# Effluent discharges from offshore oil platforms to the outer continental shelf of southern California in 2005

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## Abstract

Twenty-three offshore oil platforms produce oil and gas from the federal waters of the outer continental shelf off southern California. Activities associated with offshore petroleum extraction result in the regular discharge of contaminants to the Southern California Bight (SCB). Discharges from oil platforms can be grouped into three main categories based on their source: 1) platform operations, 2) oil and gas production (i.e., produced water), and 3) well drilling discharges. Produced water is extracted with the oil and gas and is the primary source of contaminant loading from all oil platform waste streams. The ratio of water produced increases as oil and gas reserves are extracted over time; currently over three barrels of water are produced for every barrel of oil from southern California platforms, and produced water volume is increasing over time. Changes in the historical requirements and procedures in platform monitoring requirements complicate efforts to compare produced water discharges from year to year, and prevent calculation of total loads from all platforms for most constituents. A special monitoring study was conducted in 2005 as part of a reasonable potential analysis that provided a unique opportunity to assess discharges from all oil platforms under the same monitoring requirements. Of the 23 platforms in federal waters off southern California, 13 discharged produced water in 2005, 4 discharged drilling fluids and cuttings, and 20 discharged operational wastes. Total volume of operational discharges in 2005 was 60 L x $10^9$, consisting primarily of cooling water. Drilling-related discharges have decreased in each assessment period since 1996, with both fluids and cuttings discharges down by at least 80% since 1996. Produced water discharges totaled 9.4 L x $10^9$ in 2005, representing an increase of 68% since 2000. Three platforms contributed 73% of the total produced water volume and similar contaminant load contributions in 2005. Discharges of most contaminant loads from oil platforms are relatively minor, except for several petroleum based organic contaminants, including benzene, toluene, ethylbenzene, and polycyclic aromatic hydrocarbons (PAHs). Changes in monitoring requirements following the 2005 special monitoring study would impact assessment of nearly all constituent loads. Comparison of 2005 loads under the current and future requirements indicates that many of the constituent loads will be underrepresented in future assessments due to the results of the reasonable potential analysis and the subsequent change in Environmental Protection Agency (EPA) monitoring requirements. These underrepresented loads include some of the most significant contributions from oil platform discharges, including toluene, ethylbenzene, phenols, naphthalene, and other PAHs. Only volume and oil/grease estimates would be unchanged under the new monitoring program. Changes in monitoring requirements will make it very difficult to assess trends in contaminant loading into the future.

## Introduction

Offshore oil production on the outer continental shelf (OCS) of southern California began in 1968. By 2003, the platforms of the OCS had produced over 1 billion barrels of oil and nearly 1.7 trillion cubic feet of natural gas (Syms and Voskanian 2007). Activities associated with extraction of these resources result in the regular discharge of contaminants to the SCB and adjacent coastal waters. To manage a regional resource such as the SCB, it is important to understand the sources and relative significance of contaminant loads. Since 1971, the Southern California Coastal Water Research Project (SCCWRP) has been compiling and analyzing effluent data from all major point-source dischargers to the coastal waters of the SCB. These data are used to calculate contaminant load estimates, track trends, and identify sources of greatest significance. The sources include municipal wastewater treatment plants (or publicly owned treatment works; POTWs), power generating stations, industrial facilities, and oil platforms. In 2005 there were 64 point source facilities discharging into the SCB, and approximately one-third of those were oil platforms. Historically POTWs have been the largest point source of contaminants to the SCB, while oil platforms have been minor contributors of most constituents. However, oil platforms have been significant contributors of several petroleum based organic contaminants.

Twenty-three oil platforms are located in federal waters of the Pacific OCS region, which includes the federal waters offshore Washington, Oregon, and California. All of the Pacific OCS platforms are located in southern California, from Point Arguello in western Santa Barbara County to the San Pedro Channel off Long Beach (Figure 1). The number of platforms has been stable for the past 20 years, with the last new platform erected in 1989 and no platforms decommissioned from federal waters since their installation (Bernstein *et al*. 2010). Four additional platforms located in state waters are not permitted to discharge drilling or oil production wastes, and consequently have not been included in SCCWRP assessments (Steinberger *et al*. 2004).

Discharges from offshore oil platforms can be grouped into three main categories: 1) platform operations, 2) oil and gas production (also referred to as *produced water*), and 3) well drilling discharges. Operations discharges include daily sanitary and domestic wastes, cooling water, fire control system water, deck drainage, and other minor discharges. Sanitary wastes are treated by Coast Guard-approved marine sanitation devices, which require only annual inspections. Cooling water and fire control system water may be chlorinated to prevent fouling; if chlorinated, monitoring for residual chlorine is generally required. The remaining operational discharges require only visual inspection of the receiving water to ensure no sheen or foam is being discharged.

Production discharges consist primarily of produced water, which is a saline brine that commingles with the oil and gas in a subsurface reservoir (Menzie 1982). Produced water is extracted from the reservoir with the target oil and gas, and is separated and treated before it can be discharged to the ocean or re-injected into a subsurface reservoir. Discharged produced water is the primary source of contaminant loading from all waste streams associated with off-

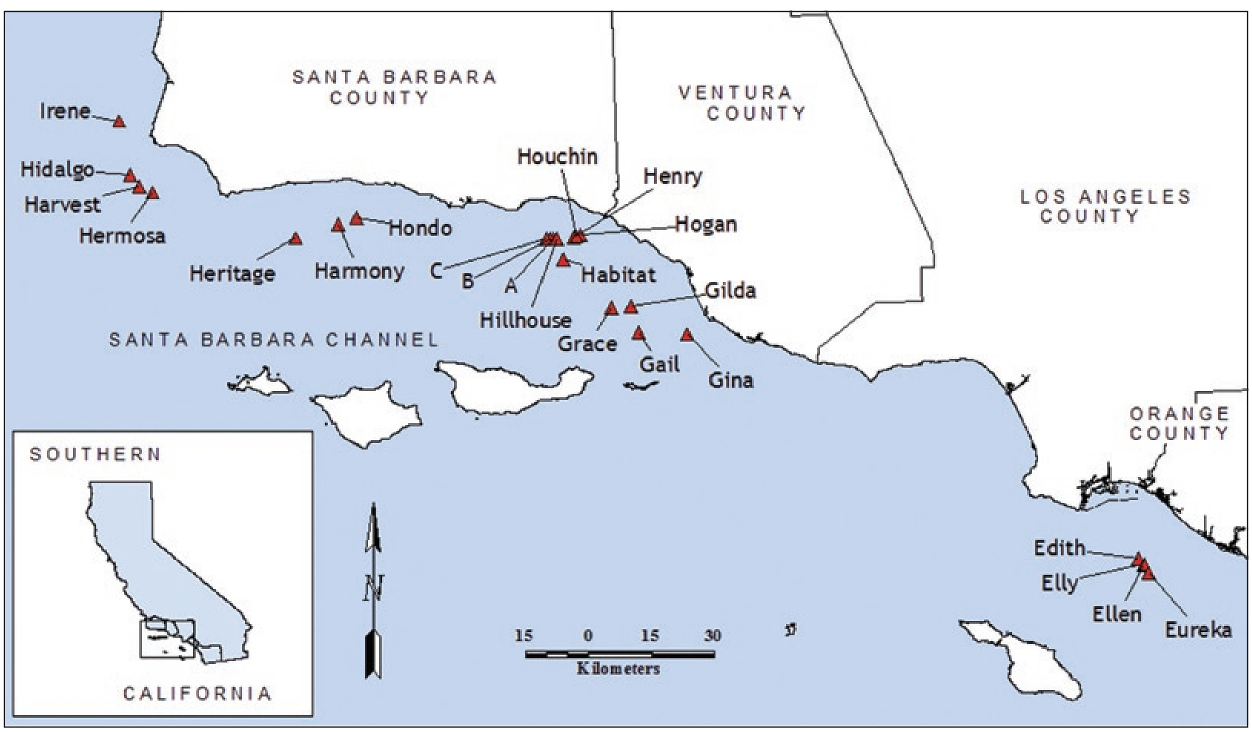


**Figure 1. Locations of oil platforms in federal watters off southern California.**

shore oil platforms (National Research Council 2003), and therefore requires the most rigorous monitoring of chemical constituents and toxicity of all platform waste streams. The quantity of produced water extracted with oil and gas is known to increase over the life of a well as the oil and gas reserves are depleted (Neff *et al*. 1987, National Research Council 2003). Annual oil production has decreased each year since peak production in 1995, while produced water has increased over the same period (Syms and Voskanian 2007). At the peak of oil production, the ratio of water to oil produced was approximately 1:1, but by 2003 had increased to approximately 3.3 barrels of water for each barrel of oil produced (Figure 2). Not all platforms discharge produced water. Producing platforms that do not discharge produced water either transfer the water to other platforms for treatment and discharge or re-inject the water either into offshore or onshore reservoirs.

Discharges from well drilling and maintenance activities include drilling fluids and drill cuttings. These discharges are only generated during the drilling of a well and are consequently variable and intermittent. Drilling fluids are a dynamic mixture of fresh or sea water, barites, lignosulfates, polymers, and other chemical compounds added to a borehole during drilling to lubricate the drill, ease the flow of drill cuttings to the surface for removal, and prevent collapse of the borehole during drilling. There are eight EPA-approved generic types of drilling fluids; however, the actual composition of fluids added to a well is adjusted during drilling to accommodate changing geological conditions encountered downhole. Drill cuttings are the solids removed as the

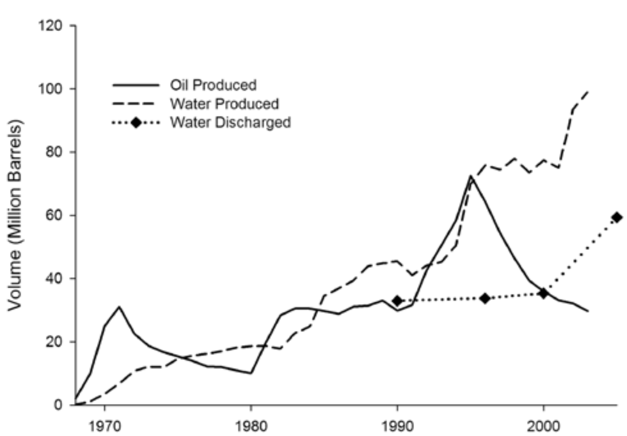


**Figure 2. Trends in annual production of oil and water since 1968 (source: Syms and Voskanian 2007), and discharge of produced water since 1990.**

well is drilled through the rock strata to reach the petroleum reservoir. Drilling-associated discharges require analysis of cadmium and mercury in drilling fluids, and monitoring for acute toxicity and sheen from all discharges.

Oil platform discharges are currently regulated under a single National Pollutant Discharge Elimination System (NPDES) general permit issued by the USEPA, with inspections and oversight by the US Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE; formerly the Minerals Management Service). Although each platform is required to monitor effluent volumes and selected chemical constituents, the specific requirements of previous and current permits have varied by platform and between assessment periods. Differences in monitoring and reporting requirements complicate efforts to compare oil platform discharges from year to year, and prevent calculation of total loads from all platforms for most constituents. Further, the lack of true total load estimates from all platforms affects comparison of oil platform discharges to other sources of contaminants in the SCB. However, the monitoring program required during the first year of the current permit provided a unique opportunity to assess discharges from all platforms under the same monitoring requirements, and this period coincided with our scheduled assessment of platform discharges in 2005.

The December 2004 NPDES general permit (CAG280000), regulating all oil platform discharges in federal waters of southern California, required each discharging platform to conduct monitoring for a reasonable potential analysis (RPA). An RPA is used to determine whether a discharge has a reasonable potential to result in or contribute to an exceedance of a water quality standard (for background on RPA rationale and procedures, see USEPA 2010). Permit limits are then established for discharges of constituents shown to have reasonable potential to exceed water quality standards at the compliance point (compliance for oil platform discharges is determined at the edge of a 100 meter mixing zone), with continued routine monitoring required to ensure compliance. Conversely, discharges of constituents that do not show a reasonable potential to exceed water quality standards may not require continued monitoring. The special monitoring study for the oil platform RPA consisted of 12 monthly monitoring events for 26 constituents in produced water, and residual chlorine in discharges of chlorinated cooling water and fire control system water. The RPA is based on the more stringent standard of either the federal Clean Water Act or the California Ocean Plan (USEPA 2004). Following completion of the RPA, the December 2009 general permit was modified to limit routine monitoring requirements to quarterly monitoring of selected constituents (USEPA 2009).

The goal of this study was to characterize discharges of all monitored waste streams from southern California offshore oil platforms in 2005. To achieve this objective, volume and chemistry data from each oil platform discharging to the ocean were compiled and standardized to allow calculation of cumulative mass emission estimates for the entire region. To assess historical trends, we then compared these data to available results from previous assessments of oil platform discharges from 1996 and 2000 (Steinberger *et al*. 2004). Oil platform effluent characteristics were also compared to discharges from the leading point sources of contaminant loads to the Southern California Bight to assess their relative regional significance. Finally we examined the impact of changing monitoring requirements on future assessments by comparing 2005 oil platform discharge loads, calculated based on the full suite of constituents, to revised loads based on the current monitoring requirements (based on the results of the RPA) under the final general permit modification (USEPA 2009).

## Methods

Annual mass emissions data for the platform waste streams were compiled from effluent volume and chemistry data provided in each platform's quarterly discharge monitoring reports (DMRs) from calendar year 2005. The DMRs, and additional chemistry and toxicity data from platform inspections, were provided by the BOEMRE. Constituents included in this assessment were based on the monitoring requirements mandated by NPDES general permit CAG280000. Chlorinated operational discharges, such as sanitary wastes, cooling water, and fire control system water were monitored for volume and residual chlorine. Produced water was monitored for volume, oil/grease, ammonia, cyanide, sulfides, selected metals, and selected petroleum-based organic constituents. Drilling associated discharges, such as drilling fluids and cuttings, were monitored for volume, toxicity, and the presence of oil by static sheen test. To facilitate comparison of drill cuttings discharges to previous assessments, the reported volumes were converted to mass using the same water/solids content (65% solids) and specific gravity (2.6 kg/L) used by Raco (1994) and Steinberger, *et al*. (2004), which were taken from Ayers (1983) and Runchal (1983), respectively.

Oil platform discharge compliance is determined using concentrations at the edge of a 100-m mixing zone based on calculated dilution ratios for each platform. However mass emissions results are based on the constituent concentrations at the discharge point (end-of-pipe concentrations). In 2005 all platforms were required to report end-of-pipe concentrations in addition to the traditional post-dilution compliance concentrations. This eliminated the need to calculate end-of-pipe concentrations from reported compliance concentrations, as was necessary for previous assessments (see Steinberger *et al*. 2004).

End-of-pipe constituent concentration data were standardized to monthly time steps. For constituents analyzed more than once per month, the arithmetic mean of all results in a given month was calculated. Where the frequency of constituent analysis was less than monthly or data for a given month were not available, the arithmetic mean of available data within the given year was calculated and used to populate months for which no data existed. The monthly flow and concentration data were then used to calculate annual discharge volumes and constituent mass emissions for each platform. Constituent concentrations below the minimum reporting level (RL) were assigned a value of zero for calculating mass emission estimates.

The annual discharge volume ($V$) for each platform waste stream was calculated from the sum of the monthly effluent volumes:

$$V = \sum_{i=1}^{12} uF_iD_i$$

where $F_i$ was the mean daily flow for the month $i$, $D_i$ was the number of days that discharge occurred during month $i$, and $u$ was the unit conversion factor for calculating the volume in liters.

Mass emission estimates ($ME$) were calculated from the product of the mean daily flow, the monthly constituent concentration, the number of days in the given month, and a unit conversion factor. The $ME$s were calculated for each constituent for each month, and then summed over all months in the year to obtain an annual estimate:

$$ME = \sum_{i=1}^{12} uF_iC_iD_i$$

where $C_i$ was the reported constituent concentration for the month $i$, and $u$ was the appropriate unit conversion factor for calculating the $ME$ in metric tons (mt), kilograms (kg), or liters (L).

Annual average flow-weighted concentrations ($FWC$) were calculated by dividing the annual $ME$ for a given constituent by the total annual effluent volume ($V$):

$$FWC = u\frac{ME}{V}$$

where $u$ was the unit conversion factor for reporting the $FWC$ in the appropriate concentration units.

This approach for calculating $FWC$ occasionally resulted in estimates below the RL for constituents that had one or more non-detected results. In these cases, the $FWC$ was reported as calculated. Constituents that were consistently not detected resulted in $FWC$ of zero, and were reported as less than the RL. When more than one RL was used for a given constituent during the year, the greatest RL was reported.

Trends in mass emissions from oil platforms were analyzed by comparing results from 2005 to results of previous assessments of discharges in 1996 and 2000 reported by Steinberger, *et al*. (2004). The relative significance of oil platform discharges was evaluated by comparing platform discharges to effluent characteristics from POTWs, which have historically been the largest point sources of contaminants in the SCB (Lyon and Stein 2009). Effluent data from POTWs in 2005 were obtained from Lyon and Stein (2008) and SCCWRP (unpublished data).

To investigate the impact of changing monitoring requirements on contaminant load estimates, we used the 2005 mass emissions data generated by the RPA monitoring program to calculate mass emissions based on the past and current monitoring requirements. The 2010 monitoring requirements were obtained from the final permit modification, Appendix C (USEPA 2009). All constituent loads that would not be monitored under the new requirements were excluded from the comparison.

## Results

### Oil Platform Discharges in 2005

Of the 23 platforms in federal waters off southern California, 13 discharged produced water in 2005, 4 discharged drilling fluids and cuttings, and 20 discharged operational wastes (Table 1; Appendix I). The number of platforms discharging operational wastes and produced water was unchanged from 2000. Producing platforms that did not discharge produced water either transferred water to other platforms for treatment and discharge or re-injected the water back into an offshore or onshore subsurface reservoir. Volumes and constituent loads from produced water transferred between platforms are included in the results for the discharging platform.

Total volume of operational discharges in 2005 was 60 L x $10^9$ (Table 1). Cooling water comprised 99% of the operational discharge volume. Fire control system water, sanitary and domestic wastes, deck drainage, and minor discharges contributed only 1% of the total operational discharge volume. Total mass emissions from operational wastes were 8.5 mt of residual chlorine and 70 kg of oil/grease.

The number of oil platforms discharging drilling fluids and cuttings was down from six in 2000 to four in 2005. Total drilling discharges in 2005 included 7 L x $10^6$ of drilling fluids and 2313 mt of cuttings (Table 1). Drilling discharges have decreased in each assessment period since 1996, with both fluids and cuttings discharges down by at least 80% since 1996 (Steinberger *et al*. 2004). Most monitoring results for 2005 drilling discharges were in compliance, including all cadmium and mercury concentrations in discharged drilling fluids, and all measures of discharges from Platform Hidalgo. Three of the drilling platforms had single drilling related exceedances during the year. Platforms Gail and Hogan each had one drilling fluids toxicity test exceedance, and Platform Heritage had one static sheen test exceedance, indicating the presence of oil in the drill cuttings.

Produced water discharges totaled 9.4 L x $10^9$ in 2005 (Table 1). This volume was exceeded only by cooling water, and accounted for 13.6% of the total volume of all fluid discharges. Produced water discharges have increased 68% since the previous assessment of discharges in 2000 (Table 2). Three platforms, Harmony, Harvest, and Hermosa, contributed 73% of the total produced water volume discharged in 2005 (Figure 3). Platform Harmony dis-

**Table 1. Total discharge volumes and mass by waste stream from all discharging oil platforms in 2005. "—" = not applicable or not analyzed.**

| Waste Stream | Number of Platforms | Volume (L x $10^6$) | Solids Mass (mt) | Oil/Grease (mt) | Residual Chlorine (mt) |
|---|---|---|---|---|---|
| **Operations Discharges** | | | | | |
| Sanitary & Domestic Wastes | 20 | 38.54 | -- | -- | 0.06 |
| Cooling Water | 9 | 59,506.04 | -- | -- | 8.26 |
| Fire Control System Water | 3 | 447.92 | -- | -- | 0.21 |
| Deck Drainage & Minor Discharges | 11 | 19.23 | -- | 0.07 | -- |
| *Total Operations Discharges* | *20* | *60,011.74* | -- | *0.07* | *8.52* |
| **Production Discharges** | | | | | |
| Produced Water | 13 | 9,447.55 | -- | 140.82 | -- |
| **Drilling Discharges** | | | | | |
| Drilling Fluids | 4 | 7.02 | -- | -- | -- |
| Drill Cuttings | 4 | -- | 2,313.26 | -- | -- |
| **Combined Discharges** | 20 | 69,466.31 | 2,313.26 | 140.89 | 8.52 |

charged a similar relative contribution in 2000, but Platforms Harvest and Hermosa each increased their total produced water discharges by 400% since 2000, resulting in their becoming a significant contribution to the total produced water volume in 2005.

Similar to produced water volume, constituent loads were dominated by the same three platforms, Harmony, Harvest, and Hermosa (Figure 3). Total mass emissions from produced water included 141 mt of oil/grease, 7 mt of toluene, 6 mt of benzene, and 1.7 mt of ethylbenzene (Table 2; Appendix II). Of the seven PAH constituents that were monitored, two were detected: naphthalene, detected in produced water from 12 platforms, and dibenzo(a,h)anthracene, detected only in Platform Harvest produced water. A total load of 620 kg of these PAHs was discharged. The remaining PAH compounds were not detected in any platform produced water.

Annual average flow-weighted concentrations varied among platforms, with the highest concentrations more evenly distributed than were mass emissions, indicating that discharge volume was the more important factor driving produced water mass emissions. In particular, Platform Habitat had some of the highest produced water *FWC*s for organic constituents (Appendix III), but discharged very little volume, resulting in minor contributions to organic contaminant loads.

Constituent mass emissions were generally higher in 2005 than in 2000. Loads of oil/grease, cyanide, and most metals, which were monitored by all discharging platforms in both periods, increased since the previous assessment (Table 2). Percent increases in constituent loads exceeded the increase in volume discharged (68%), with most 2005 loads at least twice the mass discharged in 2000. The exceptions were oil/grease and chromium, which increased 40% and 14%, respectively, and mercury, which decreased from 0.15 kg in 2000 to not detected (nd) in 2005. Limited monitoring of organic constituents under the previous permit requirements prevented direct comparison of organics loads from 2000 to 2005. Most organic constituents, which were monitored by all discharging platforms in 2005, were monitored by only two or fewer platforms in 2000 (Appendix IV). Consequently, organic loads

**Table 2. Estimated produced water mass emissions from all discharging platforms in 2000 and 2005. nd = not detected.**

| Constituent | 2000 Total | 2005 Total | Percent Change 2000-2005 |
|---|---|---|---|
| Volume (L x $10^6$) | 5,612.38 | 9,447.55 | 68 |
| Oil/grease (mt) | 100.28 | 140.82 | 40 |
| Cyanide (kg) | 3.96 | 18.31 | 362 |
| Arsenic (kg) | 5.30 | 18.92 | 257 |
| Cadmium (kg) | 0.56 | 2.92 | 420 |
| Chromium (kg) | 83.47 | 95.36 | 14 |
| Copper (kg) | 30.71 | 88.06 | 187 |
| Lead (kg) | 2.59 | 5.89 | 128 |
| Mercury (kg) | 0.15 | nd | -100 |
| Nickel (kg) | 10.27 | 41.46 | 304 |
| Selenium (kg) | nd | 6.78 | 100 |
| Silver (kg) | 1.18 | 2.99 | 154 |
| Zinc (kg) | 292.27 | 685.82 | 135 |

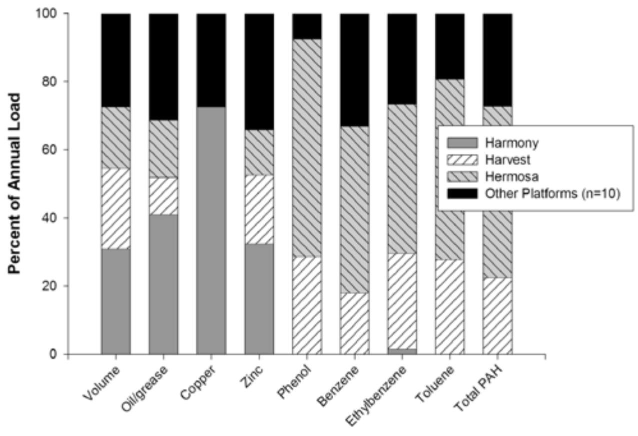


**Figure 3. Relative contribution of platforms discharging produced water for selected constituents in 2005.**

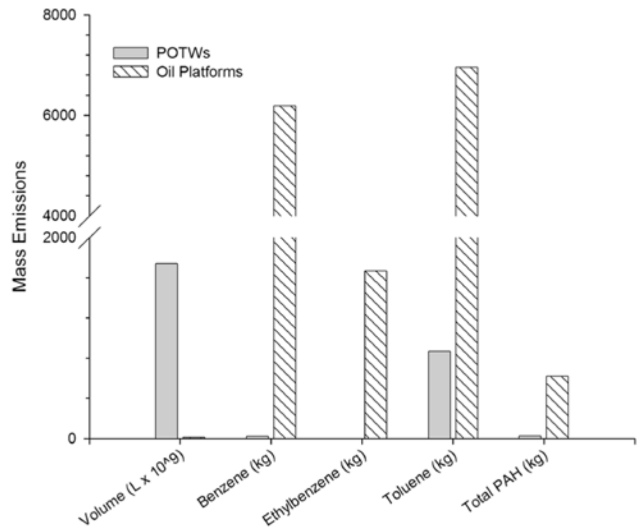


**Figure 4. Mass emissions of selected constituents from POTWs and oil platforms produced water in 2005.**

from the current and previous assessments cannot be accurately compared.

## Oil Platforms vs. POTW Discharges

Effluent from POTWs has historically been the most dominant point source of contaminants to the SCB (Lyon and Stein 2009). Compared to POTW effluent, the discharge of produced water from oil platforms in 2005 would account for only 0.5% of the combined effluent volume from both sources. As expected, based on the disparity in volume, most general constituent and metals loads from oil platforms were insignificant compared to discharges from POTWs. However, despite the difference in volumes, discharged loads of organic constituents associated with petroleum, including benzene, toluene, ethylbenzene, and PAHs, were greater from produced water than from POTWs (Figure 4). Average *FWC* for many constituents, including all organics that were analyzed by both sources, were also greater in produced water than in POTW effluent in 2005 (Table 3). The remaining constituents, with lower *FWC* in produced water, were still comparable to the concentrations found in POTW effluent.

Differences in the spatial distribution of oil platforms and POTWs affect the loading comparison from the two sources. Of the 13 platforms that discharge produced water, 3 are located outside the SCB, 9 are located in the northern SCB between Point Conception and Point Dume, and only one is located in the southern SCB between Point Dume and the US-Mexico border (Figure 1). In contrast, the majority of the POTWs are concentrated in the southern region, with 17 of the 23 SCB POTWs discharging effluent between Point Dume and the US-Mexico border. The southern SCB is dominated by discharges from POTWs (Table 4). Cyanide and most metals were not detected in produced water from the only discharging platform (Edith). Discharges of detected constituents were negligible compared to POTW loads, with the exception of total

**Table 3. Flow-weighted concentrations from combined oil platform produced water and POTW discharges in 2005. nd = not detected. "--" = data were not available.**

| Constituent | Combined Platforms FWC | Combined POTWs FWC |
|---|---|---|
| Oil/grease (mg/L) | 14.91 | 4.20 |
| Ammonia-N (mg/L) | 56.95 | 29.87 |
| Cyanide (ug/L) | 1.94 | 2.86 |
| Arsenic (ug/L) | 2.00 | 1.80 |
| Cadmium (ug/L) | 0.31 | 0.04 |
| Chromium (ug/L) | 10.09 | 1.34 |
| Copper (ug/L) | 9.32 | 16.65 |
| Lead (ug/L) | 0.62 | 3.61 |
| Manganese (ug/L) | 47.07 | 23.72 |
| Mercury (ug/L) | nd | 0.01 |
| Nickel (ug/L) | 4.39 | 12.22 |
| Selenium (ug/L) | 0.72 | 3.96 |
| Silver (ug/L) | 0.32 | 0.56 |
| Zinc (ug/L) | 72.59 | 23.57 |
| 2,4-Dimethylphenol (ug/L) | 76.21 | -- |
| Phenol (ug/L) | 66.31 | 3.02 |
| Benzene (ug/L) | 654.82 | 0.01 |
| Ethylbenzene (ug/L) | 176.57 | -- |
| Toluene (ug/L) | 736.04 | 0.50 |
| Total PAH (ug/L) | 65.58 | 0.01 |
| Undissociated Sulfides (ug/L) | 5,261.24 | -- |

PAH; the contribution of total PAH from Platform Edith accounted for 6% of the combined load. In the northern SCB, platform discharges were more significant. Produced water contributed nearly 9% of the volume from platforms and POTWs combined. Most constituent loads from platforms in the northern SCB were disproportionately higher than their volume contribution, ranging from 15% up to 100% of the combined loads of most metals, organics, oil/grease, and ammonia (Table 4). While both produced water and POTW effluent contribute significant loads of certain constituents to regional receiving waters, analyses of the environmental effects of those loads are beyond the scope of this study.

### Effects of Changing Monitoring Requirements

Changes in monitoring requirements from the RPA in 2005 to the final permit requirements in effect in 2010 would impact assessment of nearly all constituent loads. Only volume and oil/grease are required to be monitored by all platforms (Appendix V). Fourteen of the 26 constituents monitored for the produced water RPA are excluded from the new routine monitoring requirements for all platforms. Of these, only mercury was not detected in 2005. As a result, loads of 13 constituents would be completely unaccounted for under the new requirements, including 7 metals, 2 phenols, ethylbenzene, toluene, and naphthalene (Figure 5). Twelve constituents are included in the monitoring requirements for at least one, but not all platforms. This list includes five PAH compounds that were not detected in 2005. For the remaining seven constituents, the new monitoring requirements would result in load estimates being reduced to a fraction of the actual loads estimated under the more comprehensive monitoring requirements. For example, ammonia, chromium, and zinc loads would be 0.8, 1.8, and 15% of the actual values under the new monitoring program. Loads of benzene and undissociated sulfides would be minimally affected with load estimates under the new requirements being 93 and 97% of the actual (pre RPA) estimates.

## Discussion

Overall discharges from oil platforms were minor in terms of volume and mass emissions of most constituents. However, produced water is a significant source of petroleum-based organic contaminants such as benzene, ethylbenzene, toluene, and low-molecular weight PAHs. PAHs are among

**Table 4. Comparison of mass emissions from oil platform produced water and POTW effluent in 2005 by sub-region. Sub-regions are defined as north of Pt. Conception, Pt. Conception to Pt. Dume, and Pt. Dume to the U.S.-Mexico border. nd = not detected. "--" = data were not available.**

| Constituent | Outside SCB | Northern SCB | | | Southern SCB | | |
|---|---|---|---|---|---|---|---|
| | Platforms (n = 3) | Platforms (n = 9) | POTWs (n = 6) | Platforms % Contribution | Platforms (n = 1) | POTWs (n = 17) | Platforms % Contribution |
| Volume (L x $10^9$) | 4.26 | 5.15 | 55.42 | 8.51 | 0.03 | 1,686.83 | 0.00 |
| Oil/grease (mt) | 45.45 | 94.87 | 259.99 | 26.73 | 0.51 | 7,049.98 | 0.01 |
| Ammonia-N (mt) | -- | 535.25 | 1,069.74 | 33.35 | 2.76 | 50,968.84 | 0.01 |
| Cyanide (kg) | 18.31 | nd | nd | nd | nd | 4,984.92 | 0.00 |
| Arsenic (kg) | nd | 18.92 | 106.23 | 15.12 | nd | 3,033.92 | 0.00 |
| Cadmium (kg) | nd | 2.92 | nd | 100.00 | nd | 68.56 | 0.00 |
| Chromium (kg) | 2.96 | 92.40 | 88.02 | 51.21 | nd | 2,251.27 | 0.00 |
| Copper (kg) | nd | 88.06 | 158.35 | 35.74 | nd | 28,856.96 | 0.00 |
| Lead (kg) | nd | 5.89 | 33.24 | 15.05 | nd | 1,229.57 | 0.00 |
| Mercury (kg) | nd | nd | 0.21 | 0.00 | nd | 19.26 | 0.00 |
| Nickel (kg) | nd | 41.46 | 176.76 | 19.00 | nd | 21,110.29 | 0.00 |
| Selenium (kg) | nd | 6.78 | 136.80 | 4.72 | nd | 6,756.85 | 0.00 |
| Silver (kg) | nd | 2.99 | nd | 100.00 | nd | 973.27 | 0.00 |
| Zinc (kg) | 244.98 | 336.34 | 775.04 | 30.26 | 104.50 | 40,284.66 | 0.26 |
| Phenol (kg) | 607.14 | 18.05 | 8.95 | 66.86 | 1.24 | 3,575.73 | 0.03 |
| Total PAH (kg) | 483.73 | 134.45 | 0.52 | 99.61 | 1.41 | 23.10 | 5.77 |

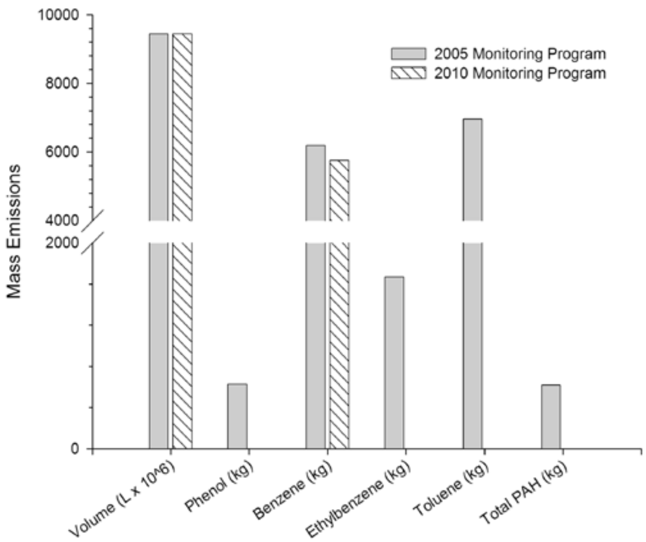


**Figure 5. Mass emission estimates based on 2005 monitoring data under the 2005 RPA monitoring program and the 2010 revised monitoring program.**

the most toxic components of petroleum (National Research Council 2003). Despite the relatively low volume discharged by oil platforms, produced water is the primary anthropogenic source of these contaminants to the SCB. Concentrations of many constituents were higher than or comparable to concentrations found in POTW effluent. Even for constituents with relatively minor produced water loads the difference in mass emissions was due to the substantially greater volume discharged by POTWs.

Produced water has been increasing over the past several years in terms of water-to-oil production ratio, total production volume, and total discharge volume. Unless re-injection of produced water keeps pace with production levels, discharge of produced water is likely to continue increasing. Under the new monitoring requirements, loads from produced water will be largely unknown. Some of the constituents for which oil platforms are the main source will no longer be routinely monitored, such as toluene, ethylbenzene, naphthalene, and phenols. Significant loads of these contaminants, potentially greater than from any other anthropogenic source, will be unaccounted for in future assessments of overall pollutant loading to the SCB.

Our analysis of 2005 loads under the current requirements indicates that many of the constituent loads will be underrepresented in future trend assessments. The 2005 RPA data provides a comprehensive snapshot of the most significant loads discharged from oil platforms. However, the usefulness of this dataset for assessing trends is limited due to reduced monitoring requirements under past and future routine monitoring programs. Changes in organic constituent loads from 2000 to 2005 cannot be accurately assessed based on the limited data collected in 2000. Future assessments will also be affected by limitations in the required data collected for platform discharges. The only significant contributions that will be fully or mostly accounted for in future assessments will be produced water volume, oil/grease, benzene, and undissociated sulfides.

It is important to note that the RPA was based on post-dilution compliance concentrations intended to protect water quality to federal or state standards at the edge of the mixing zone. Based on the EPA's analysis of RPA data, the unmonitored future loads are unlikely to exceed water quality criteria at the point of compliance. However, the unmonitored loads are still significant sources of contaminants relative to other point sources and will be difficult or impossible to quantify in the future.

Discharges from oil platforms will not continue indefinitely. Oil platforms have finite useful lives that depend on remaining oil and gas reserves and a variety of economic, technological, and regulatory factors (Bernstein *et al*. 2010). Current regulation requires decommissioning with full removal of all platform structures once the platforms cease production, although other decommissioning options are now being considered (Bernstein *et al*. 2010). Current estimates predict that nearly two-thirds of southern California OCS platforms may be decommissioned as early as 2015, with all current platforms decommissioned by 2030 (Proserv Offshore 2010). Barring installation of new platforms or extensions of the useful lives of current platforms, operation of oil platforms in southern California and their associated discharge of contaminant loads are expected to end in the next twenty years.

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**Appendix I. Discharge volumes from each oil platform by waste stream in 2005. All volumes are in L x $10^6$ unless specified. "--" = no monitored discharge.**

| Platform | Operations | | | | Production | Drilling | |
|---|---|---|---|---|---|---|---|
| | Cooling Water | Fire Control System Water | Sanitary & Domestic Wastes | Deck Drains & Minor Discharges | Produced Water | Drilling Fluids | Drill Cuttings (mt) |
| A | 0.16 | -- | 0.43 | -- | 524.25 | -- | -- |
| B | -- | -- | 0.50 | -- | 470.00 | -- | -- |
| C | -- | -- | 0.30 | 0.08 | -- | -- | -- |
| Edith | 367.49 | -- | 0.26 | -- | 30.73 | -- | -- |
| Ellen | -- | -- | -- | -- | -- | -- | -- |
| Elly | -- | -- | -- | -- | -- | -- | -- |
| Eureka | -- | -- | -- | -- | -- | -- | -- |
| Gail | 9,670.68 | 9.86 | 3.51 | 6.12 | 70.92 | 0.84 | 251.47 |
| Gilda | -- | -- | 0.99 | 0.02 | 277.36 | -- | -- |
| Gina | -- | -- | 0.25 | -- | 138.05 | -- | -- |
| Grace | -- | 39.24 | 0.72 | 6.34 | -- | -- | -- |
| Habitat | 149.20 | -- | 0.13 | 1.33 | 29.83 | -- | -- |
| Harmony | 13,713.02 | -- | 2.35 | 1.53 | 2,918.05 | -- | -- |
| Harvest | 11,024.57 | -- | 2.38 | 0.42 | 2,233.48 | -- | -- |
| Henry | -- | -- | 0.24 | -- | -- | -- | -- |
| Heritage | 14,163.89 | -- | 7.89 | 0.83 | -- | 3.25 | 1,393.80 |
| Hermosa | 5,916.41 | -- | 2.02 | 1.27 | 1,702.44 | -- | -- |
| Hidalgo | 4,500.63 | -- | 3.72 | 0.52 | 327.62 | 2.43 | 474.56 |
| Hillhouse | -- | -- | 0.42 | 0.78 | 473.49 | -- | -- |
| Hogan | -- | -- | 0.28 | -- | 251.33 | 0.50 | 193.43 |
| Hondo | -- | -- | 2.33 | -- | -- | -- | -- |
| Houchin | -- | -- | 0.17 | -- | -- | -- | -- |
| Irene | -- | 398.82 | 9.64 | -- | -- | -- | -- |

**Appendix II. Estimated produced water mass emissions from all discharging oil platforms in 2005. nd = not detected. "--" = data were not available.**

| Constituent | Total | A | B | Edith | Gail | Gilda | Gina | Habitat | Harmony | Harvest | Hermosa | Hidalgo | Hillhouse | Hogan |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Volume (L x $10^6$) | 9,447.55 | 524.25 | 470.00 | 30.73 | 70.92 | 277.36 | 138.05 | 29.83 | 2,918.05 | 2,233.48 | 1,702.44 | 327.62 | 473.49 | 251.33 |
| Oil/grease (mt) | 140.82 | 10.19 | 7.06 | 0.51 | 0.29 | 5.72 | 1.87 | 0.44 | 57.58 | 15.48 | 23.66 | 6.31 | 6.78 | 4.92 |
| Ammonia-N (mt) | 538.01 | 26.01 | 18.84 | 2.76 | 1.70 | 18.50 | 4.30 | 2.49 | 430.74 | -- | -- | -- | 21.69 | 10.96 |
| Cyanide (kg) | 18.31 | nd | nd | nd | nd | nd | nd | nd | nd | 18.31 | -- | nd | nd | nd |
| Arsenic (kg) | 18.92 | nd | nd | nd | 2.13 | nd | nd | nd | 11.45 | nd | nd | nd | 5.34 | nd |
| Cadmium (kg) | 2.92 | nd | nd | nd | nd | nd | nd | nd | 2.92 | nd | nd | nd | nd | nd |
| Chromium (kg) | 95.36 | nd | nd | nd | 0.34 | 7.14 | nd | nd | 83.18 | nd | nd | 2.96 | nd | 1.75 |
| Copper (kg) | 88.06 | 22.02 | nd | nd | 1.76 | nd | nd | 0.40 | 63.89 | nd | nd | nd | nd | nd |
| Lead (kg) | 5.89 | nd | nd | nd | nd | nd | nd | nd | 5.80 | nd | nd | nd | nd | 0.09 |
| Manganese (kg) | 444.73 | 12.94 | 11.52 | 2.33 | 72.28 | 59.07 | 9.66 | 10.02 | 24.48 | 21.50 | 163.62 | 11.81 | 22.23 | 23.27 |
| Mercury (kg) | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| Nickel (kg) | 41.46 | nd | nd | nd | 8.22 | nd | nd | nd | 23.74 | nd | nd | nd | nd | 9.50 |
| Selenium (kg) | 6.78 | nd | nd | nd | nd | nd | 4.75 | 0.76 | nd | nd | nd | nd | 1.27 | nd |
| Silver (kg) | 2.99 | nd | nd | nd | 0.03 | nd | nd | 0.02 | 2.71 | nd | nd | nd | 0.23 | nd |
| Zinc (kg) | 685.82 | 47.71 | nd | 104.50 | 0.53 | 23.16 | 11.97 | 0.62 | 221.56 | 139.01 | 90.46 | 15.52 | nd | 30.80 |
| 2,4-Dimethylphenol (kg) | 719.99 | 127.73 | 75.56 | 2.44 | 2.68 | 26.55 | 1.00 | 19.84 | nd | 151.18 | 77.81 | 37.69 | 91.41 | 106.08 |
| Phenol (kg) | 626.42 | nd | nd | 1.24 | 0.15 | nd | 0.28 | 15.35 | nd | 179.09 | 400.20 | 27.85 | 0.75 | 1.51 |
| Benzene (kg) | 6,186.48 | 132.40 | 45.09 | 71.71 | 10.70 | 107.16 | 8.16 | 148.62 | 1.98 | 1,111.23 | 3,022.05 | 1,370.65 | 68.19 | 88.53 |
| Ethylbenzene (kg) | 1,668.12 | 152.05 | 123.32 | 6.46 | 0.11 | 27.98 | 5.45 | 21.06 | 24.11 | 469.33 | 729.44 | 21.84 | 63.67 | 23.32 |
| Toluene (kg) | 6,953.75 | 257.63 | 227.88 | 47.86 | 2.57 | 125.92 | 5.28 | 160.43 | 1.46 | 1,929.28 | 3,675.69 | 144.33 | 232.34 | 143.07 |
| Benzo(a)anthracene (kg) | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| Benzo(a)pyrene (kg) | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| Benzo(b)fluoranthene (kg) | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| Benzo(k)fluoranthene (kg) | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| Chrysene (kg) | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| Dibenzo(a,h)anthracene (kg) | 3.73 | nd | nd | nd | nd | nd | nd | nd | nd | 3.73 | nd | nd | nd | nd |
| Naphthalene (kg) | 615.86 | 54.60 | 35.06 | 1.41 | 0.17 | 9.10 | 14.42 | 0.10 | nd | 135.42 | 310.67 | 33.90 | 11.79 | 9.22 |
| *Total PAH (kg)* | *619.59* | *54.60* | *35.06* | *1.41* | *0.17* | *9.10* | *14.42* | *0.10* | *nd* | *139.15* | *310.67* | *33.90* | *11.79* | *9.22* |
| Undissociated Sulfides (kg) | 49,705.85 | nd | nd | nd | 475.90 | 1,362.11 | 1,315.80 | 15.16 | 11.01 | 2,628.02 | 42,922.19 | 975.64 | nd | nd |

**Appendix III. Produced water flow-weighted concentrations from all discharging oil platforms in 2005. "<" = all results less than the minimum reporting level. "--" = data were not available.**

| Constituent | A | B | Edith | Gail | Gilda | Gina | Habitat | Harmony | Harvest | Hermosa | Hidalgo | Hillhouse | Hogan |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Oil/grease (mg/L) | 19.44 | 15.03 | 16.43 | 4.15 | 20.64 | 13.54 | 14.67 | 19.73 | 6.93 | 13.90 | 19.26 | 14.33 | 19.57 |
| Ammonia-N (mg/L) | 49.62 | 40.09 | 89.84 | 23.99 | 66.71 | 31.18 | 83.42 | 147.61 | -- | -- | -- | 45.82 | 43.62 |
| Cyanide (ug/L) | <30 | <30 | <30 | <30 | <30 | <30 | <30 | <30 | 8.20 | -- | <30 | <30 | <30 |
| Arsenic (ug/L) | <20 | <20 | <20 | 30.08 | <20 | <20 | <20 | 3.92 | <20 | <20 | <20 | 11.28 | <20 |
| Cadmium (ug/L) | <1 | <1 | <1 | <1 | <1 | <1 | <1 | 1.00 | <1 | <1 | <1 | <1 | <1 |
| Chromium (ug/L) | <5 | <5 | <5 | 4.73 | 25.73 | <5 | <5 | 28.51 | <5 | <5 | 9.02 | <5 | 6.96 |
| Copper (ug/L) | 42.00 | <30 | <30 | 24.84 | <30 | <30 | 13.28 | 21.89 | <30 | <30 | <30 | <30 | <30 |
| Lead (ug/L) | <15 | <15 | <15 | <15 | <15 | <15 | <15 | 1.99 | <15 | <15 | <15 | <15 | 0.34 |
| Manganese (ug/L) | 24.69 | 24.51 | 75.69 | 1,019.05 | 212.98 | 70.00 | 336.00 | 8.39 | 9.63 | 96.11 | 36.04 | 46.94 | 92.57 |
| Mercury (ug/L) | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 |
| Nickel (ug/L) | <80 | <80 | <80 | 115.87 | <80 | <80 | <80 | 8.13 | <80 | <80 | <80 | <80 | 37.81 |
| Selenium (ug/L) | <10 | <10 | <10 | <10 | <10 | 34.41 | 25.63 | <10 | <10 | <10 | <10 | 2.67 | <10 |
| Silver (ug/L) | <2 | <2 | <2 | 0.39 | <2 | <2 | 0.80 | 0.93 | <2 | <2 | <2 | 0.48 | <2 |
| Zinc (ug/L) | 91.00 | <60 | 3,400.00 | 7.50 | 83.50 | 86.68 | 20.74 | 75.93 | 62.24 | 53.13 | 47.37 | <60 | 122.54 |
| 2,4-Dimethylphenol (ug/L) | 243.65 | 160.76 | 79.52 | 37.81 | 95.72 | 7.24 | 665.20 | <10 | 67.69 | 45.71 | 115.04 | 193.07 | 422.09 |
| Phenol (ug/L) | <10 | <10 | 40.21 | 2.14 | <10 | 2.04 | 514.77 | <10 | 80.18 | 235.08 | 85.00 | 1.59 | 6.01 |
| Benzene (ug/L) | 252.55 | 95.94 | 2,333.31 | 150.85 | 386.35 | 59.13 | 4,983.08 | 0.68 | 497.53 | 1,775.13 | 4,183.63 | 144.02 | 352.25 |
| Ethylbenzene (ug/L) | 290.04 | 262.39 | 210.14 | 1.61 | 100.86 | 39.45 | 706.05 | 8.26 | 210.13 | 428.47 | 66.65 | 134.46 | 92.79 |
| Toluene (ug/L) | 491.43 | 484.85 | 1,557.26 | 36.25 | 453.99 | 38.27 | 5,378.76 | 0.50 | 863.80 | 2,159.08 | 440.52 | 490.71 | 569.23 |
| Total PAH (ug/L) | 104.14 | 74.59 | 46.03 | 2.43 | 32.80 | 104.44 | 3.21 | <30 | 62.30 | 182.49 | 103.48 | 24.89 | 36.70 |
| Undissociated Sulfides (ug/L) | <10.5 | <9 | <3 | 6,709.96 | 4,910.91 | 9,531.34 | 508.39 | 3.77 | 1,176.65 | 25,212.22 | 2,977.94 | <7 | <5 |

**Appendix IV. Percent change in produced water mass emissions from all discharging oil platforms between 2000 and 2005. nd = constituent was not detected in either period. "--" = constituent was not analyzed in 2000.**

| Constituent | Total | A | B | Edith | Gail | Gilda | Gina | Habitat | Harmony | Harvest | Hermosa | Hidalgo | Hillhouse | Hogan |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Volume (L x $10^6$) | 68 | -26 | 18 | 226 | -49 | 93 | -28 | -15 | 43 | 402 | 402 | 6 | -15 | -15 |
| Oil/grease (mt) | 40 | -35 | -9 | 107 | -51 | 90 | -53 | -47 | 143 | 31 | 187 | -21 | -42 | 1 |
| Ammonia-N (mt) | 46 | -- | -- | 241408 | -77 | -- | -- | -- | 32 | -- | -- | -- | -- | -- |
| Cyanide (kg) | 362 | nd | nd | nd | nd | nd | nd | nd | nd | 100 | nd | nd | nd | -100 |
| Arsenic (kg) | 257 | nd | nd | nd | 100 | nd | nd | nd | 100 | nd | nd | nd | 100 | -100 |
| Cadmium (kg) | 420 | nd | nd | nd | nd | nd | nd | -100 | 1504 | nd | nd | nd | nd | -100 |
| Chromium (kg) | 14 | nd | nd | nd | -18 | 261 | nd | -100 | 1313 | -100 | -100 | 46 | nd | -97 |
| Copper (kg) | 187 | 100 | nd | nd | -62 | -100 | -100 | 100 | 100 | nd | nd | nd | nd | 100 |
| Lead (kg) | 128 | nd | nd | nd | nd | nd | nd | nd | 359 | nd | nd | nd | nd | -94% |
| Manganese (kg) | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Mercury (kg) | -100 | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | -100 |
| Nickel (kg) | 304 | nd | nd | nd | 100 | nd | nd | nd | 100 | nd | nd | nd | nd | -8 |
| Selenium (kg) | 100 | nd | nd | nd | nd | nd | 100 | 100 | nd | nd | -- | nd | 100 | -- |
| Silver (kg) | 154 | nd | nd | nd | 100 | nd | nd | 100 | 100 | nd | nd | nd | 100 | -100 |
| Zinc (kg) | 135 | 100 | nd | 8530 | -99 | 100 | 100 | 100 | 100 | -36 | 100 | 100 | nd | -9 |
| 2,4-Dimethylphenol (kg) | 100 | -- | -- | -- | 100 | -- | -- | -- | nd | -- | -- | -- | -- | -- |
| Phenol (kg) | -20 | -100 | -100 | 100 | -100 | -100 | -100 | -80 | nd | -- | -- | -- | 126 | -- |
| Benzene (kg) | 4238 | -- | -- | -- | -88 | -- | -- | -- | -97 | -- | -- | -- | -- | -- |
| Ethylbenzene (kg) | -91 | -- | -- | -- | -- | -- | -- | -- | -100 | -- | -- | -- | -- | -- |
| Toluene (kg) | 1894 | -- | -- | -- | -96 | -- | -- | -- | -99 | -- | -- | -- | -- | -- |
| Benzo(a)anthracene (kg) | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Benzo(a)pyrene (kg) | nd | -- | -- | -- | nd | -- | -- | -- | nd | -- | -- | -- | -- | -- |
| Benzo(b)fluoranthene (kg) | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Benzo(k)fluoranthene (kg) | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Chrysene (kg) | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Dibenzo(a,h)anthracene (kg) | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Naphthalene (kg) | 100 | -- | -- | -- | nd | -- | -- | -- | nd | -- | -- | -- | -- | -- |
| *Total PAH (kg)* | 100 | -- | -- | -- | *nd* | -- | -- | -- | *nd* | -- | -- | -- | -- | -- |
| Undissociated Sulfides (kg) | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |

**Appendix V. Estimated produced water mass emissions from all discharging oil platforms based on 2005 data under the 2010 revised monitoring requirements. nd = not detected. na = not applicable. "--" = monitoring not required.**

| Constituent | Revised Total | % Actual 2005 Total | A | B | Edith | Gail | Gilda | Gina | Habitat | Harmony | Harvest | Hermosa | Hidalgo | Hillhouse | Hogan |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Volume (L x $10^6$) | 9,447.55 | 100.0 | 524.25 | 470.00 | 30.73 | 70.92 | 277.36 | 138.05 | 29.83 | 2,918.05 | 2,233.48 | 1,702.44 | 327.62 | 473.49 | 251.33 |
| Oil/grease (mt) | 140.82 | 100.0 | 10.19 | 7.06 | 0.51 | 0.29 | 5.72 | 1.87 | 0.44 | 57.58 | 15.48 | 23.66 | 6.31 | 6.78 | 4.92 |
| Ammonia-N (mt) | 4.30 | 0.8 | -- | -- | -- | -- | -- | 4.30 | -- | -- | -- | -- | -- | -- | -- |
| Cyanide (kg) | -- | 0 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Arsenic (kg) | -- | 0 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Cadmium (kg) | -- | 0 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Chromium (kg) | 1.75 | 1.8 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 1.75 |
| Copper (kg) | 22.41 | 25.5 | 22.02 | -- | -- | -- | nd | nd | 0.40 | -- | nd | nd | -- | -- | nd |
| Lead (kg) | -- | 0 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Manganese (kg) | -- | 0 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Mercury (kg) | -- | na | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Nickel (kg) | -- | 0 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Selenium (kg) | -- | 0 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Silver (kg) | -- | 0 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Zinc (kg) | 104.50 | 15.2 | -- | -- | 104.50 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 2,4-Dimethylphenol (kg) | -- | 0 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Phenol (kg) | -- | 0 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Benzene (kg) | 5,751.79 | 93.0 | -- | -- | -- | 10.70 | -- | -- | 148.62 | -- | 1,111.23 | 3,022.05 | 1,370.65 | -- | 88.53 |
| Ethylbenzene (kg) | -- | 0 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Toluene (kg) | -- | 0 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Benzo(a)anthracene (kg) | nd | na | -- | -- | -- | -- | nd | -- | -- | -- | nd | nd | -- | nd | -- |
| Benzo(a)pyrene (kg) | nd | na | nd | nd | -- | nd | nd | nd | nd | -- | nd | nd | -- | nd | nd |
| Benzo(b)fluoranthene (kg) | nd | na | nd | nd | -- | -- | nd | nd | nd | -- | nd | nd | nd | nd | nd |
| Benzo(k)fluoranthene (kg) | nd | na | nd | nd | -- | -- | nd | nd | nd | -- | nd | nd | nd | nd | nd |
| Chrysene (kg) | nd | na | -- | -- | -- | -- | nd | -- | -- | -- | nd | nd | nd | nd | -- |
| Dibenzo(a,h)anthracene (kg) | 3.73 | 100.0 | -- | -- | -- | -- | nd | -- | nd | -- | 3.73 | nd | -- | nd | nd |
| Naphthalene (kg) | -- | 0 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| *Total PAH (kg)* | *3.73* | *0.6* | *nd* | *nd* | -- | *nd* | *nd* | *nd* | *nd* | -- | *3.73* | *nd* | *nd* | *nd* | *nd* |
| Undissociated Sulfides (kg) | 48,379.03 | 97.3 | -- | -- | -- | 475.90 | 1,362.11 | -- | 15.16 | -- | 2,628.02 | 42,922.19 | 975.64 | -- | -- |