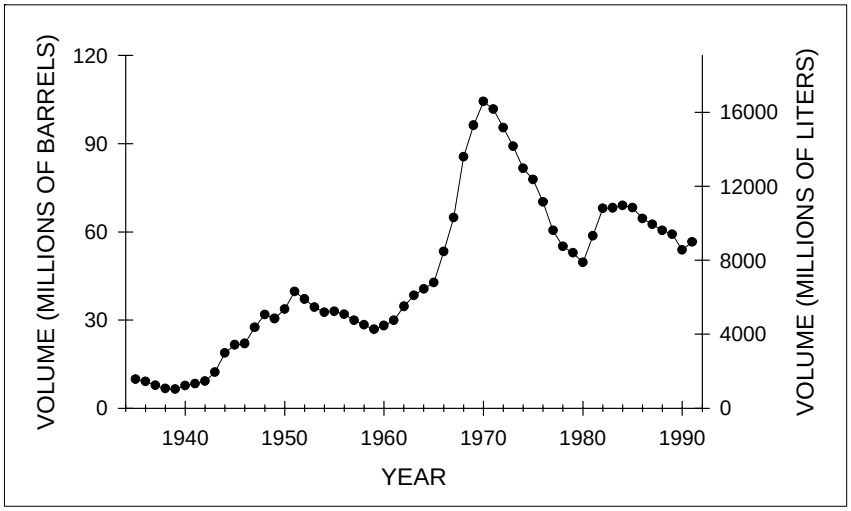
Estimated Discharges from Offshore Oil Platforms in the Southern California Bight in 1990

Offshore oil fields are an important resource in the Southern California Bight. The oil fields of the Santa Barbara Channel and Santa Maria Basin are among the largest domestic oil reserves in the United States. Offshore production increased by a factor of six from 1935 to 1991 (Figure 1; Conservation Committee of California Oil Producers 1991). In May 1993, 20 out of 23 platforms in federal waters, and five out of seven oil fields in state waters, were producing oil (Figures 2 and 3; Table 1).

Figure 1.
Annual crude oil production from California offshore oil fields (excluding oil production from gas fields), 1935-1990 (data from Conservation Committee of California Oil Producers 1991).



Offshore facilities discharge contaminants into the Southern California Bight during oil field development and production. Several governmental agencies regulate oil platform discharges (Appendix 1); however, only a few studies have reported discharges from platforms off Southern California (USDI 1975, UCLA 1976, Coats 1994, Hyland *et al.* 1994) or chemical analyses of discharges (Steinhauer *et al.* 1994).

The predominant emissions from oil platforms are drilling muds and cuttings, produced water, and sanitary wastes. Drilling muds or fluids are specially formulated mixtures of fresh- or seawater with clays, minerals, chemicals, and other materials used for cleaning drill bits, transporting cuttings, reducing friction, and stabilizing the borehole (Appendix 2). Platforms off Southern California use rotary methods of drilling in conjunction with water-based muds. Drill cuttings are particles of crushed sedimentary rock produced in the process of drilling (Neff 1987). Produced waters are natural geological formation water or introduced seawater recovered with the extraction of oil. Most produced water is a brine that may contain dissolved solids, metals, sulfur, and organic compounds at substantially higher concentrations than in seawater (Menzie 1982, Neff 1987). Sanitary wastes are produced by platform personnel.

Although platforms in state waters are permitted to discharge to the ocean, most discharges are sent to onshore facilities. Muds and cuttings are transported to landfills for disposal. Produced water is either reinjected back into the well or sent ashore to a produced water treatment facility where it may then be discharged to the ocean or to a

sewer system. Sanitary waste is either discharged to the ocean, or transported to shore and discharged to a sewer system. Platforms Esther and Eva were the only platforms in state waters that discharged sanitary waste directly to the ocean in 1990; their combined discharge was about 757 L/day.

Platforms in federal waters can either discharge to the ocean in compliance with the National Pollutant Discharge Elimination System (NPDES) permit requirements (Appendix 3) or send their discharges ashore for treatment and disposal. The objective of this study was to estimate direct ocean inputs from platforms in federal waters off Southern California in 1990.

Materials and Methods

Data summarized in this report were obtained from NPDES discharge monitoring reports (DMR) submitted to the US Environmental Protection Agency (EPA) Region IX. The term "platform" includes offshore drilling platforms and an offshore storage and treating facility (vessel).

The volume of cuttings discharged is recorded in barrels (one barrel=42 gal or 159 L). To convert to mass, the volume was corrected for water content (cuttings were assumed to be 35% water and 65% solids; Ayers 1983) and multiplied by the specific

Figure 2.
State and federal platforms in the northern Southern California Bight (modified from Conservation Committee of California Oil Producers 1991).

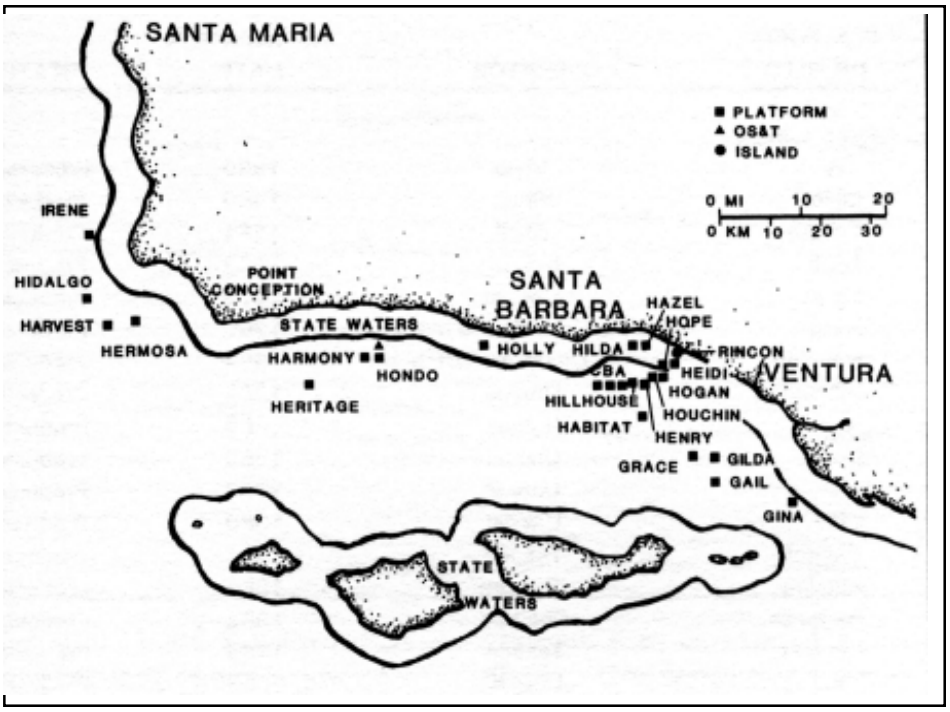


Figure 3.
State and federal platforms in the central Southern California Bight (modified from United States Department of the Interior 1984).

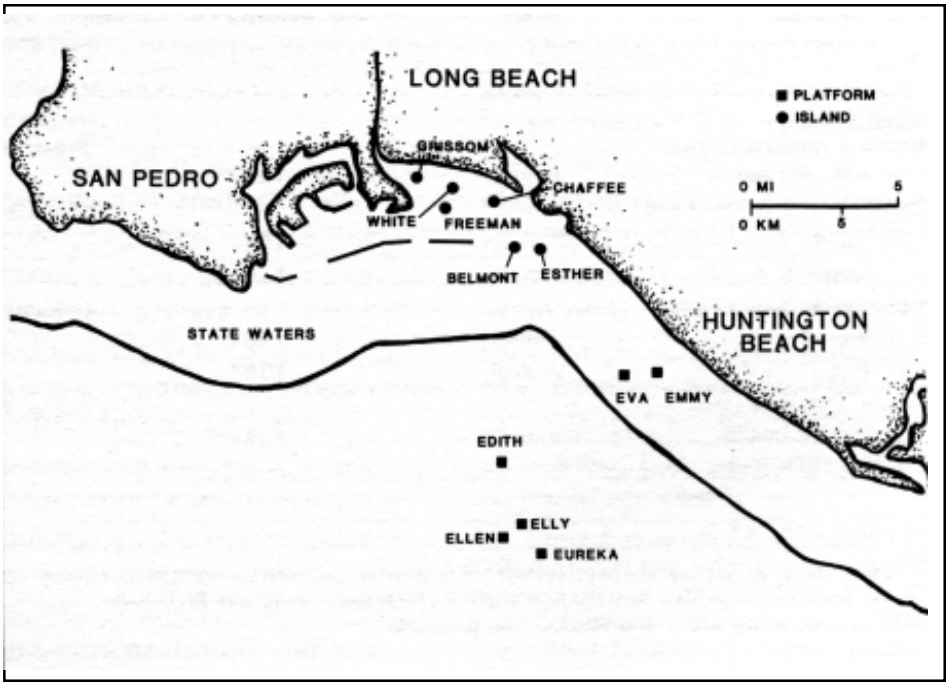


Table 1.

List of active oil platforms off Southern California in May 1993. Source for Federal Waters: M. Brickey, US Dept. Interior, Minerals Mngt. Serv., Pacific OCS Region II, Camarillo, CA, personal communication, 1993. Source for State Waters: J. Campion, State Oil and Gas Headquarters, Dept. Conservation, Div. Oil and Gas, Sacramento, CA, personal communication, 1993.

PLATFORM OR FIELD	OPERATOR	INSTALLATION DATE	STATUS	PRODUCTION (1000 bbl[a]/day)	PRODUCTION (Mmcf[b]/day)
Federal waters					
Elly	Shell	1980	Processing	-	-
Ellen	Shell	1980	Producing	3.3	0.8
Eureka	Shell	1984	Producing	6.3	1.1
Edith	Unocal	1983	Producing	0.9	0.8
Henry	Unocal	1979	Producing	1.4	0.6
Hogan	Pacific Operators Offshore	1967	Producing	0.6	1.0
Houchin	Pacific Operators Offshore	1968	Producing	0.8	0.8
Hillhouse	Unocal	1969	Producing	2.0	2.3
A	Unocal	1968	Producing	2.9	2.6
B	Unocal	1968	Producing	2.6	2.8
C	Unocal	1977	Producing	2.1	1.0
Gina	Unocal	1980	Producing	1.4	0.8
Habitat	Texaco	1981	Producing	0.02	28.2
Hidalgo	Chevron	1986	Producing	11.7	4.8
Hermosa	Chevron	1985	Producing	27.0	12.5
Harvest	Texaco	1985	Producing	26.8	11.2
Irene	Unocal	1985	Producing	13.5	3.2
Grace	Chevron	1979	Producing	0.7	1.4
Gail	Chevron	1987	Producing	8.7	22.2
Gilda	Unocal	1981	Producing	3.8	3.3
Hondo	Exxon	1976	Producing	22.0	45.8
Harmony	Exxon	1989	Nonproducing	-	-
Heritage	Exxon	1989	Nonproducing	-	-
			Total	138.5	147.2
State waters[c]					
Belmont Offshore Field	-	-	Producing	0.9	0.03
Belmont Island	Exxon	1948	-	-	
Carpinteria Offshore Field	-	-	Nonproducing	0	0
Heidi	Chevron	1965	-	-	
Hope	Chevron	1964	-	-	
Huntington Beach Field	-	-	Producing	7.0	4.5
Emmy	Shell	1961	-	-	
Eva	Unocal	1964	-	-	
Rincon Offshore Field	-	-	Producing	0.54	0.5
Rincon Island	Norris Oil	1957	-	-	-

[a]1 barrel=158.97 liters.
[b]Mmcf=Million cubic feet (1ft 3=0.0283 m^3).
[c]State production status and numbers were not broken down by platform.
[d]Includes onshore wells and subsea completions.

(Table 1. continued)

PLATFORM OR FIELD	OPERATOR	INSTALLATION DATE	STATUS	PRODUCTION (1000 bbl[a]/day)	PRODUCTION (Mmcf[b]/day)
South Ellwood Field	-	-	Producing	4.6	2.1
Holly	Mobil	1966	-	--	
Summerland Offshore Field	-	-	Nonproducing	0	0
Hilda	Chevron	1960	-	-	-
Hazel	Chevron	1957	-	-	-
Wilmington Field	-	-	-	43.4	10.0
Thums Islands	-	1964	Producing	-	-
Chafee	Thums Tract	-	-	-	-
Freeman	Thums Tract	-	-	-	-
Grissom	Thums Tract	-	-	-	-
White	Thums Tract	-	-	-	-
Esther	Chevron	1964/1986	Producing	-	-
Nonplatform[d]	-	-	Producing	1.0	0.36
			Total	57.4	17.5
			Grand Total	195.9	164.7

gravity of 2.6 (Runchal 1983; Appendix 4).

The composition of drilling mud was rarely included in the DMRs. We estimated the mass of mud additives discharged from the mean component concentration of generic mud No. 6 (i.e., 170.5 g/L), one of the two most commonly used muds at platforms off Southern California (E. Bromley, US EPA, Region IX, San Francisco, personal communication, 1992). Drilled solids in the generic muds were not included (Table 2; Appendix 3).

The mass of constituents in cuttings and mud was estimated from the product of the concentration of constituents and the mass of cuttings and mud discharged in 1990. We used data from composite samples from Platform Hidalgo (1986-90) for mean constituent concentrations (dry weight) (Steinhauer *et al.* 1994). The mass of mud (dry weight) was the sum of the estimated mass of mud additives and the estimated mass of drilled solids [using the average concentration (171 g/L) in generic muds (NRC 1983)].

Because produced water constituent analyses were only measured one to five times a year, annual constituent means were not used in mass emission calculations. Instead, mass emissions were calculated on an interval basis. For example, if the constituents were measured quarterly, the mass emission of each quarter was calculated as the product of the constituent concentration and produced water volume discharged that quarter (Appendix 4). Concentrations below detection limits were set to zero for mean and mass emission estimates.

Results

The status of platform production in 1990 was similar to that in 1993 (Table 1). However in 1990, federal platforms Hidalgo, Hermosa, Harvest, and Gail were in the development phase and all state platforms were in production (A. Copsey, Minerals Management Service, US Department of the Interior, Camarillo, CA, personal communication 1992).

Seven out of 21 active platforms in federal waters discharged cuttings and mud in 1990 (Table 3). Discharge volumes were variable and

Table 2.

The most common generic drilling fluid systems used on the California Outer Continental Shelf (NRC 1983). Adapted from Ayers *et al.* (1983) and modified by National Research Council (1983).

TYPE OF FLUID	COMPONENTS	PERMISSIBLE CONTENT	
		(lb/bbl)	(g/L)
No. 6			
Seawater/freshwater gel	Attapulgite or bentonite	10-50	29-143
	Barite	0-50	0-143
	Caustic soda	0.5-3	1-9
	Cellulose polymer	0-2	0-6
	Drilled solids	20-100[a]	57-285[a]
	Lime	0-2	0-6
	Seawater or fresh water	As needed	As needed
	Soda ash/sodium bicarbonate	0-2	0-6
No. 7			
Lightly treated lignosulfonate freshwater/seawater	Barite	0-180	0-514
	Bentonite	10-50	29-143
	Caustic soda	1-3	3-9
	Cellulose polymer	0-2	0-6
	Drilled solids	20-100	57-285
	Lignite	0-4	0-11
	Lignosulfonate	2-6	6-17
	Lime	0-2	0-6
	Seawater-to-freshwater ratio	≈1:1	≈1:1

[a] Not included in calculating the mass of mud additives discharged.

many of the platforms had only one or two types of discharges. Platform Gail discharged the largest volume of mud and mass of cuttings, mud additives, and mud solids. Sanitary wastes were discharged by 20 platforms (mean=3.4 x 10^6 L/platform/yr or 0.0025 mgd). Produced water was discharged by 11 platforms. Platform A discharged the most produced water.

Approximately 2.5 mt of trace organics and 325 mt of trace metals were discharged in drill cuttings and drilling muds from all of the platforms in 1990 (Tables 4 and 5). The majority of constituents were discharged in minor amounts. Of the total estimated metals discharged, barium accounted for 96%, lead accounted for 1.9%, and zinc accounted for 1.5%.

The concentrations of most trace metals and cyanide in produced water discharges were below detection limits (Table 6). Cadmium was below detection limits in all samples. Nickel was detected in 50% of the samples, the most of any metal, and cyanide was detected in 25% of the samples. Approximately 1 mt of trace metals was discharged in produced waters in 1990 (Table 7; accidental discharge by Elly not included). Zinc accounted for 60%, and nickel accounted for 30%, of the total mass of metals discharged.

All of the platforms discharging produced water had measurable concentrations of oil and grease, and 75% had measurable concentrations of phenols (Table 6). Oil and grease and phenols were the dominant constituents in produced waters (Table 7).

Table 3.

Primary constituents discharged in federal waters from oil platforms off Southern California in 1990. Data from National Pollutant Discharge Elimination System discharge monitoring reports submitted to US EPA Region IX, San Francisco.

PLATFORM[a]	CUTTINGS (mt)	MUD ($L \times 10^3$)	MUD ADDITIVES DISCHARGED (mt)	TOTAL MUD SOLIDS (mt)[f]	PRODUCED WATER ($L \times 10^6$)	SANITARY WASTE ($L \times 10^6$)
Elly	0	0	0	0	1[g]	0
Ellen	254	495	99	184	0	14.6
Eureka	0	0	0	0	0	10.5
Edith	0	0	0	0	176	7.9
Henry	-[c]	-	-	-	0	0
Hogan	0	0	0	0	225	0.3
Houchin	0	0	0	0	0	0.3
Hillhouse	-	-	-	-	361	2.8
A	-	-	-	-	1184	0.1
B	26	109	19[d]	38	726	0.1
C	44	142	24[d]	48	836	0.1
Gina	-	-	-	-	0	<0.1
Habitat	424	1,900	324[d]	649	21	4.8
Hidalgo	0	0	0	0	0	5.7
Hermosa	0	0	0	0	0	3.3
Harvest	0	0	0	0	0	3.8
Irene	518	702	110	230	608[h]	5.7
Grace	0	0	0	0	139	1.1
Gail	1,751	2,460	839[e]	1,260	273	4.3
Gilda	109	1,011	172[d]	345	704	0.3
Hondo	0	0	0	0	0	0.9
OS&T[b]	-	-	-	-	0	0.6
Total	3,126	6,819	1,587	2,754	5,254	67.2

[a]Data for Platform Edith, A, B, C, Gina and Gilda from April 1990 to March 1991; Platform Henry and Hillhouse: September 1989 to August 1990; Platform Hidalgo: September 1989 to September 1990; Platform Hermosa: May 1990 to May 1991; Platform Hondo and OS&T: June 1990 to May 1991.
[b]OS&T is an offshore storage and treating facility (vessel).
[c]"-"= no data.
[d]Estimate based on average concentration of generic mud No. 6; excludes drilled solids.
[e]Up to 129 mt may have been discharged in November-December 1989.
[f]Estimated from sum of mud additives and mass of drilled solids for average concentration of drilled solids in generic mud No. 6.
[g]Accidental discharge.
[h]Based on maximum flow rate.

Table 4.

Estimated mass emission of constituents in drill cuttings discharged from oil platforms in federal waters off Southern California in 1990. Mass emissions based on constituent concentrations for cuttings in Steinhauer *et al.* (1994). Mass emission of cuttings from National Pollutant Discharge Elimination System discharge monitoring reports submitted to US EPA Region IX, San Francisco.

PLATFORM[a]	THC[b] (kg)	ΣPAH[c] (kg)	NAPTHALENES[d] (kg)	FLUORENES[d] (kg)	PHENANTHRENES[d] (kg)	DIBENZOTHIOPHENES[d] (kg)	SILVER (kg)	ARSENIC (kg)
Elly	0	0	0	0	0	0	0	0
Ellen	103	11	8.9	0.71	0.91	0.71	0.14	2.5
Eureka	0	0	0	0	0	0	0	0
Edith	0	0	0	0	0	0	0	0
Henry	-[e]	-	-	-	-	-	-	-
Hogan	0	0	0	0	0	0	0	0
Houchin	0	0	0	0	0	0	0	0
Hillhouse	-	-	-	-	-	-	-	-
A	-	-	-	-	-	-	-	-
B	11	1.2	0.91	0.073	0.094	0.073	0.015	0.26
C	18	2.0	1.5	0.12	0.16	0.12	0.025	0.44
Gina	-	-	-	0	0	0	0	0
Habitat	173	19	15	1.2	1.5	1.2	0.24	4.2
Hidalgo	0	0	0	0	0	0	0	0
Hermosa	0	0	0	0	0	0	0	0
Harvest	0	0	0	0	0	0	0	0
Irene	211	23	18	1.4	1.9	1.4	0.30	5.2
Grace	0	0	0	0	0	0	0	0
Gail	713	79	61	4.9	6.3	4.9	1.0	18
Gilda	44	4.9	3.8	0.30	0.39	0.30	0.062	1.1
Hondo	0	0	0	0	0	0	0	0
OS&T[f]	-	-	-	-	-	-	-	-
Total	1,273	140	109	8.7	11.2	8.7	1.8	32

[a]Data for Platform Edith, A, B, C, Gina, and Gilda from 4/90-3/91; Platform Henry and Hillhouse: 9/89-8/90; Platform Hidalgo: 9/89-9/90; Platform Hermosa: 5/90-5/91; Platform Hondo and OS&T: 6/905/91.
[b]Total resolved and unresolved saturated and aromatic hydrocarbons.
[c]Total 2- to 5-ring PAH target compounds. PAHs include: 1) the parent compound and alkylated homologs of napthalene, fluorene, phenanthrene, and dibenzothiophene; and 2) fluoranthene, pyrene, benz[*a*]anthracene, chrysene, benzo[*b*]fluoranthene, benzo[*k*]fluoranthene, benzo[*a*]pyrene, benzo[*e*]pyrene, and perylene.
[d]Parent compound and alkylated homologs.
[e]"-" indicates no data.
[f]Offshore storage and treating facility.

MERCURY (kg)	NICKEL (kg)	LEAD (kg)	VANADIUM (kg)	ZINC (kg)
0	0	0	0	0
0.025	17	489	26.7	342
0	0	0	0	0
0	0	0	0	0
-	-	-	-	-
0	0	0	0	0
0	0	0	0	0
-	-	-	-	-
-	-	-	-	-
0.003	1.7	50	2.7	35
0.004	2.9	85	4.6	59
0	-	-	0	0
0.042	28	817	44.5	571
0	0	0	0	0
0	0	0	0	0
0	0	0	0	0
0.052	35	998	54.4	697
0	0	0	0	0
0.18	120	3,370	184	2,357
0.011	7.3	210	11.4	147
0	0	0	0	0
-	-	-	-	-
0.32	212	6,019	328	4,208

Discussion

The discharge of drill cuttings, drilling muds, and produced water varied greatly among platforms. The differences in cuttings and muds discharges results from differences in platform location, drilling phase (exploratory or development), stage of platform development, and type of mud used (e.g., denser, more expensive muds are discharged in lower volumes; Ayers 1983). The volume of produced water generated depends on the method of oil recovery, the nature of the geologic formation, and the stage of well production (Menzie 1982).

The discharge estimates for muds and cuttings would have been improved if data on the mud composition and mass discharged were included in the DMRs. Generic mud No. 6 (used for our estimates) is one of eight muds approved for use. The average density of typical cuttings was used to convert to mass because only the volume of cuttings discharged was available.

The total mass emissions of drill cuttings was 4%, mud solids was 3%, and mud additives was 2% of the combined emissions of suspended solids from the four largest municipal wastewater treatment facilities in Southern California in 1990 (SCCWRP 1992). However, the discharge of muds and cuttings can be significant during drilling. From November 1986 to January 1989, platforms Hidalgo, Harvest, Hermosa, and Irene discharged a total of 15,141 mt (dry weight) of drilling muds (Hyland *et al.* 1994). This was about 19% of the combined suspended solids emissions from the four largest municipal wastewater facilities during 1990 (SCCWRP 1992).

Except for barium, the mass of most of the constituents in drilling muds and cuttings was low. Barium is added to drill muds as barite for a weighting agent. The appearance of barium in cuttings is due to drilling mud adhering to the cuttings. Lead and zinc were also in high in drill cuttings. High concentrations may be the result of pipe-thread compound (pipe dope) that is used to lubricate the threads of drill pipes (Stein-hauer *et al.* 1994). These and other metals also originate from formation solids

Table 5.

Estimated mass emission of constituents in drilling muds discharged from oil platforms in federal waters off Southern California in 1990. Mass emissions based on mud constituent concentration data in Steinhauer *et al.* (1994). Mass emissions of cuttings from National Pollutant Discharge Elimination System discharge monitoring reports submitted to US EPA Region IX, San Francisco.

PLATFORM[a]	THC[b] (kg)	∑PAH[c] (kg)	NAPTHALENES[d] (kg)	FLURENES[d] (kg)	PHENANTHRENES[d] (kg)	DIBENZOTHIOPHENES[d] (kg)	SILVER (kg)	ARSENIC (kg)
Elly	0	0	0	0	0	0	0	0
Ellen	71.8	4.6	3.3	0.29	0.52	0.35	0.052	1.17
Eureka	0	0	0	0	0	0	0	0
Edith	0	0	0	0	0	0	0	0
Henry	-[e]	-	-	-	-	-	-	-
Hogan	0	0	0	0	0	0	0	0
Houchin	0	0	0	0	0	0	0	0
Hillhouse	-	-	-	-	-	-	-	-
A	-	-	-	-	-	-	-	-
B	14.8	0.95	0.68	0.061	0.11	0.072	0.011	0.241
C	18.7	1.2	0.86	0.077	0.13	0.091	0.013	0.304
Gina	-	-	-	0	0	0	0	0
Habitat	253	16	12	1.0	1.8	1.2	0.18	4.12
Hidalgo	0	0	0	0	0	0	0	0
Hermosa	0	0	0	0	0	0	0	0
Harvest	0	0	0	0	0	0	0	0
Irene	89.7	5.8	4.1	0.37	0.64	0.44	0.064	1.46
Grace	0	0	0	0	0	0	0	0
Gail	491	32	23	2.0	3.5	2.4	0.35	7.99
Gilda	135	8.6	6.2	0.55	0.97	0.66	0.097	2.19
Hondo	0	0	0	0	0	0	0	0
OS&T[f]	-	-	-	-	-	-	-	-
Total	1,074	69	50	4.3	7.7	5.2	0.77	17

[a]Data from Platform Edith, A, B, C, Gina, and Gilda from 4/90-3/91; Platform Henry and Hillhouse: 9/89-8/90; Platform Hidalgo: 9/89-9/90; Platform Hermosa: 5/90-5/91; Platform Hondo and OS&T: 6/90-5/91.
[b]Total resolved and unresolved saturated and aromatic hydrocarbons.
[c]Total 2- to 5-ring PAH target compounds. PAHs include: 1) the parent compound and alkylated homologs of napthalene, fluorene, phenanthrene, and dibenzothiophene; and 2) fluoranthene, pyrene, benz[*a*]anthracene, chrysene, benzo[*b*]fluoranthene, benzo[*k*]fluoranthene, benzo[*a*]pyrene, benzo[*e*]pyrene, and perylene.
[d]Parent compound and alkylated homologs.
[e]"-"=no data.
[f]Offshore storage and treating facility.

and mud additives (Ayers 1983).

The majority of produced water samples had non-detectable concentrations of metals and cyanide, but measurable amounts of phenols and oil and grease. The constituent concentrations of produced water discharges were similar to concentrations in produced water from offshore California (USDI 1975). However, the produced water constituent concentrations were 6-30 times that of produced water samples from the San Joaquin Basin oil field, a terrestrial field in central California (Rittenhouse 1969). The total volume of produced water discharged from Southern California platforms (accidental discharge from Elly not in-

BARIUM (kg)	CADMIUM (kg)	CHROMIUM (kg)	COPPER (kg)	MERCURY (kg)	NICKEL (kg)	LEAD (kg)	VANADIUM (kg)	ZINC (kg)
0	0	0	0	0	0	0	0	0
19,832	0.221	16	5.5	0.024	7.5	3.5	13	53.4
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
-	-	-	-	-	-	-	-	-
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-
4,096	0.046	3.2	1.1	0.005	1.6	0.72	2.7	11.0
5,174	0.058	4.1	1.4	0.006	2.0	0.91	3.4	13.9
0	0	0	0	0	-	-	0	0
69,951	0.779	55	19	0.084	27	12	46	188
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
24,790	0.276	20	6.9	0.030	9.4	4.4	16	66.7
0	0	0	0	0	0	0	0	0
135,805	1.51	107	38	0.16	52	24	89	365
37,185	0.414	29	10	0.045	14	6.6	24	100
0	0	0	0	0	0	0	0	0
-	-	-	-	-	-	-	-	-
296,833	3.3	234	82	0.35	114	52	194	798

cluded) was 0.3%, and the total volume of sanitary wastes was 0.004%, of effluent volume discharged from the four largest municipal wastewater treatment facilities in 1990 (SCCWRP 1992).

It was difficult to compare estimated mass emissions from produced water and municipal wastewater effluent because the most produced water constituents were below detection limits, and the detection limits were relatively high. (Detection limits of produced water constituents were 0.7-630 times those of municipal wastewater constituents.) Using the detection limits of produced water constituents, mass emissions from oil platforms in 1990 were only 0.7% of the combined mass emissions for the same constituents from the four largest municipal wastewater treatment facilities (Table 6; SCCWRP 1992).

Conclusions

In 1990, only a third of the oil platforms in federal waters discharged drilling muds and cuttings, and most trace metals and cyanide in produced waters were below detection limits. Mass emissions estimates were variable among platforms because of differences in type of rock formation, stage of drilling (exploratory, development, or production), stage of production or development, drilling mud type, and oil recovery

Table 6.

Mean constituent concentrations in produced water samples from oil platforms in federal waters off Southern California in 1990. Data from National Pollutant Discharge Elimination System discharge monitoring reports submitted to US EPA Region IX, San Francisco.

PLATFORM[a,b]	N	ARSENIC (µg/L)	CADMIUM (µg/L)	CHROMIUM (µg/L)	COPPER (µg/L)	LEAD (µg/L)	MERCURY (µg/L)	NICKEL (µg/L)
Elly[c]	2	< 1 0	<3, <10	<20, <50	<20, <50	<40, <200	< 1	<20, <10
Edith	1	< 5	< 1 0 0	< 2 0 0	< 4 0 0	< 1 0 0 0	< 1	< 8 0 0
Hogan	2	<4, <50	<20, <50	1 5 0	<20, <100	1 5	<1, <2	<10, <2
Hillhouse	1	< 1 0	< 5 0	< 5 0	-[d]	< 5 0	< 1	< 1 0 0
A	2	< 1 0	< 5 0	< 1 0 0	< 5 0	< 2 0 0	0.5	5 0
B	2	< 1 0	< 5 0	< 1 0 0	< 5 0	< 2 0 0	2.5	5 0
C	2	< 1 0	< 5 0	< 1 0 0	< 5 0	< 2 0 0	< 1	5 0
Habitat	1	2 3	< 2 5 0	< 5 0	< 1 0 0	< 2 5 0	< 1	< 2 0 0
Irene	4	< 1 - < 1 0	< 5 - < 2 0	2 0	7.5	<50, <100	0.5	< 5 0
Grace	2	< 1 0	< 5 0	5 0	< 5 0	< 2 0 0	1	1 0 0
Gail	5	< 1 0	< 5 0	< 1 0 0	< 5 0	<50, <200	1.6	6 0
Gilda	2	< 1 0	< 5 0	< 1 0 0	< 5 0	< 2 0 0	< 1	1 0 0

[a]Remaining platforms did not discharge produced water in 1990.
[b]Data from Platforms Edith, A, B, C, and Gilda from 4/90-3/91; Platform Hillhouse: 9/89-8/90.
[c]Accidental discharge.
[d]"-"=not analyzed.

methods. Platform discharges were a minor source of contaminants to the Southern California Bight in 1990 because discharge volumes were low. Mass emissions estimates for oil platform discharges could be improved if the composition and specific gravity of drilling muds, and the mass of cuttings discharged, were included in the DMRs, and if the detection limits for several produced water constituents were lower.

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SILVER (µg/L)	ZINC (µg/L)	CYANIDE (µg/L)	PHENOLS (µg/L)	OIL & GREASE (µg/L)
<1, <10	20	<20	270	97,000
<200	<400	-[d]	-	57,900
-, <100	500	<10, <50	480	15,600
<50	<100	<100	60	13,000
<50	<50	<20	140	34,700
<50	<50	<20	290	20,800
<50	<50	<20	<100	26,100
<50	<100	<20	900	15,000
<20-<50	580	28	2,700	28,700
<10, <50	<50	<20	120	11,300
22	20	14	1,120	12,200
<50	<50	15	<100, <10,000	43,000

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Acknowledgements

Author Valerie Raco thanks K. Schiff (Kinnetic Laboratories); E. Bromley, J. Hashimoto, M. Hooper, and J. Johnstone (US EPA Region IX); R.C. Ayers Jr. (Exxon Production Research Corp.); D. Panzer and A. Copsey (Minerals Management Service); and J. Nighswonger (Central Coast Regional Water Quality Control Board) for their valuable assistance.

Appendix 1

Regulating Authorities

The California State Lands Commission leases parcels in state waters <123 mi (4.8 km) of the mainland and Channel Islands]. The Minerals Management Service (MMS, US Department of the

Table 7.

Estimated mass emissions of constituents in produced water discharged from oil platforms in federal waters off Southern California in 1990. Mass emissions were based on concentration data in the National Pollutant Discharge Elimination System discharge monitoring reports submitted to US EPA Region IX, San Francisco.

PLATFORM[a]	VOLUME ($L \times 10^6$)	ARSENIC (kg)	CHROMIUM (kg)	COPPER (kg)	LEAD (kg)	MERCURY (kg)	NICKEL (kg)	SILVER (kg)
Elly	0.52[b]	-[c]	-	-	-	-	-	-
Ellen	0							
Eureka	0							
Edith	176	-	-	-	-	-	-	-
Henry	0							
Hogan	225	-	40	-	2.7	-	-	NA, -[e]
Houchin	0							
Hillhouse	361	-	-	NA[d]	-	-	-	-
A	1,184	-	-	-	-	0.6	63	-
B	726	-	-	-	-	2.2	43	-
C	836	-	-	-	-	-	48	-
Gina	0							
Habitat	20.7	0.48	-	-	-	-	-	-
Hidalgo	0							
Hermosa	0							
Harvest	0							
Irene	608	-	17	6.4	-	0.2	-	-
Grace	139	-	7	-	-	0.1	14	-
Gail	273	-	-	-	-	1.5	65	1.7
Gilda	704	-	-	-	-	-	69	-
Hondo	0							
OS&T[f]	ND[g]							
Total	5,253	0.48	64	6.4	2.7	4.6	302	1.7

[a]Data for Platforms Edith, A, B, C, Gina and Gilda from 4/90-3/91; Platform Henry and Hillhouse: 9/89-8/90; Platform Hidalgo: 9/89-9/90; Platform Hermosa: 5/905/91; Platform Hondo and OS&T: 6/905/91.
[b]Accidental discharge.
[c]"-" indicates all samples were below detection limit.
[d]NA=not analyzed.
[e]Produced water metals analyzed twice a year; silver was not analyzed in the first sample and was below detection limit in the second sample.
[f]Offshore storage and treatment facility.
[g]ND=no data.

ZINC (kg)	CYANIDE (kg)	OIL & GREASE (mt)	PHENOLS (kg)
<0.1	-	0.1	0.2
-	NA[d]	6.4	NA
134	-	3.7	111
-	-	4.8	22
-	-	42.1	161
-	-	15.0	216
-	-	20.9	-
-	-	0.3	19
470	13	16.3	1,593
-	-	1.7	16
1	1	1.8	470
-	10	30.4	-
605	24	144	2,608

Interior) leases parcels in federal waters [>3 mi, but <200 mi (320 km)]. Parcels leased thus far are <30 km from shore and most platforms are in less than 195 m of water.

The US EPA regulates the discharge of drilling fluids and cuttings during offshore oil and gas activities. Regulation is mediated through the NPDES established under section 402 of the Clean Water Act. The MMS also controls discharges in federal waters through lease stipulations and Outer Continental Shelf (OCS) operating orders under the authority of the Outer Continental Shelf Lands Act Amendment of 1978 (NRC 1983).

Appendix 2

Drilling Fluid Components

Drilling fluids are bulk constituents and special purpose additives. The principal bulk constituents (barite, clays, lignosulfonate, lignite, caustic soda, and water) account for over 98% of the mass or volume of drilling fluids discharged to the outer continental shelf.

Barite, a mineral containing 80-90% barium sulfate, is used to increase the density of the drilling fluid to control formation pressures. Depending on its source, barite may contain low concentrations of quartz, chert, silicates, and other minerals and also trace concentrations of metals. The barite most commonly used off California because of its purity is mined near Battle Mountain, Nevada (D. Panzer, US Dept. Interior, Minerals Management Service, Camarillo, CA, personal communication 1992). The highest barite concentration in mud approved for use off Southern California is 1.28 kg/L mud.

Concentrations of bentonite, the most common clay used, concentrations are normally 14-100 g/L. Clay is used to adjust the specific viscosity of the drilling fluid so formation solids can be removed from the bottom of the wellbore. Lignosulfonates are derived from sulfite pulping of wood chips (paper and cellulose production) and are used as thinning agents or clay deflocculants; concentrations range from 3-43 g/L. Lignite is a soft (low heat value) coal used as a clay deflocculant; concentrations range from 3-43 g/L. Caustic soda (sodium hydroxide) is used to control pH to obtain maximum deflocculation from the lignosulfonate and to keep lignite in solution (NRC 1983). Other special purpose additives are also used including cellulose polymers, lubricants, sodium bicarbonate, biocides, mineral oil, and vegetable oil.

Appendix 3

Permit Requirements

Fourteen of the 21 of active oil platforms in federal waters off Southern California operate under a general NPDES permit (CA0110516) for offshore oil and gas operations. The remaining platforms operate under individual permits. The general permit contains several limitations and monitoring requirements for drilling fluids, cuttings,

Table 8.

Comparison of detection limits and estimates of mass emissions for produced water discharges from oil platforms in federal waters and municipal wastewater discharges from the four largest treatment facilities (MWTF) in Southern California in 1990 (SCCWRP 1992). Platform detection limits obtained from National Pollutant Discharge Elimination System (NPDES) discharge monitoring reports submitted to US EPA. Effluent detection limits obtained from monthly or annual reports under NPDES permits.

	DETECTION LIMITS RANGE (µg/L)		MASS EMISSIONS (mt)	
CONSTITUENT	Platform	MWTF	Platform[a]	MWTF
Arsenic	1-50	0.3-1	0.1	8.2
Cadmium	3-250	0.1-5	0.3	1.0
Chromium	20-200	1-50	0.5	14
Copper	20-400	3-10	0.3	59
Lead	10-1,000	1-50	1.0	6.4
Mercury	1-10	0.1-0.5	<0.1	0.2
Nickel	10-800	1-40	0.7	40
Silver	1-200	0.4-10	0.3	9.4
Zinc	20-400	5-20	0.9	115
Cyanide	10-100	2-20	0.1	13
Phenols[b]	100-10,000	5-200	6	640
Oil & grease	1,000	100-5,000	144	21,500

[a]Detection limits were substituted for non-detectable concentrations for these estimates.
[b]EPA method 240.2 (Colorimetric test using 4-aminoantipyrene).

and produced water. Monthly discharge volumes are required for drilling fluids and cuttings. The operator must also maintain an inventory and record of volumes of drilling mud constituents, including diesel fuel and drilling mud additives added to each well.

Under the general NPDES permit, EPA identified eight basic types of mud formulations commonly used on the OCS. To insure low toxicity, bioassays with the muds were used to determine the maximum allowable concentrations of each constituent. The muds most commonly used on the California OCS are the seawater-freshwater gel (No. 6) and a lightly treated lignosulfonate freshwater-seawater mud (No.7) (Table 2) (E. Bromley, US EPA Region IX, San Francisco, personal communication, 1992).

A list of approved special additives was created based on bioassays. If drilling muds or additives have not been tested, bioassays are required. After initial mixing, constituent concentrations must not exceed 0.01 of an acutely toxic (96 h LC50) concentration. The EPA may approve an application factor for a specific waste material other than 0.01 if there is reasonable evidence for its toxicity. Contaminant analyses of barite must also be conducted.

Estimates of flow rate and oil and grease concentrations in produced water are required monthly. Daily oil and grease concentrations must not exceed 72 mg/L. Selected metals, cyanide, and phenols in produced water have daily maximum limits and these must be measured annually. Additional sampling of produced water and drilling muds are conducted at least twice a year and MMS makes a record check under the Memorandum of Agreement with the US EPA.

Appendix 4

Mass Emission Estimates

Mass emissions of cuttings were estimated from:

$M = 0.65 \; V * 2.6$

where:

M= mass of solids in kg,
V= volume in L,
0.65 = conversion of barrels (wet weight) to dry mass, and
2.6 = average specific gravity

Annual mass emissions (ME) of produced water constituents were estimated from:

$$ME = \sum_{i=1}^{n} (F_i C_i D_i)$$

where:

n = number of measurements per year
F_i = mean daily flow in interval *i*:
C_i = constituent concentration in interval *i*; and
D_i = number of days in interval *i*.