



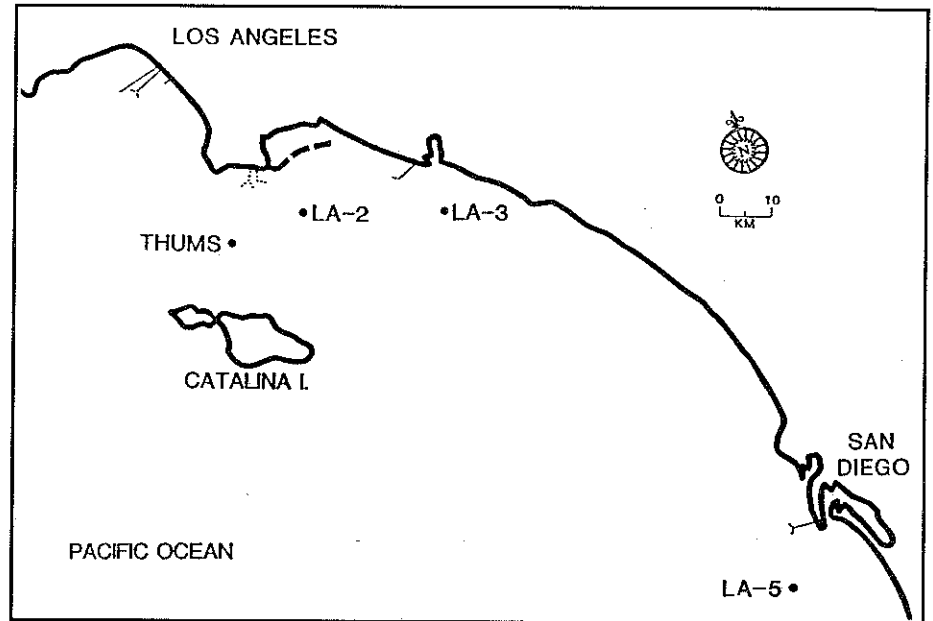
Estimates of Ocean Disposal Inputs to the Southern California Bight

Fourteen designated ocean disposal sites have been used in the Southern California Bight (SCB) since 1931 for disposal of refinery wastes, chemical wastes, filter cake, oil drilling wastes, refuse and garbage, radioactive wastes, military explosives, and miscellaneous wastes (SCCWRP 1973, Chartrand *et al.* 1985). Currently, only approved dredged materials can be released at two designated ocean disposal sites off Los Angeles (LA-2) and San Diego (LA-5), and one interim ocean disposal site off Newport Beach (LA-3) (Figure 1).

Millions of cubic yards of sediments have been removed from harbors and bays to expand coastal areas and improve navigable waters in the last decade. These harbors and bays receive inputs of stormwater runoff, and support industrial and military activities. Because they are generally poorly flushed, the sediments often have high concentrations of contaminants (Anderson *et al.* 1988, National Oceanic and Atmospheric Administration 1991). Much of the material dredged from harbors and bays is dumped at offshore sites in the SCB, yet little has been published on the magnitude of dredge inputs for the region. The objective of this study was to estimate the total mass of dredge material and associated contaminants dumped in the SCB between 1984 and 1991.

Figure 1.

Location of the dredge material disposal sites in the Southern California Bight.



Materials and Methods Permit Data

All permit applications for projects that disposed any material at sea in the SCB from January 1984 to June 1991 were examined. We obtained data from the dredge permit files of the U.S. Army Corps of Engineers (ACOE) Los Angeles District Office, the Dredge Material Tracking System (DMATS) of the U.S. Environmental Protection Agency Region IX, dredge permittees and local port authorities.

We collected data on dredging location, disposal site, completion date, volume of material disposed, and contaminant concentrations. Sediment chemistry data were obtained from technical reports, environmental impact statements, and reports for each permitted project. The trace metals included Ag, As, Cd, Cr, Cu, Hg, Ni, Pb, and Zn. The pesticides included DDT, DDE, total DDT, total identifiable chlorinated hydrocarbons (TICH), chlorinated hydrocarbons (CHC), and total organic halogens (TOH). The PCBs included individual Aroclors and total PCBs (sum of

Aroclor mixtures). There were too few measurements of organotins, oil and grease, and polycyclic aromatic hydrocarbons to estimate mass inputs.

The start and completion dates, and the actual volume of material dredged, were not available for all projects. When completion dates were not reported, the year the permit was issued was assumed to be the year of completion. When actual dredge volumes were not reported, the maximum volume estimated for the permit application was assumed to be the actual volume dredged, unless other documentation (individual dredging reports or communication with port authorities, permittees, and dredging engineers) was available.

Mass Emission Estimates

Constituent mass emissions were estimated from:

$$M = \sum_{i=1}^n (C_i V_i D)$$

where:

M = mass of constituent,

C_i = mean constituent concentration for i^{th} permit,

V_i = volume of material dredged for i^{th} permit,

D = density conversion factor from cubic yards to metric tons (mt), and

n = number of permits

The density conversion factor varied with the type of material dredged (i.e., sand, silt, clay). Density measurements for dredged materials were obtained for 17 projects in Southern California bays and harbors from 1976 to 1978 (U.S. Army Corps of Engineers 1977, 1978, 1979). Densities ranged from 0.969 to 1.361 mt/yd³; the mean density (1.087 mt/yd³; sd = 0.140) was used as the conversion factor.

Not all constituents were measured for each project. Chemical analyses and biological testing were not required for dredge material that was predominantly sand. When concentration data were missing for a constituent for a particular project, the

mean concentration of that constituent for all projects in the same harbor was used to estimate mass emissions. Constituent concentrations for sand and concentrations below detection limits were set to zero to estimate mass emissions.

Statistical Analyses

Dredge material constituent concentrations were tested for differences among harbors by nonparametric analysis of variance (Kruskal-Wallis test; Zar 1984). Data from Los Angeles and Long Beach harbors, Huntington Harbor and Anaheim Bay, and northern and southern San Diego Bay were pooled to increase sample size. The relation between dredge mass and contaminant mass was determined by Spearman rank correlation (Zar 1984).

Results

Fifty-three projects disposed 5,971,197 yd³ (4,565,577 m³) of

Table 1.

Constituent concentrations (dry weight) from sediment chemistry analyses from 37 dredging permits in Southern California bays and harbors from 1984 through 1991. Σ PCB=total PCB, Σ Pest=total pesticides, N=number samples, SD=one standard deviation.

	Los Angeles Harbor			Long Beach Harbor		
	Mean	SD	N	Mean	SD	N
Ag ($\mu\text{g/g}$)	0.75	0.24	4	0.52	0.12	15
As ($\mu\text{g/g}$)	2.3	0.38	4	0.81	3.47	23
Cd ($\mu\text{g/g}$)	1.68	3.20	27	1.07	0.21	23
Cr ($\mu\text{g/g}$)	38	14	4	32	7	23
Cu ($\mu\text{g/g}$)	44	57	27	47	39	23
Hg ($\mu\text{g/g}$)	0.32	0.34	27	0.09	0.06	23
Ni ($\mu\text{g/g}$)	17	7.1	4	13	1.6	22
Pb ($\mu\text{g/g}$)	42	38	27	27	16	23
Zn ($\mu\text{g/g}$)	75	38	4	27	41	23
Σ PCB (ng/g)	107	129	3	22	103	21
Σ Pest (ng/g)	44	47	7	582	389	22

¹ includes Huntington Harbor

*Only 4 of 42 samples had detectable mass (1-11 ng/g); detection limits ranged from <1 to <50 ng/g

dredged materials in the Southern California Bight between January 1984 and June 1991. Thirty-seven permits reported constituent concentrations for 120 dredge material samples.

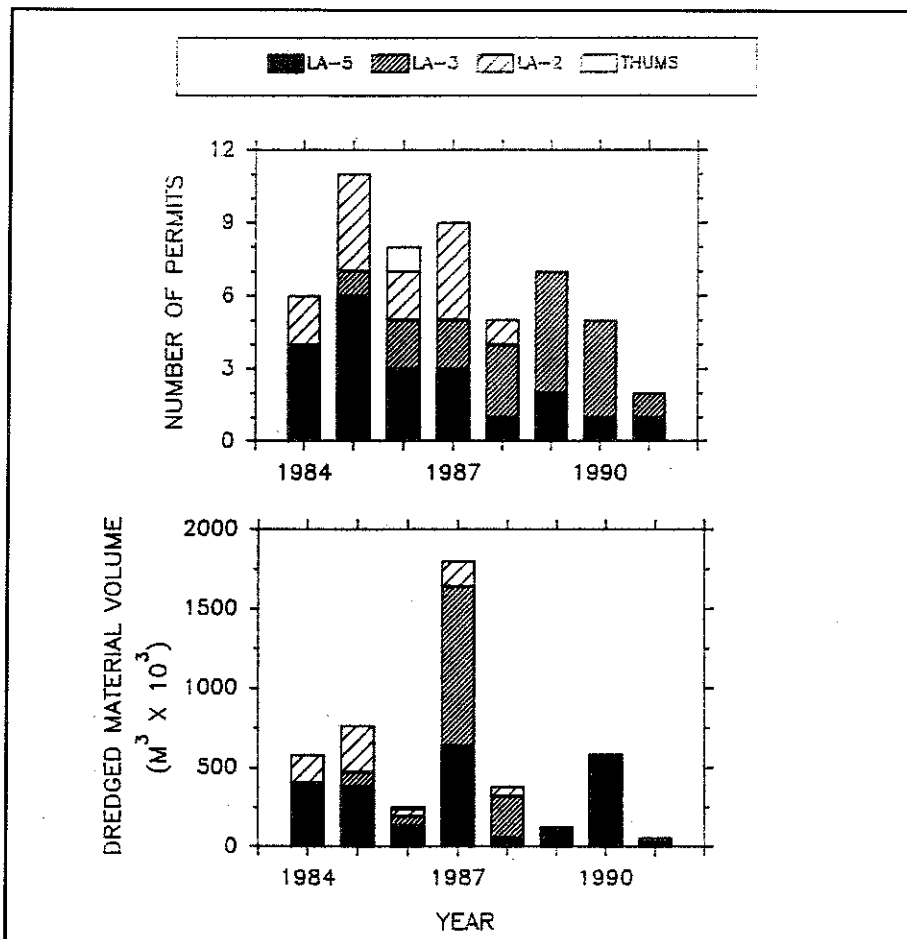
Dredging Volumes

The total annual volume of materials dumped at the disposal sites ranged from 72,000 to 2,353,800 yd³ (55,000-1,800,000 m³) (Figure 2); the average annual volume was 746,400 yd³ (570,700 m³). Most of the material was dumped at LA-5 (51%) and LA-3 (32%); lesser amounts were dumped at LA-2 (16%) and THUMS (<1%). The number of permitted projects varied from year to year and dumpsite to dumpsite (Figure 2); 21 projects dumped at LA-5, 18 projects dumped at LA-3, 13 projects dumped at LA-2, and one project dumped at THUMS. The total number of projects per year ranged from two to 11 (mean = 6.6; sd = 2.8).

Disposal sites LA-2 and LA-5 were closed from 1/89 to 2/91,

Figure 2.

The number of permits (above) and the volume of dredge materials disposed (below) by site in the Southern California Bight between January 1984 and June 1981.



Anaheim Bay ¹			Newport Bay			Dana Point Harbor			San Diego Bay		
Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD	N
1.0	0.14	2	1.15	0.92	8	0.43	0.14	9	0.71	1.00	30
4.7	0.35	2	<0.1	0.2	10	7.0	3.4	9	9.0	13	25
1.1	0.85	6	0.40	0.88	11	0.38	0.24	10	1.5	2.3	43
34	2.8	2	33	10	10	34	10	9	67	93	43
24	19	6	24	5	10	42	54	9	90	74	43
0.11	0.11	6	0.38	0.43	11	0.044	0.034	10	0.55	1.00	43
35	2.1	2	-	-	-	14	4.5	9	14	3.2	4
43	32	6	38	19	11	26	33	9	47	42	25
145	6	2	117	65	11	61	32	9	175	199	25
11	18	6	<100	-	10	<50	-	9	75	113	43
61	66	6	63	18	8	<20	-	10	*	-	42

Figure 3.
Frequency distribution of the volume of material dredged by permit (n=53).

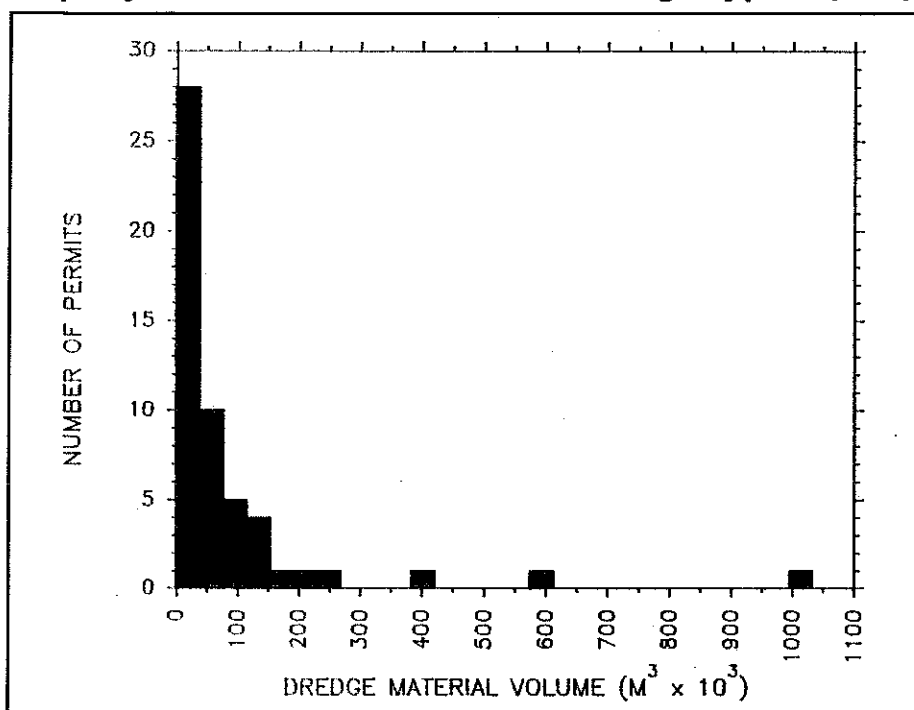


Table 2.
Estimated mass loads of selected constituents in materials disposed in the Southern California Bight from 1984 through 1991. mt=metric tons; bdl=below detection limits; Σ PCB=totalPCB; Σ Pesticides=total pesticides.

	DUMPSITE				Total
	LA-2	LA-3	LA-5	THUMS	
Solids (mt x 10 ³)	1,035.8	2,099.1	3,338.8	16.6	6,490.7
Ag (mt)	0.6	0.5	3.6	bdl	4.7
As (mt)	1.6	2.1	22.7	bdl	26.4
Cd (mt)	4.2	3.5	2.7	0.01	10.4
Cr (mt)	34.0	43.4	160.9	0.26	238.5
Cu (mt)	63.2	45.6	309.5	0.17	418.1
Hg (mt)	0.2	1.4	1.0	bdl	2.6
Ni (mt)	14.0	9.8	45.4	0.16	69.4
Pb (mt)	46.7	93.7	142.7	0.13	283.2
Zn (mt)	38.6	340.7	473.6	1.62	854.5
Σ PCB (kg)	90.4	9.2	102.3	bdl	201.9
Σ Pesticides (kg)	341.6	33.4	7.1	0.96	383.1

although projects with sand waivers continued to dump. LA-5 received material from the largest number of projects in one year (six in 1985). The THUMS Company of Long Beach was the only company permitted to dump at the THUMS disposal site northwest of Catalina Island. They dumped a relatively small amount of drilling muds and cuttings from oil and gas exploration at the site in 1985, which is no longer in use.

Most of the dredging projects dumped small quantities of dredge materials (Figure 3). The smallest projects were predominantly sand removed from private docks and marinas in Newport Harbor. These projects ranged from 195 to 1,200 yd³ (149-918 m³) and disposed of their materials at LA-3 in 1989 and 1990. Six projects dumped volumes greater than 200,000 yd³ (153,000 m³) and composed 58% of all dredge materials dumped (four at LA-5 and two at LA-3). The largest project was the deepening of Newport Harbor Back Bay that was completed in 1987. More than 1,313,000 yd³ (1,004,000 m³) were dumped at LA-3, which represented 70% of the total volume dumped at that site and 22% of the total volume dumped at all sites.

Contaminant Concentrations

Chemistry data were reported for 70% of the dredge projects representing about 90% of the total volume dumped in the SCB during the study. Seventeen percent of the projects dredged sand for which chemical analyses were not required; these projects accounted for less than 0.1% of

the total volume disposed. Thirteen percent of the projects did not report chemistry data, although the dredge material was submitted for biological testing; these projects represented 11% of the total volume disposed.

The number of chemical analyses ranged from 41 for nickel to 120 for cadmium and mercury (Table 1). Dredge materials from the larger, more industrialized harbors had the highest concentrations and largest concentration range (Figure 4). There were no significant differences among the harbors in the concentrations of Ag, As, Cd, Cr, Cu, Hg, Ni, Pb, Zn, or total PCB (Kruskal-Wallis test, $p > 0.05$). The concentrations of pesticides were significantly higher (Kruskal-Wallis test, $H = 23.35$, $p = 0.001$).

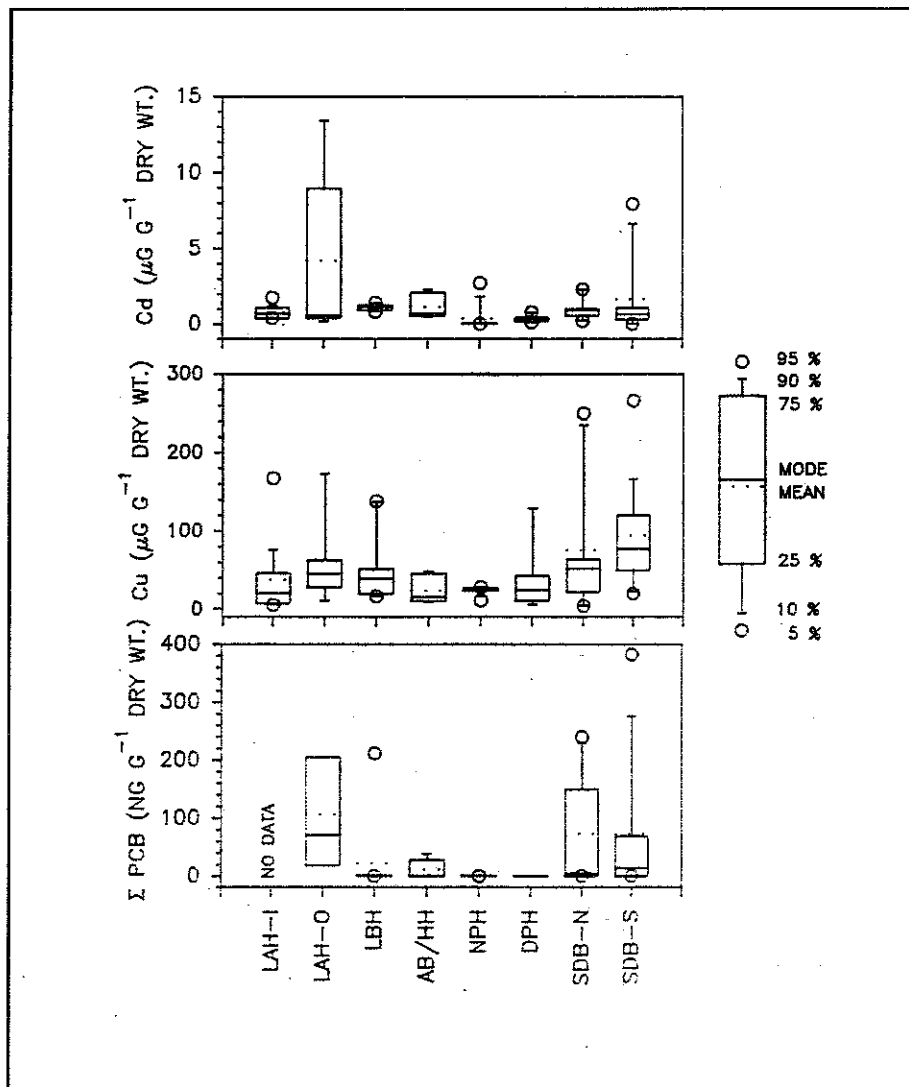
Mass Emissions Estimates

Nearly 6.5×10^6 mt of solids were dumped in the SCB during the study (Table 2). Most of this material was dumped at LA-5 and LA-3; lesser amounts were dumped at LA-2 and THUMS (Table 2). The LA-5 site received 86% of the arsenic, 77% of the silver, and 74% of the copper. The LA-3 site received 55% of the mercury. The LA-2 site received 89% of the pesticides, 45% of the total PCB, and 40% of the cadmium.

The annual mass input of dredge materials varied two orders of magnitude and the annual mass input of contaminants varied from one to three orders of magnitude (Table 3). The mass input of solids and seven of the 11 constituents was highest in 1987. The annual mass inputs of all constituents except Ag and total PCBs were posi-

Figure 4.

Box plots of the concentrations of cadmium, copper, and total PCBs in dredge materials by harbor. LAH-I = Inner Los Angeles Harbor; LAH-O = Outer Los Angeles Harbor; LBH = Long Beach Harbor; AB/HH = Anaheim Bay and Huntington Harbor; NPH = Newport Harbor; DPH = Dana Point Harbor; SDB-N = North San Diego Bay; SDB-S = South San Diego Bay.



tively correlated with the annual mass inputs of solids (Spearman r_s , $p < 0.05$).

Discussion

On average, 746,400 yd³ (811,300 mt) of sediments were removed from harbors and bays and dumped at offshore sites in

the Southern California Bight from 1984 to 1991. Over 70% of the dredge projects were small and disposed less than 100,000 yd³ (109,000 mt) of material. The disposal sites off San Diego (LA-5) and Newport Beach (LA-3) received more than 80% of the material.

Constituent inputs to each disposal site were not always

proportional to the mass of solids received. Proportionally more arsenic, silver and copper was dumped at LA-5, proportionally more mercury was dumped at LA-3, and proportionally more cadmium, total PCB, and pesticides were dumped at LA-2. The disproportionate share of contaminant mass dumped at these sites is due to sources of contaminants peculiar to the harbors and bays from which the sediment was removed.

For example, copper has been used as an antifouling agent in bottom paints of Navy ships. Dredge materials from Navy berths in San Diego Bay composed 73% of the material disposed at LA-5 and accounted for 74% of the copper dumped in the SCB. In the past, mercury mines were located along San Diego Creek just above Newport Back Bay (Orange County Environmental Management Agency, personal communication). Dredge

material from Newport Harbor and Newport Back Bay composed 77% of the material dumped at LA-3 and accounted for 54% of the mercury dumped in the SCB. The disproportionate share of pesticides dumped at LA-2 can be traced to Dominguez channel, which empties into Consolidated Slip in Los Angeles Harbor. Dominguez Channel received runoff from the Montrose Chemical Corporation, the largest manufacturer of DDT in the world and the only manufacturer in California (Chartrand *et al.* 1985). Dredge material from Los Angeles and Long Beach harbors composed all of the material dumped at LA-2 and accounted for 89% of the pesticides dumped in the SCB.

The concentrations of Cu and total PCB in dredge materials removed from Los Angeles and Long Beach harbors and San Diego Bay were compared to sediment concentrations mea-

sured by National Oceanic and Atmospheric Administration (NOAA) Mussel Watch and Benthic Surveillance Program (National Oceanic and Atmospheric Administration 1991) and by SCCWRP (Anderson *et al.* 1988). Mean Cu concentrations varied by about a factor of three in both harbors (Figure 5). The differences were not significant in San Diego Bay (Kruskal-Wallis test, $H=8.83$, $p=0.066$), but they were significant in Los Angeles and Long Beach harbors ($H=17.67$, $p=0.001$).

Mean total PCB concentrations varied by about a factor of five in both harbors (Figure 6). The differences were significant in San Diego Bay ($H=26.25$, $p<0.001$) and in Los Angeles and Long Beach harbors ($H=22.76$, $p<0.001$). In Los Angeles and Long Beach harbors, NOAA Mussel Watch, NOAA Benthic Surveillance, and SCCWRP data were not significantly different. In

Table 3.

Estimated annual mass emissions of material dumped in the Southern California Bight from 1984 through 1991. mt=metric tons; bdl=concentrations below detection limit; Σ PCB=total PCB; Σ Pesticides=total pesticides.

	1984	1985	1986	1987	1988	1989	1990	1991
Solids (mt x 10 ³)	824.7	1,083.1	352.8	2,557.8	539.5	175.6	879.0	78.3
Ag (mt)**	0.52	0.63	0.26	0.67	0.32	0.11	2.1	0.03
As (mt)	7.1	4.8	1.6	10.2	1.4	0.22	0.35	0.66
Cd (mt)*	3.6	0.96	0.44	4.1	0.90	0.09	0.29	0.03
Cr (mt)**	27.1	80.7	13.7	67.0	12.5	4.1	29.7	3.7
Cu (mt)**	76.2	77.1	16.6	126.4	41.2	3.6	70.1	7.0
Hg (mt)**	0.25	0.24	0.09	1.6	0.07	0.02	0.27	0.04
Ni (mt)**	11.2	12.9	3.9	15.5	10.5	2.4	12.0	1.2
Pb (mt)**	36.1	57.2	14.3	113.1	33.7	2.3	22.9	3.6
Zn (mt)**	99.4	122.2	42.4	449.1	45.2	9.6	67.0	19.6
Σ PCB (kg)	64.2	40.3	11.6	61.0	9.2	1.3	bdl	14.4
Σ Pesticides (kg)*	24.7	235.4	27.7	72.3	21.7	bdl	0.79	0.55

* constituent load correlated (r_s) to annual solids mass emissions at $p \leq 0.05$.
 ** constituent load correlated (r_s) to annual solids mass emissions at $p \leq 0.01$.

San Diego Harbor, NOAA Benthic Surveillance and SCCWRP data were not significantly different. Differences in Cu and PCB concentrations could be due to differences in sampling methods, analytical techniques, or methods of quantification. For example, each group differs in the number and type of Aroclors quantified. There is also substantial heterogeneity in the distribution of PCBs within harbor sediments (SCCWRP 1990).

The estimates of mass inputs from dredge material disposal presented in this study suffer from missing data, lack of standardized chemical characterization, and inconsistent reporting. Mass inputs were calculated for each permit, although some permits lacked chemical data. Chemical characterization was not consistent among permits and detection limits varied widely. Information on project start and completion dates, dredge material density, and the total volume dumped was often missing from Army Corps of Engineers permit files and was not included in the Dredged Material Tracking System.

Inconsistent analytical techniques and reporting are illustrated by the trace organic hydrocarbon data. Various projects reported pesticides as DDT, DDE, total DDT, chlorinated hydrocarbons, total identifiable chlorinated hydrocarbons, and total organic halogens. Different projects quantified different PCB Aroclor mixtures, and some projects summed the different Aroclor mixtures and reported only total PCBs. There were too few measurements of polycyclic aromatic hydrocarbons to estimate mass inputs, although harbor and bay sediments are often significantly

Figure 5.

Box plots of the concentration of copper in dredge material and sediments in Los Angeles and Long Beach harbors and in San Diego Bay. Data are from the dredging permits, the Mussel Watch Program (NOAA-MW; NOAA 1991), the Benthic Surveillance Program (NOAA-BS; NOAA 1991), and SCCWRP (Anderson and Gossett 1987). NOAA-BS sampled two stations in San Diego Harbor.

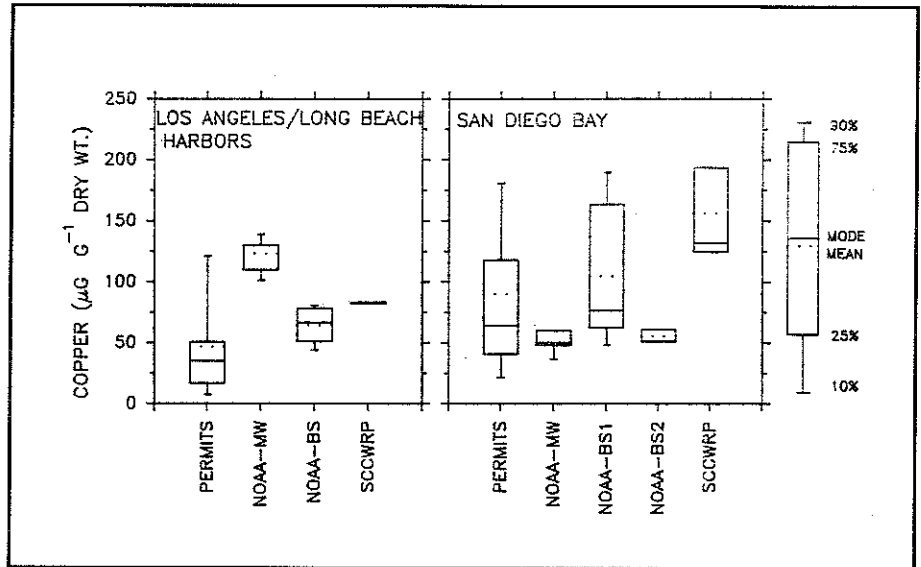
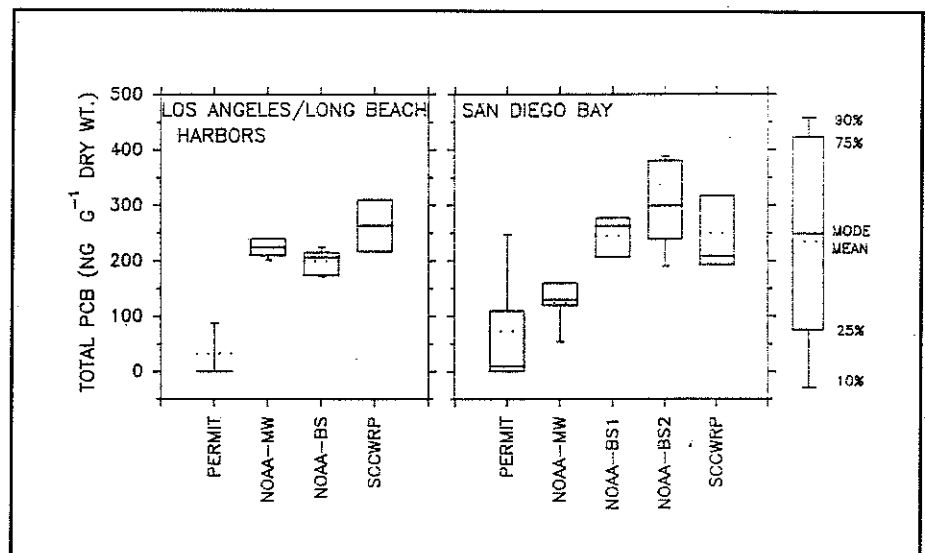


Figure 6.

Box plots of the concentration of total PCBs in dredge material and sediments in Los Angeles and Long Beach harbors and in San Diego Bay. Data are from the dredging permits, the Mussel Watch Program (NOAA-MW; NOAA 1991), the Benthic Surveillance Program (NOAA-BS; NOAA 1991), and SCCWRP (Anderson and Gossett 1987). NOAA-BS sampled two stations in San Diego Harbor.





Commercial operations in Los Angeles Harbor

contaminated (Anderson and Gossett 1987). Improved characterization of dredge materials is needed before we will be able to accurately estimate the mass emissions from dredge material disposal.

Acknowledgements

Authors Kenneth Schiff and Jeffrey Cross would like to thank Mo Chang and Sherry Stevens

(U.S. Army Corps of Engineers, Los Angeles District), Shelley Clarke and Patrick Cotter (U.S. Environmental Protection Agency, Region IX), Michael Salazar (Naval Ocean Systems Center, San Diego), Tom Rossmiller (Orange County Dept. of Harbors, Parks, and Beaches), Robert Kanter (Port of Long Beach), Larry Smith and Bob Smuda (Port of Los Angeles), Christine Stein (San Diego Uni-

fied Port Districts), Mark Shemaria (THUMS Company, Long Beach), and Karen Engelhardt, Valerie Raco, and Henry Schafer (Southern California Coastal Water Research Project). This project could not have been completed without their assistance. ■

Appendices

Appendix 1: Permit Process

The Marine Protection, Research, and Sanctuaries Act (MPRSA) of 1972, also known as the Ocean Dumping Act, regulates ocean dumping and phased out the disposal of certain types of wastes at sea (e.g., industrial wastes, sludges, etc.). This act established a permit process for ocean disposal that evaluates the environmental impacts of materials dumped at sea, allows enforcement of permit conditions, and establishes a process to designate and manage ocean disposal sites. Dredge material disposal in the SCB requires a federal permit from the Army Corps of Engineers (ACOE).

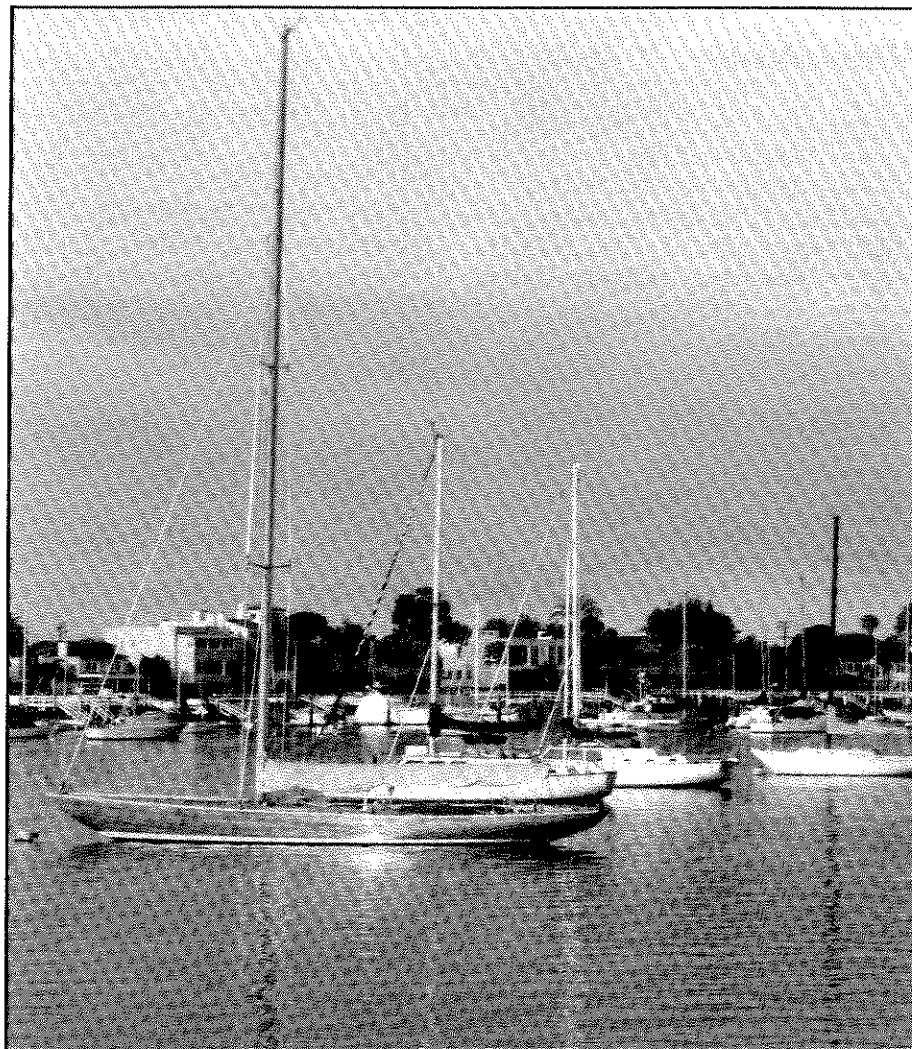
Ocean dumping permits are evaluated on a project-by-project basis. The Army Corps of Engineers administers all permits under the Dredged Material Disposal permit process of the MPRSA, Section 103. Permit approval is contingent upon guidelines established by the U.S. Environmental Protection Agency (EPA) Ocean Dumping Regulations (40 CFR 220-229). In the SCB, all permit applications are submitted to the ACOE Los Angeles District Office and reviewed by EPA Region IX, San Francisco. The ACOE releases

each application for public comment and solicits opinions from federal, state, and local government agencies. The California Coastal Commission must also approve the dredging permit under a Coastal Consistency Determination.

The EPA criteria for disposal of dredged materials are based on environmental acceptability, chemical analyses, and biological tests. Permits to dredge rock, gravel, shell fragments, or sand are generally approved without extensive chemical or biological testing. Coarse grained materials, characteristic of high energy environments, generally have low organic content and low contaminant concentrations. They are used for beach replenishment if grain size is compatible with the receiving environment.

If the dredge material does not meet the exclusion criterion [40 CFR 227.13 (b)], it is submitted for chemical analyses, liquid/suspended particulate and solid phase bioassays, and bioaccumulation tests with approved species (U.S. EPA/U.S. Army Corps of Engineers 1991). Testing determines the potential for adverse biological effects resulting from disposal. If contaminant concentrations are low and bioassay and bioaccumulation results are not significant, then a permit for ocean disposal may be issued.

Dredge material that does not meet the chemical, toxicity, or bioaccumulation standards may still be dredged. Alternative disposal sites, such as sanitary landfills or diked disposal areas, must be found. Diked disposal areas, where dredge material is used for fill, are planned for the 2020 Los Angeles/Long Beach Harbor Expansion Project.



Early morning in Newport Bay

Appendix 2: Designated Dumpsites

The LA-2 disposal site is located 6.7 nm south of the breakwater at San Pedro; it has a radius of 915 m and ranges from 118 to 320 m in depth (U.S. Environmental Protection Agency 1988). The LA-5 disposal site is located 10 nm southwest of San Diego; it has a radius of 915 m and ranges from 145 to 200 m in depth (U.S. Environmental Protection Agency 1987). The LA-3 disposal site is located 9 nm south of Newport Harbor; it has a

radius of 915 m and averages 457 m deep (U.S. Army Corps of Engineers, Los Angeles District, personal communication). The THUMS site, which is not currently in use, was designated in 1985 for the disposal of drilling muds and cuttings from oil and gas development in Long Beach Harbor. It is located 16 nm southwest of the Long Beach Harbor breakwater; it has a radius of 2.8 km and is approximately 890 m deep (U.S. Environmental Protection Agency 1985).

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