Effluent discharges to the Southern California Bight from power generating stations in 2005

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Abstract

Nearly 17 million residents consume an average of 122 million megawatts of electricity per year in the counties bordering the Southern California Bight (SCB). Thirteen power generating stations (PGS) located along the coast of the SCB help to meet this regional electricity demand. Twelve of the facilities are powered by conventional fossil fuels, primarily natural gas, and one is powered by nuclear fuel. Each facility uses seawater or estuarine water drawn from adjacent water bodies to dissipate heat generated in the electricity production process. The cooling water is then discharged along with waste streams produced within the plants. The intake and discharge of once-through cooling water results in several impacts, including impingement and entrainment of aquatic organisms, thermal pollution, and discharge of contaminant loads. This study focuses on the contaminant loads from PGS in 2005 and continues an ongoing series of assessments of point sources discharge emissions and trends in the SCB. Combined discharges of cooling water and in-plant wastes from PGS totaled 7 trillion liters in 2005. This volume was 4 times greater than the 1.7 trillion liter effluent volume discharged by municipal wastewater treatment plants, historically the largest point source of contaminants to the SCB. Mass loads of several metals and organic constituents from PGS combined discharges were greater than from any other point source, including 180 metric tons (mt) of arsenic, 104 mt of zinc, and 167 mt of phenols. The majority of the volume and constituent loads from PGS result from the discharge of cooling water. Cooling water accounted for over 99% of the total PGS discharge in 2005; with in-plant wastes contributing just 0.11% of the combined discharge. Constituent mass emissions from in-plant wastes were similarly minor, generally contributing less than 1% of the loads discharged in the combined effluent. California recently adopted a statewide policy to reduce the use of once-through cooling water by existing PGS facilities. The policy requires each facility to reduce intake of cooling water by 93%, primarily to address the impacts of impingement and entrainment of aquatic organisms. The restriction of cooling water use will also significantly decrease the volume and constituent loads from PGS discharges in the future.

Introduction

The SCB region is one of the most densely populated coastal regions in the United States (Crossett *et al*. 2004). The five coastal counties bordering the SCB were home to nearly 17 million people in 2005 (US Census Bureau 2009). The large population creates significant demand for electricity; average annual electricity consumption for the five SCB coastal counties was over 122 million megawatt hours between 2006 and 2008 (California Energy Commission 2010). To help meet this regional demand, 13 PGSs are located along the coast of the SCB from Ventura County to San Diego (Figure 1; Appendix I). Twelve of these facilities are powered by conventional fossil fuels, primarily natural gas, and one, San Onofre Nuclear Generating Station (SONGS), is powered by nuclear fuel. Each facility uses seawater or estuarine water drawn from adjacent water bodies to dissipate heat generated in the electricity production process. Large volumes of water are drawn in, circulated once through the facility, used to cool power generating equipment, and discharged to nearby receiving waters. The cooling water is chlorinated to prevent fouling within the facilities' pipes. Wastes generated within the facilities are also discharged by injecting the in-plant waste streams into the outgoing cooling water effluent.

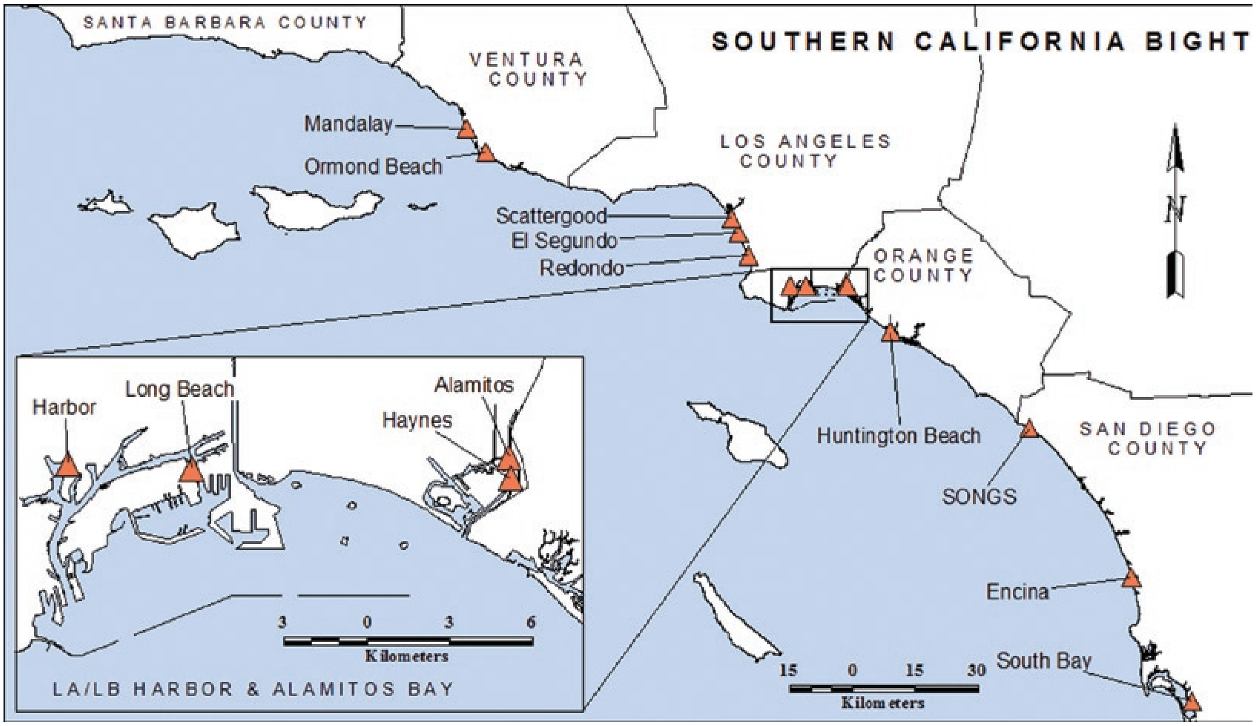

Figure 1. Locations of coastal power generating stations along the SCB.

The use of once-through cooling water by PGS results in several impacts to coastal waters where intake and discharge occur. Intake of cooling water can cause impingement of larger marine organisms, including fish, mammals, and turtles, and also results in entrainment and high mortality of smaller organisms, including planktonic larvae and eggs (Jensen and Gregorio 2010). Discharge of heated cooling water also produces thermal pollution, and the combined cooling water and in-plant waste discharge results in contaminant loading to the receiving waters. This study focuses on the contaminant loading from PGS discharges. 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 discharge data are used to calculate total mass emission estimates for selected contaminants, track trends, and identify sources of greatest significance. The coastal PGS were among 64 major point source facilities discharging to the SCB in 2005, with the other sources being municipal wastewater treatment plants (publicly owned treatment works; POTWs), oil platforms, and other industrial facilities (Lyon and Stein 2008, 2009b, 2010, SCCWRP unpublished data).

Effluent discharges and associated compliance monitoring requirements for each facility are stipulated by their National Pollutant Discharge Elimination System (NPDES) permit, which have been issued by the California Regional Water Quality Control Boards. Although each facility is required to monitor its discharge flow and chemistry, the specific constituents and minimum analysis frequencies vary by facility. NPDES permits also do not require integration of data from multiple dischargers or classes of dischargers to assess the cumulative impact to a water body and relative contributions from different sources. This poses a challenge to environmental resource managers who need to evaluate pollutant loads and trends from all sources on a regional or larger scale.

The goal of this study was to characterize both combined discharges and in-plant wastes from power generating stations in 2005. To achieve this objective, flow and chemistry data from PGS facilities discharging to the SCB were compiled and standardized to allow calculation of cumulative mass emission estimates for the entire bight. To assess trends, we then compared these effluent data to results from the previous assessment of PGS discharges from 2000. PGS combined discharges were also compared to effluent from the leading point source of contaminants to the SCB, POTWs, to assess their relative significance.

METHODS

Annual mass emissions estimates for the power generating stations were calculated from effluent flow and chemistry data provided in each facility's discharge monitoring reports, which were obtained from the California Regional Water Quality Control Boards. All PGS facilities monitored combined discharge, which consists of commingled once-through cooling water and in-plant waste streams. Most facilities (all except South Bay) also monitored in-plant waste streams prior to injection into the combined effluent stream. Monitored in-plant waste stream types varied by facility (Appendix I), and were reported either as individual waste streams or as total low volume wastes (LVW). To evaluate in-plant waste discharges among facilities with different monitored waste streams, all reported waste streams were used to calculate volumes and constituent mass emissions, and were then summed to generate in-plant waste totals. Constituents included in this assessment were selected based on the availability of data and on the known influence of these constituents in the marine environment. General constituents included solids, biochemical oxygen demand (BOD), oil and grease, ammonia, and cyanide. Selected metals, phenols, dichlorodiphenyltrichloroethane (DDT), polychlorinated biphenyl (PCB), and polycyclic aromatic hydrocarbons (PAH) were also analyzed.

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 facility. 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 facility 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 the 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. *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 Ci was the reported constituent concentration for the month i, and u was the appropriate unit conversion factor for calculating the *ME* in metric tons, kilograms, or liters.

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 PGS facilities were analyzed by comparing results from 2005 to results of the previous assessment of discharges in 2000 (Steinberger and Stein 2004). The same thirteen PGS facilities were operating in both periods. A miscalculation of SONGS in-plant waste volume for 2000 was discovered, which caused an overestimation of in-plant volume, and solids and oil/grease load estimates. Corrected values for these constituents were used in the historical comparison. The relative significance of PGS discharges was evaluated by comparing combined and in-plant waste discharges to effluent characteristics from POTWs, which have historically been the largest point sources of contaminants in the SCB (Lyon and Stein 2009a). Effluent data from POTWs in 2005 were obtained from Lyon and Stein (2008) and SCCWRP (unpublished data).

Results

Combined Discharges in 2005

Combined discharge volume from the 13 PGS facilities to the SCB was 7,002 L x 10^9 in 2005 (Table 1). This volume was less than 60% of the total flow capacity of all facilities (Appendix I). Discharges from individual facilities ranged from 70 L x 10^9 (Harbor and Long Beach) to 2,805 L x 10^9 (SONGS). Combined discharge from the nuclear powered facility, SONGS, accounted for 40% of the total discharge volume, and was 2.5 times greater than any other facility (Table 1). Combined discharge from all facilities decreased 31% from 2000 to 2005. Only three facilities, Haynes, Huntington Beach, and Scattergood, discharged greater volumes in 2005 than in 2000 (Table 1). Combined discharges from all other plants decreased, with reductions ranging from 13% (SONGS) to 80% (Redondo).

Total mass emissions from PGS combined discharges in 2005 included 7,111 mt of suspended solids and 84 L x 10^3 of settleable solids (Table 2). PGS facilities also discharged 31,170 mt of ammonia, 713 mt of oil/grease, 309 mt of BOD, and 288 mt of residual chlorine. Individual metals loads ranged from 20 kg of mercury up to 180 mt of arsenic (Table 2). Other significant metals loads included 104 mt of zinc, 87 mt of nickel, 64 mt of copper, and 23 mt of chromium. Monitoring of organic constituents in combined discharge varied by facility. Phenols were analyzed by four facilities resulting in an estimated minimum load of 167 mt (Appendix II). DDT, PAH, and PCB constituents were analyzed by seven PGS, with estimated total loads of 2 mt of PAH and 5 kg of PCB discharged. DDT was not detected in discharge from any PGS in 2005.

As the largest volume discharger, SONGS also contributed the greatest mass of many constituents, including ammonia, arsenic, chromium, copper, lead, and nickel (Appendix II). Haynes and Scattergood discharged the greatest loads of zinc, accounting for 27% and 25% of the total load, respectively. Organic constituent loads were discharged primarily by Long Beach, with 91% of the detected PAH load, and Alamitos, with the only detected PCBs. The highest average constituent concentrations were distributed among the facilities depending on the constituent. SONGS discharged the highest average concentrations of ammonia, copper, and nickel (Appendix III). Arsenic and zinc concentrations were highest in Scattergood effluent, while Mandalay contributed the highest concentrations of chromium and phenols. Combined discharge from

Table 1. Power generating station combined discharge and in-plant waste volumes by facility in 2005, with relative contributions and percent change from 2000. "--" = data were not available.

Facility	Combined Discharges			In-Plant Wastes			
	Volume (L x 10^6)	Relative Contribution (%)	Change 2000-2005 (%)	Volume (L x 10^6)	Relative Contribution (%)	Change 2000-2005 (%)	Contribution to Combined Discharge (%)
Alamitos Generating Station	490,076.73	7.00	-57.22	117.43	1.56	2.27	0.02
El Segundo Generating Station	342,484.21	4.89	-39.89	211.37	2.81	-4.63	0.06
Encina Power Station	244,310.03	3.49	-69.30	63.40	0.84	-55.74	0.03
Harbor Generating Station	70,083.06	1.00	-24.74	2.33	0.03	-98.36	0.00
Haynes Generating Station	1,070,443.42	15.29	5.89	264.32	3.51	-13.46	0.02
Huntington Beach Generating Station	349,906.60	4.00	54.37	27.98	0.37	-81.43	0.01
Long Beach Generating Station	70,385.10	1.01	-49.03	3,038.63	40.35	52.89	4.32
Mandalay Generating Station	297,068.38	4.24	-15.37	181.36	2.41	61.51	0.06
Ormond Beach Generating Station	466,283.23	6.66	-30.90	293.96	3.90	-47.26	0.06
Redondo Beach Generating Station	179,709.91	2.57	-80.31	2,560.61	34.00	93570.17	1.42
San Onofre Nuclear Generating Station	2,805,356.55	40.06	-12.74	521.88	6.93	-62.42	0.02
Scattergood Generating Station	407,935.95	5.83	16.21	246.92	3.28	61.30	0.06
South Bay Power Plant	208,175.00	2.97	-69.01	--	--	--	--
Combined Total	**7,002,218.16**	**100.00**	**-31.06**	**7,530.20**	**100.00**	**42.63**	**0.11**

Table 2. Estimated mass emissions from power generating station discharges in 2005, with percent change from 2000 and comparison to POTW discharges. nd = not detected. "--" = data were not available.

Constituent	Combined Discharges					In-Plant Wastes			
	PGS 2005	PGS 2000	% Change 2000-2005	POTW 2005	PGS : POTW Ratio	PGS 2005	PGS 2000	% Change 2000-2005	% Contribution to Combined Discharge
Volume (L x 10^9)	7,002.22	10,156.34	-31.06	1,742.25	4.02	7.53	5.28	42.63	0.11
Suspended Solids (mt)	7,111.08	8,626.16	-17.56	43,297.12	0.16	69.14	36.72	88.32	0.97
Settleable Solids (L x 10^3)	83.82	nd	100.00	216,464.84	0.00	3.55	8.99	-60.54	4.23
Oil/grease (mt)	712.56	1,671.07	-57.36	7,309.94	0.10	11.24	8.17	37.56	1.58
Residual Chlorine (mt)	288.17	450.21	-35.99	--	--	--	--	--	--
BOD (mt)	309.46	--	--	60,971.64	0.01	0.91	0.14	550.93	0.29
Ammonia-N (mt)	31,169.67	7,680.91	305.81	52,038.56	0.60	0.05	2.43	-97.74	0.00
Nitrate-N (mt)	100.90	93.40	8.03	518.93	0.19	--	--	--	--
Cyanide (kg)	553.63	nd	100.00	4,984.48	0.11	3.76	nd	100.00	0.68
Arsenic (kg)	179,543.35	10,260.17	1649.91	3,140.11	57.18	20.67	0.04	47969.74	0.01
Cadmium (kg)	1,123.63	3,550.68	-68.35	68.59	16.38	0.28	nd	100.00	0.02
Chromium (kg)	22,816.23	22,011.30	3.66	2,339.30	9.75	10.68	3.54	201.38	0.05
Copper (kg)	64,476.88	5,231.06	1132.58	29,015.27	2.22	58.55	15.61	275.18	0.09
Lead (kg)	6,043.99	1,669.01	262.13	1,262.82	4.79	4.26	0.23	1759.32	0.07
Mercury (kg)	20.45	nd	100.00	19.52	1.05	0.06	nd	100.00	0.29
Nickel (kg)	86,617.07	nd	100.00	21,287.05	4.07	22.74	1.12	1928.20	0.03
Selenium (kg)	4,312.52	nd	100.00	6,893.68	0.63	0.23	nd	100.00	0.01
Silver (kg)	173.77	nd	100.00	973.27	0.18	0.02	nd	100.00	0.01
Zinc (kg)	104,391.09	112,681.05	-7.36	41,059.75	2.54	263.30	27.87	844.79	0.25
Total Phenols (kg)	167,110.13	--	--	3,584.66	46.62	40.81	nd	100.00	0.02
Chlorinated Phenols (kg)	nd	nd	nd	nd	--	nd	nd	nd	nd
Nonchlorinated Phenols (kg)	nd	nd	nd	4,307.28	--	nd	nd	nd	nd
Total DDT (kg)	nd	--	--	nd	--	nd	nd	nd	nd
Total PAH (kg)	2,146.47	--	--	23.59	90.99	247.93	nd	100.00	11.55
Total PCB (kg)	5.06	--	--	nd	--	nd	nd	nd	nd

Encina produced the highest chronic toxicity levels among PGS facilities (Appendix III).

In-Plant Wastes in 2005

All PGS except South Bay monitored in-plant wastes in addition to combined discharge. Total in-plant waste volume was 7.53 L x 10^9, constituting just 0.11% of the total combined discharge from PGS in 2005 (Table 1). The total in-plant waste volume discharged in 2005 was 43% higher than the volume discharged in 2000. The primary facilities and waste streams responsible for the overall increase were yard drains, dewatering pumps, and retention basin discharges from Redondo Beach, retention basin discharges from Long Beach, and all in-plant waste streams from Scattergood. Long Beach and Redondo Beach were the largest individual dischargers of in-plant wastes, contributing 40% and 34% of the total volume, respectively (Table 1). Harbor contributed the least in-plant waste volume due to diversion of most in-plant wastes to the sanitary sewer system, resulting in a 98% decrease in in-plant waste volume discharged from this facility between 2000 and 2005. The largest contributor of combined discharges, SONGS, accounted for only 7% of the total in-plant waste volume.

Most constituent mass emissions from in-plant wastes produced minor contributions to the overall loads found in PGS combined discharge. In-plant waste loads of all constituents except settleable solids, oil/grease, and total PAH contributed less than 1% of the combined discharge emissions (Table 2). Several in-plant waste constituent loads, including suspended solids, BOD, cyanide, mercury, and zinc accounted for less than 1% of the combined load but were still proportionately greater than the 0.11% volume contribution. Ammonia and the remaining metals loads were all proportionately less than the in-plant volume contribution, indicating that the vast majority of the nutrient and metals loads discharged in PGS combined effluent originate in the cooling water, rather than in-plant waste streams that are commingled with the cooling water prior to discharge. The largest constituent loads from in-plant wastes were 69 mt of suspended solids, 11 mt of oil/grease, 263 kg of zinc, and 248 kg of PAH compounds (Table 2). Long Beach, the largest in-plant volume discharger, also discharged the greatest in-plant loads of many constituents, including suspended solids, cyanide, arsenic, cadmium, lead, mercury, and zinc (Appendix IV). Long Beach was also the only facility to detect PAH compounds in in-plant wastes at concentrations greater than the minimum reporting levels used by other PGS facilities. Redondo Beach, the second largest volume contributor, detected fewer constituents in its in-plant waste and was the largest contributor of only oil/grease emissions (Appendix IV).

The highest average flow-weighted concentrations varied between combined discharge and in-plant wastes by constituent. Average concentrations of ammonia, arsenic, cadmium, and selenium were highest in combined discharge (Appendix III). The highest average concentrations of solids, oil/grease, chromium, copper, lead, zinc, and PAHs were detected in in-plant wastes (Appendix V). However in-plant waste concentrations ultimately had little effect on the constituent loads due to the relatively insignificant volumes discharged.

PGS vs. POTW Discharges

Effluent from POTW facilities has historically been the most dominant point source of contaminants to the SCB (Lyon and Stein 2009a). PGS combined discharge volume was 4 times greater than POTW effluent volume in 2005 (Table 2). The combined discharge from SONGS alone was greater than the total volume discharged by all POTWs (2,805 and 1,742 L x 10^9, respectively). Despite the greater volume, PGS contributed relatively minor loads of general constituents, including solids, oil/grease, BOD, ammonia, nitrate, and cyanide. However, loads of most metals, phenols, and total PAH from PGS combined discharges exceeded POTW effluent loads (Table 2; Figure 2). Several of the larger loads discharged by PGS were disproportionately greater than those from POTWs, i.e. more than 4 times greater than POTW loads. Chromium emissions from PGS combined discharge were nearly 10 times greater than from POTW effluent. The load differential was even greater for arsenic, cadmium, phenols, and total PAH, ranging from 16 to 91 times greater loads from PGS discharges (Table 2). In-plant waste discharges from PGS were relatively insignificant compared to POTW effluent. Total in-plant waste volume was less than 0.5% of POTW effluent volume. Constituent loads from PGS in-plant wastes were also substantially lower than POTW effluent loads with only one exception. Total PAH emissions from PGS in-plant wastes exceeded POTW effluent emissions by an order of magnitude, 248 to 24 kg, respectively (Table 2).

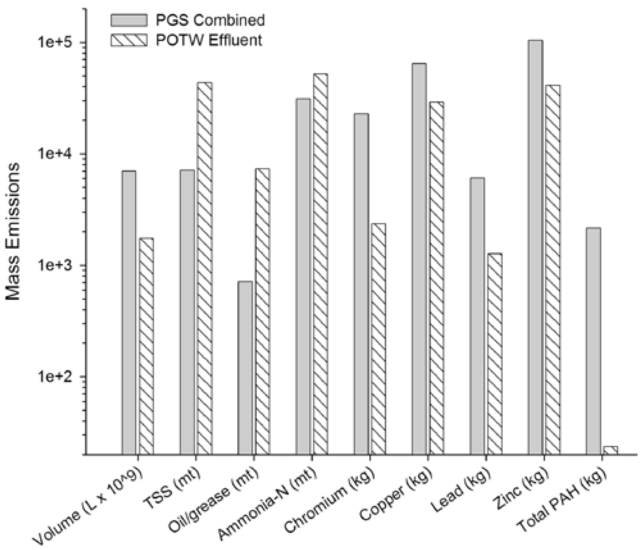

Figure 2. Mass emissions of selected constituents from PGS combined discharges and POTW effluent in 2005.

Discussion

Combined discharges from PGS facilities represent the largest point source volume discharged to the SCB. The large volume has the potential to deliver substantial contaminant loads to nearshore receiving waters. PGS loads of general contaminants and monitored nutrients were significantly lower than those discharged from POTWs. In contrast, metals and organic constituent loads were several times greater than those from POTWs. Monitored in-plant wastes accounted for insignificant proportions of the combined volume and most constituent loads, indicating that the driving factor in PGS discharges was once-through cooling water. Cooling water accounted for greater than 99% of the combined volume from PGS facilities. It is likely that the large volume of cooling water drawn from marine and estuarine water bodies contains significant amounts of naturally occurring constituents. The exact source of constituents in cooling water, whether occurring in the intake water or derived from unmonitored inputs such as leaching from metal pipes during circulation, cannot be determined from the available data. Regardless of the origin, cooling water contributes significant loads of several contaminants, particularly metals, to the combined discharges from PGS facilities.

The use of once-through cooling water also results in other impacts, including thermal pollution from discharge of heated water, impingement of large aquatic organisms, and entrainment and mortality of smaller organisms, larvae, and eggs. Section 316(b) of the Clean Water Act requires facilities using cooling water to utilize the best technology available to minimize adverse environmental impacts, however there is no national standard for implementing this requirement for existing power plants (SWRCB 2010). In 2010, the California State Water Resources Control Board (SWRCB) adopted a statewide policy on once-through cooling water that establishes targets for compliance with Section 316(b) for coastal PGS facilities in California (SWRCB 2010). The California cooling water policy requires existing coastal facilities to reduce their intake of cooling water by at least 93%, equivalent to the level achieved with a recirculated wet cooling system.

The new statewide policy sets compliance requirements and deadlines for each PGS facility. Each conventional-fueled PGS must reduce cooling water intake flow by at least 93% of its permitted design flow. Compliance can be achieved by 1) converting to a closed-cycle wet cooling system that recirculates a lower volume of water, 2) converting to an air cooling system, or 3) if neither of those options are feasible, implementing structural or operational controls that reduce impingement and entrainment to comparable levels with ongoing monitoring for compliance (SWRCB 2010). Compliance deadlines for the conventional-fueled PGS are staggered, with the first facility expected to be in compliance by the end of 2011 and the last facilities required to achieve compliance by the end of 2020. Nuclear-powered facilities have additional regulatory and safety issues that must be taken into account. The cooling water policy requires nuclear-powered PGS to conduct special studies to examine alternatives for achieving compliance with the cooling water policy. The studies are to be completed within three years, and compliance with provisions resulting from the special studies is required by the end of 2022. Depending on the results of the special studies, the SWRCB may issue facility-specific requirements for nuclear-powered PGS. Therefore, the impact of the policy on future cooling water volume from nuclear facilities, including SONGS, is unknown at this time.

The California cooling water policy was intended primarily to address the impacts of impingement and entrainment, but will also have a significant effect on contaminant loads from PGS. Reducing cooling water flow by 93% will likely result in corresponding reductions in constituent emissions not originating from in-plant wastes. In addition to the overall reduction in PGS contaminant loads, implementation of the policy will cause a shift in the relative contributions of volumes and loads from PGS facilities. In 2005, combined discharges from SONGS contributed 40.1% of the total volume from PGS, cooling water discharges from conventional-powered facilities accounted for 59.8%, and in-plant wastes made up only 0.1%. Assuming that cooling water from conventional-fueled facilities is reduced by 93%, while in-plant wastes and SONGS discharges remain unchanged, at least until the outcome of the SONGS special study is known, projected cooling water discharges from conventional-fueled PGS would be reduced to just 9.4% of the total PGS volume (Figure 3). The relative significance of SONGS discharges would increase to 90% of the total PGS volume, while the in-plant waste contribution would increase slightly to 0.2% of the total volume. The reduction of cooling water volume from PGS discharges also affects the relative impact of POTWs on overall volume discharged from the two largest point sources to the SCB. In 2005 combined PGS discharges were 4 times greater than POTW effluent volume. Reducing cooling water from conventional-fueled facilities by 93% would result in a projected 56% decrease in total PGS volume, assuming in-plant waste and SONGS discharges were unchanged. Since combined discharges from SONGS alone were greater than total POTW discharges in 2005, projected PGS volumes would still exceed POTW effluent volume, but by a margin reduced from 4:1 to less than 2:1 (Figure 3).

Another factor influencing volumes and contaminant loads discharged from coastal PGS is the use of electricity from out of state and renewable sources. California imports approximately 32% of its total electricity from neighboring states and generates approximately 24% of the electricity produced in-state from renewable resources, including hydro-electric, geothermal, wind, and solar (Nyberg 2009). The southern California coastal PGS already operate well below their maximum capacity. From 2001 to 2006 all PGS combined operated at an average of only 31% of total generating capacity. SONGS operated at 83% of total capacity, while the conventional facilities combined for just 21% of their total capacity (Jensen and Gregorio 2010). Increasing capacity of renewable energy could further reduce the need to operate coastal PGS, resulting in additional decreases in cooling water discharge. In 2008 California established new statewide renewable energy targets, which mandated that all utilities in California generate 33% of their electricity from renewable sources by 2020 (Executive Order S-14-08). Restrictions on the use of cooling water and increasing availability of renewable energy are likely to reduce the impact of PGS facilities on contaminant loads to the SCB in the future.

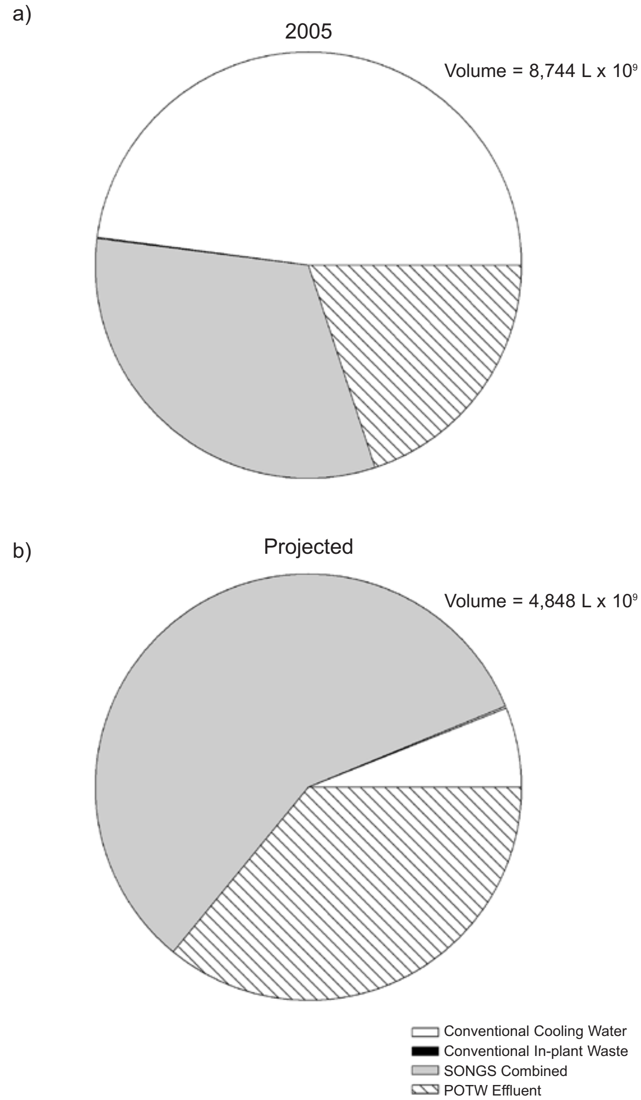

Figure 3. Composition of PGS and POTW discharges in 2005 (a) and projected composition following compliance with the adopted California cooling water policy (b). Projection assumes that conventional cooling water volume is reduced by 93%, in-plant waste, SONGS discharge, and POTW volumes are unchanged. The projected total volume is 45% less than the 2005 total volume.

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Appendix I. Power generating stations discharging to the SCB in 2005. MW = megawatt, one million watts. MGD = million gallons per day. MCW = metal cleaning waste. LVW = unspecified low-volume waste.

Facility	Operator	Regional Board	NPDES Permit	Electricity Generating Capacity (MW)	Permitted Discharge Flow (MGD)	Monitored Waste Streams	Discharge Location
Alamitos Generating Station	AES California	Los Angeles	CA0001139	1,970	1,273	Combined discharge, sanitary waste, MCW (no discharge), LVW	San Gabriel River
El Segundo Generating Station	NRG Energy	Los Angeles	CA0001147	670	399	Combined discharge, sanitary waste, MCW (no discharge), retention basin	Santa Monica Bay
Encina Power Station	NRG Energy	San Diego	CA0001350	951	857	Combined discharge, MCW (no discharge), LVW	San Diego Coastal
Harbor Generating Station	City of Los Angeles Dept. of Water and Power (DWP)	Los Angeles	CA0000361	227	108	Combined discharge, LVW	Los Angeles Harbor
Haynes Generating Station	City of Los Angeles DWP	Los Angeles	CA0000353	1,606	968	Combined discharge, sanitary waste, reverse osmosis waste, MCW, settling basin	San Gabriel River
Huntington Beach Generating Station	AES California	Santa Ana	CA0001163	880	514	Combined discharge, boiler blowdown, retention basin	Orange County Coastal
Long Beach Generating Station	NRG Energy	Los Angeles	CA0001171	560	265	Combined discharge, oil recovery system (no discharge), retention basin	Long Beach Harbor
Mandalay Generating Station	Reliant Energy, Inc.	Los Angeles	CA0001180	436	253	Combined discharge, MCW (no discharge), LVW	Ventura Coastal
Ormond Beach Generating Station	Reliant Energy, Inc.	Los Angeles	CA0001198	1,612	685	Combined discharge, MCW (no discharge), LVW	Ventura Coastal
Redondo Beach Generating Station	AES California	Los Angeles	CA0001201	1,340	892	Combined discharge, MCW (no discharge), yard drains & dewatering pumps, retention basin	Santa Monica Bay
San Onofre Nuclear Generating Station							
Unit 1 (Decommissioned)	Southern California Edison Company	San Diego	CA0001228	0	37	Combined discharge, sanitary waste, LVM	San Diego Coastal
Unit 2	Southern California Edison Company	San Diego	CA0108073	1,127	1,219	Combined discharge, LVW	San Diego Coastal
Unit 3	Southern California Edison Company	San Diego	CA0108181	1,127	1,219	Combined discharge, LVW	San Diego Coastal
Scattergood Generating Station	City of Los Angeles DWP	Los Angeles	CA0000370	803	495	Combined discharge, cooling tower blowdown, reverse osmosis waste, MCW (no discharge), settling basin	Santa Monica Bay
South Bay Power Plant	Dynegy, Inc.	San Diego	CA0001368	696	601	Combined discharge	San Diego Bay

Appendix II. Estimated mass emissions from power generating station combined discharges by facility in 2005. nd = not detected. "--" = data were not available.

Constituent	Combined Total	Alamitos	El Segundo	Encina	Harbor	Haynes	Huntington Beach	Long Beach	Mandalay	Ormond Beach	Redondo Beach	Scattergood	SONGS	South Bay
Volume (L x 10^9)	7,002.22	490.08	342.48	244.31	70.08	1,070.44	349.91	70.39	297.07	466.28	179.71	407.94	2,805.36	208.18
Suspended Solids (mt)	7,111.08	--	--	1,022.41	397.75	--	4,319.94	--	--	--	--	--	--	1,370.98
Settleable Solids (L x 10^3)	83.82	--	--	--	--	--	--	--	--	--	--	--	83.82	--
Oil/grease (mt)	712.56	--	--	--	25.24	--	181.35	--	--	--	--	--	--	505.98
Residual Chlorine (mt)	288.17	55.24	36.06	nd	8.32	16.35	41.40	5.59	33.02	54.93	10.83	0.07	26.36	nd
BOD (mt)	309.46	--	--	--	309.46	--	--	--	--	--	--	--	--	--
Ammonia-N (mt)	31,169.67	--	91.31	--	nd	--	67.64	0.00	nd	nd	nd	nd	31,010.72	--
Nitrate-N (mt)	100.90	--	nd	--	nd	--	--	nd	0.29	79.27	21.35	nd	--	--
Cyanide (kg)	553.63	88.35	nd	--	63.07	--	nd	402.10	nd	nd	--	--	0.11	--
Arsenic (kg)	179,543.35	734.54	557.01	nd	nd	36,704.68	132.15	265.33	nd	nd	nd	23,795.81	117,353.84	nd
Cadmium (kg)	1,123.63	35.07	10.18	nd	nd	94.32	923.73	3.12	nd	nd	nd	57.20	nd	nd
Chromium (kg)	22,816.23	285.45	229.34	nd	nd	nd	19.98	28.23	2,091.36	1,669.26	1,024.34	286.61	17,181.65	nd
Copper (kg)	64,476.88	2,080.99	525.74	nd	564.87	11,745.76	2,261.28	260.85	3,297.46	nd	1,420.72	4,456.14	37,151.34	711.73
Lead (kg)	6,043.99	354.23	51.65	nd	nd	1,515.32	739.09	35.19	nd	nd	nd	295.79	3,052.73	nd
Mercury (kg)	20.45	17.18	nd	nd	nd	nd	2.93	0.34	nd	nd	nd	nd	nd	nd
Nickel (kg)	86,617.07	445.67	153.48	nd	1,135.35	21,149.89	1,077.90	120.83	nd	nd	nd	6,374.34	56,159.63	--
Selenium (kg)	4,312.52	4.80	15.49	--	nd	--	nd	0.63	nd	nd	nd	4,291.60	nd	--
Silver (kg)	173.77	104.75	nd	--	nd	50.87	16.32	nd	nd	nd	nd	1.84	nd	nd
Zinc (kg)	104,391.09	10,752.64	1,881.48	nd	728.86	28,472.81	9,999.59	1,408.02	7,010.81	2,278.43	6,102.92	25,971.12	9,784.39	nd
Total Phenols (kg)	167,110.13	--	--	--	--	--	--	--	83,179.15	83,930.99	--	--	--	--
Chlorinated Phenols (kg)	nd	--	--	--	--	--	nd	--	--	--	--	--	nd	--
Nonchlorinated Phenols (kg)	nd	--	--	--	--	--	nd	--	--	--	--	--	nd	--
Total DDT (kg)	nd	nd	nd	--	nd	--	nd	nd	nd	nd	--	--	--	--
Total PAH (kg)	2,146.47	45.21	0.17	--	nd	--	156.97	1,944.12	nd	nd	--	--	--	--
Total PCB (kg)	5.06	5.06	nd	--	nd	--	nd	nd	nd	nd	--	--	--	--

Appendix III. Flow-weighted concentrations from power generating station combined discharges by facility in 2005. "<" = all results less than the minimum reporting level. "--" = data were not available.

Constituent	Alamitos	El Segundo	Encina	Harbor	Haynes	Huntington Beach	Long Beach	Mandalay	Ormond Beach	Redondo Beach	Scattergood	SONGS	South Bay
Suspended Solids (ug/L)	--	--	4,184.88	5,675.45	--	12,345.97	--	--	--	--	--	--	6,585.73
Settleable Solids (uL/L)	--	--	--	--	--	--	--	--	--	--	--	0.03	--
Turbidity (NTU)	--	--	1.74	--	--	--	--	--	--	--	--	4.10	--
Oil/grease (ug/L)	--	--	--	360.10	--	518.28	--	--	--	--	--	--	2,430.54
Residual Chlorine (ug/L)	112.71	105.30	<40	118.78	15.27	116.37	79.36	111.17	117.81	60.29	0.17	9.40	<40
BOD (ug/L)	--	--	--	4,415.59	--	--	--	--	--	--	--	--	--
Ammonia-N (ug/L)	--	266.60	--	<0.2	--	193.30	0.06	<0.1	<0.1	<0.1	<0.2	11,054.11	--
Nitrate-N (ug/L)	--	<0.5	--	<0.4	--	--	<0.05	0.97	170.00	118.78	<0.5	--	--
Cyanide (ug/L)	0.18	<0.05	--	0.90	--	<50	5.71	<0.05	<0.05	--	--	<0.01	--
Arsenic (ug/L)	1.50	1.63	<0.5	<29	34.29	0.38	3.77	<10	<10	<10	58.33	41.83	<1.0
Cadmium (ug/L)	0.07	0.03	<0.5	<4.5	0.09	2.64	0.04	<2.0	<2.0	<5.0	0.14	<4.0	<0.5
Chromium (ug/L)	0.58	0.67	<0.5	<6.5	<1.5	0.06	0.40	7.04	3.58	5.70	0.70	6.12	<10
Copper (ug/L)	4.25	1.54	<2.5	8.06	10.97	6.46	3.71	11.10	<5.0	7.91	10.92	13.24	3.42
Lead (ug/L)	0.72	0.15	<2.5	<2.0	1.42	2.11	0.50	<5.0	<5.0	<10	0.73	1.09	<5.0
Mercury (ug/L)	0.04	<0.01	<0.1	<1.0	<0.2	0.01	<0.01	<0.2	<0.2	<0.5	<0.2	<.07	<0.1
Nickel (ug/L)	0.91	0.45	<2.5	16.20	19.76	3.08	1.72	<5.0	<5.0	<5.0	15.63	20.02	--
Selenium (ug/L)	0.01	0.05	--	<9.5	--	<10	0.01	<10	<10	<15	10.52	<26	--
Silver (ug/L)	0.21	<0.01	--	<3.0	0.05	0.05	<0.01	<2.0	<2.0	<5.0	<0.01	<3.0	<1.0
Zinc (ug/L)	21.94	5.49	<10	10.40	26.60	28.58	20.00	23.60	4.89	33.96	63.66	3.49	<20
Total Phenols (ug/L)	--	--	--	--	--	--	--	280.00	180.00	--	--	--	--
Chlorinated Phenols (ug/L)	--	--	--	--	--	<5.0	--	--	--	--	--	<1.0	--
Nonchlorinated Phenols (ug/L)	--	--	--	--	--	<25	--	--	--	--	--	<50	--
Total DDT (ug/L)	<0.005	<0.1	--	<0.15	--	<0.5	<0.005	<0.05	<0.05	--	--	--	--
Total PAH (ug/L)	0.09	<0.01	--	<25	--	0.45	27.62	<5.0	<5.0	--	--	--	--
Total PCB (ug/L)	0.01	<1.0	--	<1.3	--	<0.5	<1.0	<0.5	<0.5	--	--	--	--
Acute Toxicity (TUa)	--	--	0.40	--	--	--	--	--	--	--	--	--	--
Chronic Toxicity (TUc)	0.89	1.00	7.03	3.12	2.63	1.91	1.00	1.00	1.00	1.00	2.85	3.72	2.61

Appendix IV. Estimated mass emissions from power generating station in-plant waste discharges by facility in 2005. nd = not detected. "--" = data were not available.

Constituent	Combined Total	Alamitos	El Segundo	Encina	Harbor	Haynes	Huntington Beach	Long Beach	Mandalay	Ormond Beach	Redondo Beach	Scattergood	SONGS	South Bay
Volume (L x 10^6)	7,530.20	117.43	211.37	63.40	2.33	264.32	27.98	3,038.63	181.36	293.96	2,560.61	246.92	521.88	--
Suspended Solids (mt)	69.14	1.56	3.63	0.06	<0.01	1.74	0.10	48.13	1.58	2.35	6.58	1.14	2.27	--
Settleable Solids (L x 10^3)	3.55	0.35	nd	--	--	nd	--	--	--	--	--	--	3.20	--
Oil/grease (mt)	11.24	0.49	0.43	0.14	<0.01	0.17	0.08	3.03	0.56	1.58	3.60	0.20	0.98	--
BOD (mt)	0.91	0.11	0.01	--	0.01	0.78	--	--	--	--	--	--	--	--
Ammonia-N (mt)	0.05	--	--	0.02	--	--	0.02	--	--	--	--	--	0.01	--
Cyanide (kg)	3.76	--	nd	nd	<0.01	0.40	nd	3.04	nd	nd	nd	0.32	nd	--
Arsenic (kg)	20.67	--	0.23	nd	<0.01	2.05	0.01	17.62	nd	nd	nd	0.76	<0.01	--
Cadmium (kg)	0.28	--	0.02	nd	<0.01	0.03	<0.01	0.22	nd	nd	nd	0.01	nd	--
Chromium (kg)	10.68	nd	0.10	nd	0.01	0.20	<0.01	2.16	nd	3.35	nd	4.81	0.04	--
Copper (kg)	58.55	--	3.22	nd	0.03	1.70	0.60	14.73	0.93	31.16	2.14	3.89	0.14	--
Iron (kg)	12.28	--	--	--	--	12.28	--	--	--	--	--	--	--	--
Lead (kg)	4.26	--	0.03	nd	0.01	0.16	0.08	3.78	nd	nd	nd	0.19	<0.01	--
Mercury (kg)	0.06	--	nd	nd	nd	nd	<0.01	0.06	nd	nd	nd	nd	nd	--
Nickel (kg)	22.74	--	0.42	nd	0.02	0.70	0.18	5.77	nd	13.49	1.17	0.97	0.02	--
Selenium (kg)	0.23	--	0.01	nd	<0.01	0.05	0.11	0.02	nd	nd	nd	0.04	nd	--
Silver (kg)	0.02	--	nd	nd	<0.01	0.01	0.01	nd	nd	nd	nd	nd	nd	--
Zinc (kg)	263.30	--	7.87	nd	1.18	9.67	1.99	124.89	2.73	83.19	6.35	24.63	0.80	--
Total Phenols (kg)	40.81	--	--	--	--	--	--	--	40.81	nd	--	--	--	--
Chlorinated Phenols (kg)	nd	--	--	nd	--	--	nd	--	--	--	--	--	nd	--
Nonchlorinated Phenols (kg)	nd	--	--	nd	--	--	nd	--	--	--	--	--	nd	--
Total DDT (kg)	nd	--	nd	--	nd	nd	nd	nd	nd	nd	nd	nd	--	--
Total PAH (kg)	247.93	--	0.01	--	nd	nd	--	247.92	nd	nd	nd	nd	--	--
Total PCB (kg)	nd	--	nd	--	nd	nd	nd	nd	nd	nd	nd	nd	--	--

Appendix V. Flow-weighted concentrations from power generating station in-plant waste discharges by facility in 2005. "<" = all results less than the minimum reporting level. "--" = data were not available.

Constituent	Alamitos	El Segundo	Encina	Harbor	Haynes	Huntington Beach	Long Beach	Mandalay	Ormond Beach	Redondo Beach	Scattergood	SONGS	South Bay
Suspended Solids (ug/L)	13,256.52	17,184.86	878.33	1,972.77	6,572.67	3,567.43	15,840.47	8,739.00	7,985.00	2,570.77	4,609.24	4,349.75	--
Settleable Solids (uL/L)	3.00	<0.01	--	--	<0.01	--	--	--	--	--	--	6.12	--
Turbidity (NTU)	--	--	--	--	--	--	--	--	--	--	--	0.63	--
Oil/grease (ug/L)	4,202.48	2,024.83	2,129.85	301.58	645.69	2,859.25	998.28	3,070.26	5,358.53	1,404.66	795.38	1,868.68	--
BOD (ug/L)	951.43	26.28	--	4,647.79	2,956.75	--	--	--	--	--	--	--	--
Ammonia-N (ug/L)	--	--	300.00	--	--	836.88	--	--	--	--	--	23.94	--
Cyanide (ug/L)	--	<0.05	<5.0	1.09	1.51	<50	1.00	<50	<50	<0.05	1.28	<20	--
Arsenic (ug/L)	--	1.07	<0.5	0.24	7.77	0.32	5.80	<10	<10	<10	3.08	<0.01	--
Cadmium (ug/L)	--	0.12	<0.5	0.46	0.10	0.07	0.07	<2.0	<2.0	<2.0	0.03	<4.0	--
Chromium (ug/L)	--	0.47	<0.5	3.74	0.75	0.15	0.71	<5.0	11.40	<5.0	19.48	0.07	--
Copper (ug/L)	--	15.24	<2.5	13.12	6.43	21.38	4.85	5.15	106.00	0.84	15.77	0.27	--
Iron (ug/L)	--	--	--	--	46.47	--	--	--	--	--	--	--	--
Lead (ug/L)	--	0.14	<2.5	5.01	0.61	2.94	1.24	<5.0	<5.0	<5.0	0.76	<0.01	--
Mercury (ug/L)	--	<0.01	<0.1	<1.0	<1.0	0.02	0.02	<0.2	<0.2	<0.2	<1.0	<0.7	--
Nickel (ug/L)	--	1.99	<2.5	7.57	2.64	6.60	1.90	<5.0	45.90	0.46	3.93	0.04	--
Selenium (ug/L)	--	0.06	<50	0.23	0.19	3.91	0.01	<10	<10	<10	0.14	<4.0	--
Silver (ug/L)	--	<0.01	<0.5	0.01	0.04	0.18	<0.01	<2.0	<2.0	<2.0	<0.2	<4.0	--
Zinc (ug/L)	--	37.24	<10	504.70	36.60	71.25	41.10	15.05	283.00	2.48	99.76	1.53	--
Total Phenols (ug/L)	--	--	--	--	--	--	--	225.00	<0.1	--	--	--	--
Chlorinated Phenols (ug/L)	--	--	<2.7	--	--	<5.0	--	--	--	--	--	<1.0	--
Nonchlorinated Phenols (ug/L)	--	--	<1.5	--	--	<25	--	--	--	--	--	<50	--
Total DDT (ug/L)	--	<0.1	--	<0.15	<0.15	<0.05	<0.01	<0.05	<0.05	<0.05	<0.17	--	--
Total PAH (ug/L)	--	0.03	--	<25	<25	--	81.59	<5.0	<5.0	<5.0	<26	--	--
Total PCB (ug/L)	--	<1.0	--	<1.3	<1.3	<0.5	<1.0	<0.5	<0.5	<0.5	<1.3	--	--