CLEAN

Central Coast Long-term Environmental Assessment Network

REGIONAL MONITORING PROGRAM

Annual Report 2007–2008

January 31, 2009

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2007–2008 Annual Report

Central Coast Long-term Environmental Assessment Network

Submitted to:

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1.0 Executive Summary

The 2007-2008 Central Coast Long-term Environmental Assessment Network (CCLEAN) annual report incorporates the results from 2007-2008 with historic data. Analyses were performed to determine program areas where efficiencies could be implemented to improve the program and guide management actions to reduce loads of persistent organic pollutants (POPs) being discharged to the ocean. Major findings are as follows:

- Nearshore waters of Monterey Bay continue to be impaired due to PCB concentrations that exceed the Ocean Plan objective for the protection of human health. PCBs in Monterey Bay do not exhibit consistent trends over time. Although there have been samples of nearshore water that have approached or exceeded the Ocean Plan objectives for DDTs and PAHs, there are not consistent patterns of exceedences for these two POPs that would warrant special concern. A minimum of six and a maximum of 60 samples would be required to detect a significant trend in PCB concentrations below the Ocean Plan objective. Some reduction in the variation among samples would be afforded at one site by sampling only in the wet season, but single-season sampling would not reduce variation at the other site.
  Recommendation: Sampling of nearshore waters should continue to document the effects on ocean waters caused by discharges from land, but stakeholders should consider the merits of reducing sampling frequency to annual in the wet season.
- DDT concentrations in sediments at CCLEAN sites have been stable, except for large increases measured at two sites in 2006. All DDT measurements in sediment samples have exceeded the National Oceanic and Atmospheric Administration, Effects Range Low (NOAA ERL; Long et al. 1998; Long et al, 2000), although these DDT concentrations have had no obvious ecological effects. Nevertheless, they are of concern because of the documented distribution of DDTs from Monterey Bay onto the continental shelf and slope (Hartwell, 2008). Continued annual sampling frequency would be able to detect DDT trends below the NOAA ERL in 2 to 10 years.
  Recommendation: No changes should be considered to CCLEAN sediment sampling until several years of data from the revised site configuration have been evaluated and the effects of emerging contaminants of concern that CCLEAN has just begun to measure have been examined.
- Mussels along the shore of Monterey Bay contain high concentrations of POPs, primarily Dieldrin. Dieldrin concentrations exceeding the California Office of Environmental Health Hazard Assessment (OEHHA) human health alert level have been frequently measured at two locations. These high Dieldrin concentrations constitute an impairment of the shellfish collection beneficial use and are a potential risk to humans and wildlife that consume mussels. Five to 19 years would be required to detect a significant decline

in Dieldrin concentrations below the OEHHA alert level at the current annual wet-season sampling frequency.

Recommendation: Mussel sampling should continue unchanged.

- There have been no bacterial impairments to the water contact recreation beneficial use associated with discharges from any of the CCLEAN wastewater treatment plants. No exceedences of Ocean Plan objectives were noted at any near-discharge sampling sites and additional analyses suggest these differences were due to discharges from the Salinas and Pajaro rivers. Wastewater discharges were not correlated with receiving water bacteria concentrations at any discharge, although nearby rivers and local rainfall were correlated with receiving water bacteria concentrations.

  Recommendation: Given the absence of wastewater effects on receiving-water bacteria concentrations and the apparent effects of nearby rivers, CCLEAN stakeholders should consider elimination of this monitoring requirement in favor of other work that would be valuable to them, such as targeted studies to determine the vertebrate sources of bacteria measured in receiving waters.
- Each of the rivers exhibited unique characteristics in concentrations of some POPs. Patterns of POP concentrations in the San Lorenzo River were indicative of consistent inputs that increased in response to rainfall. Both the Pajaro and Salinas rivers exhibited large unexplained fluctuations in POPs, especially legacy agricultural contaminants, suggesting large episodic releases of POPs in their watersheds that were not clearly associated with rainfall or river flow rate. These results demonstrate that high loads of POPs from the rivers are not due exclusively to high discharge volumes. High POP concentrations, without high rainfall or river flows, can also account for high loads of POPs entering the ocean.

  Recommendation: Greater vigilance is needed to determine whether episodic discharges of POPs are resulting from human activities. Stakeholders, including resource management and water quality regulatory agencies and the Monterey Bay National Marine Sanctuary should seek funding to reinstate the wet-season and dry-season sampling of POP discharges from major rivers to document the results of ongoing efforts in agricultural and other types of land use to implement best management practices and low-impact development.
- Concentrations of most POPs in wastewater remain lower than those previously measured in rivers and exceedences of a maximum permitted effluent limit has been very rare. Each of the wastewater discharges displayed unique patterns of POP concentrations. Each wastewater discharge exhibited large differences among samples for several POPs, suggesting there are factors other than discharge volume and rainfall that are causing the observed variation. Some results suggest infiltration into the sewage collection system as sources of POPs. Cases of higher POP concentrations in wet-season samples than in dry-season samples and positive correlations with wastewater discharge volume, in the absence of correlations with rainfall, could indicate differences in removal efficiency at higher rates of throughput in those treatment plants. Concentrations and homologue composition of polybrominated biphenyl ethers (PBDEs) in CCLEAN wastewater discharges have varied over the two years they have been measured but each wastewater discharge differs from the others. Concentrations of PBDEs in mussels have not decreased in the past two years.

Recommendation: Wastewater monitoring should continue as it is currently conducted. Analysis of dioxins/furans and perfluorinated compounds began in October 2008 and several years of data for those contaminants should be evaluated before considering revisions to wastewater sampling.

2.0 Program Background

The complexity of environmental issues affecting nearshore marine waters today have led to general agreement that their protection is only possible by implementing regional approaches to monitoring and resource management. Nearshore marine waters are affected by point-source discharges, storm runoff, rivers, discharges from ships, and aerial deposition. At the same time, many marine resources are diminishing under pressure from increasing usage. In the late 1990s, multiple agencies in the Monterey Bay area began working toward implementation of a regional approach to monitoring watersheds and marine waters.

CCLEAN is a long-term monitoring program that has been designed by program participants through a commitment to environmental stewardship in order to fulfill several regulatory objectives. CCLEAN is currently funded by the City of Santa Cruz, the City of Watsonville, Dynegy, Moss Landing, Monterey Regional Water Pollution Control Agency (MRWPCA), and Carmel Area Wastewater District (CAWD), under the direction of the California Regional Water Quality Control Board, Central Coast Region (Water Board). CCLEAN fulfills a significant component of the subscribing agencies' compliance to their NPDES monitoring commitments, with an emphasis on receiving water monitoring. In addition, it represents a significant portion of their contributions to their communities' efforts at sustainability of their coastal environments. However, CCLEAN is also the current mechanism by which the Water Board fulfills part of its obligations under a monitoring framework developed to provide an ecosystem-based Water Quality Protection Program for the Monterey Bay National Marine Sanctuary. The monitoring framework evolved to fulfill the Water Board's obligations to the Management Plan for the Sanctuary. The Sanctuary's Management Plan includes a Memorandum of Agreement among eight federal, state, and regional agencies (including the Central Coast Regional Water Quality Control Board). The Water Board's framework for partial fulfillment of this Water Quality Protection Program is the Central Coast Ambient Monitoring Program (CCAMP). This multidisciplinary program includes sampling in watersheds that flow into coastal regions, in estuarine coastal confluences, and at coastal sites. The goal of CCAMP is to "collect, assess, and disseminate scientifically based water quality information to aid decision-makers and the public in maintaining, restoring, and enhancing water quality and associated beneficial uses." CCLEAN provides the initial nearshore component of CCAMP. CCLEAN has been underway since 2001 and its Quality Assurance Project Plan (QAPP) is being revised to incorporate recent program changes, and to retain consistency with the Water Board surface water ambient monitoring program (SWAMP) requirements for data compatibility.

Within the framework of CCAMP, the goal of the CCLEAN program is to assist stakeholders in maintaining, restoring, and enhancing nearshore water and sediment quality to support associated beneficial uses in the Central Coast Region, including recreation, wildlife habitat and biological communities. The program's objective is to use high-quality data to address the following questions and objectives:

- What are the major sources of contaminants to nearshore waters?
- What are the effects of wastewater discharges in nearshore waters?
- Do nearshore waters and sediments comply with California Ocean Plan?
- What are the status and long-term trends in the quality of nearshore waters, sediments, and associated beneficial uses?
- Develop a long-term database on trends in the quality of nearshore waters, sediments and associated beneficial uses.
- Ensure that the database is compatible with other regional monitoring efforts and regulatory requirements.
- Ensure that data are presented in ways that are understandable and relevant to the needs of stakeholders.

To answer these questions, CCLEAN uses various graphical and statistical approaches, as well as comparisons of data with numeric and narrative objectives, guidelines and alert levels from the California Ocean Plan (State Water Resources Control Board, 2005), Central Coast Basin Plan (RWQCB, 1997), California State Mussel Watch Program (California State Mussel Watch Program, 2003), California Office of Environmental Health Hazard Assessment (Office of Environmental Health Hazard Assessment, 2003), and the National Oceanic and Atmospheric Administration (Long, Field & MacDonald, 1998; Long et al., 2000).

3.0 Report Organization and Scope

This document incorporates the results from 2007-2008 in focused examinations designed to improve the efficiency of the CCLEAN program and guide management actions to reduce loads of persistent organic pollutants (POPs) being discharged to the ocean. Graphical and statistical presentations emphasize seven POP groups that have been associated with beneficial use impairments in previous CCLEAN reports (Table 1). Results are organized according the major program objectives listed in Section 2.

Program monitoring activities during 2007-2008 (program year = July 1, 2007 – June 30, 2008) and their relationship to program objectives are shown in Table 2. Sampling sites are shown in Figure 1 and the dates of sampling are shown in Table 3. All sampling methods have been described in previous CCLEAN reports (CCLEAN, 2007). Sediment sampling is normally conducted annually, but it was suspended in 2007-2008 to enable a detailed analysis of historic CCLEAN sediment data collected between October 2001 and October 2006. Sediment sampling resumed in October 2008 at the sites indicated in Figure 1.

Table 1. POP groups emphasized in this report.

POP Group	Names of Compounds Included
Lo-weight PAHs	Biphenyl, Naphthalene, 1-methylnapthalene, 2-methylnapthalene, 2,6-dimethylnapthalene, 2,3,5-trimethylnapthalene, Acenaphthene, Acenaphthylene, Anthracene, Dibenzothiophene, Fluorene, Phenanthrene, 1-methylphenanthrene
Hi-weight PAHs	Benz(a)anthracene, Chrysene, Fluoranthene, Pyrene, Benzo(a)pyrene, Benzo(e)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Dibenz(a,h)anthracene, Perylene, Benzo(ghi)perylene, Indeno(1,2,3-cd)pyrene
DDTs	o,p'-DDT, p,p'-DDT = (1,1,1-trichloro-2,2-bis(*p*-chlorophenyl)ethane) o,p'-DDD, p,p'-DDD = (1,1-dichloro-2,2-bis(*p*-chlorophenyl)ethane) o,p'-DDE, p,p'-DDE = (1,1-dichloro-2,2-bis(*p*-chlorophenyl)ethylene)
Dieldrin	1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4α,5,6,7,8,8α-octahydro-1,4-endo,exo-5,8-dimethanonaphthalene
Chlordanes	trans-Chlordane, cis-Chlordane, trans-Nonachlor, cis-Nonachlor, Oxychlordane, Heptachlor, Heptachlor epoxide
PCBs	Polychlorinated biphenyl congener numbers = 5, 8, 18, 20, 21, 28, 31, 33, 43, 44, 49, 52, 56, 60, 61, 66, 70, 73, 74, 76, 80, 86, 87, 89, 90, 93, 95, 97, 99, 101, 105, 106, 110, 111, 115, 116, 117, 118, 127, 128, 132, 138, 139, 141, 149, 151, 153, 156, 158, 160, 163, 164, 168, 170, 174, 177, 180, 181, 182, 183, 187, 190, 194, 195, 196, 201, 203
PBDEs	Polybrominated diphenyl ether congener numbers: 7, 8, 10, 11, 12, 13, 15, 17, 25, 28, 30, 32, 33, 35, 37, 47, 49, 51, 66, 71, 75, 77, 79, 85, 99, 100, 105, 116, 119, 120, 126, 128, 138, 140, 153, 154, 155, 166, 181, 183, 190, 203, 206, 207, 208, 209

Table 2. Sampling sites, parameters sampled, frequency of sampling, applicable water-quality stressors, and relevant program objectives for CCLEAN during the 2007–2008 program period.

Sampling Sites	Parameters Sampled at Each Site	Frequency of Sampling	Applicable Water-quality Stressors and Program Objectives
Water Sampling Four wastewater discharges (Santa Cruz, Watsonville, MRWPCA, CAWD) in effluent and two rivers (San Lorenzo, Pajaro)	30-day flow proportioned samples using automated pumping equipment, solid-phase-extraction techniques for persistent organic pollutants (POPs).	Twice per year (wet season and dry season)	Sources, loads, trends, effects and permit compliance for: POPs
	Grabs of effluent for ammonia and nitrate, turbidity, temperature, conductivity, pH, urea, orthophosphate, dissolved silica and total suspended solids	Monthly	Sources, loads, trends and permit compliance for: Nutrients
	Evaluate satellite imagery for algal blooms	Periodically	Effects of: Nutrients
30-ft contour sites for Santa Cruz, Watsonville and MRWPCA	Grabs for total and fecal coliform, *enterococcus*	At least monthly	Sources, trends, effects and permit compliance for: Pathogen indicators
Two nearshore background sites	30-day time-integrated samples using automated pumping equipment and solid-phase-extraction techniques for: POPs, nitrate, ammonia, urea, orthophosphate and dissolved silica, total suspended solids, temperature, conductivity, pH, total and fecal coliform, *enterococcus*	Twice per year (wet season and dry season)	California Ocean Plan compliance for: POPs Nutrients Pathogen indicators
Mussel Sampling Five rocky intertidal sites	One composite of 30-40 mussels for POPs, total and fecal coliform, and *enterococcus*	Annually in the wet season	Status, trends, effects and alert level comparisons for: POPs Pathogen indicators

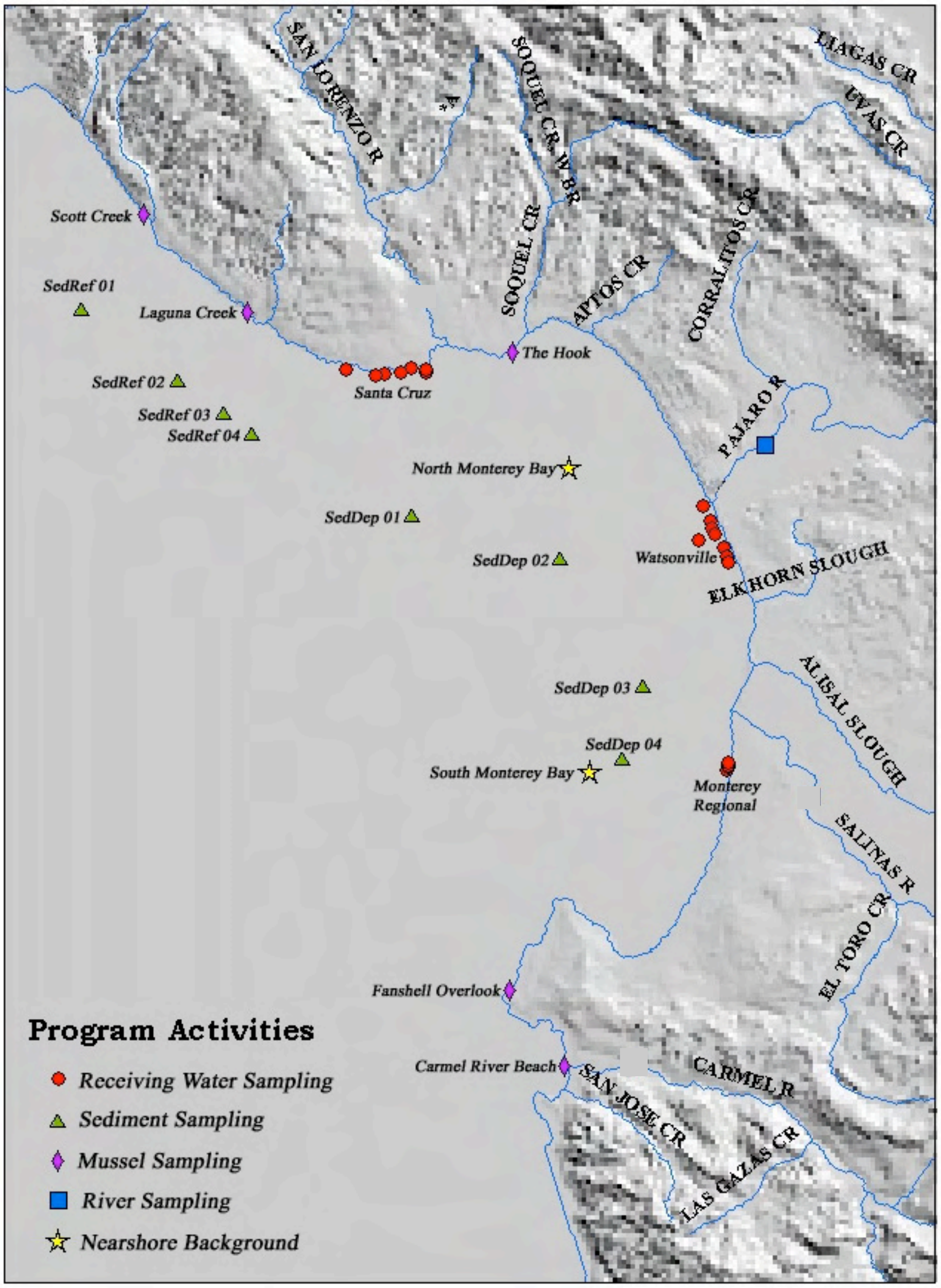

Figure 1. Locations of CCLEAN sampling sites for receiving water, sediment, mussels, and rivers.

Table 3. Dates, volumes and numbers of samples collected for CCLEAN in 2007–2008.

Matrix & Season	Site	Start Date	Ending Date	
Effluent				Number of Liters
Dry	Santa Cruz	August 30, 2007	October 4, 2007	204
	Watsonville	August 30, 2007	October 4, 2007	226
	MRWPCA	August 31, 2007	October 4, 2007	240
	CAWD	August 31, 2007	October 4, 2007	216
Wet	Santa Cruz	February 11, 2008	March 19, 2008	200
	Watsonville	February 11, 2008	March 14, 2008	203
	MRWPCA	February 12, 2008	March 14, 2008	203
	CAWD	February 11, 2008	March 14, 2008	226
River Sampling				Number of Liters
Dry	San Lorenzo River	August 30, 2007	October 5, 2007	438
	Pajaro River	August 30, 2007	October 5, 2007	252
Wet	San Lorenzo River	February 14, 2008	March 19, 2008	259
	Pajaro River	February 15, 2008	March 13, 2008	545
Nearshore Sampling				Number of Liters
Dry	North	August 29, 2007	October 8, 2007	200
	South	August 29, 2007	October 8, 2007	200
Wet	North	February 15, 2008	March 18, 2008	200
	South	February 15, 2008	March 18, 2008	200
Mussel Sampling				Mussels for POPs/Bacteria
	Scott Creek		March 4, 2008	47/30
	Laguna Creek		March 4, 2008	49/30
	The Hook		March 4, 2008	44/30
	Fanshell Overlook		March 4, 2008	45/30
	Monterey Creek		March 4, 2008	45/30
	Carmel River Beach		March 4, 2008	45/30

4.0 Results for Program Objectives

4.1 What are the status and long-term trends in the quality of nearshore waters, sediments, and associated beneficial uses?

Several elements of the CCLEAN program provide data that enable assessment of both the status and trends in the quality of nearshore waters, sediments and associated beneficial uses (see Table 1). These include sampling of nearshore waters for POPs, nutrients and bacteria; sediments for POPs and benthic infauna; and mussels for POPs and bacteria. Analysis of status involves comparisons with the objectives, guidelines and alert levels described in Section 2. Describing status also documents compliance with the Ocean Plan and other applicable regulatory guidelines, which can also indicate contaminant effects. Analysis of trends involves statistical tests to determine whether measured parameters are changing over time. The characteristics of the trend data can also be examined to determine how many samples are required to detect a specified amount of change.

The analyses in this section are focused on particular contaminants that previously have been associated in CCLEAN reports either with a status that indicated impairment to beneficial uses or were very close to an impairment. These include the following:

- PCBs, PAHs and DDTs in nearshore waters (i.e., exceeded 30-day average in California Ocean Plan [Ocean Plan])
- DDTs in sediments (i.e., exceeded NOAA ERL)
- Dieldrin in mussels (i.e., exceeded California Office of Environmental Health Hazard Assessment [OEHHA] human health alert level).

All of these impairments were discussed in CCLEAN (2007a). In addition to these previously noted impairments to beneficial uses, this consideration of status and trends also includes analysis of bacteria monitoring in ocean waters by each wastewater treatment plant. The following sections discuss the current status and trends of these contaminants in the associated matrices.

4.1.1 Status and Trends of PCBs, PAHs and DDTs in Nearshore Waters

Nearshore waters in Monterey Bay frequently exceed the Ocean Plan objective for 30-day average concentrations of PCBs. (Figure 2). The majority of samples from both sites have exceeded the Ocean Plan objective, with some samples exceeding this objective by up to 80%. There have been no consistent differences between sites or between wet-season and dry-season samples.

With the exception of the March 2006 sample from the northern Monterey Bay site, PAHs have been below the Ocean Plan objective for the protection of human health (Figure 3). Both sites exhibited relatively high concentrations of PAHs in March 2006, but displayed no substantial differences between sites or between wet-season and dry-season samples.

After the first sample from the northern Monterey Bay site equaled the Ocean Plan objective for DDTs, none of the samples collected since then have been close (Figure 4). There have been generally similar concentrations between sites, with wet-season samples usually exhibiting higher DDT concentrations than corresponding dry-season samples.

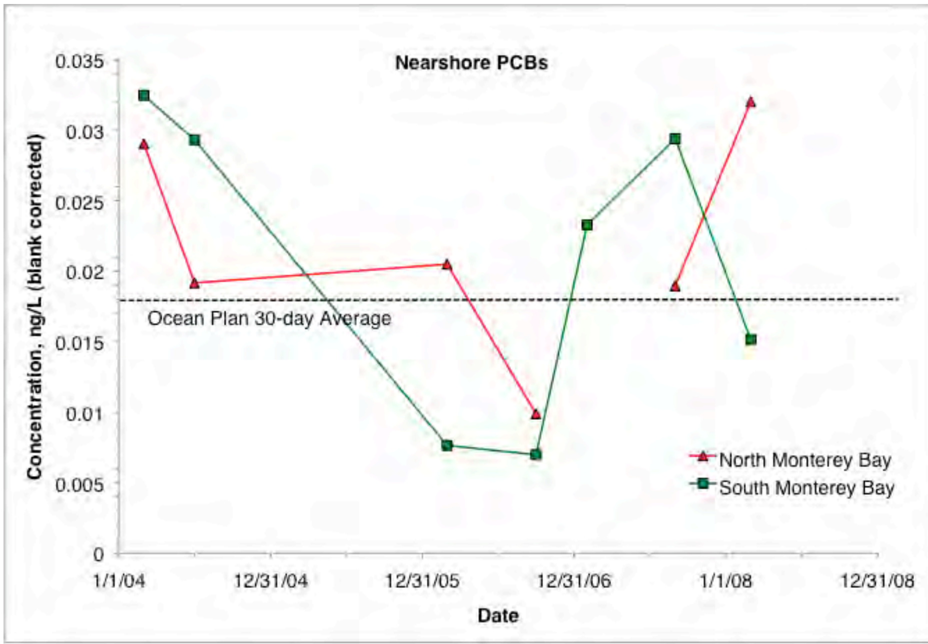

Figure 2. Concentrations of PCBs in nearshore waters at two CCLEAN sites in Monterey Bay. Concentrations of Ocean Plan PCBs have been blank corrected (concentrations in lab blanks subtracted).

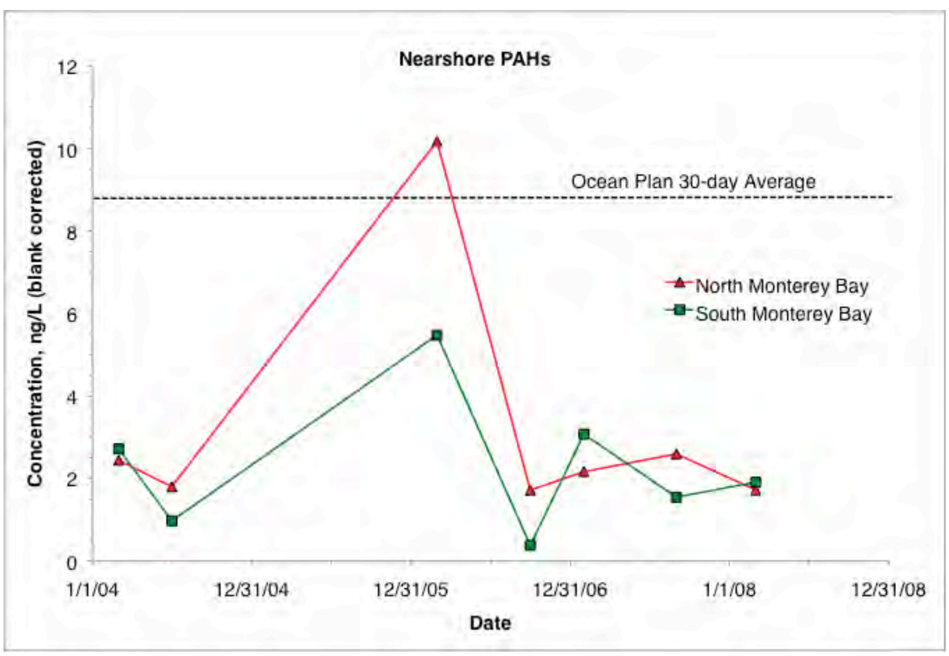

Figure 3. Concentrations of Ocean Plan PAHs in nearshore waters at two CCLEAN sites in Monterey Bay.

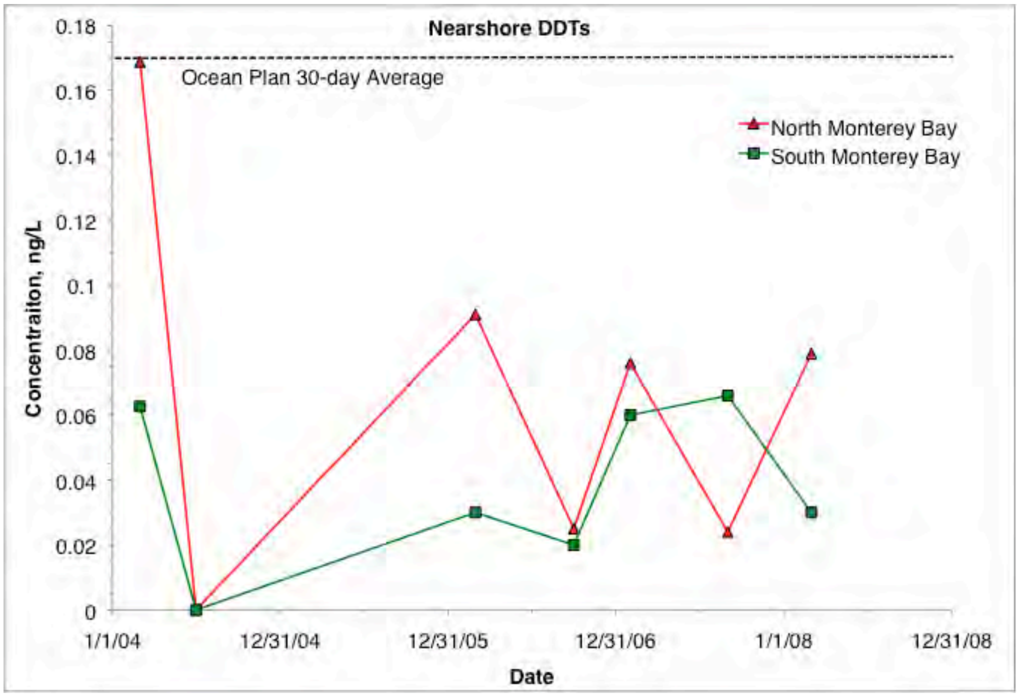

Figure 4. Concentrations of DDTs in nearshore waters at two CCLEAN sites in Monterey Bay.

Statistical analyses revealed that none of these POPs had any significant upward or downward trends over the fours years of sampling in nearshore waters. Nevertheless, given the more consistent exceedences of the Ocean Plan detected for PCBs, additional analyses were done to determine how many samples would be needed to detect a statistically significant decline below the Ocean Plan objective.

The ability to detect a trend is limited by the amount of variation among the samples in which the trend is to be detected. Such trend detection is important because it allows us to efficiently collect observations to determine whether a particular impairment is getting better or worse. For example, if management actions have been effective at reducing the observed impairment. Using a simple formula that includes variation among samples and the potential number of samples analyzed (Gerrodette, 1987), it is possible to estimate the number of samples required to detect a specified amount of change (i.e., a significant trend with a specific amount of increase or decrease). It is often possible to reduce the amount of variation among samples by using only those from a common season, especially if there are seasonal patterns.

The trend analysis assumes that changes are linear, but it makes no assumptions about the time interval between samples. This means the samples needed to achieve a required amount of change can be spaced over time according to available funds, regulatory imperatives or other stakeholder considerations.

In order the estimate the number of samples needed to detect a significant decline in PCBs below the Ocean Plan objective, data from both CCLEAN nearshore sites were analyzed from both seasons, as well as from just the wet season. The results show that for the southern Monterey Bay site, no reduction in variation is achieved through analysis of just wet-season samples, but analysis of just wet-season samples from the northern Monterey Bay site does reduce the variation among samples.

Regardless of whether samples from just the wet season or samples from both seasons are analyzed, it will take several years to detect a significant decline in PCBs below the Ocean Plan objective (Figure 5). Overall average PCB concentrations from the southern Monterey Bay site and the northern Monterey Bay site were 13% and 17% greater than the Ocean Plan objective, respectively. For just wet-season samples, average concentrations at these two sites were 8% and 34% above the Ocean Plan objective, respectively. If samples were collected only in the wet season, it would take at least six years to detect a decline below the Ocean Plan objective at the northern Monterey Bay site (red line in Figure 5). If both wet-season and dry-season samples were collected, it would take at least 22 samples (i.e., 11 years) and 60 samples (i.e., 30 years) to detect significant changes at the northern Monterey Bay and southern Monterey Bay sites (black and green dashed lines), respectively. Consequently, scaling back to annual wet-season sampling might actually reduce the length of time needed to detect a significant change at the northern Monterey Bay site, but would not affect the amount of time needed to detect a significant change at the southern Monterey Bay site.

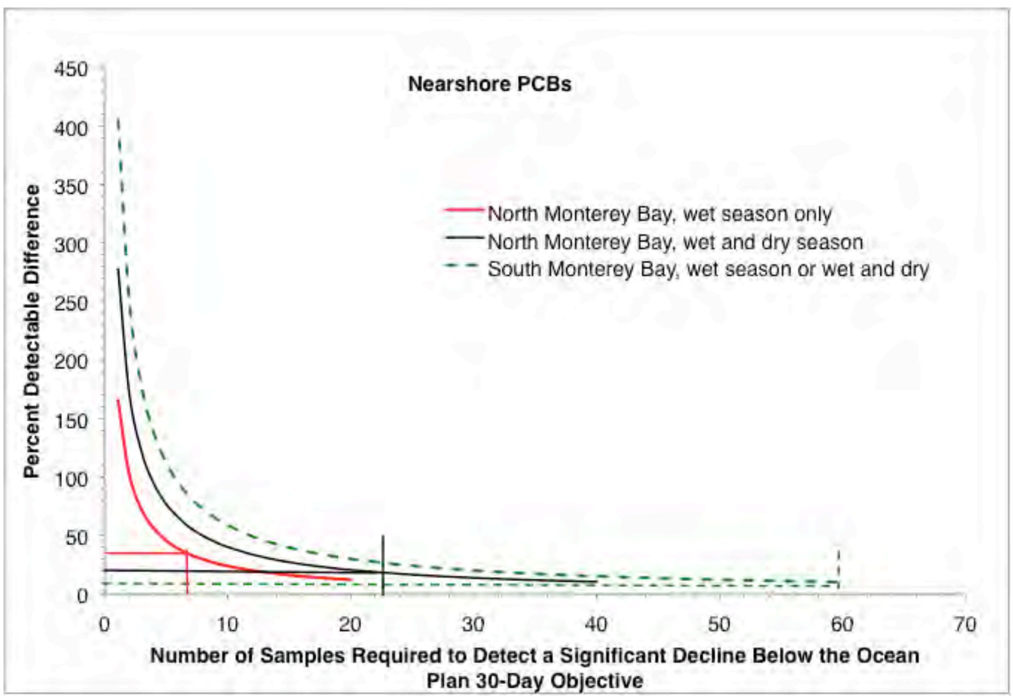

Figure 5. The numbers of samples required to detect a significant decline below the Ocean Plan objective for PCBs at two CCLEAN nearshore sites under two sampling strategies (i.e., sampling in both wet season and dry season and sampling in just the wet season).

4.1.1.2 Conclusions

Nearshore waters of Monterey Bay continue to be impaired due to PCB concentrations that exceed the Ocean Plan objective for the protection of human health. PCBs in Monterey Bay do not exhibit consistent trends over time. Although there have been samples of nearshore water that have approached or exceeded the Ocean Plan objectives for DDTs and PAHs, there are not consistent patterns of exceedences for these two POPs that would warrant special concern.

Statistical analyses indicated a minimum of six and a maximum of 60 samples would be required to detect a significant trend in PCBs concentrations below the Ocean Plan objective. Some reduction in the variation among samples would be afforded at one site by sampling only in the wet season, but single-season sampling would not reduce variation at the other site.

4.1.1.3. Recommendations

Sampling of nearshore waters should continue in order to document the effects on ocean waters caused by discharges from land. Nevertheless, stakeholders should consider the merits of reducing sampling frequency to annual in the wet season. Such a program revision could provide funds for other program elements prioritized by participants that might address other issues, such as work needed to inform implementation of management actions to reduce contaminant effects.

4.1.2 Status, Trends and Effects of DDTs in Sediments

DDTs in sediments at all eight CCLEAN stations consistently exceeded the concentration above which 10% of samples nationwide exhibited toxicity in 1,513 laboratory bioassays in an analysis conducted by the National Oceanic and Atmospheric Administration (Long et al., 2000). Although this alert level has been consistently exceeded in CCLEAN sediment samples, no ecological effects have been associated with high DDT concentrations in CCLEAN samples. DDT concentrations were similar among CCLEAN sites and did not vary substantially among years, except for very high unexplained concentrations measured at sites SedRef 02 and SedDep 01 in 2006 (Figure 6). These two sites are the two historic CCLEAN sediment sites that have been retained in the redesigned sediment sampling element of the program.

Because sites SedRef 02 and SedDep 01 have been retained in the revised CCLEAN sediment sampling program, their historic data provide a basis for estimating the number of samples required to detect a decline below the NOAA ERL. This analysis examined the data under two scenarios: 1) variation among samples based on data from 2001–2005 and 2) variation among samples based on data from 2001–2006. While elimination of 2006 from the analyses reduced the variation among samples, the amount of reduction from the average DDT concentrations needed to get below the NOAA ERL was marginally diminished from 83% to 78% for SedRef 02 and from 80% to 73% for SedDep 01. In both scenarios, the amount of decline assumed in the analysis was set to 80%.

The number of samples required to detect a decline below the NOAA ERL for DDTs in sediments ranged from 2 to 10, depending on the scenario (Figure 7). If the variation among samples is more accurately indicated by the period 2001–2005, it would take two and three samples to detect a significant decline at SedRef 02 and SedDep 01, respectively. If the high DDT concentrations measured in 2006 reflect the true variation among samples, it will take 10 samples to detect a significant decline at both sites. At the current annual sampling frequency, these numbers of samples equal the number of years to detect trends.

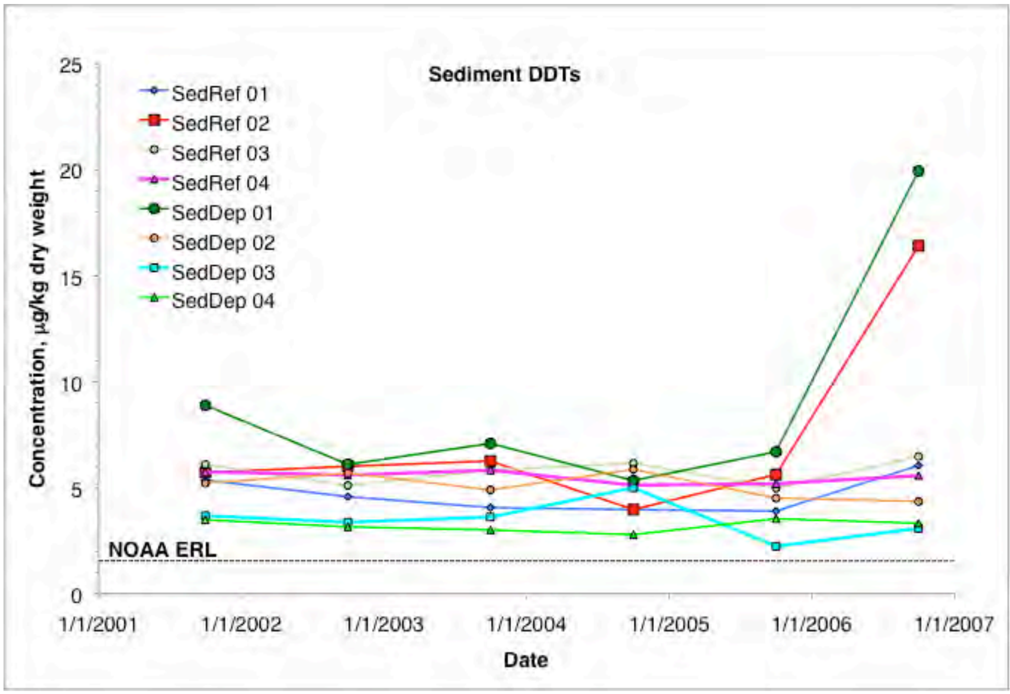

Figure 6. DDTs measured in sediments from eight CCLEAN sites in Monterey Bay.

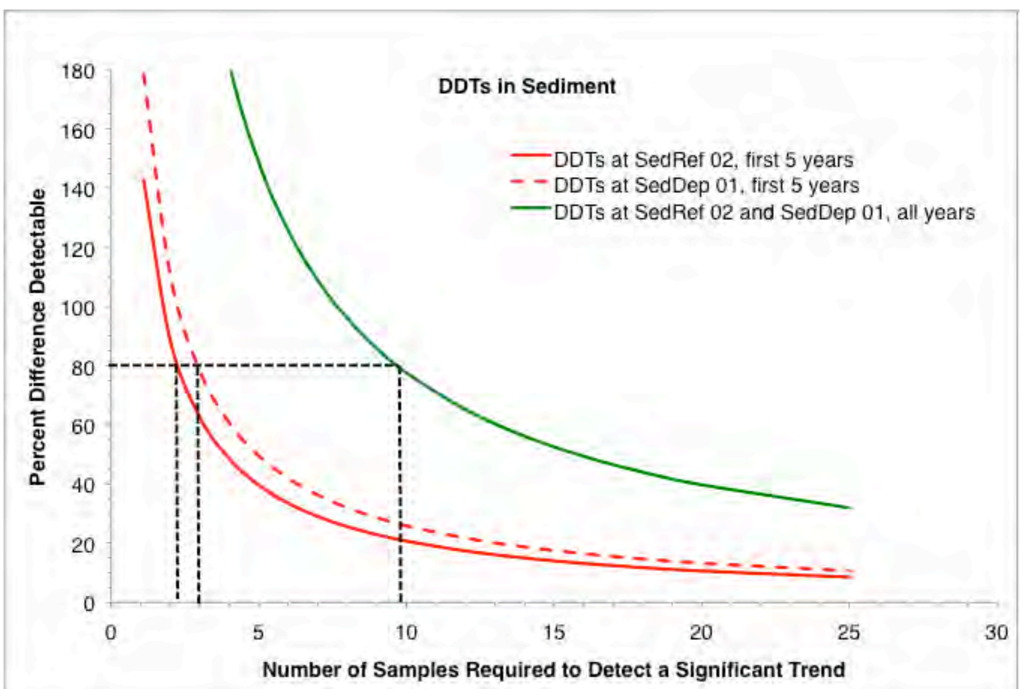

Figure 7. The numbers of samples required to detect a significant decline below the NOAA ERL for DDTs at two CCLEAN sediment sites under two scenarios (i.e., variation based on analysis of data from 2001–2005 and analysis of data from 2001–2006).

4.1.2.1 Conclusions
DDT concentrations in sediments at CCLEAN sites have been stable, except for large increases measured at two sites 2006. All DDT measurements in CCLEAN samples have exceeded the NOAA ERL. Although these DDT concentrations have had no obvious ecological effects, they are of concern and require continued measurement because of the documented distribution of DDTs from Monterey Bay onto the continental shelf and slope (Hartwell, 2008). Continued annual sampling frequency would be able to detect DDT trends below the NOAA ERL in 2 to 10 years.

4.1.2.2 Recommendations
No changes should be considered to CCLEAN sediment sampling until several years of data from the revised site configuration have been evaluated. Moreover, the program should be maintained in its current form because there are other emerging contaminants of concern that CCLEAN has just begun to measure, whose effects on benthic communities have not previously been examined.

4.1.3 Status and Trends of Dieldrin in Mussels
The OEHHA human health alert level for Dieldrin has consistently been exceeded in mussels from The Hook, with frequent exceedences also occurring at Laguna Creek (Figure 8). The March 2006 sample from Fanshell Overlook also exceeded the OEHHA alert level, coincident with high levels measured at Laguna Creek and The Hook. Previous analyses have shown that concentrations of Dieldrin and other POPs in mussels are correlated with rainfall and river discharges and that the trends in mussel POP concentrations are not declining (CCLEAN, 2007; Hardin et al., 2007). Consequently, impairments to mussels due to Dieldrin continue with no apparent improvement.

The average concentrations of Dieldrin in mussels at The Hook and Laguna Creek would need to decline by 35% and 23%, respectively, to indicate elimination of the impairment at these sites. If future management actions reduce the Dieldrin impairment of mussels, five to 19 samples will be required to document the trend (Figure 9), or five to 19 years at the current annual sampling frequency.

4.1.3.1 Conclusions
Mussels along the chore of Monterey Bay contain high concentrations of POPs, primarily Dieldrin. Dieldrin concentrations exceeding the OEHHA human health alert level are frequently measured at two locations. These high Dieldrin concentrations constitute an impairment of the shellfish collection beneficial use and are a potential risk to humans and wildlife that consume mussels. Five to 19 years would be required to detect a significant decline in Dieldrin concentrations below the OEHHA alert level at the current annual wet-season sampling frequency.

4.1.3.2 Recommendations
Mussel sampling should continue unchanged. The mussel data collected have been very valuable in documenting impairments of beneficial uses, as well as supporting assessments of contaminant sources.

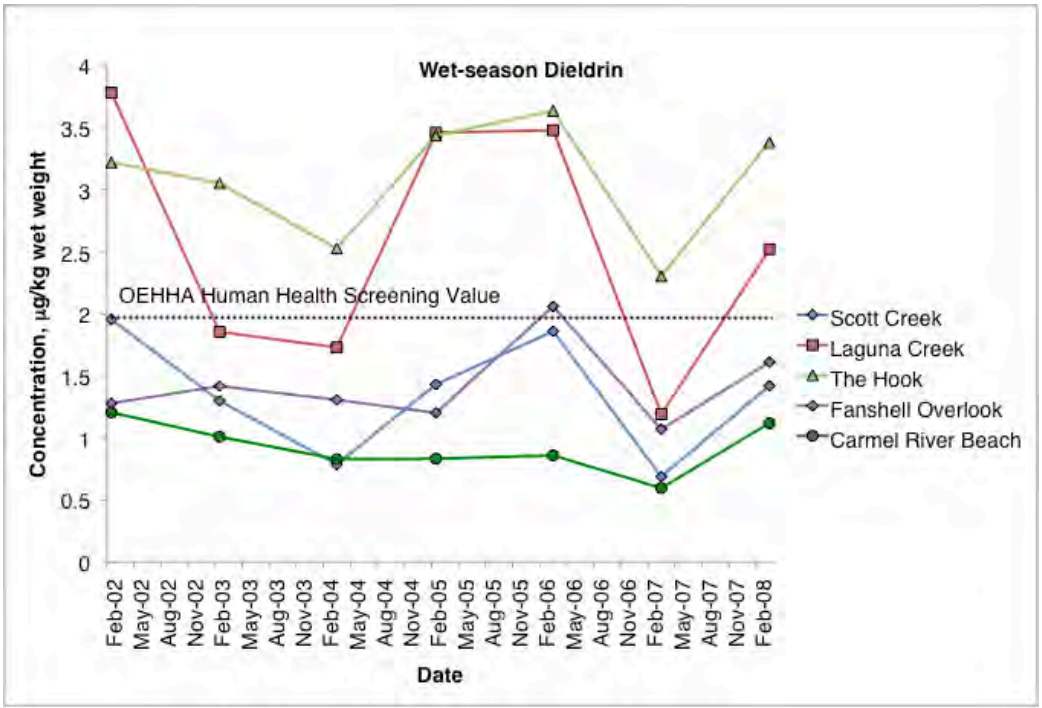

Figure 8. Dieldrin measured in mussels from five CCLEAN sites in the Monterey Bay area.

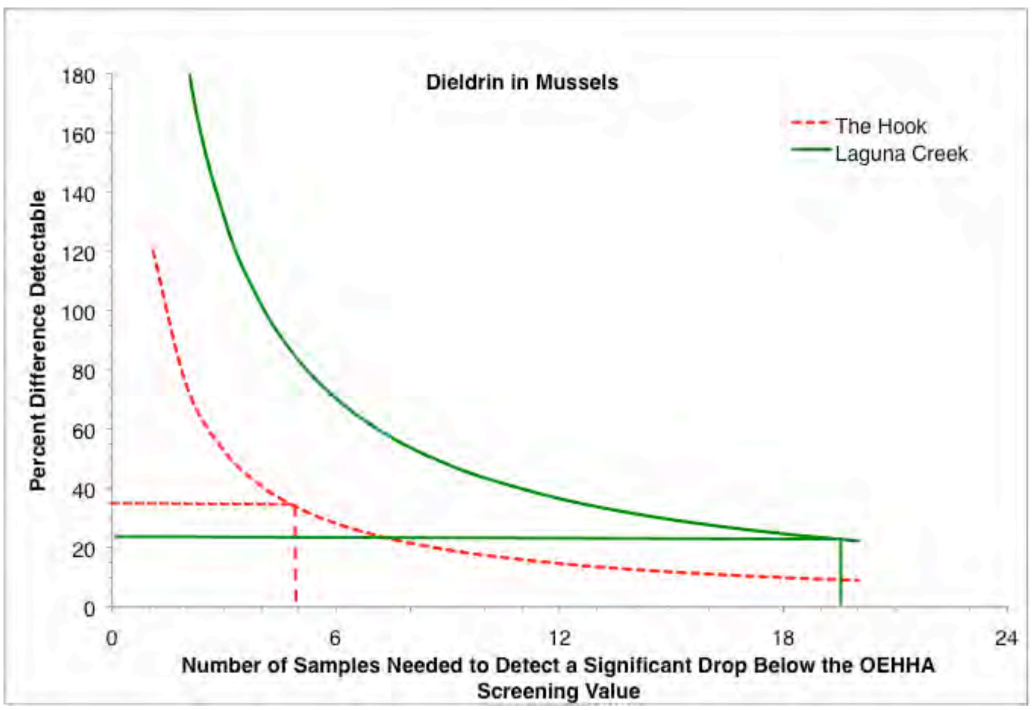

Figure 9. The numbers of samples required to detect a significant decline below the OEHHA human health alert level for Dieldrin at two CCLEAN sediment sites.

4.1.4 Status, Trends and Effects of Bacteria in Receiving Waters

The Ocean Plan limits the bacterial concentrations in ocean waters designated for use in water-contact recreation. These objectives are as follow:

30-day Geometric Mean:
i. Total coliform density shall not exceed 1,000 per 100 ml;
ii. Fecal coliform density shall not exceed 200 per 100 ml; and
iii. Enterococcus density shall not exceed 35 per 100ml.
Single Sample Maximum:
i. Total coliform density shall not exceed 10,000 per 100 ml;
ii. Fecal coliform density shall not exceed 400 per 100ml;
iii. Enterococcus density shall not exceed 104 per 100 ml; and
iv. Total coliform density shall not exceed 1,000 per 100 ml when the fecal coliform/total coliform ratio exceeds 0.1.

Receiving water data collected by the City of Santa Cruz, City of Watsonville MRWPCA from July 2001 through June 2008 were compared with these objectives to assess the status of ocean waters for water contact recreation and the potential effects of wastewater on bacterial concentrations. CAWD is required to sample receiving water bacteria only if the total coliform concentration in their wastewater exceeds 2,400 MPN/100ml three or more times in a 30-day period, which has not occurred during the existence of the CCLEAN program. Because only Santa Cruz samples bacteria in receiving waters more than once per month, with that being in effect only since July 2005, 30-day geometric means could not be calculated for most data and geometric means were, instead, calculated over the entire period of CCLEAN sampling, from July 2001 through June 2008.

There are no indications that the wastewater discharges are causing impairments to water contact recreation due to bacterial concentrations. Only the Ocean Plan *Enterococcus* single sample objective for water contact recreation was exceeded at the far-field receiving water monitoring station adjacent to the MRWPCA discharge (Table 4). This sample location has the potential to be effected by the Salinas River discharge. Moreover, in all cases except Watsonville and for the single sample objective for *Enterococcus* at Santa Cruz, the sites nearest the discharges had lower values than the sites farther from the discharges.

There also are no temporal trends in bacteria concentrations near the CCLEAN wastewater discharges. Bacteria concentrations near each discharge tended to be greatest during the winter and spring months and lower in the summer and fall months (Figure 10, Figure 11 and Figure 12). Statistical analysis of bacteria concentrations relative to time found no significant trends.

In addition to comparing bacteria data with Ocean Plan objectives, several statistical procedures were used to evaluate the possible effects of wastewater discharges on bacterial concentrations in the ocean. First, paired t-tests were performed to see if there were significant differences in bacteria concentrations between the station nearest to and a station farther from each respective wastewater discharge. It should be noted that the receiving water monitoring sites for the City of Santa Cruz are not located in relation to the wastewater discharge, but are situated along the shore to reflect actual bacterial exposures by swimmers and surfers, so these statistical tests may

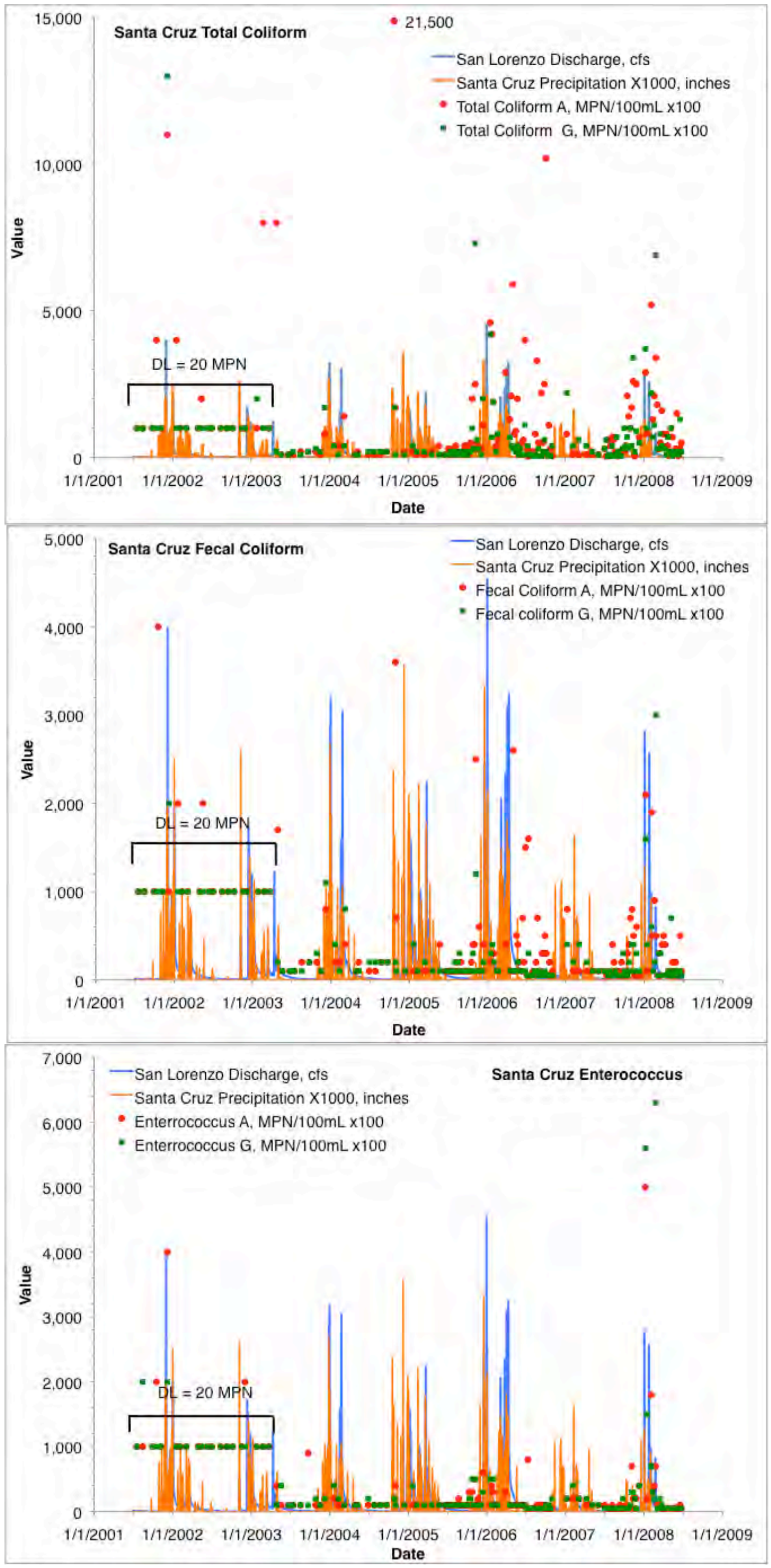

Figure 10. Receiving water bacteria measured at two stations near and far from the Santa Cruz wastewater discharge between July 2001 and June 2008, compared with local rainfall and flows from the San Lorenzo River. Values are scaled to fit on the same graph.

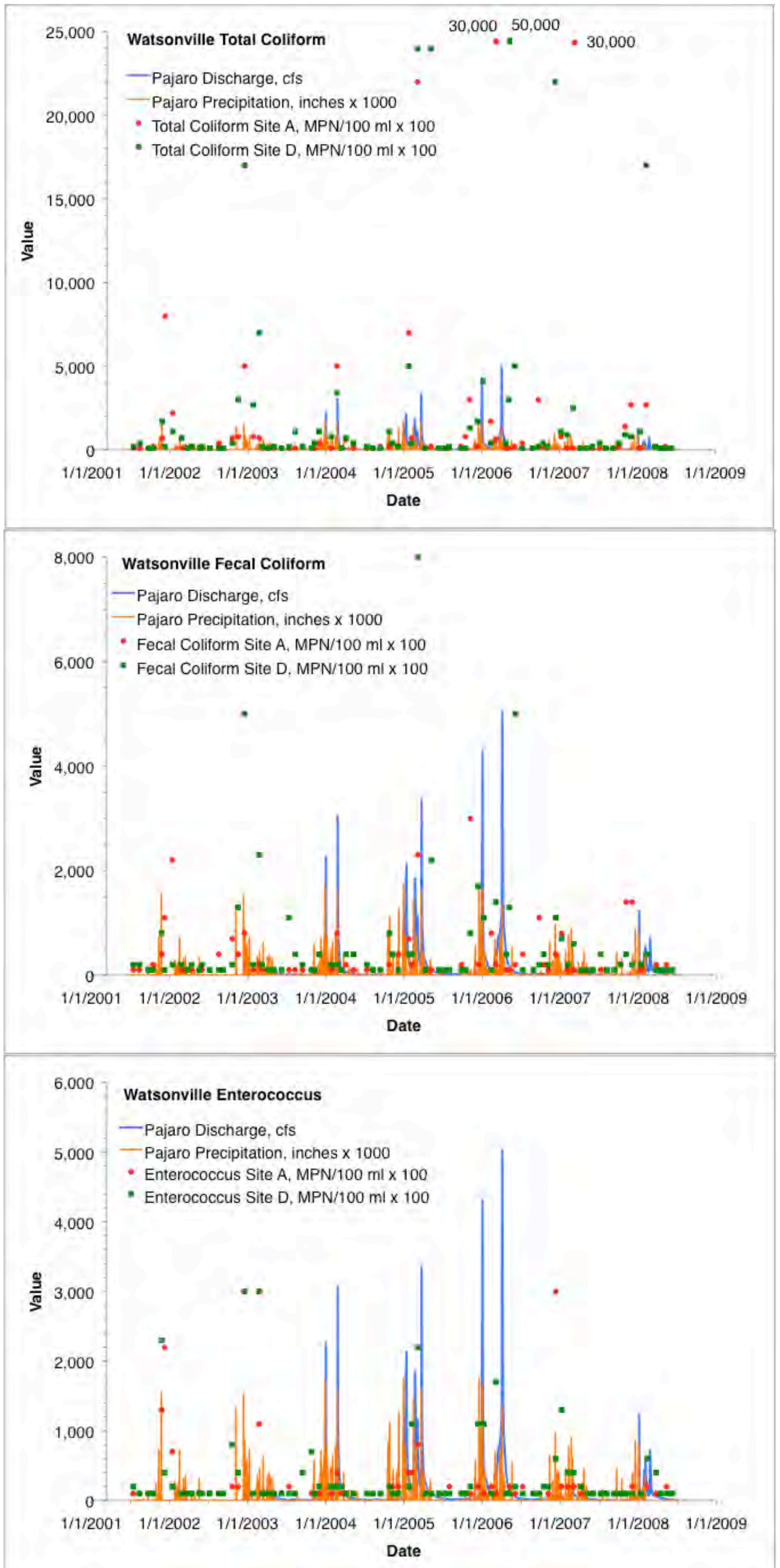

Figure 11. Receiving water bacteria measured at two stations near and far from the Watsonville wastewater discharge between July 2001 and June 2008, compared with local rainfall and flows from the Pajaro River. Values are scaled to fit on the same graph.

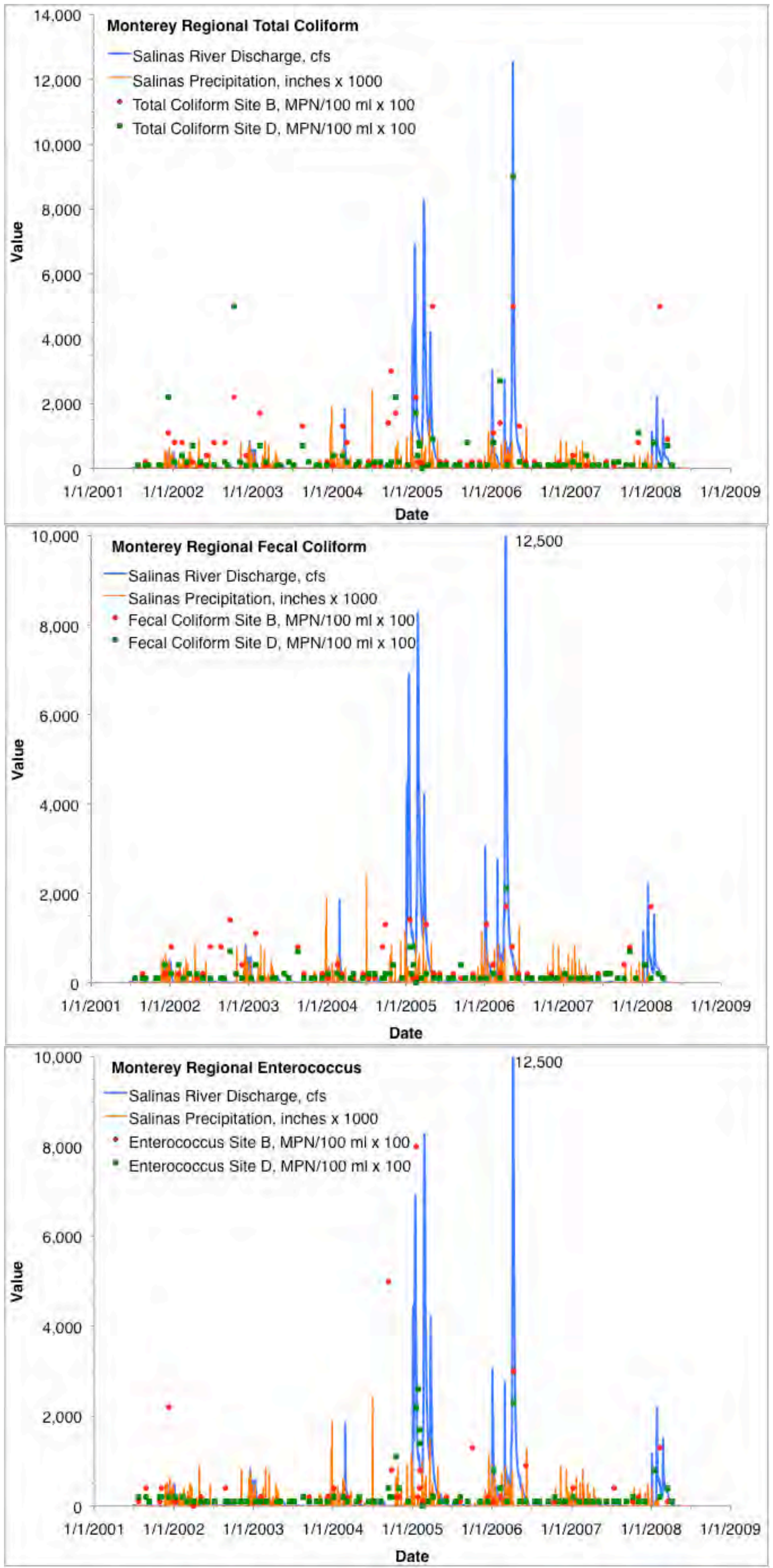

Figure 12. Receiving water bacteria measured at two stations near and far from the MRWPCA wastewater discharge between July 2001 and June 2008, compared with local rainfall and flows from the Salinas River. Values are scaled to fit on the same graph.

be less informative about the direct effects of the Santa Cruz discharge on receiving water bacteria concentrations. These paired t-tests found only two significant differences between the near- and far-field sites, which were higher fecal coliform at the near-field sites than at the far-field sites for both Watsonville and MRWPCA (Table 5). The comparisons between sites at the Watsonville discharge generally were closer to being statistically significant ($p = 0.05$) than were comparisons for the other discharges, suggesting a tendency for higher values at the near-field site than at the far-field site.

Table 4. Geometric means and single sample maxima for indicator bacteria in receiving waters adjacent to ocean outfalls for three CCLEAN wastewater dischargers.

			MPN/100 ml	
Agency	**Site**	**Total Coliform**	**Fecal Coliform**	**Enterococcus**
		Geometric Means for 2001 - 2008		
Santa Cruz	A (far)	4.18	1.78	1.09
	G (near)	2.59	1.24	1.06
Watsonville	A (far)	3.04	1.99	1.58
	D (near)	4.71	2.53	1.85
MRWPCA	D (far)	2.15	1.55	1.72
	B (near)	2.70	2.13	1.82
		Single Sample Maxima for 2001 - 2008		
Santa Cruz	A (far)	215	40	50
	G (near)	130	30	63
Watsonville	A (far)	300	30	30
	D (near)	500	80	30
MRWPCA	D (far)	90	21	240
	B (near)	50	17	80

Table 5. Results of paired t-tests for differences in bacteria concentrations between near-field and far-field sites adjacent to each wastewater discharge.

		Probability	
Agency	**Total Coliform**	**Fecal Coliform**	**Enterococcus**
Santa Cruz	0.9957	0.9980	0.2236
Watsonville	0.1225	0.0389 (D>A)	0.0767
MRWPCA	0.1600	0.0007 (B>D)	0.6899

Because differences between near-field and far-field sites could be due to factors other than the wastewater discharges, another test was performed to see whether ocean bacteria concentrations were statistically correlated with nearby rivers discharges, local rainfall or wastewater discharges, individually or in combination. These three parameters were used as independent variables in stepwise linear regressions to see if they explained a significant amount of the variation in bacteria concentrations at each site. The City of Watsonville measured bacteria concentrations in their wastewater until October 2007 and these data were used for the independent variable representing possible wastewater effects at the Watsonville discharge. Neither MRWPCA nor

Santa Cruz routinely measured wastewater bacteria concentrations, so the volume of wastewater discharged was used as an independent variable in the analyses of the effects of those discharges. For the MRWPCA analyses, Salinas River flow and Salinas rainfall were used. For Watsonville, Pajaro River flow and Pajaro rainfall were used. For Santa Cruz, San Lorenzo River flow and DeLaveaga rainfall were used. River flows were obtained from US Geological Survey (USGS) gauging stations available through the California Data Exchange Center (http://thunder.water.ca.gov/) and rainfall data were obtained from the California Climate Data Archive (http://www.calclim.dri.edu/). In this analysis, all the variables were put into the model and those with a significance probability greater than 0.05 were sequentially removed until only significant variables remained. The resulting equations estimate the concentrations of the indicator bacteria predicted from the independent variables.

The stepwise linear regressions indicated that bacteria concentrations at receiving water monitoring sites were not correlated with any of the wastewater discharges (Table 6). Bacteria concentrations were most often correlated with discharges from nearby rivers, with local rainfall being a significant variable in two cases. Consequently, the higher fecal coliform concentrations at near-field sites at Watsonville and MRWPCA noted above (Table 4) were most likely due discharges from the Pajaro River and Salinas River, respectively.

Table 6. Results of stepwise linear regressions to test for effects of river flows, local rainfall and wastewater discharges on bacteria concentrations at sites near to and far from each wastewater discharge.

Indicator	Agency	Site	r^2	p	Model
Total Coliform					
	Santa Cruz	A (far)	-	NS[1]	None
		G (near)	0.174	<0.0001	TotColi = 4.4 + 49.74 rainfall
	Watsonville	A (far)	0.159	0.0002	TotColi = 7.5 + 0.11 Pajaro flow
		D (near)	0.465	<0.0001	TotColi = 4.6 + 0.11 Pajaro flow + 465 rainfall
	MRWPCA	D (far)	0.591	<0.0001	TotColi = 2.58 + 0.009 Salinas flow
		B (near)	0.300	<0.0001	TotColi = 4.70 + 0.006 Salinas flow
Fecal Coliform					
	Santa Cruz	A (far)	-	NS[1]	None
		G (near)	-	NS[1]	None
	Watsonville	A (far)	0.078	0.0108	Fecal = 2.87 + 0.008 Pajaro flow
		D (near)	0.410	<0.0001	Fecal = 2.32 + 0.04 Pajaro flow
	MRWPCA	D (far)	0.698	<0.0001	Fecal = 1.49 + 0.002 Salinas flow
		B (near)	0.257	<0.0001	Fecal = 2.81 + 0.002 Salinas flow
Enterococcus					
	Santa Cruz	A (far)	-	NS[1]	None
		G (near)	-	NS[1]	None
	Watsonville	A (far)	0.284	<0.0001	Entero = 1.49 + 0.015 Pajaro flow
		D (near)	0.466	<0.0001	Entero = 1.66 + 0.016 Pajaro flow + 25 rainfall
	MRWPCA	D (far)	-	NS[1]	None
		B (near)	0.262	<0.0001	Entero = 2.87 + 0.005 Salinas flow

4.1.4.1 Conclusions

There have been no bacterial impairments to the water contact recreation beneficial use associated with discharges from any of the CCLEAN wastewater treatment plants. Only the Ocean Plan *Enterococcus* single sample objective for water contact recreation was exceeded once at the farfield receiving water monitoring station adjacent to the MRWPCA discharge. Statistical analyses detected only two differences between near-field and far-field samples, with near-field sites at MRWPCA and Watsonville having higher concentrations of fecal coliform than far-field sites. Additional analyses suggest these differences are due to discharges from the Salinas and Pajaro rivers. Moreover, wastewater discharges were not significantly correlated with receiving water bacteria concentrations at any discharge, although nearby rivers and local rainfall were correlated with receiving water bacteria concentrations.

4.1.4.2 Recommendations

Given the absence of wastewater effects on receiving-water bacteria concentrations and the apparent effects of nearby rivers, CCLEAN stakeholders should consider elimination of this monitoring requirement. As with improvements in program efficiency associated with potential reductions in sampling frequency for nearshore waters, elimination of receiving water monitoring for bacteria could provide funds for other program elements prioritized by participants to address other issues. For example, targeted studies could be performed to determine the vertebrate sources of bacteria measured in receiving waters, which could further document that wastewater is not a source of impairment.

4.2 What are the major sources of contaminants to nearshore waters?

CCLEAN has previously documented that discharges from rivers contain the greatest loads of contaminants to ocean waters from the sources measured in the Monterey Bay area (CCLEAN, 2007). For some POPs, such as DDTs, loads from rivers constitute over 98% of the total mass of contaminant washing into ocean waters, with the remainder being discharged in wastewater. CCLEAN also has documented that the majority of these POP loads are discharged during the wet season, resulting in higher wet-season concentrations of POPs in mussels at all locations around Monterey Bay. Nevertheless, despite this important information, no in-depth analysis has been performed on seasonal patterns of POPs in rivers and wastewater to determine whether high wet-season loads are the result of high wet-season concentrations or just greater volumes of flow from each source.

An evaluation of seasonal patterns in POP concentrations is important because such patterns can provide an understanding of the activities or processes on land that are the ultimate sources of the POPs. For example, if consistently higher concentrations occur in wet-season discharges, it suggests that more highly contaminated locations are being eroded by storm runoff. If lower concentrations occur in the wet season, it suggests dilution of non-erodible sources by rainfall. Inconsistent seasonal concentration patterns characterized by occasional extreme values for a POP could indicate sporadic activities that release large amounts of the contaminant. With this understanding, it could be possible to design targeted studies to more precisely determine the POP sources and implement management actions to reduce their discharge into the ocean.

Seven POPs were put into three groups for this analysis, based upon their predominant historic uses. PAHs are widely distributed in the environment from vehicle operations, asphalt erosion and combustion of wood and other carbon-based items. PAHs were further subdivided into low-molecular weight (lo-weight) forms and high-molecular weight (hi-weight) forms, which are indicative of petroleum and combustion products, respectively. Agricultural contaminants included two legacy pesticides, DDTs and Dieldrin, which were historically applied to crops and for mosquito control before their ban over 20 years ago. Urban and industrial contaminants included Chlordanes, which were used extensively to treat termites around homes and on golf courses, PCBs, which were used as coolant in large electrical transformers, and PBDEs, which are currently used as flame retardants in foam furniture and plastic cases for electronic equipment. We have only two years of PBDE data, which precluded statistical analysis of data patterns.

This analysis of concentration patterns was performed on both rivers and wastewater discharges. Because they discharge most of the loads from rivers and because we have only two dry-season samples from the Carmel River, these analyses emphasized the San Lorenzo, Pajaro and Salinas rivers. These three rivers also contain different mixes of land uses within their watersheds. Sampling ended in the Salinas River in March 2007. All four wastewater discharges were analyzed.

The statistical tests used for this analysis were the same as for the analysis of wastewater effects on receiving water bacteria discussed in Section 4.1.4. Paired t-tests were used to determine if there are differences in POP concentrations between dry-season and wet-season samples. Second, stepwise linear regressions were performed to determine whether POP concentrations are correlated with local rainfall or the volume of river discharges. Because sampling occurs over a 30-day period, which can include wide variation in daily river flow and rainfall, the 95th percentile of river flows and daily rainfall, as well as the maximum hourly rainfall rate during the 30-day sampling period were used as the independent variables in the linear regressions.

4.2.1 Sources of POPs Discharged by Rivers

4.2.1.1 San Lorenzo River

Many POPs discharged in the San Lorenzo River exhibited differences between wet-season and dry-season samples. PAH concentrations varied greatly among samples, with higher concentrations of hi-weight PAHs in wet-season samples than in their respective dry-season samples. There also were unusually high concentrations of lo-weight PAHs in the July 2005 and March 2006 samples. Hi-weight PAHs usually predominated during the wet-season samples (Figure 13a). Concentrations of DDTs and Dieldrin varied relatively little among samples and also were generally higher in wet-season samples than in dry-season samples and concentrations of DDTs were approximately 10 times greater than those of Dieldrin (Figure 13b). PCBs also differed little among samples (13c). Chlordanes and PBDEs fluctuated more than PCBs and had slightly higher concentrations than PCBs.

These observations of seasonal differences were substantiated by paired t-tests, which showed wet-season concentrations were significantly greater than dry-season concentrations for hi-weight PAHs, DDT, Chlordanes, and PCBs (Table 7). The results for lo-weight PAHs and Dieldrin were marginally non-significant.

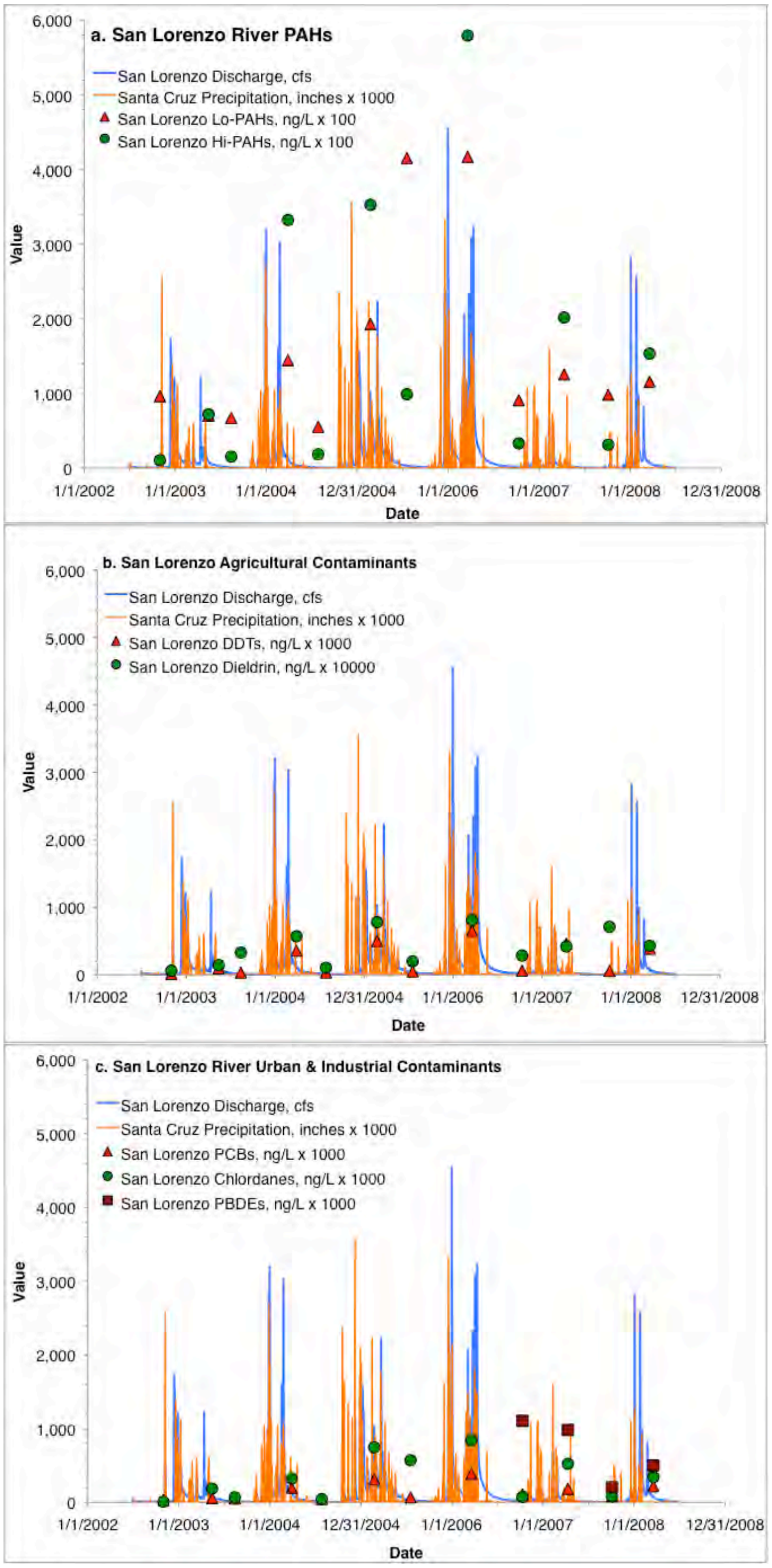

Figure 13. Temporal patterns of POP concentrations in the San Lorenzo River compared with local rainfall and river discharge volume. Values are scaled to fit on the same graph.

Table 7. Results of paired t-tests for differences in POP concentrations between wet-season and dry-season samples from the San Lorenzo River.

POP	Probability
Lo-weight PAHs	0.0767
Hi-weight PAHs	0.0059 (wet>dry)
DDT	0.0018 (wet>dry)
Dieldrin	0.0771
Chlordanes	0.0032 (wet>dry)
PCBs	0.0086 (wet>dry)

Results from the linear regression analyses for the San Lorenzo River revealed significant correlations with rainfall for most POPs (Table 8). Hi-weight PAHs, DDTs and Chlordanes were correlated with the maximum hourly rainfall during the same 30-day sampling period and Dieldrin and PCBs were significantly correlated with the 95th percentile of daily rainfall during the same 30-day period. An absence of significant correlations for lo-weight PAHs is consistent with the high dry-season concentrations noted above.

Table 8. Results of stepwise linear regressions to test for effects of river flows and local rainfall on POP concentrations in the San Lorenzo River.

POP	r^2	p	Model
Lo-weight PAHs	-	NS[1]	None
Hi-weight PAHs	0.544	0.0062	Hi-PAHs = 513 + 7223 max rainfall
DDTs	0.517	0.0084	DDTs = 0.091 + 0.903 max rainfall
Dieldrin	0.362	0.0384	Dieldrin = 0.027 + 0.034 95th rainfall
Chlordanes	0.367	0.0368	Chlordanes = 0.175 + 0.967 max rainfall
PCBs	0.409	0.0252	PCBs = 0.084 + 0.157 95th rainfall

These results suggest that the most of the tested POPs are consistently present in the San Lorenzo River watershed and that they are entering the river in storm runoff. The high concentration of lo-weight PAHs in the 2005 dry-season samples, followed by similarly high concentrations in the succeeding wet-season sample, are consistent with a short-term petroleum discharge somewhere in the watershed that would have occurred between March 2005 and July 2005. Moreover, the higher concentrations of hi-weight PAHs due to rainfall are consistent with combustion products washing off roadways.

4.2.1.2 Pajaro River

Concentrations of POPs discharged by the Pajaro River exhibited inconsistent differences between wet-season and dry-season samples. As for the San Lorenzo River, PAH concentrations varied greatly among samples (Figure 14a). In the Pajaro, there were no consistent patterns in the predominance of hi-weight or lo-weight PAHs. Concentrations of DDTs exhibited substantial variation (Figure 14b), while Dieldrin, Chlordanes, PCBs and PBDEs varied relatively less among samples (Figure 14b and Figure 14c). Similar to the San Lorenzo River, concentrations of DDTs

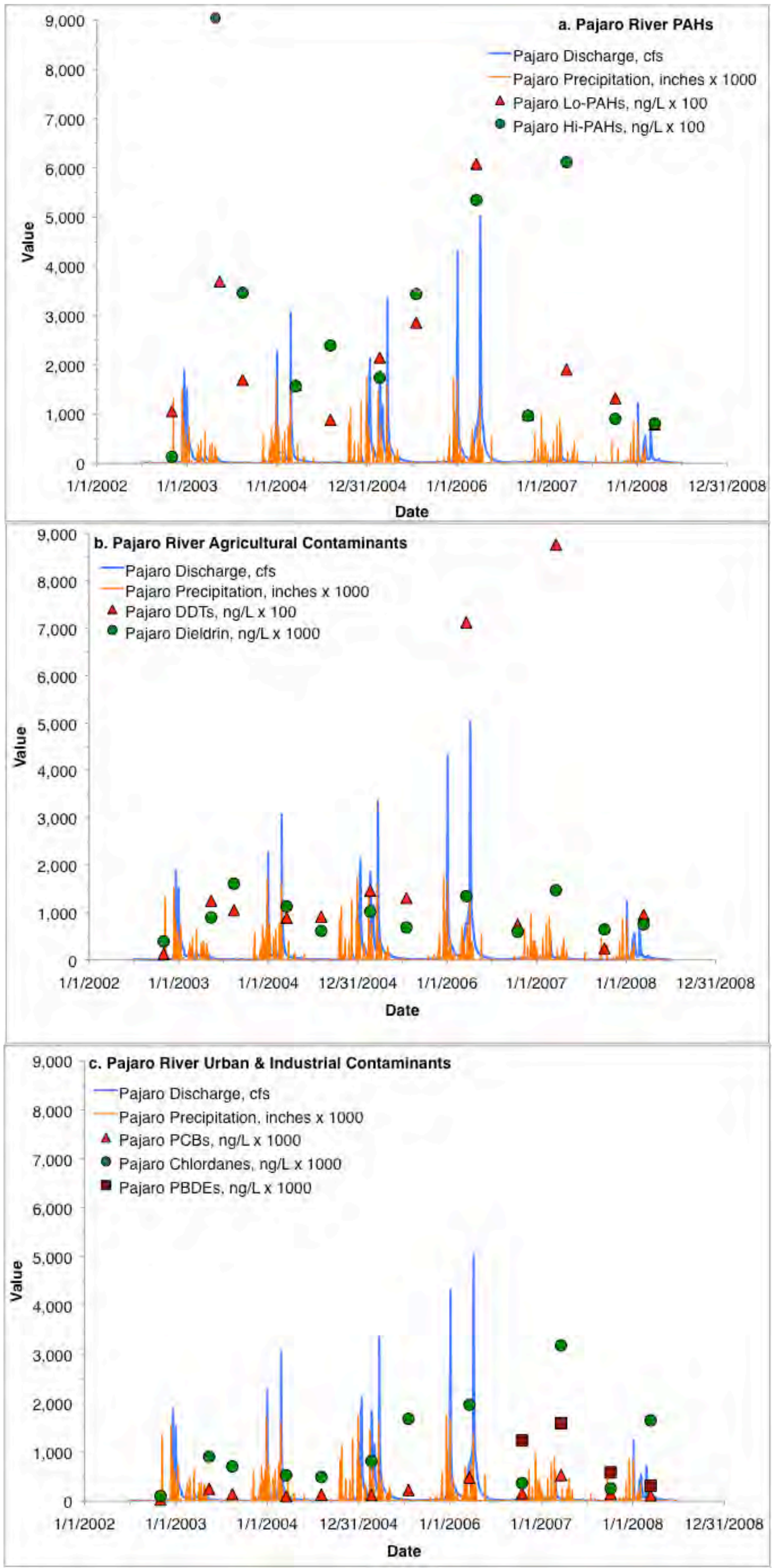

Figure 14. Temporal patterns of POP concentrations in the Pajaro River compared with local rainfall and river discharge volume. Values are scaled to fit on the same graph.

in the Pajaro River were approximately 10 times greater than the concentrations of Dieldrin. Concentrations of Chlordanes and PBDEs always exceeded those of PCBs.

Paired t- tests revealed relatively fewer significant differences between seasons, with wet-season samples exceeding corresponding dry- season samples for lo-weight PAHs, Chlordanes and PCBs (Table 9). Seasonal differences in DDTs and Dieldrin were marginally non-significant.

Table 9. Results of paired t-tests for differences in POP concentrations between wet-season and dry-season samples from the Pajaro River.

POP	Probability
Lo-weight PAHs	0.0481 (wet>dry)
Hi-weight PAHs	0.1212
DDTs	0.0571
Dieldrin	0.0689
Chlordanes	0.0452 (wet>dry)
PCBs	0.0232 (wet>dry)

Results from the linear regression analyses for the Pajaro River revealed significant correlations with the tested environmental variables only for hi-weight PAHs (Table 10). This means that, while there were significant differences between paired dry-season and wet-season samples for lo-weight PAHs, Chlordanes and PCBs, concentrations of these POPs did not vary linearly relative to either river flow or rainfall. Hi-weight PAHs were correlated with the maximum hourly rainfall and the 95th percentile of river flow during the same 30-day sampling period.

Table 10. Results of stepwise linear regressions to test for effects of river flows and local rainfall on POP concentrations in the Pajaro River.

POP	r^2	p	Model
Lo-weight PAHs	-	NS[1]	None
Hi-weight PAHs	0.625	0.0121	Hi-PAHs = 2950 + 20802 max rainfall – 5.5 95th Pajaro flow
DDTs	-	NS[1]	None
Dieldrin	-	NS[1]	None
Chlordanes	-	NS[1]	None
PCBs	-	NS[1]	None

These results for the Pajaro River suggest very different spatial and temporal patterns among POPs entering the river. While lo-weight PAHs, Chlordanes and PCBs are significantly higher in wet-season samples than in corresponding dry-season samples, this seasonal pattern is not correlated with either rainfall or river flow and may suggest sporadic dry-season activities in the watershed that release these POPs, which then find their way into the river during the following wet season. Nevertheless, the temporal patterns of high concentrations differed among these three POPs, indicating they are resulting from different activities and have different sources.

4.2.1.3 Salinas River

As noted for the Pajaro River, concentrations of POPs measured in the Salinas River exhibited inconsistent differences between wet-season and dry-season samples (Figure 15). Both lo-weight and hi-weight PAHs fluctuated substantially among samples (Figure 15a). Nevertheless, the Salinas River was unique among the rivers in that lo-weight PAHs were consistently found in higher concentrations than hi-weight PAHs. Concentrations of DDT, Dieldrin, Chlordanes and PCBs all varied substantially among samples, with very high concentrations detected for all of them in the March 2004 samples (Figure 15b and Figure 15c). As for both the other rivers, concentrations of DDTs in the Salinas River were approximately 10 times greater than the concentrations of Dieldrin and PCBs and Chlordanes were usually slightly greater than PCBs.

Paired t-tests between dry-season and wet-season samples from the Salinas produced very different results from the other rivers. There were no significant differences among seasons for any of the tested POPs, although higher wet-season concentrations of hi-weight PAHs were only marginally non-significant (Table 11).

Stepwise linear regression analysis of POPs in the Salinas River revealed that only PAHs appeared to vary according to either river flow or rainfall (Table 12). Both lo-weight PAHs and hi-weight PAHs were positively correlated with river flow. When the effects of both river flow and the 95^{th} percentile of rainfall were taken into consideration, lo-weight PAHs were negatively correlated with rainfall.

The absence of seasonal differences and significant correlations for DDTs, Dieldrin, PCBs and Chlordanes in the Salinas River is probably due to very high concentrations of these POPs measured in March 2004. Field observations made at the time indicated very high sediment loads in the Salinas River, which were attributed to intense rainfall that occurred in late February. Nevertheless, maximum hourly rainfall rates in Salinas during this period were not extraordinary compared to the maximum noted in March 2006 (i.e., 0.2 inches per hour versus 0.26). Notable is the absence of especially high concentrations of these POPs associated with much higher river flows in March 2005 and March 2006. Consequently, the source of these high suspended-sediment loads and accompanying high POP concentrations remain unexplained. If these observed high sediment loads and high POP concentrations were associated with intense rainfall, at best they document how highly episodic events can have profound effects on loads of contaminants entering the ocean. The daily loads of DDTs from the Salinas River were 2.7 g, 2.1 g, and 1.5 g per day in March 2004, March 205 and March 2006, respectively. If these sediment loads and POP concentrations were not associated with intense rainfall, at worst they suggest sporadic activities in the watershed that release high concentrations of POPs, which are washed into the river by succeeding rainfall.

4.2.1.4 Conclusions

Each of the rivers exhibited unique characteristics in concentrations of some POPs. Patterns of POP concentrations in the San Lorenzo River were indicative of consistent inputs that increased in response to rainfall, with only lo-weight PAHs suggesting episodic, non-rainfall events causing

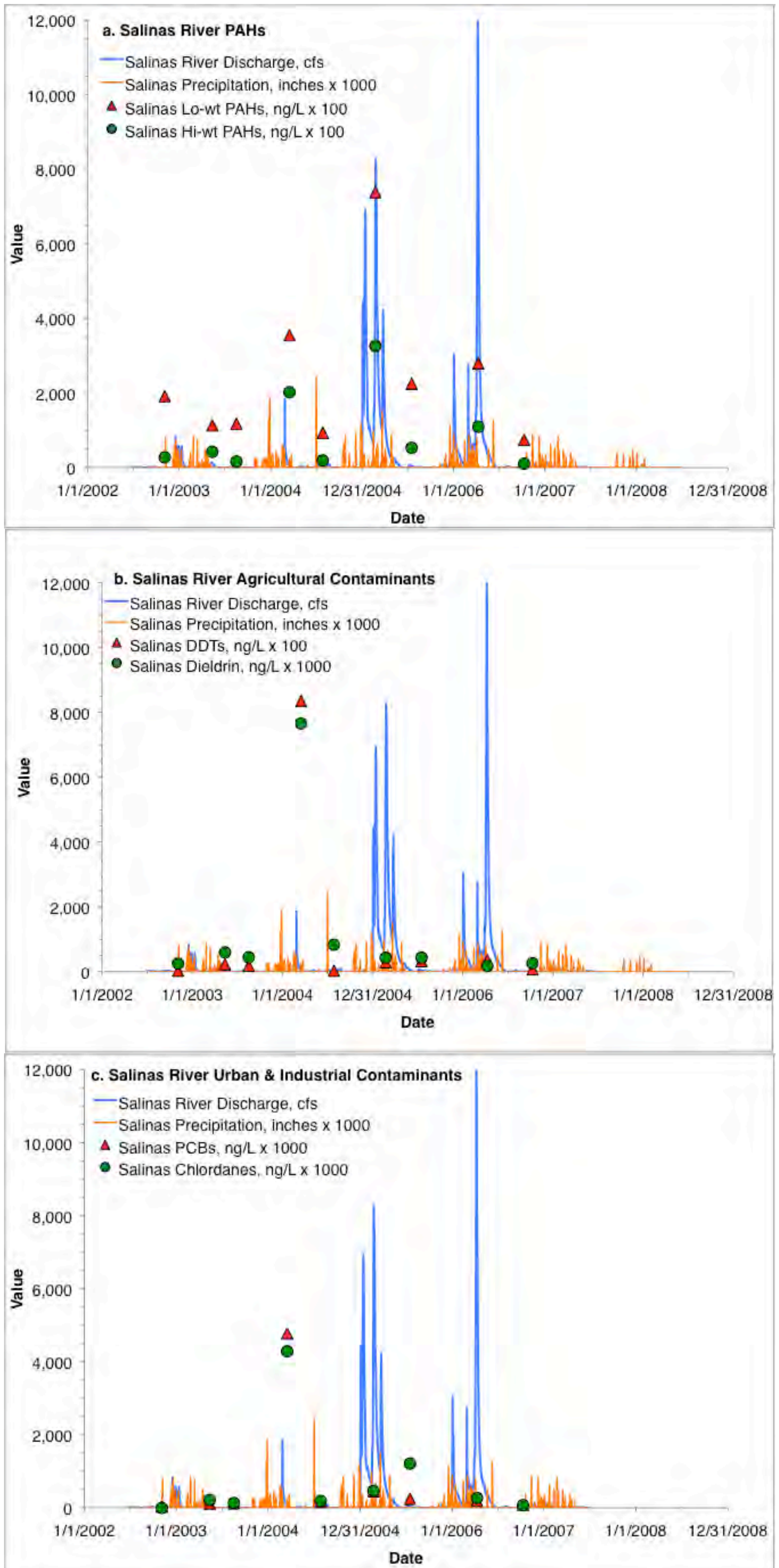

Figure 15. Temporal patterns of POP concentrations in the Salinas River compared with local rainfall and river discharge volume. Values are scaled to fit on the same graph.

higher concentrations. Both the Pajaro and Salinas rivers had large unexplained fluctuations in POPs, especially legacy agricultural contaminants, which suggest large unexplained releases of POPs in their watersheds. These releases could have been due to various factors, but the differences in the timing of peak concentrations between the Pajaro River and the Salinas River suggest human activities in their respective watershed might have been responsible.

Table 11. Results of paired t-tests for differences in POP concentrations between wet-season and dry-season samples from the Salinas River.

POP	Probability
Lo-weight PAHs	0.1327
Hi-weight PAHs	0.0614
DDTs	0.1794
Dieldrin	0.2085
Chlordanes	0.2335
PCBs	0.1771

Table 12. Results of stepwise linear regressions to test for effects of river flows and local rainfall on POP concentrations in the Salinas River.

POP	r^2	p	Model
Lo-weight PAHs	0.955	<0.0001	Lo-PAHs = 1743 + 2.80 Salinas flow – 1908 95th rainfall
Hi-weight PAHs	0.900	<0.0001	Hi-PAHs = 273 + 95th Salinas flow
DDTs	-	NS[1]	None
Dieldrin	-	NS[1]	None
Chlordanes	-	NS[1]	None
PCBs	-	NS[1]	None

These results demonstrate that high loads of POPs from the rivers are not due exclusively to high discharge volumes. Very high POP concentrations, without exceptionally high rainfall or river flows, can also account for high loads of POPs entering the ocean.

All three of the analyzed rivers were similar in the relative concentrations of some POPs. For example, Chlordanes and PCBs had similar concentrations, although Chlordanes were slightly higher than PCBs in the San Lorenzo and Pajaro rivers.

4.2.1.5 Recommendations

The unexplained high variation in POP concentrations in the Pajaro and Salinas rivers suggest that greater vigilance is needed to determine whether episodic discharges are resulting from sporadic human activities. Such vigilance would require cooperation among land-use, resource-protection and water-quality regulators. Moreover, to document the results of ongoing efforts in agricultural and other types of land use to implement best management practices and low-impact development, stakeholders, including resource management and water quality regulatory agencies and the Monterey Bay National Marine Sanctuary, should seek sources of funding to reinstate the wet-season and dry-season sampling of POP discharges from major rivers. Recent assessments of regional monitoring coordination and infrastructure by the Monterey Bay National Marine

Sanctuary's Central Coast Water Quality Data Synthesis, Assessment and Management (SAM; http://www.ccamp.net/sam/index.php/Main_Page) have placed a priority on collecting POP load data from the major rivers in the Sanctuary.

4.2.2 Sources of POPs Discharged by Wastewater

4.2.2.1 City of Santa Cruz

POPs discharged in Santa Cruz wastewater differed in their patterns of fluctuation between wet-season and dry-season samples (Figure 16). There were relatively high concentrations of both lo-weight and hi-weight PAHs in August 2003 with greater variations in lo-weight PAHs than in hi-weight PAHs. Concentrations of lo-weight PAHs were consistently greater than those for hi-weight PAHs (Figure 16a). Concentrations of DDTs varied inconsistently among samples, while Dieldrin was generally slightly higher in wet-season samples than in the preceding dry-season sample. Concentrations of DDTs and Dieldrin were similar. Chlordanes, PCBs and PBDEs also varied inconsistently. Concentrations of PBDEs were higher than those for Chlordanes, which were higher than PCBs (Figure 16b and Figure 16c).

There were no differences between wet-season and dry-season samples of Santa Cruz wastewater, except for higher concentrations of Dieldrin in wet-season samples (Table 13). Within-season trend analysis found a significant decline in wet-season DDTs ($r^2 = 0.600$, $p = 0.0408$) from February 2002 through March 2008. None of the POPs tested were correlated with the average volume of wastewater discharged, 95th percentile of daily rainfall or maximum hourly rainfall during the 30-day sampling period, except for Dieldrin, which was positively correlated with the average wastewater discharge volume (Table 14).

Table 13. Results of paired t-tests for differences in POP concentrations between wet-season and dry-season samples from Santa Cruz wastewater.

POP	Probability
Lo-weight PAHs	0.9162
Hi-weight PAHs	0.5424
DDTs	0.8203
Dieldrin	0.0257 (wet>dry)
Chlordanes	0.6150
PCBs	0.8500

Table 14. Results of stepwise linear regressions to test for effects of river flows and local rainfall on POP concentrations in Santa Cruz wastewater.

POP	r^2	p	Model
Lo-weight PAHs	-	NS[1]	None
Hi-weight PAHs	-	NS[1]	None
DDTs	-	NS[1]	None
Dieldrin	0.587	0.0014	Dieldrin = 0.012 discharge – 0.298
Chlordanes	-	NS[1]	None
PCBs	-	NS[1]	None

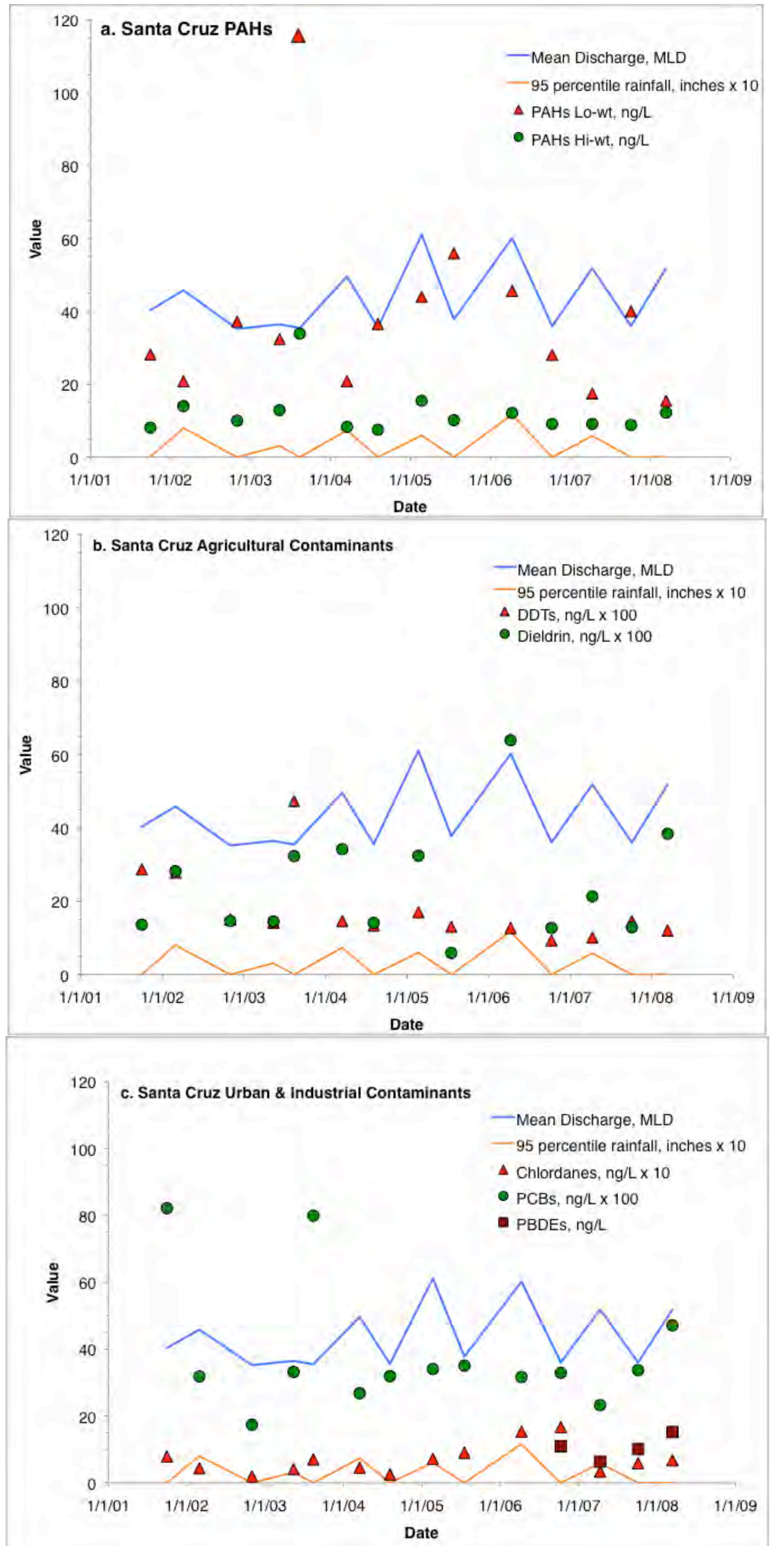

Figure 16. Temporal patterns of POP concentrations in Santa Cruz wastewater compared with local rainfall and wastewater discharge volume. Values are scaled to fit on the same graph.

4.2.2.2 City of Watsonville

As for Santa Cruz, concentrations of most POPs discharged in City of Watsonville wastewater exhibited inconsistent differences between wet-season and dry-season samples (Figure 17). With the exception of a high concentration of lo-weight PAHs in October 2001, there was relatively little variation in PAH concentrations, although concentrations of wet-season hi-weight PAHs were always higher than for the preceding dry-season. Concentrations of lo-weight PAHs were greater than those for hi-weight PAHs in all but one sample (Figure 17a). Concentrations of DDTs in Watsonville varied substantially among samples, with no obvious differences between seasons, whereas Dieldrin in wet-season samples was always higher than in the preceding dry-season sample (Figure 17b). Unlike Santa Cruz, Watsonville wastewater generally had higher concentrations of DDTs than Dieldrin. PCBs concentrations varied four-fold among sampling periods, with relatively high and inconsistent fluctuations. (Figure 17c). PBDEs were higher in wet-season samples than in the preceding dry-season samples and were substantially higher than Chlordanes, which were higher than PCBs.

Consistent with the patterns observed in Figure 17, there were few significant differences between wet-season and dry-season samples of Watsonville wastewater. Wet-season and dry-season samples differed significantly in concentrations of only hi-weight PAHs and Dieldrin (Table 15). Analysis of trends within seasons detected as significant increase in dry-season Dieldrin in Watsonville wastewater from 2001 through 2007 ($r2 = 0.640$, $p = 0.0307$). Seasonal patterns in PBDE concentrations could not be tested because of insufficient samples. Stepwise linear regression indicated that both of these POP were positively correlated with rainfall; hi-weight PAHs were correlated with 95th percentile rainfall and Dieldrin was positively correlated with the maximum hourly rainfall during the 30-day sampling period.

Table 15. Results of paired t-tests for differences in POP concentrations between wet-season and dry-season samples from Watsonville wastewater.

POP	Probability
Lo-weight PAHs	0.9464
Hi-weight PAHs	0.0022 (wet>dry)
DDTs	0.0542
Dieldrin	0.0046 (wet>dry)
Chlordanes	0.4972
PCBs	0.1145

Table 16. Results of stepwise linear regressions to test for effects of river flows and local rainfall on POP concentrations in Watsonville wastewater.

POP	r^2	p	Model
Lo-weight PAHs	-	NS[1]	None
Hi-weight PAHs	0.317	0.0362	Hi-PAHs = 9.7+ 95th rainfall
DDTs	-	NS[1]	None
Dieldrin	0.379	0.0191	Dieldrin = 0.162 + 0.413 max rainfall
Chlordanes	-	NS[1]	None
PCBs	-	NS[1]	None

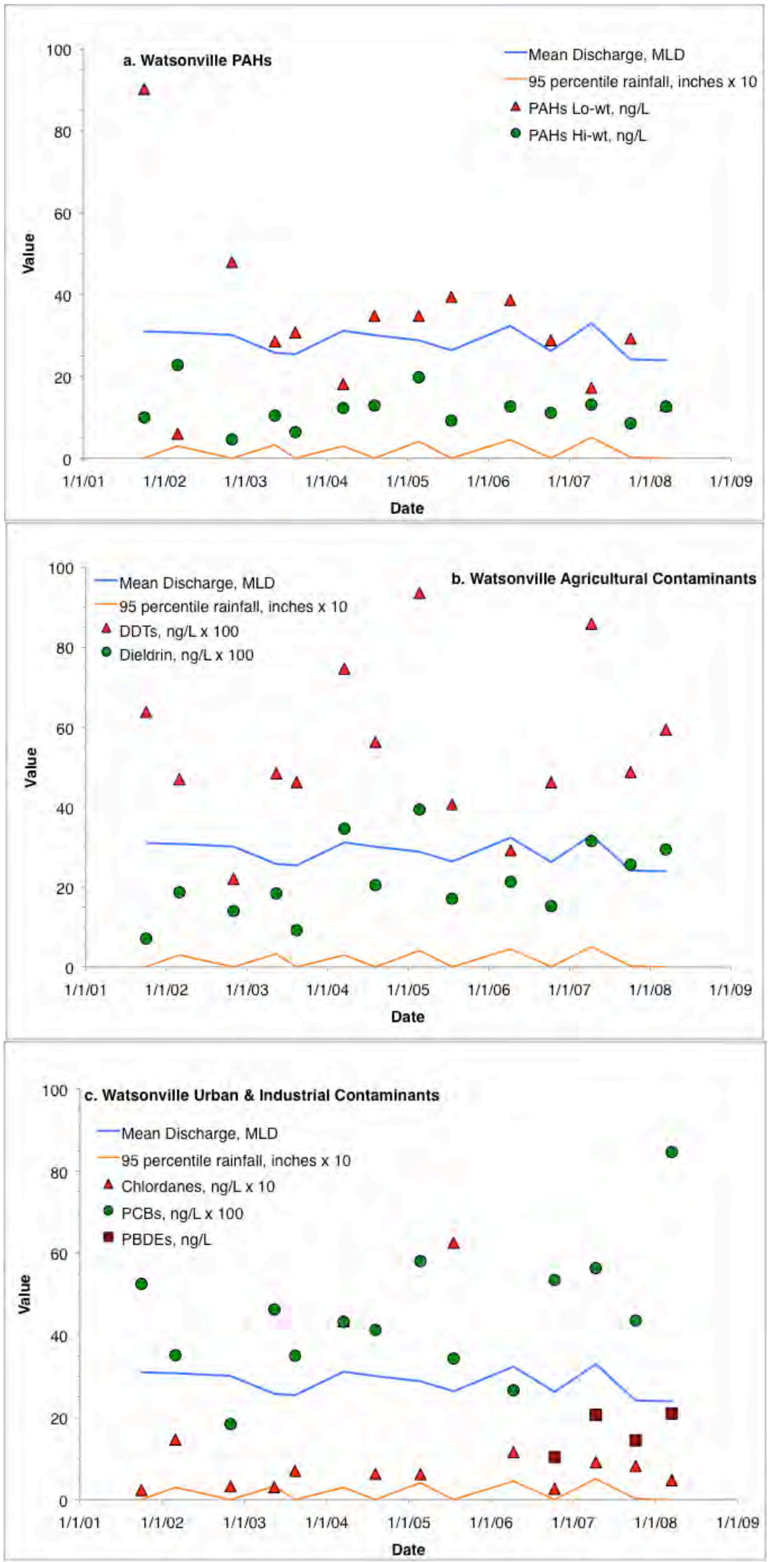

Figure 17. Temporal patterns of POP concentrations in Watsonville wastewater compared with local rainfall and wastewater discharge volume. Values are scaled to fit on the same graph.

4.2.2.3 Monterey Regional Water Pollution Control Agency

The MRWPCA wastewater discharge exhibited large differences in discharge volume between dry-season and wet-season sampling periods, due to reclamation practices that provide highly-treated wastewater for agricultural irrigation. Despite the large differences in discharge volume, concentrations of most POPs in the MRWPCA wastewater generally exhibited very little variation, except for single instances of high concentrations for lo-weight PAHs (Figure 18a), PCBs (Figure 18c) and highly variable concentrations of DDTs (Figure 18b). Concentrations of wet-season hi-weight PAHs were always higher than for the preceding dry-season. Unlike Santa Cruz and Watsonville, concentrations of hi-weight PAHs in MRWPCA wastewater were generally greater than those for lo-weight PAHs (Figure 18a) and like Watsonville, but different from Santa Cruz, MRWPCA wastewater had higher concentrations of DDTs than Dieldrin. As with Santa Cruz and Watsonville, concentrations of PBDEs were higher than those for Chlordanes, which were higher than PCBs.

Consistent with the patterns observed in Figure 18, there were few significant differences between wet-season and dry-season samples in MRWPCA wastewater. Only hi-weight PAHs had higher concentrations in wet-season samples than in preceding dry-season samples (Table 17). Analysis of trends within season found a significant decline in wet-season hi-weight PAHs in MRWPCA wastewater. As for Watsonville, stepwise linear regression indicated that this POP was positively correlated with rainfall (i.e., 95th percentile rainfall for Watsonville and maximum hourly rainfall for MRWPCA) (Table 18).

Table 17. Results of paired t-tests for differences in POP concentrations between wet-season and dry-season samples from MRWPCA wastewater.

POP	Probability
Lo-weight PAHs	0.9013
Hi-weight PAHs	0.0062 (wet>dry)
DDT	0.8432
Dieldrin	0.7966
Chlordanes	0.4151
PCBs	0.6149

Table 18. Results of stepwise linear regressions to test for effects of river flows and local rainfall on POP concentrations in MRWPCA wastewater.

POP	r^2	p	Model
Lo-weight PAHs	-	NS[1]	None
Hi-weight PAHs	0.491	0.0052	Hi-PAHs = 14.7 + max rainfall
DDT	-	NS[1]	None
Dieldrin	-	NS[1]	None
Chlordanes	-	NS[1]	None
PCBs	-	NS[1]	None

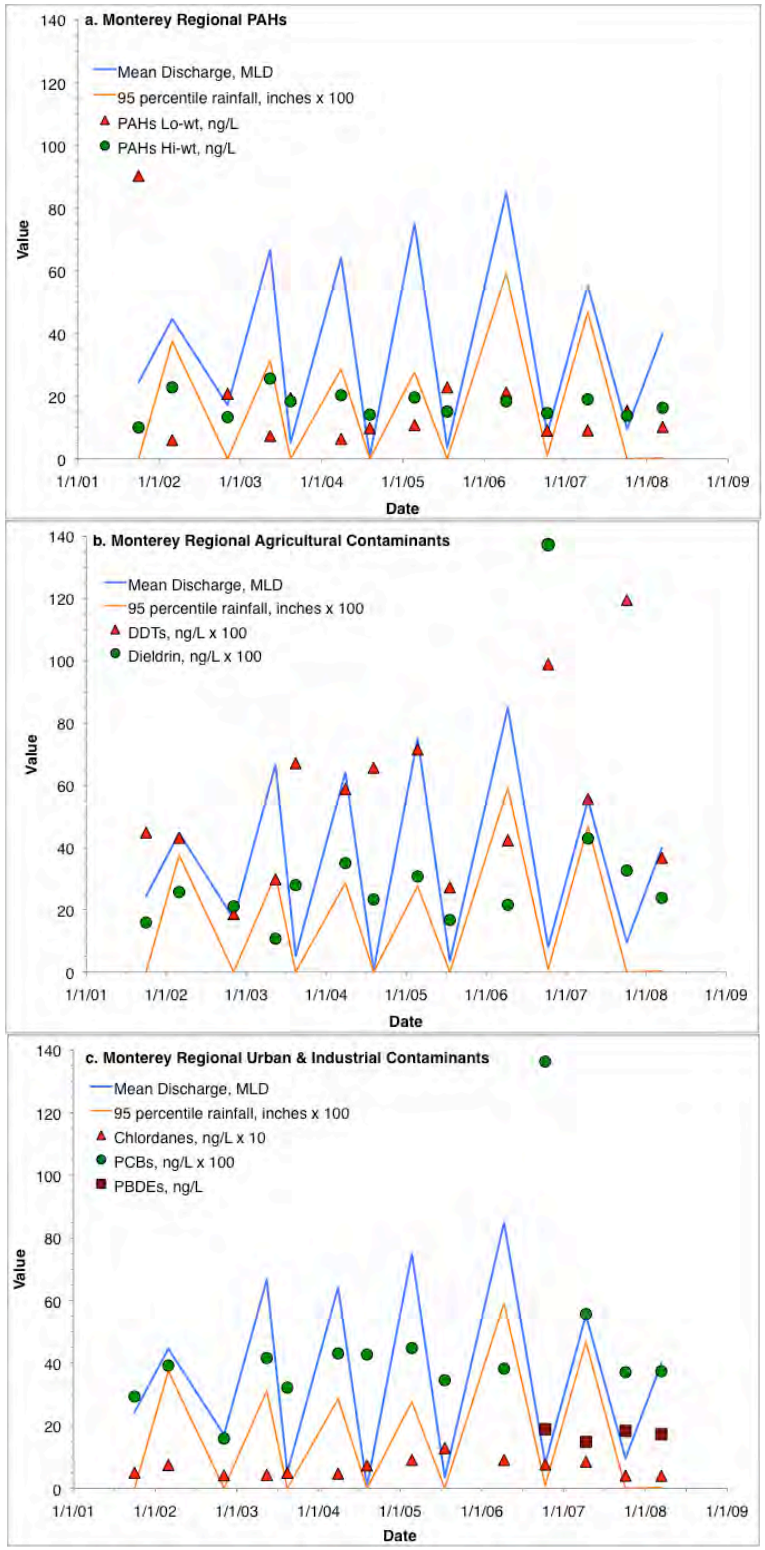

Figure 18. Temporal patterns of POP concentrations in MRWPCA wastewater compared with local rainfall and wastewater discharge volume. Values are scaled to fit on the same graph.

4.2.2.4 Carmel Area Wastewater District

Similar to the MRWPCA wastewater discharge the CAWD wastewater discharge is characterized by large fluctuations in discharge volume associated with dry-season reclamation efforts. Unlike the MRWPCA discharge, concentrations of most POPs discharged in CAWD wastewater varied greatly among samples (Figure 19). Unique to any of the river or wastewater discharges, lo-weight PAHs were generally lower in wet-season samples than in dry-season samples (Figure 19a). Also in contrast to the other discharges, neither lo-weight PAHs nor hi-weight PAHs consistently dominated PAH concentrations. Only Dieldrin exhibited generally higher concentrations in wet-season samples than in preceding dry-season samples (Figure 19b). There were relatively large variations among samples for concentrations of Dieldrin and PCBs (Figure 19b and Figure 19c). As in samples from other dischargers, concentrations of PBDEs in CAWD wastewater were approximately 10 times greater than those for Chlordanes, which were approximately 10 times higher than PCBs. Concentrations of PBDEs quadrupled from October 2006 to March 2008 (Figure 19c).

Paired t-tests for CAWD samples discerned significant differences between wet-season and dry-season samples only for Dieldrin (Table 19), although a standard analysis of variance between seasons found significantly higher concentrations of lo-weight PAHs in dry-season samples than in wet-season samples ($r2 = 0.3759$, $p = 0.0197$). There were no significant trends within season in the concentrations of POPs. Linear regressions found that both Dieldrin and lo-weight PAHs were correlated with wastewater discharge volume, except that discharge volume was positively correlated with Dieldrin and negatively correlated with lo-weight PAHs (Table 20). These correlations are consistent with the respective seasonal differences in concentrations for these two POPs.

Table 19. Results of paired t-tests for differences in POP concentrations between wet-season and dry-season samples from CAWD wastewater.

POP	Probability
Lo-weight PAHs	0.9929
Hi-weight PAHs	0.5216
DDTs	0.2507
Dieldrin	0.0134 (wet>dry)
Chlordanes	0.7302
PCBs	0.6399

Table 20. Results of stepwise linear regressions to test for effects of river flows and local rainfall on POP concentrations in CAWD wastewater.

POP	r^2	p	Model
Lo-weight PAHs	0.336	0.0298	Lo-PAHs = 48 – 4.11 discharge
Hi-weight PAHs	-	NS[1]	None
DDTs	-	NS[1]	None
Dieldrin	0.441	0.0096	Dieldrin = 0.1 + 0.082 discharge
Chlordanes	-	NS[1]	None
PCBs	-	NS[1]	None

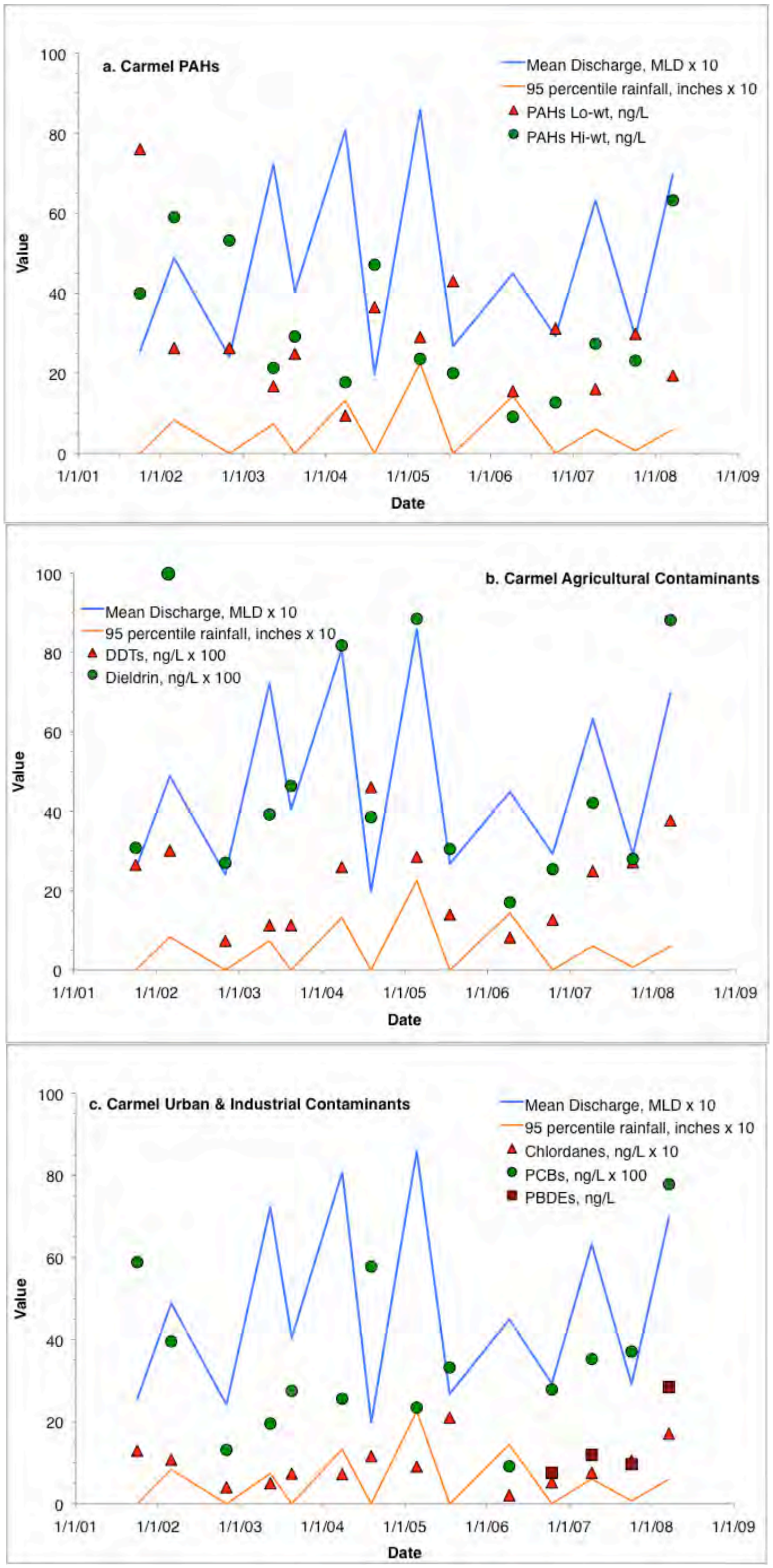

Figure 19. Temporal patterns of POP concentrations in CAWD wastewater compared with local rainfall and wastewater discharge volume. Values are scaled to fit on the same graph.

4.2.2.5 PBDEs in Wastewater

Produced commercially since the 1970s for use as flame retardants, PBDEs are chemically similar to PCBs. With PBDEs, the phenyl rings are separated by an oxygen atom and ring substitution is by bromine, rather than by chlorine. As with PCBs, there are potentially 209 compounds (congeners) that differ according to the number and placement of halogen atoms. PBDEs with the same number of bromine atoms are called homologues and, because the same number of bromine atoms can be distributed among different bonds on the phenyl rings, most homologues can include several different congeners. Commercial PBDE formulations are nominally based on the five-, eight- and 10-bromine homologues (penta-, octa- and deca-BDEs), although a recent study (La Guardia *et al*., 2006) reported all tested formulations contained a mixture of homologues. Total global market demand for PBDEs in 2001 was 67,390 metric tons, with 83% coming from deca-BDE, 11% from penta-BDEs and 6% from penta-BDEs.

Each of the three main formulations of PBDEs is used in slightly different ways. PBDEs are used as additive flame retardants in thermoplastics. The major use of deca-BDE is in high-impact polystyrene, but it is also used in a wide range of other plastics for electrical and electronic equipment. Penta-BDE is used primarily in the furniture industry, mostly as a flame retardant in polyurethane foam in mattresses and cushions. Nevertheless, only 7.5% of polyurethane foam used for mattresses and cushions in the United States is treated with penta-BDE. The majority of treated foam products are sold in California, which is the only state with ignition resistance requirements for furniture. Octa-BDE is used primarily as a flame retardant in acrylonitrile butadiene styrene (ABS) computer and monitor cases.

Tests have shown that some PBDEs, mostly those with lower numbers of bromine atoms, are toxic. Exposure of test animals to lower brominated PBDEs resulted in thyroid effects and possible immune suppression (Agency for Toxic Substances and Disease Registry, 2004). Studies also have shown very high concentrations of PBDEs in women's breasts in the San Francisco Bay area, with an inverse relationship between age and concentration that suggests recent exposures (Petreas et al., 2003; She et al., 2002). Consequently, the use of some PBDE formulations has been limited due to their persistence, toxicity and apparent propensity to bioaccumulate. In 2004, the European Union banned products with greater than 0.1% penta- and octa-BDE. In 2003, the California legislature also passed legislation (AB 302) that states "a person may not manufacture, process, or distribute in commerce a product, or a flame-retarded part of a product, containing more than one-tenth of 1 percent of pentaBDE or octaBDE, by mass." This ban went into effect in January 2008.

CCLEAN previously documented higher concentrations and loads of PBDEs associated with wastewater discharges than with rivers (CCLEAN, 2008). Certain PBDE congeners have been shown to be significant risk for sea otters dying due to protozoal infection (Miller et al., 2007). Consequently, close attention is being given to PBDEs in CCLEAN wastewater discharges.

Each of the four CCLEAN wastewater discharges are characterized by subtly different profiles of PBDE homologues, which have varied some since measurements began in September 2006. PBDEs in all four discharges were dominated by tetra-BDEs and penta-BDEs (Figure 20). In Santa Cruz wastewater, deca-BDE had concentrations approximately half those of tetra-BDEs and penta-BDEs (Figure 20a), whereas Watsonville wastewater sometimes had equal amounts of tetra-BDEs, penta-BDEs and deca-BDEs (Figure 20b). Similar to Santa Cruz, PBDEs in MRWPCA wastewater were consistently dominated by tetra-BDEs and penta-BDEs, with deca-BDEs at about half the concentration of the two dominant homologues (Figure 18c). PBDEs in CAWD wastewater always had nearly equal concentrations of tetra-BDEs, penta-BDEs and deca-BDEs (Figure 20d). In all four discharges, di-BDEs hepta-BDEs and octa-BDEs were consistently present in very low concentrations. As previously suggested (CCLEAN, 2008), the unique PBDE homologue compositions in each of the wastewater discharges could be due to different PBDE sources or consistent effects of the different wastewater treatment processes at each facility.

PBDE concentrations in all the wastewater discharges varied through time. Concentrations of PBDEs increased substantially at Santa Cruz, Watsonville and CAWD in March 2008, with most of the increase due to tetra-BDEs, penta-BDEs and deca-BDEs. Slight increases in several other homologues also occurred at all of these sites. MRWPCA's PBDE concentrations declined in March 2008 from the high measured in March 2007, with the decrease due mostly to tetra-BDEs and penta-BDEs.

PBDE concentrations in mussels have not changed substantially during the two years since measurement of PBDEs began (Figure 21). Consistent with spatial patterns observed for most other POPs in mussels from CCLEAN sites, The Hook had the highest concentrations of PBDEs. Unlike the other POPs, however, the site with the second highest concentration of PBDEs in mussels was Carmel River Beach. Although this site is near both the CAWD wastewater discharge and the mouth of the Carmel River, very small loads of PBDEs have previously been measured from both these sources (CCLEAN, 2008), suggesting the PBDE concentrations in the mussels could be related to nearby urban storm runoff. While PBDE concentrations in mussels have changed appreciably over two years, the concentrations in mussels from CCLEAN sites are substantially lower than those measured in mussels in San Francisco Bay (CCLEAN, 2008).

4.2.2.5 Conclusions

For most POPs, concentrations in wastewater remain lower than those previously measured in rivers. Moreover, over the life of the CCLEAN program, only one excedeence of a maximum permitted effluent POP concentration has been documented (Table 21).

Each of the wastewater discharges displayed unique patterns of POP concentrations. Among the wastewater dischargers, only Santa Cruz had higher concentrations of Dieldrin than of DDT. The PAH signatures of the discharges also differed, as shown by differences in the amount of variation through time and differences in the dominance of lo-weight versus hi-weight PAHs.

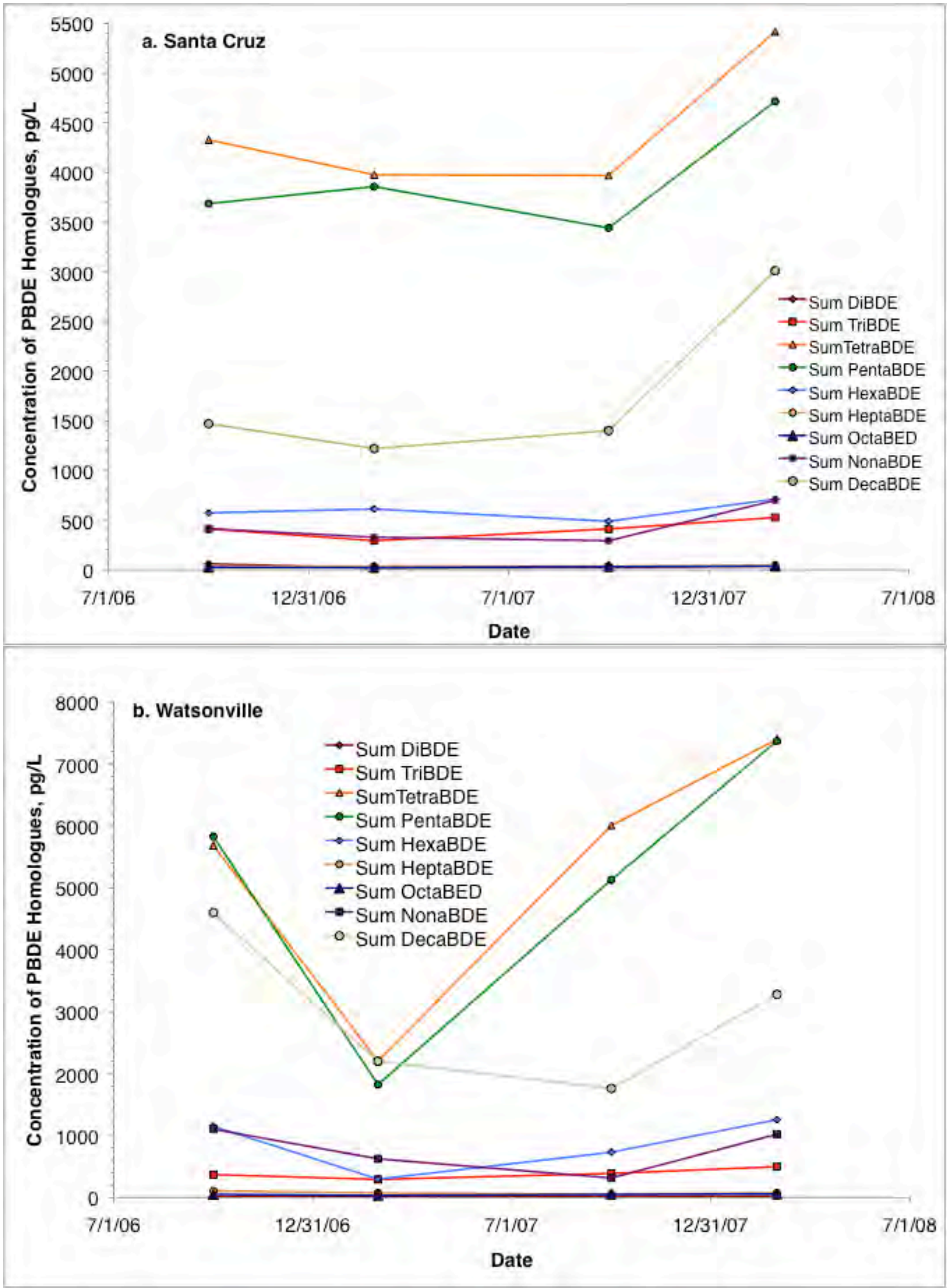

Figure 20 a and b. Temporal patterns in PBDE homologue concentrations in wastewater discharged by the City of Santa Cruz and the City of Watsonville.

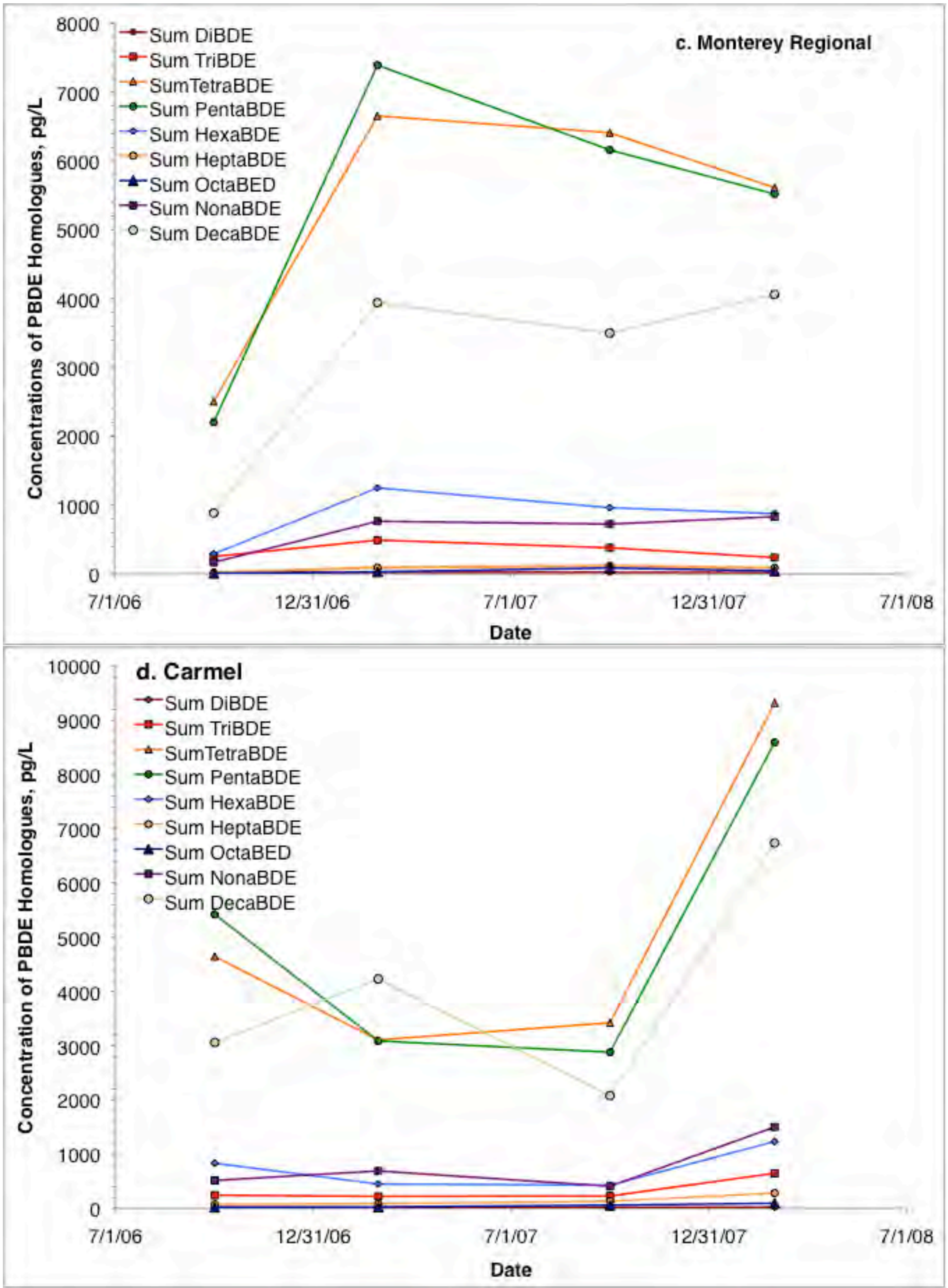

Figure 20 c and d. Temporal patterns in PBDE homologue concentrations in wastewater discharged by the MRWPCA and CAWD.

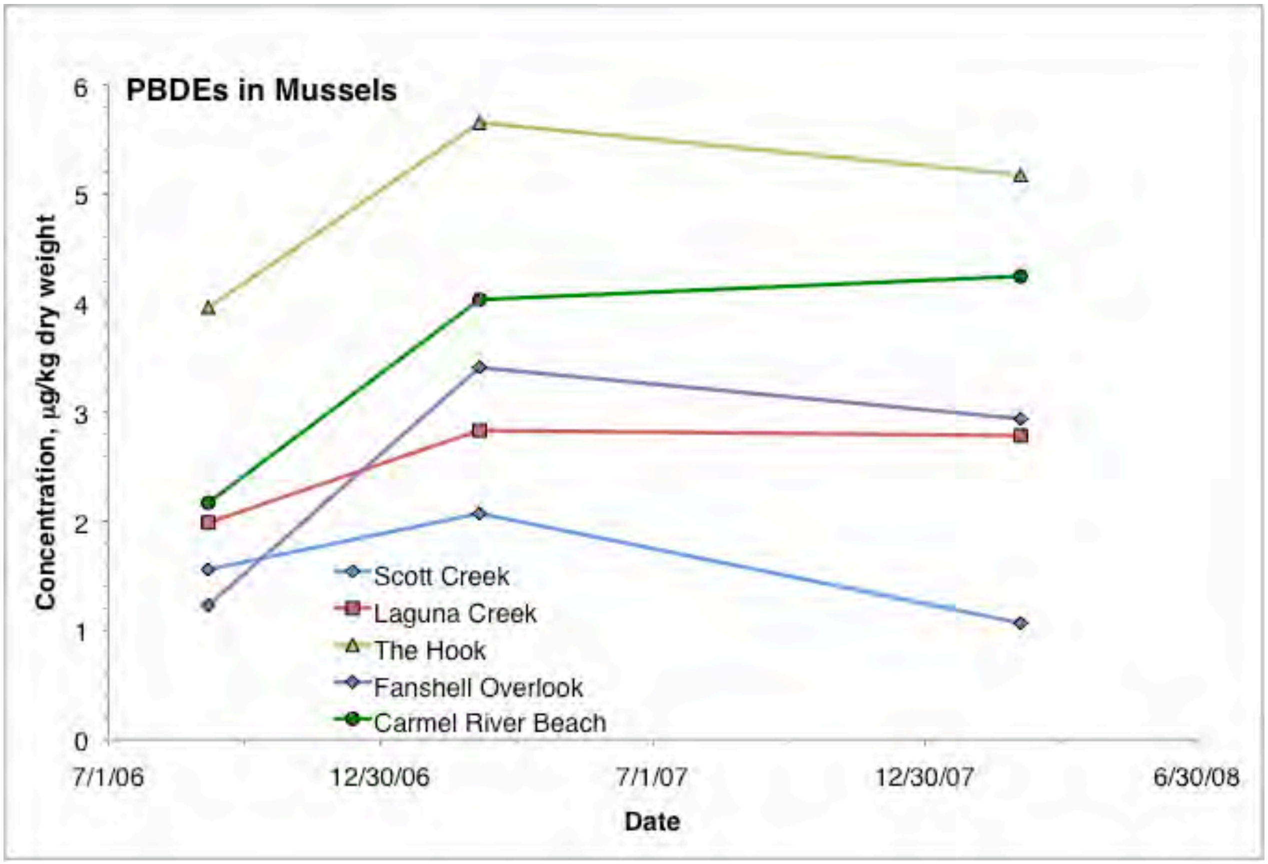

Figure 21. PBDE concentrations in mussels from five CCLEAN sites in the Monterey Bay area.

Table 21. Permit effluent limits for POP concentrations for each CCLEAN discharger, compared with the highest concentration measured since the beginning of CCLEAN in 2001.

	Permit Effluent Limits, ng/L (highest measured concentration)			
Agency	**PAHs**	**Chlordanes**	**DDT**	**PCBs**
Santa Cruz	1010 (156.66)	2.65 (1.668)	19.55	2.19 (0.821)
Watsonville	748 (100.239)	1.955 (4.348)	14.45	1.615 (0.846)
MRWPCA	1284.8 (100.24)	3.358 (1.285)	24.82	2.774 (1.364)
CAWD	1070 (115.97)	2.81 (2.099)	20.74	2.32 (0.778)

Compared to rivers, there were relatively few differences in wastewater POP concentrations between wet-season and dry-season samples and relatively few significant correlations with discharge volume or rainfall. Nevertheless, each wastewater discharge exhibited large differences among samples for several POPs. These results mean that, in most cases, there are factors other than discharge volume and rainfall that are causing the observed variation. This unexplained temporal variation in wastewater POP concentrations could be associated with variations in influent loadings and characteristics that alter treatment efficiencies, as well as from unanticipated discharges to the sewage system of materials with higher POP concentrations.

Some results suggest infiltration into the sewage collection system as sources of POPs. The patterns of hi-weight PAHs and Dieldrin at Watsonville and hi-weight PAHs at MRWPCA will likely become more obvious with implementation of plans to divert urban stormwater to some CCLEAN wastewater treatment plants. Higher concentrations of Dieldrin in wet-season samples than in dry-season samples and positive correlations with wastewater discharge volume at Santa Cruz and CAWD, in the absence of correlations with rainfall, could indicate differences in removal efficiency at higher rates of throughput in those treatment plants.

Concentrations and homologue composition of PBDEs in CCLEAN wastewater discharges have varied over the two years they have been measured. Total concentrations and the PBDE homologue composition of each wastewater discharge differs from the others. Concentrations of PBDEs in mussels have not decreased in the past two years.

4.2.2.6 Recommendations

The wastewater monitoring should continue as it is currently conducted. Analysis of dioxins/furans and perfluorinated compounds began in October 2008 and several years of data for those contaminants should be evaluated before considering revisions to wastewater sampling.

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