.8	4.6	3.4	3.3	3.5	3.5	3.2	-[d]	-[d]	-[d]	-[d]	-[d]
39	26	22	27	26	10	13	16	18	14	12	6.5	10	9.8
18	16	12	12	8.9	7.4	8.2	5.4	5.5	5.2	4.0	5.0	4.3	3.1
16	16	14	9.0	3.4	1.9	1.3	1.1	0.5	0.6	0.7	1.0	0.4	0.4
140	110	88	57	29	22	14	10	11	6.8	6.7	7.0	6.5	4.2
251	239	202	125	76	68	59	47	48	45	49	53	49	59
87	118	105	61	50	27	8.0	2.5	3.4	1.8	1.3	2.4	1.2	0.8
0.9	0.9	0.7	0.4	0.4	0.4	0.2	0.2	0.03	0.02	0.03	0.02	0.03	0.03
133	118	127	76	63	54	40	33	31	31	28	30	34	35
6.5	5.8	8.2	7.2	6.7	7.6	7.3	7.0	7.2	6.6	7.4	7.8	7.4	8.4
24	26	22	15	11	11	9.4	7.9	6.9	6.0	5.7	5.4	4.9	5.6
369	375	336	261	151	146	115	125	98	82	72	86	91	82
310	48	51	53	26	20	17	6.4	13	9.2	7.9	3.1	1.4	2.1
1,209	46	37	5	-[g]	-[g]	-[g]	-[g]	-[g]	-[g]	-[g]	-[g]	-[g]	-[g]
-[h]	-[h]	-[h]	-[h]	-[h]	-[h]	-[h]	-[h]	-[h]	-[h]	-[h]	-[h]	161	394

IV. SMALL PUBLICLY OWNED TREATMENT WORKS

Description of Source

Publicly owned treatment works (POTWs) are facilities that receive and treat sanitary waste from the surrounding municipality. The sources of sanitary waste include inputs from domestic and industrial sewerage systems. In southern California, POTWs are divided into large and small categories based largely on flow; large POTWs range from 200 to 370 MGD, while small POTWs range from < 1 to 30 MGD. This section addresses the small POTWs.

Fifteen small POTWs discharge directly to the coastal oceans in the SCB (Figure IV-1). Thirteen of these facilities provide secondary treatment prior to discharge (Table IV-1). One facility provides tertiary treatment and another facility provides advanced primary and secondary treatment. All but one of these POTWs discharge their treated effluents through outfalls that are located on the sea bed, typically at a depth of 30 m. The only exception is the San Clemente Island outfall whose disharge is near the surf zone.

Methods

Effluents from small POTWs have been routinely monitored for over two decades for a variety of general constituents, nutrients, trace metals, and organic constituents, in accordance with their NPDES permits. Compliance monitoring data from 1994 were used to estimate mass emissions for this study. Final effluent samples were collected just prior to discharge and, depending upon the constituent, were measured at intervals ranging from daily to annually. The effluent monitoring data were obtained from the discharger's monitoring reports and/or agency reports of waste discharge to the RWQCBs (RWQCB data files).

Mass emissions were calculated according to Equation 3:

$$ME = \sum_{i=1}^{n} (C_i * Q_i * T_i) \qquad \text{Equation (3)}$$

where:

$$
\begin{aligned}
\mathbf{ME} &= \text{Annual mass emissions} \\
\mathbf{C} &= \text{Mean constituent concentration for month } i \\
\mathbf{Q} &= \text{Mean daily effluent flow for month } i \\
\mathbf{T} &= \text{Number of days in month } i \\
\mathbf{n} &= \text{Months of the year.}
\end{aligned}
$$

The main limitation to this approach is the occurrence of non-detectable quantities (NDs) below the analytical laboratory reporting level. All NDs were assigned a value of zero for this study. Concentrations and mass emissions were calculated on a monthly basis

and months with no data reported were assigned the annual mean concentration, even if the annual mean concentration was below the reporting level. The second limitation to this approach is the lack of common constituents. Mass emissions were estimated for those constituents where any data was found, even if that constituent was not measured by all facilities.

Results and Discussion

The 15 small POTWs in the SCB cumulatively discharged over 181 x 10^9 L (131 MGD) in 1995 (Tables 4-2, 4-3). The Encina Wastewater Authority discharged the largest volume in 1994 (28 x 10^9 L). Five of the small POTWs discharged less than 2 x 10^9 L.

A comparison of concentrations among facilities was limited by the large number of NDs (Table IV-2). Only three constituents were measured in common among all small POTWs that did not have reporting level complications including suspended solids, BOD, and ammonia. The Goleta Sanitary District had the highest concentrations of all three of these constituents.

The range in mass emissions among small POTWs for selected constituents varied significantly (Table IV-3). For example, the suspended solids mass emissions ranged from 0.2 to 248 MT in 1994. Only nine of the 24 constituents examined for mass emissions were estimated for five or more facilities. Six of the nine largest constituent mass emissions were from the Encina Wastewater Authority, owing largely to the higher volume of its discharges. The City of Oxnard Perkins Wastewater Treatment Plant dominated the remaining three constituent mass emissions. This facility also discharges substantial volumes annually.

The combined mass emissions from small POTWs have decreased for the majority of constituents between 1987 and 1994, although flows have remained relatively the same (Table IV-4). Mass emissions have decreased for suspended solids (59%), oil and grease (57%), and BOD (47%). Although arsenic and silver have increased, seven other trace metals have decreased, for an average trace metal reduction of 29%. Chlorinated hydrocarbons such as total DDT and total PCBs were not detected in 1987; therefore, comparisons of these elements could not be made. The reductions in mass emissions from small POTWs is equally attributable to increased treatment and reclamation, source control, and pretreatment programs.
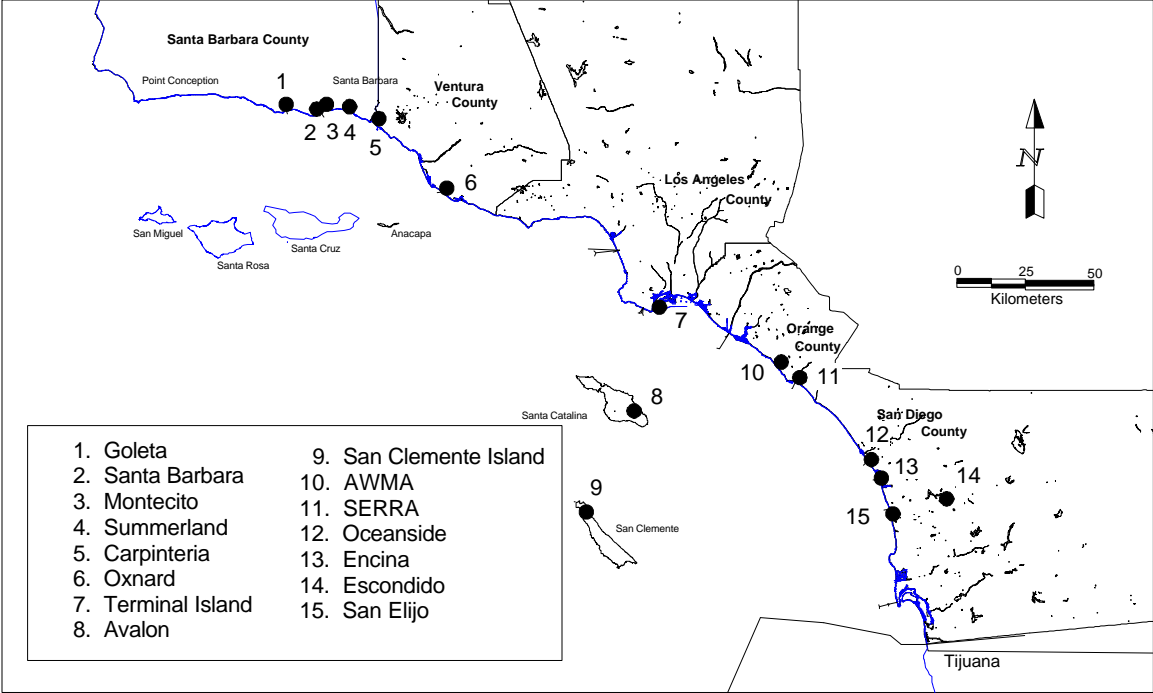
FIGURE IV-1. Location of small publicly owned treatment works in the Southern California Bight.

TABLE IV-1. Names of the governing agencies and the small municipal wastewater treatment facilities that discharged to the Southern California Bight in 1995.

CENTRAL REGIONAL WATER QUALITY CONTROL BOARD
    Goleta Sanitary District - Goleta Wastewater Treatment Plant
    City of Santa Barbara - El Estero Wastewater Treatment Plant
    Montecito Sanitary District - Montecito Wastewater Treatment Plant
    Summerland Sanitary District - Summerland Wastewater Treatment Plant
    Carpinteria Sanitary District - Carpinteria Wastewater Treatment Plant

LOS ANGELES REGIONAL WATER QUALITY CONTROL BOARD
    City of Oxnard - Perkins Wastewater Treatment Plant
    City of Los Angeles - Terminal Island Wastewater Treatment Plant
    City of Avalon - Santa Catalina Island Sewage Treatment Plant
    U.S. Navy - Navy Auxiliary Landing Field - San Clemente Island Sewage Treatment
      Plant

SAN DIEGO REGIONAL WATER QUALITY CONTROL BOARD
    AWMA (Aliso Water Management Agency) - Aliso Ocean Outfall
        El Toro Wastewater Reclamation Plant
        Los Alisos Wastewater Treatment Plant
        AWMA Joint Regional Treatment Plant
        AWMA Coastal Water Treatment Plant
    SERRA (South East Regional Reclamation Authority) - SERRA Ocean Outfall
        Capistrano Beach Wastewater Treatment Plant
        Moulton Niguel Water District 3A Treatment Plant
        City of San Clemente Wastewater Treatment Plant
        Santa Margarita Water District
            Oso Creek Water Reclamation Plant
            Chiquita Water Reclamation Plant
        Jay B. Latham Regional Wastewater Treatment Plant
    City of Oceanside Water Utilities Department - Oceanside Ocean Outfall
        La Salina Wastewater Treatment Plant
        San Luis Rey Wastewater Treatment Plant
        Fallbrook Sanitary District, Plant 1 and Plant 2
    Encina Wastewater Authority - Encina Ocean Outfall
        Meadow Lark Water Reclamation Plant
        Shadow Ridge Water Reclamation Plant
        Gafner Water Reclamation Plant
    San Elijo Joint Powers Authority - San Elijo Water Pollution Control Facility
        City of Escondido, Hale Avenue Resource Recovery Facility (treated separately
        from San Elijo)

TABLE IV-2. Volume and level of effluent treatment for the small municipal wastewater treatment facilities that discharged to the Southern California Bight in 1995.

Municipal Wastewater Facility[a]	Flow (mgd)	Level of Treatment
Goleta	5.2	Primary/Secondary
Santa Barbara	8.1	Secondary
Montecito	1.1	Secondary
Summerland	0.17	Tertiary
Carpinteria	1.5	Secondary
Oxnard	19.5	Secondary
Terminal Island	16.9	Secondary
Avalon	0.67	Secondary
San Clemente Island	0.028	Secondary
AWMA	18.9	Secondary
SERRA	17.9	Secondary
Oceanside	12.9	Secondary
Encina	21.8	Secondary
San Elijo + Escondido	18.4	Secondary
Total	143.1	

[A]See Table IV-1 for complete facility names.
mgd = Millions of gallons per day (1 mgd = 3,785,000 L/day).

TABLE IV-3. Means and coefficients of variation of annual constituent concentrations in effluents from small municipal wastewater treatment facilities that discharged to the Southern California Bight in 1995.

Constituent	Goleta[a] Mean	CV	Santa Barbara[a] Mean	CV	Montecito[a] Mean	CV	Carpinteria[a] Mean	CV	Summerland[a] Mean	CV	Oxnard[a] Mean	CV	Terminal Island[a] Mean	CV
Flow (mgd)	5.16	15	8.09	23	1.10	20	0.17	20	1.51	17	19.5	8	16.9	8
Flow (millions of L/day)	19.5	15	30.6	23	4.18	20	0.66	20	5.70	17	73.9	8	64.1	8
Suspended Solids (mg/L)	33.6	19	11.8	30	7.6	22	6	27	17	32	6.6	20	6	30
Settleable Solids(mL/L)	0.15	27	0.3	129	-	-	nd	-	0.3	71	0.04	148	<0.04[b]	-
BOD (mg/L)	47.1	16	7.8	22	5.2	28	4	74	14	23	15.9	16	3	27
Oil and Grease (mg/L)	7.2	10	2.2	23	3.5	93	0.26	346	2.1	14	2	27	3	23
Nitrate-N (mg/L)	NA	-	NA	-	NA	-	NA	-	NA	-	3.9	87	NR	-
Nitrite-N (mg/L)	NA	-	NA	-	NA	-	NA	-	NA	-	0.9	65	NA	-
Ammonia-N (mg/L)	33.7	12	19.6	35	0.5	27	0.2	186	3	295	15	28	0.3	70
Organic N (mg/L)	NA	-	NA	-	NA	-	NA	-	NA	-	2.2	44	NA	-
Cyanide (ug/L)	9	157	<20[b]	-	<10	-	<40	-	<100	-	36	66	<10	-
Turbidity (NTU)	31	8	5.1	56	1.1	9	1.7	51	4.6	78	2.5	15	2.5	34
Acute Toxicity (TUa)	0.4	107	0.82	67	-	-	NA	-	0	-	0.47	99	0.07	234
Chronic Toxicity (TUc)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Macrocystis pyrifera	-	-	-	-	-	-	-	-	-	-	-	-	NA	-
Germ tube length	-	-	-	-	-	-	<17.86	-	-	-	-	-	NA	-
Germination	-	-	-	-	-	-	<17.86	-	-	-	-	-	NA	-
Strongylocentrotus purpuratus	-	-	<17.86	-	-	-	<17.86	-	-	-	-	-	NA	-
Menidia beryllina	-	-	-	-	-	-	<17.86	-	-	-	-	-	0.25	181
Arsenic (ug/L)	<5[b]	-	4	101	<5	-	<50	-	1	141	2.7	36	4	38
Cadmium (ug/L)	<5[b]	-	<10	-	<2	-	<10	-	<1	-	<4	-	<2	-
Chromium (ug/L)	0.7	346	<10	-	<10	-	<50	-	<10	-	<10	-	0.4	316
Copper (ug/L)	31	67	15	47	<10	-	<50	-	<50	-	13.1	36	0.8	346
Lead (ug/L)	0.5	346	3	47	<2	-	<50	-	<5	-	3.22	245	<3	-
Mercury (ug/L)	<0.5	-	<0.2	-	<0.2	-	<2	-	<1	-	0.22	153	<0.3[b]	-
Nickel (ug/L)	4	346	<40	-	<10	-	NA	-	<10	-	26.8	31	2	200
Selenium (ug/L)	nd	-	0.5	141	NA	-	NA	-	<5	-	-	-	14	64
Silver (ug/L)	0.4	97	<10	-	20	-	<50	-	<10	-	<4	-	0.04[e]	190
Zinc (ug/L)	41	49	60	-	30	-	30	-	<50	-	53.1	210	47	23
Phenols (ug/L)	-	-	<100	-	-	-	-	-	16	-	-	-	-	-
Chlorinated	14	40	<50[b]	-	<50[b]	-	-	-	<50[b]	-	<10	-	<7	-
Nonchlorinated	20	-	<50[b]	-	<50[b]	-	-	-	<50[b]	-	0.8	346	-	-
DDT (ug/L)	<0.02	-	-	-	<0.2	-	NA	-	<0.1	-	0.01	253	<13	-
PCB (ug/L)	<0.1	-	-	-	<2	-	NA	-	<0.5	-	<0.2[b]	-	<0.06	-

Second half of table IV-3.

Avalon[a]		San Clemente Island[a]		AWMA[a]		SERRA[a]		Oceanside[a]		Encina[a]		San Elijo[a]		Escondido[a]	
Mean	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**
0.67	22	0.028	21	18.9	10	17.9	7	12.9	7	21.8	10	3.07	4	15.3	5
2.52	22	0.107	21	71.5	10	67.9	7	49.0	7	82.6	10	11.6	4	57.9	5
19	15	4	83	9.7	18	13.3	49	7.8	40	7.4	14	9.4	18	7.7	30
0.07	117	nd	-	0.08	245	0.2	21	0.2	240	0.06	30	0.2	43	<0.1	-
2	30	8	134	5.8	13	5.9	10	4.1	53	28	10	6.7	9	7.2	19
4.9	127	0.8	272	5.1	8	1.4	113	2.0	77	0.7	70	0.7	66	0.8	128
51	33	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1.0	95	0.13	-	14.2	14	27	30	22.0	10	24.2	13	20	36	23.1	13
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<20	-	nd	-	<50[b]	-	<20	-	<20	-	1.3	120	nd	-	20	141
3.4	39	1.1	57	3.7	12	4.5	53	4.3	30	4.3	12	4	17	3.1	23
0.15	200	-	-	-	-	-	-	1.02	19	0.76	48	<1	-	0.42	113
-	-	-	-	-	-	-	-	33.3	245	20.63	56	-	-	20.23	88
<17.86	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4	141	nd	-	<3[b]	-	2	118	<70[b]	-	4	20	0.8	200	0.33	200
<5[b]	-	10	-	<20[b]	-	<10[b]	-	<5[b]	-	14	19	3	200	0.4	122
<10	-	nd	-	<50[b]	-	<200[b]	-	2	200	42	52	nd	-	2	67
<20	-	nd	-	7	173	85	169	<6[b]	-	118	35	nd	-	11	63
<50[b]	-	nd	-	1	173	3	137	<70[b]	-	68	86	28	62	0.73	200
<1[b]	-	nd	-	<0.5[b]	-	<0.5	-	<1	-	<0.2	-	nd	-	<0.5	-
<40	-	nd	-	<50[b]	-	<25	-	<25[b]	-	59	31	nd	-	8	52
<5[b]	-	-	-	2	173	9.5	141	<40	-	5	13	3	115	0.95	120
<10	-	nd	-	<30[b]	-	<10	-	<10[b]	-	18	39	5	20	2	200
84	-	40	-	25	54	93	49	11	75	234	51	48	20	75	35
-	-	nd	-	-	-	-	-	-	-	-	-	-	-	-	-
<20[b]	-	-	-	<100[b]	-	<100[b]	-	<20[b]	-	<4	-	nd	-	<20	-
<20[b]	-	-	-	<260[b]	-	<260[b]	-	<50[b]	-	<42	-	nd	-	<20	-
<10[b]	-	nd	-	-	-	<0.04	-	<0.27	-	<5.6	-	nd	-	<0.1	-
<50[b]	-	nd	-	-	-	<1.2	-	<5.2	-	<0.65	-	nd	-	<0.5	-

[a]The number of significant figures are those reported by the agencies. See Appendix 1 for complete facility names.
[b]Maximum of the range of detection limits reported.
nd = Not detected
NR = Not reported in annual report.
Dash = Not applicable, or data not found
NA = Not analyzed..

TABLE IV-4. Estimates of constituent mass emissions from small municipal wastewater treatment facilities that discharged to the Southern California Bight in 1995.

Constituent	Goleta	Santa Barbara	Montecito	Summerland	Carpinteria	Oxnard	Terminal Island	Avalon	San Clemente Island
Flow[a] (L x 10^9/ yr)	7.1	11	1.5	0.24	2.1	27	23	0.92	0.04
Suspended solids (mt)	245	137	12	1.4	36	179	146	17	0.14
BOD (mt)	342	89	8.2	0.95	30	430	69	1.7	0.33
Oil and Grease (mt)	51	24	5.6	0.04	4.4	52	77	4.4	0.03
Nitrate-N (mt)	-	-	-	-	-	106	-	46	-
Nitrite-N (mt)	-	-	-	-	-	24	-	-	-
Ammonia-N (mt)	242	209	0.83	0.04	7.9	409	6.7	0.98	0.005
Organic N (mt)	-	-	-	-	-	59	-	-	-
Cyanide (kg)	64	-	-	-	-	975	-	-	-
Arsenic (kg)	-	40	-	-	2.1	74	88	3.8	-
Cadmium (kg)	-	-	-	-	-	-	-	-	0.39
Chromium (kg)	4.4	-	-	-	-	-	9.4	-	-
Copper (kg)	230	170	-	-	-	360	20	-	-
Lead (kg)	4.6	33	-	-	-	94	-	-	-
Mercury (kg)	-	-	-	-	-	6.1	-	-	-
Nickel (kg)	27	-	-	-	-	720	42	-	-
Selenum (kg)	-	5.8	-	-	-	-	319	-	-
Silver (kg)	2.9	-	30	-	-	-	1.1	-	-
Zinc (kg)	299	671	46	6.6	61	1,457	1,108	78	1.6
Phenols (kg)	-	-	-	-	33	-	-	-	-
Chlorinated	100	-	-	-	-	-	-	-	-
Nonchlorinated	143	-	-	-	-	23	-	-	-
DDT (kg)	-	-	-	-	-	0.3	-	-	-
PCB (kg)	-	-	-	-	-	-	-	-	-

Second half of table IV-4.

AWMA	SERRA	Oceanside	Encina	San Elijo	Escondido	Total
26	25	18	30	4.2	21	197
255	332	136	223	40	164	1,924
151	147	72	842	28	153	2,364
134	34	36	19	3.1	18	463
-	-	-	-	-	-	152
-	-	-	-	-	-	24
369	659	393	727	86	489	3,599
-	-	-	-	-	-	59
-	-	-	37	-	426	1,502
-	44	-	120	3.1	6.8	382
-	-	-	432	11	8.3	452
-	61	36	1,257	-	32	1,400
175	2,076	-	3,513	-	233	6,777
35	67	-	2,016	116	16	2,382
-	-	-	5.1	-	-	11
-	-	-	1,765	-	158	2,712
52	236	-	135	13	20	781
-	-	-	533	21	38	626
653	2,285	197	7,190	202	1,589	15,844
-	-	-	-	-	-	33
-	-	-	-	-	-	100
-	-	-	-	-	-	166
-	-	-	-	-	-	0.3
-	-	-	-	-	-	0

Dash = Constituent was below detection limits, not analyzed, or data was not found.
[a]Annual flow volumes are the sum of the mean daily flow per month times the number of days in each month.

V. INDUSTRIAL DISCHARGERS

Description of Source

Industrial facilities have the potential to be significant contributors of pollutants to the coastal waters because many of these facilities discharge chemicals containing byproducts of industrial and/or manufacturing processes. Unlike POTWs, industrial facilities generate their own wastes. Many industrial facilities provide some type of waste treatment prior to discharge. In southern California, industrial facilities are divided into power generating and non-power generating industrial facilities. This section addresses the non-power generating industrial facilities.

In 1995, 10 industrial facilities discharged directly into harbors, bays, and coastal oceans of the SCB (Figure V-1, Table V-1). Five were petroleum-related facilities involved in the refining of oil and gas that discharged refinery and process wastes, hazardous cooling water (waste stream that might contain toxicants, corrosives, ignitable or reactive substances), and other miscellaneous wastes. Two facilities that discharged process wastes were salt manufacturing companies (Morton Salt Co. and Western Salt Co.). The remaining three facilities included the U.S. Borax Co. (hazardous cooling water), the University of California, Scripps Institute of Oceanography (miscellaneous wastes associated with aquaria), and the U.S. Navy (non-contact cooling water). In most instances, discharges were located at or near the sea surface; eight of the ten facilities discharged to harbors or bays rather than the open coast.

Methods

Over 87 non-power generating industrial facilities are permitted by the RWQCBs in the SCB. However, only 10 of these facilities discharge below the tidal prism either directly to the ocean or to bays and harbors. For the purposes of this report, we did not calculate mass emissions for facilities that discharged directly to storm drains above the tidal prism, or that discharged solid waste, groundwater dewatering, or on-site stormwater runoff (unless it was commingled with another targeted discharge).

The effluents from industrial facilities are routinely monitored for a variety of general constituents, nutrients, trace metals, and organic constituents, in accordance with their NPDES permit. Compliance monitoring data were used during 1995 to estimate mass emissions. Final effluent samples were collected just prior to discharge and, depending upon the constituent, were measured at intervals ranging from daily to annually. The effluent monitoring data was obtained from the discharger's monitoring reports and/or its reports of waste discharge to the RWQCBs (RWQCB data files).

Mass emissions were calculated according to Equation 4:

$$ME = \sum_{i=1}^{n} (C_i * Q_i * T_i) \qquad \text{Equation (4)}$$

where:

ME	=	Annual mass emissions
C	=	Mean constituent concentration for month i
Q	=	Mean daily effluent flow for month i
T	=	Number of days in month i
n	=	Months of the year.

The main limitation to this approach is the occurrence of non-detectable quantities (ND) below the analytical laboratory reporting level. All NDs were assigned a value of zero for this study. Since we calculated concentrations and mass emissions on a monthly basis, months with unreported data were assigned the annual mean concentration, even if the annual mean concentration was below the reporting level. The concentrations for a facility with serial outfalls were determined using flow as a weighting factor.

The second limitation to this approach is the lack of common constituents. Estimated mass emissions were estimated for any constituent that reported data, even if that constituent was not measured by all facilities.

Results and Discussion

The 10 industrial facilities in the SCB cumulatively discharged over 23 x 10^9 L (17 MGD) in 1995 (Tables V-2 and V-3). The petroleum-related facilities contributed 18 x 10^9 L (13 MGD) of these discharges. The largest of these petroleum-related facilities was the Chevron El Segundo Oil Refinery, which discharges into Santa Monica Bay.

Not a single constituent measured was in common among all facilities for which comparable data existed (Table V-2). Fourteen constituents were measured by four or more facilities; 12 of these constituents were below reporting levels.

The range in mass emissions among industrial facilities varied by a factor ranging from 10 (copper) to 27,000 (BOD) (Table V-3). The mass emissions for combined trace metals was 2.2 MT. The single most abundant trace metal was zinc (1.1 MT). Of the organics analyzed, only phenols were detected, accounting for 1.4 MT. The Chevron El Segundo facility comprised the highest mass emissions of all industrial facilities. This finding reflects the facility's large volume, lower reporting levels, and larger numbers of detectable results.

A dramatic decline in the number of petroleum-related facilities that discharge directly to the open coast has occurred over the past two decades (Table V-3). In 1971, 28 petroleum-related industries discharged directly to the ocean; only one remained in 1995. Twenty-six of the 28 facilities discharged produced water (a refining process effluent) in 1971, generating 500 MT of suspended solids and 100 MT of oil and grease from a combined flow of 6 MGD. In contrast, no facilities discharged produced water in 1995. The Chevron El Segundo refinery was the only facility that discharged directly to the

ocean in 1995 and its discharge was composed of process waste. Flow from this facility had decreased 89% compared to 1971 and mass emissions of suspended solids and oil and grease had decreased accordingly (93 and 95%, respectively).

Table V-1. Industrial facilities that discharged into southern California bays, harbors, tidal prisms of storm channels, or directly into the Southern California Bight in 1995.

Agency	Facility	ID No.*	Waste Type	Location	Discharge Location
Chevron U.S.A. Inc.	El Segundo Oil Refinery	1	PROC/SW	El Segundo	Pacific Ocean
Unocal Corp.	Los Angeles Oil Refinery	2	HCW	Wilmington	L.A. Harbor
Mobil Oil Corp.	Southwestern Terminal- Area 1	3	MISC 1/SW	Terminal Is.	L.A. Harbor
U.S. Borax Inc.	Wilmington Plant	4	HCW	Wilmington	L.A. Harbor
ARCO Products Co.	Los Angeles Refinery	5	PROC	Carson	Dominguez Channel
Texaco Incorporated	Los Angeles Plant	6	HCW	Wilmington	Dominguez Channel
U.S. Dept. of the Navy	Long Beach Naval Shipyard	7	NONCON	Terminal Is.	Long Beach Harbor
Morton Int. Inc.	Ocean Salt Company	8	PROC	Long Beach	Long Beach Harbor
University of Calif	Scripps Inst. of Oceanography	9	MISC 2	La Jolla	Pacific Ocean
Western Salt Company	Western Salt Company	10	PROC	Chula Vista	San Diego Bay

*Key to location on Figure V-1.
**Type refers to wastes discharged in 1995. Other types of wastes may be allowed to be discharged under the same permit.
HCW = Hazardous cooling water which contains toxic, corrosive, ignitable, or reactive substances and must be managed according to Department of Health Services standards.
MISC 1 = Steam condensate, tank washing waste, and ship ballast water.
MISC 2 = Aquarium seawater to which copper sulfate and antibiotics have been added, seawater from a physiological research laboratory, and storage tank seawater.
NONCON = Noncontact cooling water.
PROC = Process waste (waste produced as part of the industrial/manufacturing process).
SW = Stormwater runoff.
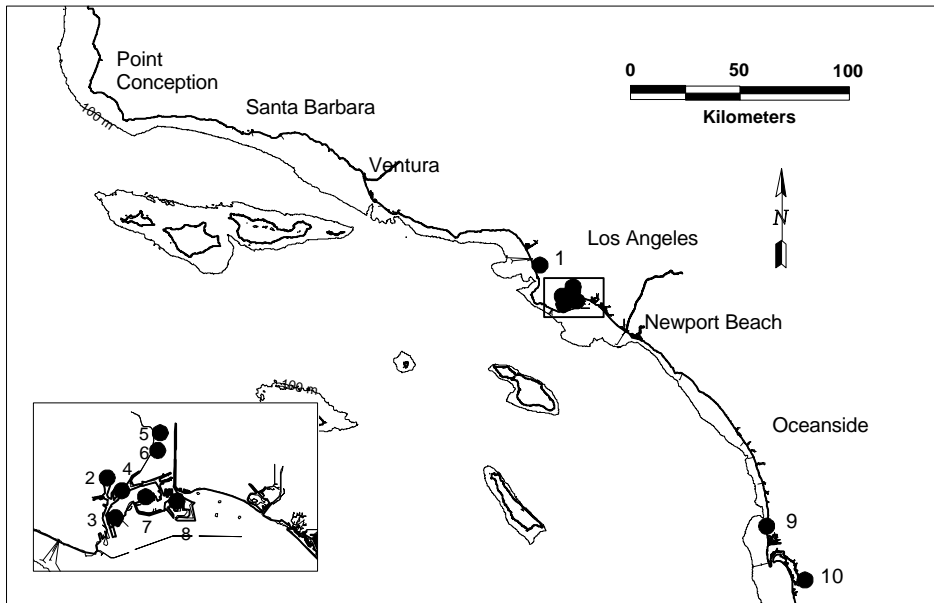
FIGURE V-1. Location of industrial dischargers in the Southern California Bight. See Table 1 for a list of facilities.

TABLE V-1. Means and coefficients of variation (CVs) of annual constituent concentrations in effluents from industrial dischargers in southern California in 1995.

Constituent	Chevron El Segundo Refinery Waste		Unocal Refinery Wilmington H, CW		Mobil Terminal Terminal Island Misc. 1 Waste		U.S. Borax Wilmington H, CW		ARCO Refinery Carson Process Waste		Texaco Refinery Wilmington H, CW		LBNSY Terminal Island NONCON [a]		Morton Ocean Salt Long Beach Process Waste		SIO La Jolla Misc. Waste 2		Western Salt Chula Vista Process Waste	
	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
Flow (mgd)	7.79	8	2.1	59	0.007	157	0.73	2	0.72	346	2	36	2.4	12	0.002	18	0.52	11	0.006	96
Flow (million L/day)	29.5	8	8.1	59	0.03	157	2.8	2	2.7	346	7.7	36	9.1	12	0.006	18	2	11	0.02	96
Suspended Solids (mg/L)	18	57	NA	-	3	116	NA	-	7.8	-	6	59	29[b]	176	89	49	2.3	0.4	100	45
Settleable Solids (mL/L)	0.1	189	NA	-	ND	-	NA	-	NA	-	0.1	0	NA	-	<0.1	-	<0.2[c]	-	<0.1	-
BOD (mg/L)	13[d]	53	NA	-	NA	-	NA	-	8	-	12	47	NA	-	NA	-	NA	-	0.58	-
Oil and Grease (mg/L)	5.9	26	NA	-	2.3	99	NA	-	3	-	7.1	17	0.1	166	4	181	5.3	42	NA	-
Ammonia-N (mg/L)	3.6	50	NA	-	NA	-	0.16	154	2	-	6	103	NA	-	NA	-	NA	-	21.7	-
Cyanide (µg/L)	<15.6	-	NA	-	<25	-	NA	-	NA	-	NA	-	<20	-	NA	-	NA	-	NA	-
Turbidity (NTU)	12	122	NA	-	NA	-	NA	-	15	-	NA	-	6.3	66	NA	-	0.3	16	NA	-
Acute Toxicity (TUa)	0.6	84	0	-	0.15	200	0.06	200	ND	-	NA	-	0.12	200	NA	-	NA	-	NA	-
Chronic Toxicity (TUc)	-	-	NA	-	NA	-	NA	-	2	-	NA	-	-	-	NA	-	NA	-	NA	-
Selenastrum capricornutum	NA	-	NA	-	NA	-	NA	-	2.5	-	NA	-	NA	-	NA	-	NA	-	NA	-
Macrocystis pyrifera	NA	-	1	-	NA	-	NA	-	NA	-	NA	-	NA	-	NA	-	NA	-	NA	-
Ceriodaphnia, survival	NA	-	NA	-	NA	-	NA	-	1.5	-	NA	-	NA	-	NA	-	NA	-	NA	-
Ceriodaphnia, reproduction	NA	-	NA	-	NA	-	NA	-	9	-	NA	-	NA	-	NA	-	NA	-	NA	-
Dendraster excentricus	2.9	265	NA	-	NA	-	NA	-	NA	-	NA	-	NA	-	NA	-	NA	-	NA	-
Strongylocentrotus purpuratus	0	-	1.25	-	NA	-	NA	-	NA	-	NA	-	NA	-	NA	-	NA	-	NA	-
Pimephales promelas, larval survival	NA	-	NA	-	NA	-	NA	-	2.5	-	NA	-	NA	-	NA	-	NA	-	NA	-
Pimephales promelas, larval growth	NA	-	NA	-	NA	-	NA	-	2.5	-	NA	-	NA	-	NA	-	NA	-	NA	-
Menidia beryllina	NA	-	1	-	NA	-	NA	-	NA	-	NA	-	NA	-	NA	-	NA	-	NA	-
Arsenic (µg/L)	21	13	<5	-	NA	-	NA	-	10.8	-	NA	-	<5	-	NA	-	NA	-	NA	-
Cadmium (µg/L)	0.4	98	<5	-	NA	-	NA	-	ND	-	NA	-	<5	-	NA	-	NA	-	NA	-
Chromium (µg/L)	1.9	110	<10	-	NA	-	NA	-	2.2	-	24	150	<20[e]	-	NA	-	NA	-	NA	-
Copper (µg/L)	2.8	232	<10	-	NA	-	NA	-	3	-	NA	-	<5	-	NA	-	14	23	NA	-
Lead (µg/L)	1.3	181	<3	-	NA	-	NA	-	0.5	-	NA	-	<5	-	NA	-	NA	-	NA	-
Mercury (µg/L)	<0.198	-	<0.2	-	NA	-	NA	-	ND	-	NA	-	0.02	0	NA	-	NA	-	NA	-
Nickel (µg/L)	12	71	<32	-	NA	-	NA	-	ND	-	NA	-	<5	-	NA	-	NA	-	NA	-
Selenium (µg/L)	59	43	<5	-	NA	-	NA	-	6.2	-	NA	-	<2	-	NA	-	NA	-	NA	-
Silver (µg/L)	0.04	346	<10	-	NA	-	NA	-	ND	-	NA	-	<5	-	NA	-	NA	-	NA	-
Zinc (µg/L)	12	346	260	-	NA	-	NA	-	91	-	NA	-	12[c]	103	NA	-	NA	-	NA	-
Phenols (µg/L)	88.5	41	NA	-	150	200	NA	-	ND	-	167	98	NA	-	NA	-	NA	-	NA	-
Chlorinated Phenols (µg/L)	<84	-	NA	-	NA	-	NA	-	NA	-	NA	-	NA	-	NA	-	NA	-	NA	-
Nonchlorinated Phenols (µg/L)	<50[b]	-	NA	-	NA	-	NA	-	NA	-	NA	-	NA	-	NA	-	NA	-	NA	-
Total DDT (µg/L)	ND	-	<0.11	-	NA	-	NA	-	NA	-	NA	-	NA	-	NA	-	NA	-	NA	-
Total PCB (µg/L)	ND	-	<1.1[b]	-	NA	-	NA	-	NA	-	NA	-	NA	-	NA	-	NA	-	NA	-

[a] Flow weighted.
[b] Corrected for mass found in receiving water.
[c] Maximum of the range of detection limits reported.
[d] CBOD = Carbonaceous biochemical oxygen demand.
[e] Chromium VI only.
[f] Colorimetric method.
[g] Gas chromatography/mass spectrometry (GC/MS) or gas chromatography (GC) method.
MISC 1 = Steam condensate, tank washing waste, and ship ballast water.
MISC 2 = Aquarium seawater to which copper sulfate and antibiotics have been added; seawater is from a
physiological research laboratory, and storage tank seawater.

NONCON = Noncontact cooling water.
PROC = Process waste (waste produced as part of the industrial/ manufacturing process).
SIO = Scripps Institute of Oceanography.
CW = Cooling water.
SW = Stormwater runoff.
H = Hazardous: contains toxic, corrosive, ignitable, or reactive substances and must be managed according to Department of Health Services standards.
LBNSY = Long Beach Naval Shipyard.
NA = Not analyzed.
ND = Not detected.

TABLE V-2. Estimated constituent mass emissions from industrial dischargers in southern California in 1995.

Constituent	Chevron El Segundo Oil Refinery	Unocal L.A. Oil Refinery	Mobil Southwestern Terminal	U.S. Borax Wilmington Plant	ARCO L.A. Oil Refinery	Texaco L.A. Oil Refinery	U.S.Dept. Navy Long Beach Naval Shipyard
Flow (L x 10^9)	10.8	3	0.01	1	1	2.8	3.3
Suspended Solids (mt)	193	NA	0.02	NA	8	17	91[b]
BOD (mt)	137[a]	NA	NA	NA	8.2	33	NA
Oil and Grease (mt)	63	NA	0.03	NA	3.1	20	0.4
Ammonia-N (mt)	39	NA	NA	0.05	2	16	NA
Cyanide (kg)	ND	NA	ND	NA	NA	NA	ND
Arsenic (kg)	224	ND	NA	NA	11	NA	ND
Cadmium (kg)	4.3	ND	NA	NA	ND	NA	ND
Chromium (kg)	21	ND	NA	NA	2.2	73	ND
Copper (kg)	32	ND	NA	NA	3.1	NA	ND
Lead (kg)	15	ND	NA	NA	0.5	NA	ND
Mercury (kg)	ND	ND	NA	NA	ND	NA	0.07
Nickel (kg)	134	ND	NA	NA	ND	NA	ND
Selenium (kg)	625	ND	NA	NA	6.3	NA	ND
Silver (kg)	0.4	ND	NA	NA	ND	NA	ND
Zinc (kg)	161	773	NA	NA	93	NA	41[b]
Phenols (kg)	946	NA	0.9	NA	ND	455	NA
Chlorinated Phenols (kg)	ND	NA	NA	NA	NA	NA	NA
Nonchlorinated Phenols (kg)	ND	NA	NA	NA	NA	NA	NA
Total DDT (kg)	ND	ND	NA	NA	NA	NA	NA
Total PCB (kg)	ND	ND	NA	NA	NA	NA	NA

[a] CBOD = Carbonaceous biochemical oxygen demand.
[b] Corrected for mass found in intake water.

NA = Not analyzed.

ND = Not detected.

TABLE V-3. Combined mass emission estimates for coastal petroleum industries with direct discharge* into the Southern California Bight.

	Mass Emissions			
Constituent	1971-1972	1987	1989	1995
Produced water				
Number of facilities	26	3	4	0
Flow (mgd)	6	3	4	0
Suspended solids (mt)	500	-	38	0
Oil and grease (mt)	100	40	54	0
Process waste (Chevron El Segundo Refinery)				
Flow (mgd)	72	6	9	8
Suspended solids (mt)	2,800	-	196	193
Oil and grease (mt)	1,290	60	91	63

*Does not include harbor, storm channel (eg. ARCO L.A. Refinery), or river discharges.

VI. POWER GENERATING STATIONS

Description of Source

Power generating stations (PGSs) are facilities that generate electricity for utility companies. In southern California, PGSs use steam generating power plants to create the electricity. The steam is generated by burning fossil fuels or by nuclear fission. The steam is cooled using large volumes of ocean water. Ocean water used in the cooling towers is cycled through once and does not contact industrial machinery before being discharged. Therefore, it is assumed that no additional pollutants are generated during the cooling process other than heat. The exception is chlorine, which PGSs periodically add to their cooling water to retard the growth of marine fouling organisms.

"Once-through," non-contact cooling water is not the PGSs' only waste stream. Most PGSs have a variety of other smaller volume, in-plant waste streams including, but not limited to, sanitary wastes, boiler blowdown, and metal cleaning wastes. Often, these in-plant waste streams are commingled with the cooling water to produce a combined discharge to the coastal oceans. All PGSs discharge near the surface or in shallow waters; five of the 13 PGSs discharge into harbors or bays.

Thirteen PGSs discharged to the SCB in 1995 (Figure VI-1). These PGSs were operated by Southern California Edison, the City of Los Angeles Department of Water and Power, and the San Diego Gas and Electric Company (Table VI-1). These companies no longer own most of the PGSs; they were sold to private operators after power utility deregulation in the mid-1990s.

Methods

Only in-plant waste streams were examined for mass emission estimates from PGSs. The effluents from PGSs have been routinely monitored for a variety of general constituents, trace metal, and organic constituents in accordance with the facility's NPDES permits. However, some PGSs measure individual in-plant waste streams while others combine waste streams prior to analysis (termed low-volume waste). The 1995 compliance monitoring data were used to estimate the facility's mass emissions. In-plant waste streams were often sampled just prior to discharge and, depending upon the constituent, were measured at intervals ranging from daily to semi-annually. The effluent monitoring data were from the discharger's monitoring reports and/or its reports of waste discharge to the RWQCBs. (RWQCB data files).

Mass emissions for each in-plant waste stream were calculated according to Equation 5 and then summed for total mass emissions:

$$ME = \sum_{i=1}^{n} (C_i * Q_i * T_i) \qquad \text{Equation (5)}$$

where:

ME	=	Annual mass emissions
C	=	Mean constituent concentration for month i
Q	=	Mean daily effluent flow for month i
T	=	Number of days in month i
n	=	Months of the year.

The main limitation of this approach is the occurrence of non-detectable quantities (NDs) below the analytical laboratory reporting level. All NDs were assigned a value of zero for the purposes of this study. Since we calculated concentrations and mass emissions on a monthly basis, months with unreported data were assigned the annual mean concentration, even if the annual mean concentration was below the reporting level.

To determine discharge concentrations, volume-weighted mean concentrations were used by waste stream type according to Equation 6:

$$\text{Conc} = \frac{\displaystyle\sum_{j=1}^{n} (C_j * V_j)}{\displaystyle\sum_{j=1}^{n} (V_j)} \qquad \text{Equation (6)}$$

where:

Conc	=	Volume-weighted mean concentration
V	=	Discharge volume for waste stream j
C$_j$	=	Concentration for waste stream j
n	=	Number of different waste streams.

Results and Discussion

The total cooling water flow from all 13 coastal PGSs was $9{,}125 \times 10^9$ L (6,506 MGD) during 1995 (Table VI-2, 6-3). In contrast, the total in-plant waste flow was 5.7×10^9 L (4.1 MGD). The plants with the largest in-plant discharge volume were Redondo Generating Station, Long Beach Generating Station, and the Ormond Beach Generating Station. The PGS with the largest combined discharge was the San Onofre Nuclear Generating Station (SONGS). The SONGS facility had three times the flow measured from the Alamitos PGS, the PGS with the second largest discharge volume.

The PGSs operated by the San Diego Gas and Electric Company measured the largest number of constituents, utilized the lowest reporting levels, and often had the highest frequency of measurements. All PGSs are required to sample and report other constituents in specific waste

streams when discharged, such as trace metals in metal cleaning waste. However, the other facilities may not have discharged this type of waste during the year.

Only two of the 23 constituents analyzed for effluent concentration could be compared among facilities (Table VI-2). The reporting levels for the two constituents (TSS, oil, and grease) differed by an order of magnitude among the facilities. The variability of TSS and oil and grease concentrations also spanned an order of magnitude among facilities. The Redondo Beach PGS had the highest concentrations of TSS and oil and grease. However, intra-facility variability was also evident, with the Haynes PGS reporting coefficients of variation of 112 to 233%. Often, the large variations were the result of non-detectable measurement values.

The Long Beach and Haynes PGS generated the highest loads of TSS and oil and grease of all PGS facilities in the SCB (Table VI-3). Together, these two plants represented over three-quarters of the TSS and one-third of the oil and grease discharged by all of the PGSs combined.
The annual combined discharge of cooling water to the SCB from PGSs increased by 17% between 1970 and 1994, but decreased 10% between 1994 and 1995 (Figure VI-2). In general, cooling water discharges were highest during the 1980s, but have since declined as more power is being imported from outside of the SCB.
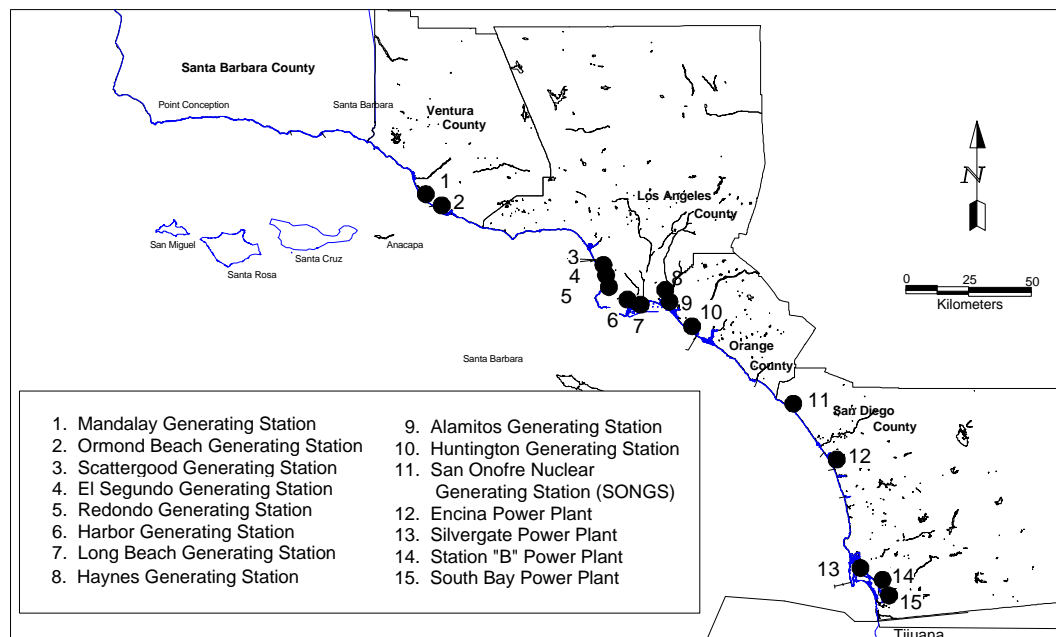
FIGURE VI-1. Location of power generating stations in the Southern California Bight..

TABLE VI-1. Names, locations, and organizations of the power generating stations that discharge to the Southern California Bight.

Power Generating Station	Location	Organization*
LOS ANGELES REGIONAL WATER QUALITY CONTROL BOARD		
Mandalay Generating Station	Oxnard	SCE
Ormond Beach Generating Station	Port Hueneme	SCE
Scattergood Generating Station	El Segundo	CLADWP
El Segundo Generating Station	El Segundo	SCE
Redondo Generating Station	Redondo Beach	SCE
Harbor Generating Station	Los Angeles Harbor	CLADWP
Long Beach Generating Station	Long Beach Harbor	SCE
Haynes Generating Station	Long Beach	CLADWP
Alamitos Generating Station	Long Beach	SCE
SANTA ANA REGIONAL WATER QUALITY CONTROL BOARD		
Huntington Beach Generating Station	Huntington Beach	SCE
SAN DIEGO REGIONAL WATER QUALITY CONTROL BOARD		
San Onofre Nuclear Generating Station (SONGS)	San Onofre	SCE
Encina Power Plant	Carlsbad	SDGE
Silvergate Power Plant	San Diego Bay	SDGE
Station "B" Power Plant	San Diego Bay	SDGE
South Bay Power Plant	San Diego Bay	SDGE

*CLADWP = City of Los Angeles Department of Water and Power.
SCE = Southern California Edison Company.
SDGE = San Diego Gas and Electric Company.

TABLE VI-2. Flow and constituent concentrations from in plant waste effluents of power generating stations di scharging to the Southern California Bight in 1995.[a]

Constituent	Mandalay		Ormond Beach		Scattergood		El Segundo		Redondo		Harbor		Long Beach	
	Mean[a]	CV	Mean[a]	CV	Mean[a]	CV	Mean[a]	CV	Mean[a]	CV	Mean[a]	CV	Mean[a]	CV
In-plant Flow (mgd)	0.07	103	0.51	44	0.17	42	0.15	3	1.38	40	0.06	57	1.03	39
In-plant Flow (million L/day)	0.26	103	1.93	44	0.64	42	0.57	3	5.22	40	0.23	57	3.90	39
Suspended Solids (mg/L)	7	33	5.20	31	7	88	41.9	163	15.6	140	1.6	107	26.6	85
Settleable Solids(mL/L)	-	-	-	-	-	-	<0.001	-	-	-	-	-	<0.1	-
BOD (mg/L)	-	-	-	-	-	-	0.06	51	-	-	-	-	0.16	50
Oil and Grease (mg/L)	6	33	5.74	38	0.6	159	5.8	60	4.6	39	<3	-	7.1	53
Ammonia-N (mg/L)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cyanide (µg/L)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Turbidity (NTU)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Toxicity (TUa)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Arsenic (µg/L)	-	-	-	-	-	-	-	-	-	-	-	-	0.28	52
Cadmium (µg/L)	-	-	-	-	-	-	-	-	-	-	-	-	<5[e]	-
Chromium (µg/L)	-	-	-	-	<15	-	-	-	-	-	-	-	0.077	109
Copper (µg/L)	-	-	nd	-	-	-	-	-	nd	-	-	-	-	-
Lead (µg/L)	-	-	-	-	-	-	-	-	-	-	-	-	<10[e]	-
Mercury (µg/L)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nickel (µg/L)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Selenium (µg/L)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silver (µg/L)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Zinc (µg/L)	-	-	-	-	16.9	100	-	-	-	-	-	-	-	-
Phenols (µg/L)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Chlorinated	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nonchlorinated	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DDT (µg/L)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PCB (µg/L)	-	-	-	-	-	-	-	-	-	-	-	-	-	-

[a]The number of significant figures of constituent concentrations are those reported by the power generating stations.
[b]Includes only retention basin data. Data does not include yard drains or boiler blowdown wastes.
[c]Calculated from estimates of discharges given in units of pounds per day.
[d]Unit 1 in-plant waste was not analyzed for 1995.
[e]Maximum detection limit reported.
CV=Coefficient of variation
NTU=Nephelometric turbidity units
TUa=(toxic units acute)= 100/96hr LC50 (percent waste giving 50% survival). If greater than 50% survival: TUa= Log (100-percent survival in 100% waste)/1.7
UR=Unacceptable results to improper sampling and analysis procedures.

FIGURE VI-3. Constituent mass emissions calculations for power generating stations for the year 1995.

Constituent	Mandalay Haynes	Ormond Beach	Scattergood	El Segundo	Redondo	Harbor	Long Beach	
In-plant Flow (L x 10^9/ yr)	0.09 0.10	0.71	0.24	0.21	1.92	0.08	1.42	
Suspended Solids (mt)	0.60	3.5	1.7	8.9	33	0.15	44	1.3
BOD (mt)	- 0.02	-	-	0.01	-	-	0.05	
Oil and Grease (mt)	0.65	4.6	0.18	1.2	8.5	-	9.5	0.03
Ammonia-N (mt)	-	-	-	-	-	-	-	-
Cyanide (kg)	-	-	-	-	-	-	-	-
Arsenic (kg)	- -	-	-	-	-	-	0.10	
Cadmium (kg)	-	-	-	-	-	-	-	-
Chromium (kg)	- -	-	-	-	-	-	0.02	
Copper (kg)	-	-	-	-	-	-	-	0.24
Lead (kg)	-	-	-	-	-	-	-	-
Mercury (kg)	-	-	-	-	-	-	-	-
Nickel (kg)	-	-	-	-	-	-	-	-
Selenium (kg)	-	-	-	-	-	-	-	-
Silver (kg)	-	-	-	-	-	-	-	-
Zinc (kg)	-	-	3.7	-	-	-	-	
Phenols (kg)	-	-	-	-	-	-	-	-
Chlorinated	-	-	-	-	-	-	-	-
Nonchlorinated	-	-	-	-	-	-	-	-
DDT (kg)	-	-	-	-	-	-	-	-
PCB (kg)	-	-	-	-	-	-	-	-

VII. DREDGED MATERIAL

Description of Source

Dredged materials are any bottom sediments excavated from the navigable waterways of the United States (EPA 40 CFR sec.227.13). Dredged materials are a byproduct of development, such as the construction of ports and marinas. Southern California is home to the largest commercial port complex (Los Angeles/Long Beach Harbor) and military facilities (San Diego Bay) on the west coast of the United States. Dredging is also used to maintain the navigable waterways for shipping. However, potential pollutants can be incorporated into these bottom sediments before they are dredged as they accumulate land-based sources, inputs from shipping and boating activities, aerial fallout, and other anthropogenic activities.

Regulation of dredging and spoil disposal to the coastal waters of the nation is under the jurisdiction of the United States Army Corps of Engineers (USACE). The USACE is the principal permitting agency for all dredging projects in the SCB, although all permits are subject to the criteria and scrutiny of the Environmental Protection Agency (U.S. EPA), the Regional Water Quality Control Boards, the United States Fish and Wildlife Service, and the California Coastal Commission. When project permits involving dredged materials are approved, these agencies dictate where the dredged materials will be disposed. Disposal options include shoreline replenishment for materials of sufficient quality and texture to be placed on the beach, offshore disposal at designated disposal sites if the materials are of sufficient quality to protect aquatic life, or at upland or confined aquatic disposal sites if the materials are of insufficient quality to be disposed of at sea. The quality of the dredged materials is determined by testing as part of the permitting process according to the U.S. EPA and the USACE (1991).

Currently, three off-shore dredged material disposal sites are found in the SCB (Figure VII-1). Two of the disposal sites are designated and the third is designated on an interim basis. The first disposal site is located 5.2 nm offshore Los Angeles (LA-2), at a depth of 210 m, and typically serves the Port of Los Angeles and Long Beach. The second disposal site is located 4.3 nm offshore of Orange County (LA-3), at a depth of 50 m, and typically serves Newport Harbor and Anaheim Bay. The third disposal site is located 6.0 nm offshore San Diego (LA-5), at a depth of 220 m, and typically serves San Diego Bay.

Methods

The dredged materials disposed of at the three offshore disposal sites between 1991 and 1997 were targeted for mass emission calculations for this study. The dredged materials at offshore sites were targeted because materials placed on the beach for shoreline replenishment were determined to be free of chemical hazards. The material placed at upland or confined aquatic disposal sites are presumed rendered harmless to the environment. The period of 1991 to 1997 was selected because standardized dredged

materials testing (U.S. EPA and USACE 1991) was instituted during that time, enabling some comparability among dredged material evaluations.

Projects disposing of dredged materials at offshore disposal sites are obligated to conduct chemical testing of the dredged materials (often toxicological testing is also necessary). The sediment chemistry information from these tests was used to estimate mass emissions for dredged materials. The sediment chemistry data are catalogued in the USACE's Ocean Disposal Database (ODD; Vicksburg, MI). The ODD concisely delineates all necessary information regarding a requested project, including, but not limited to, permit and disposal dates, quantity disposed, method of dredging, disposal site information, dredging location, and sediment chemistry data. Sediment chemistry data were inspected for number of observations, detection limit, number of observations above the detection limit, lowest experimental value, highest experimental value, and mean value.

Dredged material mass emissions were calculated on a project-by-project basis. The mean value provided in the ODD was used for mass emission calculations. The calculation of mass emissions per constituent was based on Equation 7:

$$ME = \sum_{i=1}^{n} (C_i * V_i * d * k) \qquad \text{Equation (7)}$$

where:

C = Sediment concentration for the ith project
V = Total volume disposed (in m^3) for the ith project
n = Number of dredging projects in the SCB between 1991 and 1997
d = Density conversion factor
k = Unit conversion constant.

Two main assumptions were used in these calculations. The first assumption addresses the density conversion factor. Densities of dredged materials are rarely reported to the USACE as part of the permitting process. However, densities of various dredged materials in previous projects ranged from 0.969 to 1.361 MT/yd^3 (Schiff *et al.* 1992). The density conversion factor used in this report was the mean density of these previous projects, 1.087 MT/yd^3.

The second assumption required for mass emission calculations was estimating values for missing data. Most of the volume of dredged materials disposed of at sea had accompanying sediment chemistry data. However, 42 projects that discharged dredged materials at sea within the SCB did not have sediment chemistry data included in the ODD. Moreover, some of the projects in the ODD did not report all analytes. Therefore, missing data were assigned a value equal to the mean of all projects.

Results and Discussion

The total volume of dredged materials disposed of into the SCB between 1991 and 1997 was 2,687,247 m^3 (Figure VII-2). Forty-two projects were permitted in this period. Eighteen projects were carried out in 1991, 10 in 1992, 7 in 1993, 1 in 1995, 1 in 1996, and 3 in 1997. No projects were executed in 1994.

Most projects were relatively small in volume (Figure VII-3). Approximately 76% of the projects were under 50,000 m^3, and 62% were less than 1,000 m^3. Disposal site LA-5 received slightly more than 75% of the total volume disposed of into the SCB between 1991 and 1997, LA-2 received 22% of the total, and LA-3 received only 3% of the total volume of dredged materials. The two largest projects comprised volumes of 462,124 m^3 and 1,442,903 m^3, and were disposed of at sites LA-2 (1993) and LA-5 (1997), respectively. The range in project size was from 76 m^3 to 1,442,903 m^3.

The LA-2 disposal site received anomalously higher mass emissions relative to the volume disposed of over the seven-year period (Table VII-2). The most prominent anomaly occurred for total organic carbon, tributyltin, nickel, mercury, and DDT. The LA-3 disposal site also received disproportionate levels of DDT and selenium relative to the dredge volume received. The LA-5 disposal site received only minor enrichments of mass emissions for cadmium, oil and grease, and polyaromatic hydrocarbons (87%, 78%, and 86%, respectively). Although LA-5 had predominantly lower contaminant levels, it received the largest total mass emissions because it received the largest volume of materials.

This assessment was limited by the projects with no sediment chemistry data. The extrapolation of unreported chemistry data from existing data has the potential to bias results since we noted disproportionate levels of contaminants among disposal sites. The second potential limit in our assessment was the quality and completeness of the ODD. Currently, the ODD is maintained and operated by the USACE.
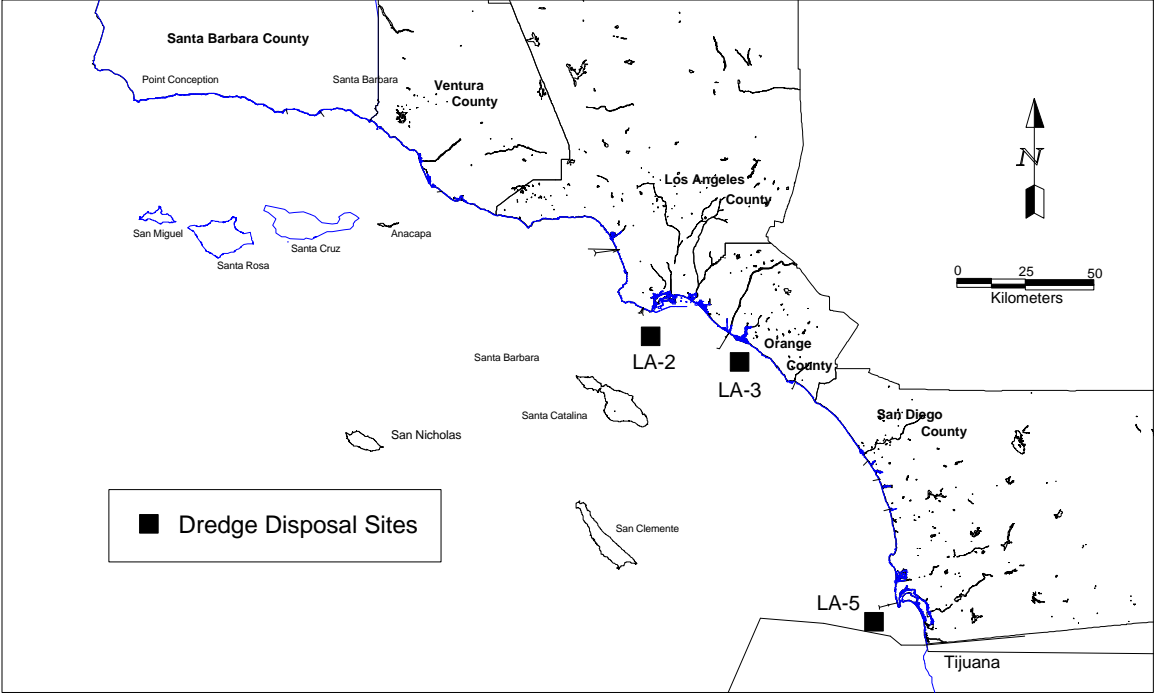
FIGURE VII-1. Location of dredged material disposal sites in the Southern California Bight.
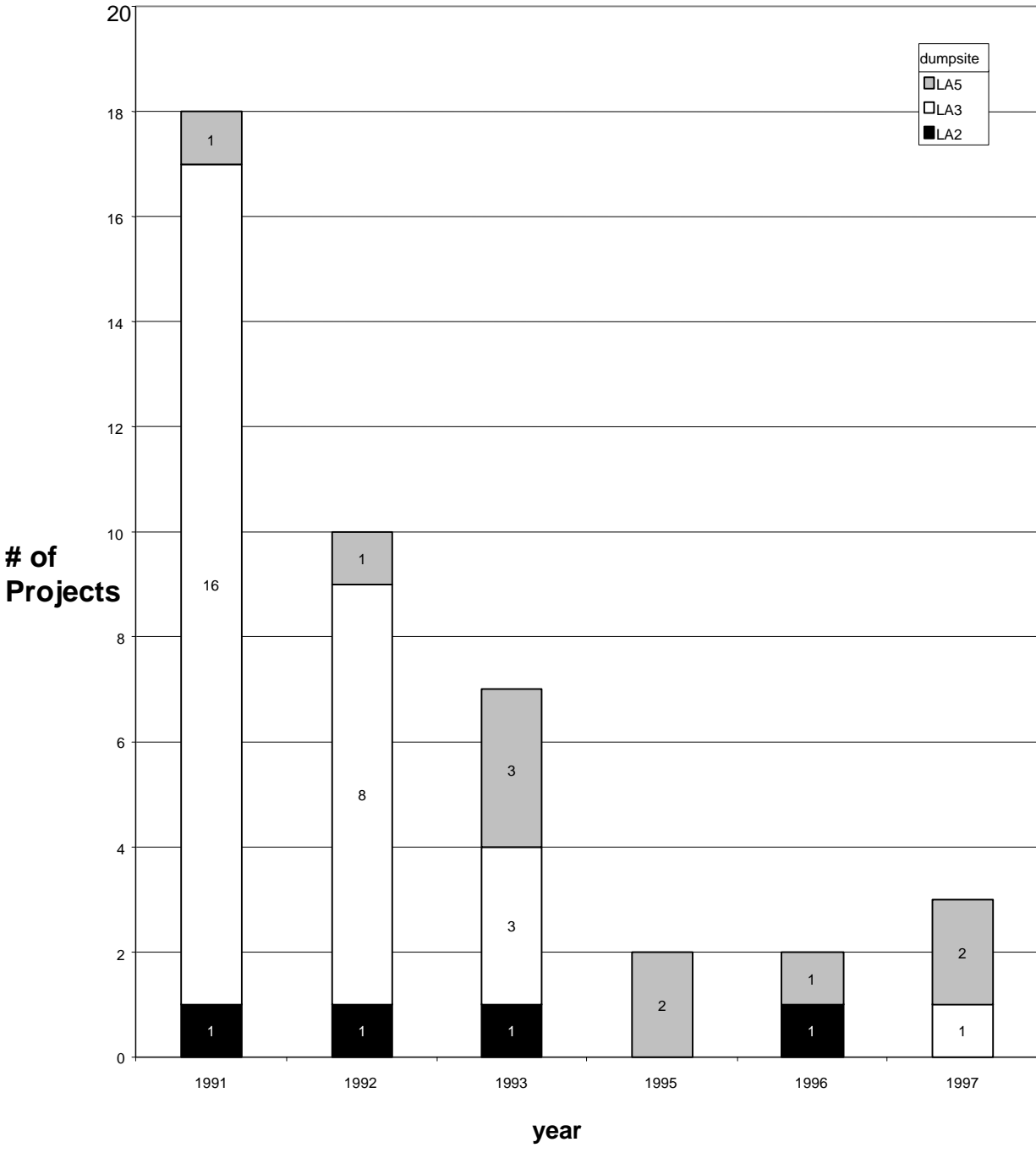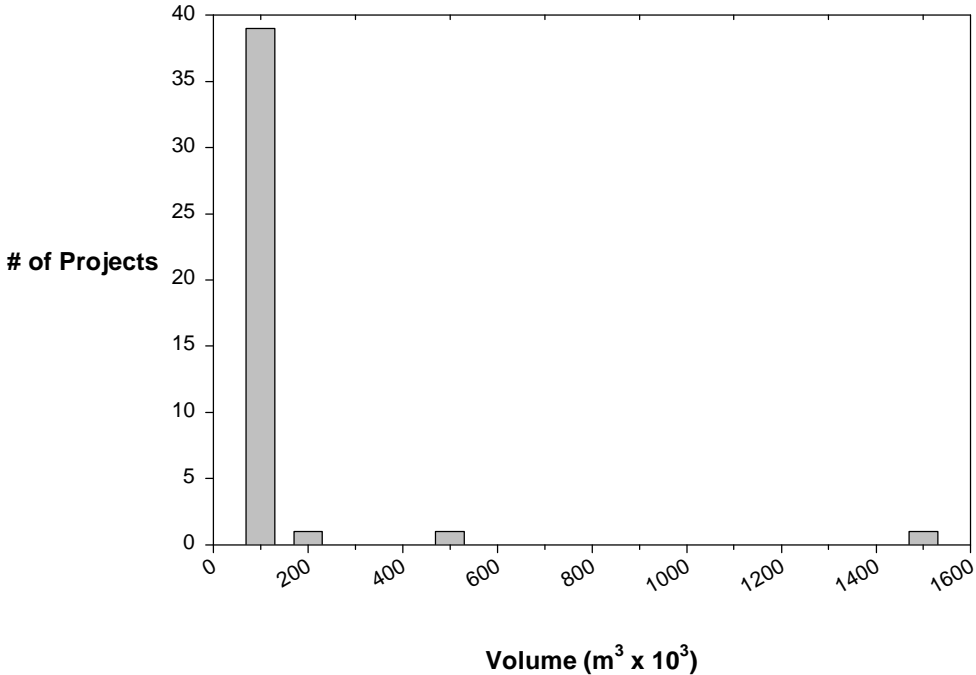
FIGURE VII-2. Number of dredging projects per year between 1991 and 1997.

Dredging Project Volumes 1991-1997

FIGURE VII-3. Distribution of dredge project volumes in the southern California Bight between 1991 – 1997.

TABLE VII-1. Estimated constituent mass emissions for dredge material disposal at nearshore disposal sites in the Southern California Bight.

Constituents	Annual Average	1991	1992	1993	1994	1995	1996	1997
Volume(m^3 x 10^3)	383	60	101	671	0.0	225	103	1,521
Arsenic	1.4	0.06	0.73	4.0	-	0.64	0.44	3.7
Cadmium	0.24	0.01	0.03	0.17	-	0.75	0.05	0.65
Chromium	7.4	0.94	3.2	19	-	4.2	2.7	22
Copper	10	0.92	3.0	24	-	5.4	3.5	36
Total DDT[a](kg)	2.6	1.1	1.2	8.3	-	0.0	0.32	7.0
Lead	6.4	0.34	1.8	12	-	3.5	1.9	25
Mercury	0.07	0.02	0.01	0.29	-	0.05	0.03	0.10
Nickel	3.1	0.44	2.8	10	-	1.0	0.75	6.8
Oil and Grease	29	6.3	1.2	51	-	18	7.99	118
Selenium	0.06	0.72	0.03	0.06	-	0.0	0.0	0.26
Total PCB[a](kg)	6.8	0.06	3.8	40	-	0.0	2.4	1.2
Silver	0.12	0.02	0.02	0.21	-	0.11	0.06	0.43
TOC	61	14	115	296	-	0.12	0.07	0.51
Total PAH[a](kg)	103	6.5	9.4	406	-	90	42	165
Tributyltin	2.6	0.70	0.01	14	-	0.0	1.3	2.4
Zinc	17	2.2	6.7	41	-	13	6.8	46

[a]Organics were calculated in kilograms; all other constituents were calculated in metric tons.
Dash= No projects during 1994.

VIII. OIL PLATFORMS

Description of Source

Offshore oil fields are an important resource in the SCB. The oil fields of the Santa Barbara Channel and Santa Maria Basin are among the largest domestic oil reserves in the United States. Offshore oil production increased by a factor of five from 1935 to 1998 (Figure VIII-1; Conservation Committee of California Oil Producers 1991, United States Department of the Interior 2000). In 1996, active platforms were operating in federal waters; 22 were actively producing oil and one (Platform Elly) functioned strictly as a processing platform.

Offshore oil platforms in federal waters (>3 to <200 mi offshore) discharge contaminants into the SCB during oil field development and production. Oil platforms produce a number of waste types. The predominant emissions are drilling muds and cuttings, produced water, and sanitary wastes. Drilling muds are specially formulated mixtures of freshwater or seawater with clays, minerals, chemicals, and other materials used for cleaning drill bits, transporting cuttings, reducing friction, and stabilizing the borehole. Drill cuttings are particles of crushed sedimentary rock produced in the process of drilling (Neff *et al.*1987). Produced waters are natural geological formation water or introduced seawater recovered with the extraction of oil. Most produced water is brine that may contain dissolved solids, metals, sulfur, and organic compounds at substantially higher concentrations than in seawater (Menzie 1982, Neff 1987). Other waste streams are discharged from offshore oil platforms, but traditionally have not contributed many pollutants. These other waste streams include non-contact cooling water for marine engines, fire control system test water, well completion fluids, and well treatment fluids.

Methods

The discharges from oil platforms are monitored by oil company personnel in compliance with NPDES permits issued by the U.S. EPA. Flow and chemical constituent data were obtained from NPDES discharge monitoring reports submitted to the U.S. EPA Region IX in San Francisco, CA. Annual mass emissions were calculated by platform for the mid-1990s. Contiguous 12-month periods were evaluated for each platform, but they did not necessarily coincide for all platforms (Figure VIII-2). The target year for the drilling discharges was 1996, but quarterly reports were unavailable and 1995 or 1997 quarterly reports were used to maintain continuous temporal emissions.

Three types of assessments were performed. First, total volumes or mass by discharge type were calculated. To report total drill cuttings discharged, cuttings were converted to mass in units of barrels (1 barrel = 42 gallons) by correcting for water content (cuttings were assumed to be 35% water and 65% solids; Ayers 1983) and multiplying by the specific gravity of cuttings estimated to be 2.6 (Runchal 1983):

$$M = d * V * g \qquad\qquad \text{Equation (8):}$$

where:

M	=	Mass of solids in kg
d	=	0.65; density conversion factor
V	=	Volume in L,
g	=	2.6; specific gravity.

Second, annual mean concentrations were calculated from produced water concentrations before dilution with seawater. The platforms typically report discharge concentrations after dilution; therefore, most produced water discharge concentrations were back calculated for concentrations prior to dilution using Equation 9:

$$C_e = C_o + (D_m * (C_o - C_s)) \qquad\qquad \text{Equation (9)}$$

where:

C_e	=	Effluent concentration
C_o	=	Concentration in the discharge after dilution
D_m	=	Minimum probable initial dilution expressed as parts seawater per part wastewater
C_s	=	Background seawater concentration listed in the Platform's NPDES permits.

Finally, annual contaminant mass emissions were estimated. Frequency of analysis for constituent analyses in the various types of discharge wastes varied from annually to monthly. Mass emissions were calculated on the interval measured and then summed over all intervals according to Equation 10:

$$ME = \sum_{i=1}^{n} (C_i * Q_i * T_i) \qquad\qquad \text{Equation (10)}$$

where:

Q_i	=	Mean daily flow in interval i
C_i	=	Constituent concentration in interval i
T_i	=	Number of days in interval i
n	=	Number of measurements per year.

The main limitation in each of these approaches is the occurrence of non-detectable quantities (NDs) below the analytical laboratory reporting level. A second limitation is that discharge monitoring reports usually have a separate page corresponding to each discharge type and there were missing pages in the DMR. Because many platform

discharges are discontinuous, it was assumed that discharge monitoring reports without corresponding discharge data represented no discharge of that particular waste for that time period. All NDs were assigned a value of zero for the purposes of this study.

Discharges from oil platforms did not fall into the categories selected for the summary tables. Therefore, the following categories of discharges were combined and labeled as "other" liquids in the summary tables: cement wash seawater, control fluid from blowout preventer, deck drainage, drilling seawater, excess cement slurry, fugitive paint, and $H_2 S$ gas processing water. No discharges were reported for additionally permitted waste streams including ballast water, bilge water, oil free drainage, and produced sand.

Results and Discussion

Cooling water was the dominant form (82%) of liquid waste discharged from the oil platforms (Table VIII-1). However, non-contact cooling water is "once-through" seawater and receives no additional inputs (except periodic chlorine additions); therefore, it is not considered to be a large contributor. The volume of produced water, which may contain additional pollutant inputs, comprised 15% of the total flow. The remaining types of waste discharge comprised less than 3% of the annual discharge volume. Drill cuttings were the dominant type of solid waste discharged, comprising more than 99% of the total solid mass.

Ammonia had the highest concentration (99 mg/L) of the constituents measured (Table VIII-2). Five out of 16 metal concentrations (31%) were detectable with nickel having the highest concentration of 0.01 mg/L. The organic compound with the highest concentration was toluene at 1 mg/L.

The constituent discharged in the highest amount was ammonia at 336,547 kg (Table VIII-3). Total metals discharged from oil platforms in 1996 were 121 kg. The metal discharged in the highest amount was nickel at 64 kg. The highest organic compound discharged was toluene at 3,270 kg.

All volumes and masses of discharge wastes from the platforms were higher in 1996 compared to 1990. The two largest increases were drill cuttings (54%) and drilling muds (79%) (Table VIII-4). A large portion of the discharged cuttings (68%) and mud (40%) were from two platforms, Harmony and Heritage. Oil production from these platforms started in 1993 and was in the early stages of development during the study period. Between 1990 and 1996, produced water volume increased 0.5%, while individual mass emissions in produced water decreased from 30 to 100%. This reduction is not attributable to an increase in detection limits as the majority (75%) have decreased. Several factors influence the amount of wastes discharged by oil platforms each year such as drilling for new wells on the platform and the life stage of the existing wells on the platform. As a result, waste discharge amounts often vary. For example, the amount of produced water discharged often increases over the life of a well (Neff *et al.* 1987).
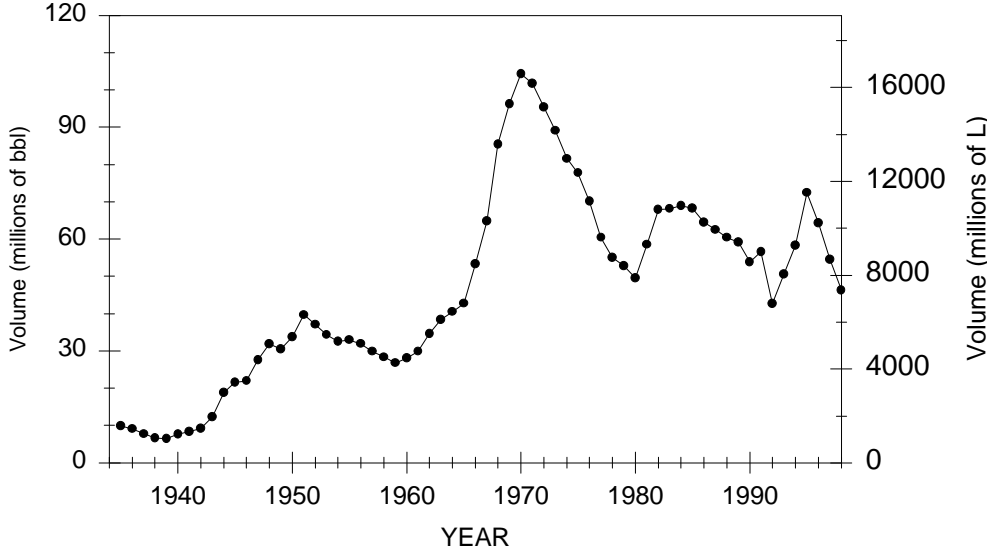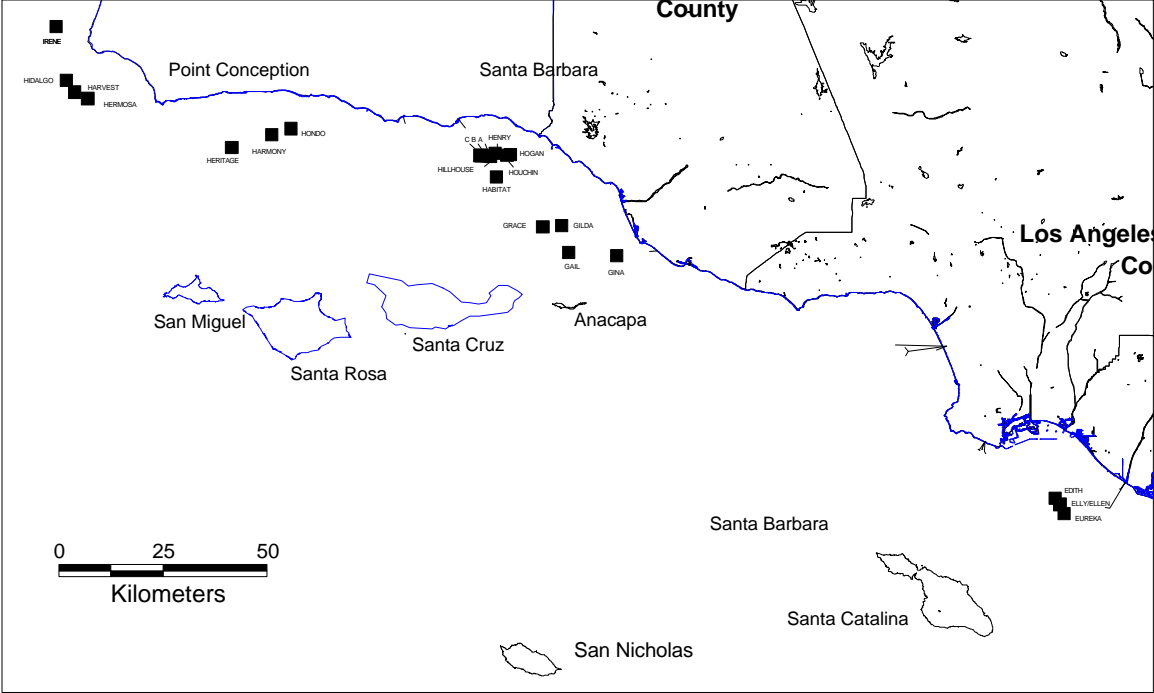
Figure VIII-1. Oil production in the southern California Bight.

FIGURE VIII-2. Location of oil platforms in the Southern California Bight.

TABLE VIII-1. Amounts of the major types of waste discharged in federal waters from oil platforms off Southern California in 1996.

Waste Type	Discharge Amount
Drill Cuttings (mt)	10,342
Sandblast Materials (mt)	30
Total solid mass	**10,372**
Drilling Mud (L x 10^6)	57
Cooling Water (L x 10^6)	29,360
Produced Water (L x 10^6)	5,306
Fire Control System Test Water (L x 10^6)	994
Sanitary Waste (L x 10^6)	87.7
Well Completion and Treatment Fluids (L x 10^6)	20
Other Liquids* (L x 10^6)	35
Total Liquid Volume (L x 10^6)	**35,860**

*Other liquids = Cement wash seawater, control fluid from blowout preventer, deck drainage, drilling seawater, excess cement slurry, fugitive paint, and H_2S gas processing water.

TABLE VIII-2. Constituent concentrations[a] measured in discharge waste from oil platforms in federal waters off southern California. All concentrations in mg/L unless otherwise noted.

Constituent	Cooling Water	Produced Water	Fire Control System Test Water	Sanitary Waste	Well Completion and Treatment Fluids
Oil and Grease	NA	14.1	NA	NA	17
Ammonia	NA	99	NA	NA	217
Residual Chlorine	0.02	NA	1.52	2.0	NA
Cyanide	NA	<0.06[b]	NA	NA	NA
Antimony	NA	<0.12[b]	NA	NA	NA
Arsenic	NA	<0.06[b]	NA	NA	NA
Barium	NA	<0.02[b]	NA	NA	NA
Beryllium	NA	<0.004[b]	NA	NA	NA
Cadmium	NA	<0.3[b]	NA	NA	NA
Total Chromium	NA	0.002	NA	NA	NA
Copper	NA	0.00004	NA	NA	NA
Lead	NA	<0.1[b]	NA	NA	NA
Mercury	NA	0.000006	NA	NA	NA
Molybdenum	NA	<0.04[b]	NA	NA	NA
Nickel	NA	0.01	NA	NA	NA
Selenium	NA	<0.05[b]	NA	NA	NA
Silver	NA	<0.02[b]	NA	NA	NA
Thallium	NA	<1[b]	NA	NA	NA
Vanadium	NA	<0.02[b]	NA	NA	NA
Zinc	NA	0.009	NA	NA	NA
Ra226 (pCi/L)	NA	23.1	NA	NA	NA
Ra228 (pCi/L)	NA	4.0	NA	NA	NA
Phenols	NA	0.3	NA	NA	NA
2,4-Dimethylphenol	NA	0.1	NA	NA	NA
Benzene	NA	0.7	NA	NA	NA
Ethylbenzene	NA	0.1	NA	NA	NA
Toluene	NA	1.0	NA	NA	NA
Bis(2-ethylhexyl)phthalate	NA	<0.05[b]	NA	NA	NA
Benzo(A)pyrene	NA	<0.025[b]	NA	NA	NA
Naphthalene	NA	0.05	NA	NA	NA

[a] Before seawater dilution.
[b] Maximum detection limit.
NA = not analyzed.

TABLE VIII-3. Mass emissions of constituents measured in discharge waste from oil platforms in federal waters off southern California. All mass emissions in kilograms unless otherwise noted.

Constituent	Cooling Water	Produced Water	Fire Control System Test Water	Sanitary Waste	Well Completion and Treatment Fluids	Total
Flow (L x 106)	29,360	5,306	994	88	20	35,768
Oil and Grease	NA	74,824	NA	NA	77	74,901
Ammonia	NA	336,421	NA	NA	125	336,547
Residual Chlorine	537	NA	1,449	158	NA	2,143
Antimony	NA	0	NA	NA	NA	0
Arsenic	NA	0	NA	NA	NA	0
Barium	NA	0	NA	NA	NA	0
Beryllium	NA	0	NA	NA	NA	0
Cadmium	NA	0	NA	NA	NA	0
Total Chromium	NA	10	NA	NA	NA	10
Copper	NA	0.19	NA	NA	NA	0
Lead	NA	0	NA	NA	NA	0
Mercury	NA	0.03	NA	NA	NA	0
Molybdenum	NA	0	NA	NA	NA	0
Nickel	NA	64	NA	NA	NA	64
Selenium	NA	0	NA	NA	NA	0
Silver	NA	0	NA	NA	NA	0
Thallium	NA	0	NA	NA	NA	0
Vanadium	NA	0	NA	NA	NA	0
Zinc	NA	46	NA	NA	NA	46
Cyanide	NA	0	NA	NA	NA	0
Ra226 (pCi)	NA	27	NA	NA	NA	27
Ra228 (pCi)	NA	4.69	NA	NA	NA	5
Phenols	NA	1426	NA	NA	NA	1,426
2,4-Dimethylphenol	NA	319	NA	NA	NA	319
Benzene	NA	2461	NA	NA	NA	2,461
Ethylbenzene	NA	568	NA	NA	NA	568
Toluene	NA	3270	NA	NA	NA	3,270
Bis(2-ethlyhexyl)phthalate	NA	0	NA	NA	NA	0
Benzo(A)pyrene	NA	0	NA	NA	NA	0
Naphthalene	NA	175	NA	NA	NA	175

NA = not analyzed.

TABLE VIII-4. Comparison of the 1990 and 1996 major discharge types from oil platforms in federal water off southern California.

Discharge Type	1990	1996	Percent Change	1990 Maximum Reporting Limit (mg/L)	1996 Maximum Reporting Limit (mg/L)
Drill Cuttings (mt)	3,126	10,342	54	-	-
Drilling Mud (L x 10^6)	7	57	79	-	-
Produced Water (L x 10^6)	5,254	5,306	0.5	-	-
Oil and Grease (mt)	144	75	-32	1	NF
Cyanide (kg)	24	ND	-100	0.1	0.06
Arsenic (kg)	0.48	ND	-100	0.05	0.06
Cadmium (kg)	ND	ND	0	0.25	0.3
Chromium (kg)	64	10	-72	0.2	0.06
Copper (kg)	6.4	0.2	-94	0.4	0.04
Lead (kg)	2.7	ND	-100	1	0.1
Mercury (kg)	4.6	0.03	-99	0.01	0.05
Nickel (kg)	302	64	-65	0.8	0.2
Selenium (kg)	NA	ND	-	NA	0.05
Silver (kg)	1.7	ND	-100	0.2	0.02
Zinc (kg)	605	46	-86	0.4	0.1
Total Phenols (kg)	2,608	1,745	-20	10	0.2
Sanitary Waste (L x 10^6)	67.2	87.7	13	-	-

NA = Not analyzed
Dash= Not applicable
ND = Not detected
NF = Not found

IX. INTEGRATION AMONG SOURCES

Environmental managers use mass emission estimates for two primary reasons: The first reason is to compare the relative risk among sources. Mass emission estimates enable managers to evaluate which sources contribute the most (or least) pollutants to receiving water bodies such as the coastal oceans. The second reason environmental managers utilize mass emissions is to evaluate trends. If mass emissions are increasing over time, then this trend provides managers the information they need to begin evaluating management actions such as investigating fates or assessing impacts. Alternatively, managers can use decreasing trends to assess the effectiveness of management actions they have already taken.

This study was specifically designed for comparing sources (Table IX-1) in the SCB. It was found that runoff, POTWs, and dredged materials contributed the majority of potential pollutants. These three sources comprised between 93 to 100% of 23 different constituents evaluated among eight sources. Runoff was the dominant source of TSS, nitrate, mercury, zinc, and total DDT. Large POTWs were the dominant source of BOD, nitrite, ammonia, total phosphorous, copper, nickel, selenium, and silver. Dredged material disposal was the dominant source of oil and grease and total PCBs.

The relative contributions of individual sources cannot be used in isolation and many contributions must be taken in context. For example, runoff contributed the vast majority of TSS. However, TSS discharged from rivers, creeks, and storm drains are much different in composition than TSS discharged from POTWs. Moreover, inputs of trace metals from runoff are a combination of anthropogenic contributions as well as natural contributions from normal erosion processes. The degree that estimated runoff loads are anthropogenic or natural is presently unknown. Finally, relative loadings should be taken in the context of magnitude. For example, dredged materials contributed 100% of the total PCB emissions to the SCB. However, the total load only amounted to 6 kg, a reasonably small quantity.

Although not specifically designed for this purpose, data from this report can be used to evaluate trends in mass emissions. Mass emissions from stormwater runoff, POTWs, and ocean disposal were also estimated during the early 1970s (SCCWRP 1973). Although volumes from these three sources have nearly doubled over the last two and one-half decades, their combined mass emissions have dramatically declined for most of the constituents evaluated (Table IX-2). Five constituents declined by 90 to 100% and another five constituents decreased by at least 75%. Nitrate was the only constituent that increased between 1971 and 1995, mostly from runoff load estimates.

Temporal comparisons have limitations, particularly for stormwater runoff. Runoff load estimates from 1971 were generated from empirically derived measurements rather than modeled estimates. Hence, approximately one-third of the total watershed area was estimated in 1971 compared to 100% of the watershed area in the present study. In addition, loads were based on 1971 gaged runoff volumes, as opposed to long-term

average rainfall as was used herein. Precipitation in 1971 was approximately 30% below the long-term average used. Regardless of the potential underestimates from 1971, loads for half of the constituents decreased between 1971 and the mid-1990s. Runoff constituents that showed the largest reductions were those with extensive source control measures including lead, total DDT, and total PCBs.

Mass emissions for five constituents discharged in runoff increased between 1971 and the mid-1990s (Table IX-2). These included TSS (100,000%), nitrate and phosphate (200 and 20%, respectively), copper (100%), and zinc (60%). These constituents are increasingly being considered for stormwater runoff management actions including impacts to receiving waters and TMDLs.

The loads from POTWs had the greatest reductions between 1971 and 1995 (Table IX-2). Unlike stormwater runoff, there are fewer limitations to the comparisons. Discharge volumes increased by one-third while trace metals decreased by an average of 90% and chlorinated hydrocarbons decreased to below detection limits. These declines are attributable to increased treatment, pretreatment, source control, reclamation, and cessation of biosolids discharges. In all, it is estimated that over $5 billion has been spent on treatment plant upgrades alone.

Like POTWs, dredged material disposal has shown dramatic declines because of increased management actions (Table IX-2). Copper, total DDT, and total PCBs have all been reduced by nearly 100%; cadmium, chromium, lead, nickel, silver, and zinc have been reduced an average of 85%. Many of the declines have resulted from increased regulatory guidance. In 1971, industrial and military wastes were dumped extensively in the SCB while monitoring of the discharged wastes was infrequent. In fact, large quantities of total DDT were dumped at sea as industrial process waste during this period (Chartrand 1985). The early 1970s ushered in the enforcement of the Ocean Dumping Act, which prohibited ocean disposal of these types of wastes. Currently, only dredged materials approved by the USACE and the U.S. EPA are permitted to discharge at sea.

TABLE IX-1. Total mass emissions to the Southern California Bight and percent of load by source.

Constituent (units)	Total	Runoff	Large POTWs	Small POTWs	Ocean Dumping	Industrial Facilities	Power Plants	Platform
					Percent Contribution			
Year		Average	1996	1995	Average 1991-97	1995	1995	1995
Flow (L x 10^9)	11,707	8.0	13.1	1.7	-	0.2	76.8	0.3
Suspended Solids (mt x 10^3)	356,351	99.8	0.0	0.0	0.2	0.0	0.0	0.0
BOD (mt)	161,099	12.8	85.7	1.5	-	0.1	0.0	-
Oil and Grease (mt)	41,853	-	45.9	1.1	52.6	0.2	0.1	0.2
Nitrate-N (mt)	3,144	86.5	8.4	4.8	-	-	0.2	-
Nitrite-N (mt)	219	31.0	58.0	11.0	-	-	-	-
Ammonia-N (mt)	45,425	0.9	91.0	7.9	-	0.1	0.0	-
Organic N (mt)	5,880	-	99.0	1.0	-	-	-	-
Phosphate (mt)	2,310	22.0	78.0	-	-	-	-	-
Total Phosphorus (mt)	1,841	-	100.0	-	-	-	-	-
Cyanide (mt)	8.0	-	81.2	18.8	-	0.0	0.0	-
Arsenic (mt)	12.0	38.6	41.8	3.2	14.0	2.0	0.5	0.0
Cadmium (mt)	2.9	20.5	33.6	15.5	8.2	0.1	22.1	0.0
Chromium (mt)	27.4	40.5	25.6	5.1	26.9	0.4	1.5	0.0
Copper (mt)	97.5	36.6	54.3	6.9	0.0	0.0	2.0	0.0
Lead (mt)	24.7	49.8	9.7	9.6	26.0	0.1	4.8	0.0
Mercury (mt)	1.1	72.9	2.0	1.0	4.3	0.0	19.9	0.0
Nickel (mt)	47.4	24.4	62.9	5.7	6.6	0.3	0.0	0.1
Selenium (mt)	9.7	4.7	80.3	8.0	-	6.5	0.0	0.0
Silver (mt)	6.9	11.5	77.7	9.0	1.7	0.0	0.0	0.0
Zinc (mt)	298.7	53.8	28.8	5.3	5.5	0.4	6.2	0.0
Phenols (mt)	165.5	-	98.3	0.0	-	0.8	0.0	0.9
Chlorinated	2.9	-	96.6	3.4	-	0.0	0.0	-
Nonchlorinated	95.0	-	99.8	0.2	-	0.0	0.0	-
Total DDT (kg)	27.2	78.3	11.4	1.1	9.2	0.0	0.0	-
Total PCB (kg)	6.3	0.0	0.0	0.0	100.0	0.0	0.0	-
Chlorpyrifos (kg)	15.1	100.0	-	-	-	-	-	-
Diazinon (kg)	13.9	100.0	-	-	-	-	-	-

mt = Metric tons
Dash = Missing data

TABLE IX-2. Constituent mass emissions to the Southern California Bight from surface (stormwater) runoff, publicly owned treatment works (POTWs), and dredged materials (ocean dumping) during 1995-96 and 1971-72.

Constituent	Mid-1990s				Early 1970s				Percent Change 1970-1995			
	Typical Year Runoff	POTWs	Ocean Dumping	Total	Runoff	POTWs	Ocean Dumping	Total	Runoff	POTW	Ocean Dumping	Total
Flow (L x 10^9)	934	1,726	-	2,660	75	1,284	-	1,359	1145.1	34.4		95.7 [a]
Susp Solid (mt x 10^3)	355,721	75.4	544.6	356,340.7	274	278	-	552	129725.1	-72.9		64454.5 [a]
Oil and Grease (mt)	-	19,661	22,000	41,661	4,400	65,000	-	69,400		-69.8		-40.0 [a]
Nitrate-N (mt)	2,720	417	-	3,137	980	530	-	1,510	177.6	-21.3		107.8 [a]
Ammonia-N (mt)	427	44,936	-	45,363	440	59,400	-	59,840	-3.0	-24.4		-24.2 [a]
Phosphate (mt)	508	1,802	-	2,310	410	13,300	-	13,710	23.8	-86.5		-83.2 [a]
Cadmium (mt)	0.6	1.4	0.2	2.3	1.2	54	14	69.2	-50.2	-97.3	-98.3	-96.7
Chromium (mt)	11.1	8.4	7.4	26.8	25	649	28	702	-55.6	-98.7	-73.7	-96.2
Copper (mt)	35.7	59.8	10.0	95.5	18	567	28	613	98.5	-89.5	-100.0	-84.4
Lead (mt)	12.3	4.8	6.4	23.5	90	211	28	329	-86.3	-97.7	-77.1	-92.9
Mercury (mt)	0.82	0.03	0.05	0.90	0.06	2.9	1.5	4.46	1264.7	-98.9	-96.8	-79.8
Nickel (mt)	11.5	32.5	3.1	47.2	17	313		330	-32.1	-89.6		-85.7
Silver (mt)	0.80	6.03	0.12	6.95	1.1	15	1.5	17.6	-27.4	-59.8	-92.0	-60.5
Zinc (mt)	160.8	101.8	16.5	279.1	101	1,680	56	1,837	59.2	-93.9	-70.5	-84.8
Total DDT (kg)	21.3	3.0	2.5	27.0	119	19,000	14,000	33,119	-82.1	-100.0	-100.0	-99.9
Total PCB (kg)	bdl [b]	bdl	6.3	6.3	246	9,700	28,000	37,946	-100.0	-100.0	-100.0	-100.0

[a] Only runoff and POTW used for this comparison
[b] Below detection limits

X. CONCLUSIONS

Two general types of conclusions were reached during this study. The first set of conclusions (numbers 1 through 5) are based upon the mass emission estimates that were generated for stormwater and other discharges. The second type of conclusions (numbers 6 through 8) are based upon our review of stormwater monitoring programs and our ability to integrate results across agencies to make regionwide assessments.

Mass Emissions-based Conclusions

1) *Stormwater runoff, POTWs, and dredged materials discharged the majority of potential pollutants to the coastal oceans of the SCB.*

Runoff, POTWs, and dredged materials contributed the majority of most potential pollutants to the SCB. These three sources comprised between 93 and 100% of the 23 different constituents evaluated among sources. Stormwater runoff was the dominant source of TSS, nitrate, mercury, zinc, and total DDT. Large POTWs were the dominant source of BOD, nitrite, ammonia, total phosphorous, copper, nickel, selenium, and silver. Small POTWs contributed less than 10% of any constituent. Dredged material disposal was the dominant source of oil and grease and total PCBs.

The relative contributions of individual sources cannot be used in isolation and many contributions must be taken in context. For example, stormwater runoff contributed the vast majority of TSS. However, TSS discharged from rivers, creeks, and storm drains are much different in composition than TSS discharged from POTWs. Moreover, inputs of trace metals from stormwater runoff are a combination of anthropogenic contributions as well as natural contributions from normal erosion processes. The degree that estimated stormwater runoff loads are anthropogenic or natural is presently unknown. Finally, relative loadings need to be taken in the context of magnitude. For example, dredged materials contributed 100% of the total PCB emissions to the SCB. However, the total load only amounted to 6 kg, a reasonably small quantity.

2) *The combined mass emissions from all sources have dramatically declined since 1971.*

Although flows from stormwater runoff, POTWs, and ocean dumping have nearly doubled over the last 25 years, mass emissions have dramatically declined for nearly every constituent evaluated. Five constituents declined by 90 to 100% and another five constituents declined by at least 75%. Nitrate was the only constituent that increased between 1971 and 1995, mostly as the result of stormwater runoff load estimates.

The temporal comparisons present various limitations including different approaches to estimating runoff loads that potentially underestimate loads in 1971. Regardless, the cumulative mass emissions for the majority of constituents have decreased over the last 25 years. The largest reductions were for those constituents with extensive source control measures including lead, total DDT, and total PCBs. Runoff emissions decreased the least compared to POTWs and dredge and may have increased for some constituents including TSS, nitrate, phosphate, copper, and zinc.

3)   *The majority of stormwater runoff mass emissions are generated from highly to moderately urbanized watersheds.*

Highly urbanized (>25% imperviousness) and moderately urbanized (10 – 25% imperviousness) watersheds represented approximately two-thirds of the watershed area and contributed the majority of mass emissions for 16 of 18 constituents. Except for TSS and mercury, highly to moderately urbanized watersheds generated between 52 and 70% of the total stormwater runoff loads to the coastal oceans of the SCB.

4)   *Pollutant fluxes are higher from urban or agricultural land uses than fluxes from open land uses.*

Commercial and industrial land uses had the highest pollutant fluxes for 11 of 17 constituents including most trace metals, BOD/COD, and TSS. Agricultural land uses had the highest fluxes for pesticides such as total DDT and chlorpyrifos. In contrast, open land uses had the lowest fluxes for all but one of the constituents (mercury).

5)   *Stormwater runoff is a chronic source of fecal indicator bacteria to coastal oceans.*

Fecal indicator bacteria (total coliforms, fecal coliforms, and enterococcus) were ubiquitously high in the regional stormwater quality inventory. The concern over fecal indicator bacteria and its potential risk to humans is elevated in light of new state regulations and guidelines being promulgated for health departments. The first state regulation (AB411) identifies thresholds for each of the indicators. Between 86 and 97% of the samples in the water quality inventory exceeded these thresholds, depending upon the indicator. Other investigators have identified a disproportionately high frequency of exceedences on beaches near perennially flowing storm drains (Noble *et al.* 2000) and have noted that swimmers near storm drains have an increased health risk (Haile *et al.* 1999). The second state regulation (AB538) creates guidelines for identifying sources of fecal indicator bacteria in storm drain discharges. However, sources of these indicator bacteria are not human specific and can be birds and other mammals, such as dogs and

cats. Unfortunately, the state of the science for tracking human-specific sources is still developing.

Stormwater Monitoring-based Conclusions

6)   *Existing stormwater monitoring programs in the SCB are among the best in the nation, but lack comparability in monitoring design and implementation, creating difficulties for making regionwide assessments.*

Six major (Phase I municipal NPDES) stormwater monitoring programs are presently in place in the SCB with two more being developed. However, these programs interact infrequently. For example, current monitoring programs do not routinely exchange data, compare results to determine relative concentrations or loads among watersheds, collate results to make regionwide assessments, or conduct cooperative studies to address regional runoff issues that affect all stormwater management programs.

Even if existing monitoring programs attempted to share data, differences in monitoring design, information management, and sampling techniques would limit comparability and hinder large-scale assessments. Stormwater monitoring programs in the SCB have two basic designs: mass emission monitoring and land use monitoring. Mass emission monitoring provides empirical data and land use monitoring provides data for model development. Both designs are appropriate depending upon the management need, yet each answers distinctly different monitoring questions. The various monitoring programs in the SCB had one design, the opposite design, or a combination of both designs.

A second limitation of current monitoring programs is information management. While creating the regional water quality database, we found that each monitoring agency stores different types of data in varying formats. As a result, no unifying guideline had been established for the types of monitoring data and how they needed to be archived. As a result, we found data sets that lacked necessary information such as runoff flows, storm volumes, precipitation, station information, etc.

A third limitation of monitoring design is sampling techniques. Sampling techniques for stormwater monitoring in the SCB vary from flow-paced composite samples and time-paced composite samples to grab samples. Moreover, a large range of samples (4 to 40+) is used to generate the composite samples among programs. Different sampling techniques lead to bias and, since monitoring is conducted typically on a county-wide basis, one county or set of watersheds may appear to have elevated concentrations or produce greater loads due to sampling.

7)   *Stormwater runoff models are limited by several factors including data
       availability.*

Stormwater runoff water quality has been sampled more in the SCB than in most
areas of the nation (Smullen *et al*. 1999). It is estimated that four coastal counties
surrounding the SCB cumulatively expend $1.6 million annually on water quality
assessment (Schiff *et al*. in press), resulting in an abundance of water quality data.
A review of NPDES stormwater water quality data identified only 816 station-
events from over 30 cities nationwide; the data set from the SCB produced more
than double the station-events (1,766) in just four counties. The SCB data set is
larger than some national programs (i.e., USGS at 1,144 station-events) and is
similar in effort to the Nationwide Urban Runoff Program (NURP at ca. 2,000
station events; U.S. EPA 1983).

Despite the wealth of water quality samples collected in the SCB, gaps still exist
in the data set. The first data gap results from inadequate and often conflicting
and changing land use information. The most detailed land use information
available was used for the present study model including information from
Southern California Associated Governments (SCAG), San Diego Associated
Governments (SanDAG), and the Los Angeles Department of Public Works (LA
DPW). However, detailed land use information was not available for several
areas of our modeled domain including Santa Barbara County. Moreover, land
uses are constantly changing. Updated land use information will soon be
necessary for future model runs. Since the present model is driven by land use
data, insufficient information can lead to bias and limit the quality and usefulness
of the results.

The second identified data gap occurred in the area of water quality information
from specific land uses. While several land uses had been sampled by multiple
county programs, agricultural land uses were drastically underrepresented in our
water quality database. Lack of sufficient sample size could introduce bias since
the two sample sites might not be representative of all agricultural land uses in the
SCB. It is unknown to what extent the two agricultural land uses surveyed for
this study are representative of the total agricultural land uses.

The third identified data gap was inconsistent or nonexistent data for specific
constituents. This data gap applied in particular to several potentially important
constituents including diazinon, chlorpyrifos, and dissolved trace metals. In
addition, reduced data sets were noted for MTBE, total DDT, and total PCBs.

8)   *Large variations in reporting levels and how non-detectable samples are used for
       generating loads dramatically affect mass emission estimates.*

Non-detectable quantities (NDs) always hinder mass emission estimations
because their true load is unknown. The regional water quality database showed

that reporting levels routinely varied by an order of magnitude among monitoring programs, often with a concurrent increase in NDs. In addition, environmental managers assign NDs to values using different rationale and methodology. Some managers assign NDs to zero, which may underestimate the true load. Other managers assign NDs at the laboratory reporting level, which may overestimate the true load. When mass emissions were calculated based on NDs = 0 and NDs = reporting level, loads varied according to the frequency of the NDs. Constituents with few NDs were typically stable, while constituents with numerous NDs ranged widely. Extreme examples of this phenomenon included chlorpyrifos (15 to 1,526 kg), diazinon (14 to 783 kg), and total PCBs (0 to 626 kg).

XI. RECOMMENDATIONS

1)   *Establish monitoring effort for two other potentially large sources of pollutant contributions.*

One finding from this study is that stormwater runoff, large POTWs, and dredged materials are the largest contributors of pollutants to the coastal oceans of the seven sources we surveyed. This finding is apparent only because these sources have existing monitoring programs to assess their inputs. Two additional sources that could contribute large quantities of potential pollutants are presently unmonitored. In southern California, atmospheric deposition is a potentially large, unmonitored source because responsibility for monitoring this source falls between the jurisdictions of the Regional Water Quality Control Boards and the Air Quality Management Districts (AQMD). The mission of the AQMD is to protect human health (primarily from inhalation), and therefore it focuses on air concentrations. Atmospheric deposition, which is the mechanism that impacts aquatic ecosystem health, is not routinely monitored and few special studies have been conducted in this area. However, atmospheric deposition is a large source of pollutants in other parts of the country including the single largest source of nutrients to Chesapeake Bay or PCBs to the Great Lakes. Moreover, atmospheric pollutant deposition can collect on urban surfaces and wash off during subsequent rain events to be incorporated into runoff loads.

A second source that can potentially contribute large quantities of pollutants to sensitive receiving water bodies are vessel antifouling bottom paints. These paints are specially formulated to release copper, thereby preventing the attachment of algae and sessile organisms to boat hulls. While many of the commercial boatyards and shipyards in the SCB have become heavily regulated to reduce bottom paint emissions, regular episodic releases due to underwater hull cleaning for thousands of recreational vessels have gone unmonitored.

It is recommended that monitoring programs be established for these sources to evaluate their contributions of pollutants to the SCB.

2)   *Improve the effectiveness and cost-efficiency of current stormwater runoff monitoring programs. At least three areas need to be considered including monitoring design, information management and exchange, and sampling techniques.*

The largest stormwater monitoring programs in the SCB are designed independently, and comparability among programs is lacking. However, the optimal design to maximize effectiveness and increase cost-efficiency has not been evaluated. Part of the problem is that many programs are relatively new and typically focus on characterizing stormwater discharges. As stormwater

monitoring programs continue to mature and evolve, they will become focused on management questions and addressing management needs. At least three areas need to be addressed to create an efficient and effective monitoring program, including monitoring design, information management, and sampling techniques.

Two types of designs were found to exist in the SCB: mass emission monitoring and land use monitoring. Both types are appropriate depending upon the management need, but the maximum utility of both designs and how and where they can best be applied have not been fully evaluated. For example, several monitoring programs currently measure multiple land use sites. However, it is still not known whether three, four, five, or more land use categories are necessary to optimize modeling parameters. In addition, this study found little or no difference in water quality from similar land uses from various programs, which may indicate the need for more land use categories. If additional land use categories were necessary, perhaps land use monitoring could be coordinated among agencies to maintain levels of effort similar to (or lesser than) the present effort. Similarly, shared resources could be an effective means for other monitoring program designs including best management practice (BMP) evaluations, special studies, or method development.

In order for monitoring agencies to create integrated designs, information management will need to be addressed on a regionwide scale. Currently, SCB stormwater monitoring programs do not share data and each program maintains separate data systems with varying types of information. A recommended unifying approach would allow each agency to maintain its own information management system, while creating a single file transfer protocol (ftp). The single ftp approach outlines the minimum data types and specific designs for exchanging information in ASCII delimited formats that can be imported into virtually every data system created. The goal would be to focus on the necessary data and not the software requirements; many monitoring agencies have already invested in large, proprietary information management systems. Their management would be unwilling to change software systems or, alternatively, do not have the expertise or resources inhouse to establish and train users in sophisticated data management systems with state-of-the-art hardware and software. The ftp approach for distributed data systems enables maximum flexibility while maintaining data integrity and quality assurance. This approach has been successfully used in the SCB for other types of environmental monitoring.

The third area targeted for improving effectiveness and efficiency is sampling techniques. Currently, sampling techniques and effort vary substantially among monitoring agencies, but no assessment has been made to determine the most appropriate technique. The optimum sampling strategy, number of samples per storm, and number of storms per season need to be evaluated. The optimum strategy should focus on the sampling design as a method to detect trends in

concentration or mass emissions and identify the minimum number of samples or storms needed to generate mean concentrations with desired levels of confidence.

3)   *Determine the relationship between mass emissions and impacts to beneficial uses.*

This study demonstrated that mass emissions from stormwater runoff are large and could be considered a potential threat to receiving waters. However, large mass emissions alone do not automatically infer environmental degradation. A second element needs to be considered including concentration of the discharge and the receiving water environmental characteristics. Very little monitoring has been accomplished in the SCB, or around the state of California, to assess whether stormwater runoff loads or concentrations result in receiving water impacts. Several monitoring programs have integrated toxicity testing into their effluent characterization studies to begin addressing these questions.

The largest receiving water studies to date have been conducted in Santa Monica Bay and Newport Back Bay. Both studies determined that stormwater runoff samples were toxic and utilized toxicity identification evaluations (TIEs) to determine the toxic constituent(s). Receiving water monitoring tools, such as TIEs, have the potential to dramatically improve stormwater management actions since the results can be used to focus management actions on specifically identified impairments.

4)   *Improve data resolution to obtain more precise estimates of runoff mass emissions. This resolution should occur in at least two areas including land use and water quality data.*

Modeling results were limited by the resolution of the data in the model. Two areas were identified (land use and water quality data) where increased resolution would be beneficial. It is recommended that land use data be improved, particularly for Santa Barbara County. It is also recommended that water quality data be improved in three areas. First, additional sampling of agricultural runoff should be investigated to determine if currently used constituent concentrations are representative and, if not, to determine which agricultural activities need to be characterized. Second, additional constituents should be considered based upon potential water quality impacts, proportion of cumulative load, or increasing trends. For example, organophosphate pesticides such as diazinon and chlorpyrifos are undermonitored although they have been identified as constituents responsible for toxicity in several watersheds. Third, an evaluation of detection limits should be conducted to assess whether non-detectable quantities are severely biasing mass emission estimates.

5)   *Evaluate more complex watershed models that integrate pollutant fate and transport processes. These models are especially useful for TMDL development throughout the SCB.*

A land use-based model was used to generate mass emission estimates for runoff. The model was simplistic, but could be applied to a wide variety of watersheds with the existing information generated by current stormwater monitoring programs in the SCB. However, this model makes several assumptions, the largest being that pollutants generated at greater distances inland are transported to the ocean with the same efficiency as pollutants that are generated nearest the coast. We know this is not always the case, particularly for constituents that can degrade or transform over time such as bacteria or nutrients.

Additional models have been developed that incorporate fate and transport processes within the watershed. While more complex, these predictive models account for hydrodynamic processes as well as water quality dynamics including pollutant transformations, degradation rates, and sequestering. The negative factors for applying these models include the data necessary to generate reliable results. The advantages include their vastly improved predictive capability. While the simple models can generate load estimates, the capability to alter model parameters and predict future management actions is the fundamental feature that will enable many managers to improve TMDLs in the SCB. Rerunning the predictive model with an array of management actions will help regulators and stakeholders evaluate which actions have the highest potential for effectively reducing loads and/or concentrations.

Existing complex watershed models, such as SWMM and HSPF, were developed and have been applied predominantly in the eastern United States. These models have not been used extensively in the SCB, and their predictive capabilities have not been validated locally. It is imperative that these models be evaluated in our semi-arid environments where flows are not uniform and many streams are effluent-dominated waterways. It is possible that these previously developed models could be modified for our unique water quality situations. However, the model modifications, calibrations, and verifications need to occur before management can use them with confidence.

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