MODEL MONITORING FOR SMALL PUBLICLY-OWNED TREATMENT WORKS IN THE SAN DIEGO REGION

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EXECUTIVE SUMMARY

This document presents a "model" ocean monitoring program for Small Publicly Owned Treatment Works (POTWs) in the San Diego region. The goal of this document is to present a guide for both regulatory and regulated agencies for developing or renegotiating an effective and efficient ocean monitoring program that answers specific management questions of interest. While this guidebook does not list site-specific requirements, it does detail the management questions that need to be answered and identifies the important factors that need to be considered when designing individual monitoring programs.

The Small POTW model monitoring program follows on previous model monitoring efforts by Large POTWs and Municipal Stormwater Agencies. To ensure that differences between Large and Small POTW discharges and potential receiving water impacts were considered, a committee with representatives of the five Small POTWs and the Regional Water Quality Control Board (RWQCB) in San Diego was convened. Over a one-year period, this committee reached consensus on model designs for four monitoring elements; effluent, water quality, sediment, and fish. Within each monitoring element, this document describes the management questions to be addressed, an inventory of existing effort (based on the year 2000), the ability of existing effort to answer the management question(s), and recommendations for altering existing monitoring to align itself with the model monitoring program.

The model monitoring program for Small POTWs has a philosophy and framework suitable for addressing the needs of multiple audiences. Although monitoring is a necessary requirement of a National Pollutant Discharge Elimination System (NPDES) permit, this monitoring should effectively address specific monitoring questions. If the data are not being used to answer a specific question, the need for the monitoring should be scrutinized. Alternatively, when a monitoring question is answered, there is an expectation that some management action shall occur. Finally, monitoring should be adaptive and that more monitoring should be allocated to discharges that result in greater environmental impact. In contrast, when little to no impact is observed, adaptive triggers should be in place for reducing the level of effort. The group agreed to a three-part framework to apply these philosophies including core monitoring, regional monitoring, and special studies. Core monitoring is typically site specific and will continue for the length of the NPDES permit. Regional monitoring is less frequent (i.e., once every five years), but more spatially distributed and addresses questions about cumulative impacts. Special studies can occur at either large or small spatial scales, but are directed projects with a distinct beginning, middle, and end. Hence, special study set-asides for NPDES permits provide the flexibility needed by permittees and regulators to address unique circumstances within an individual agency and could be negotiated on a year-by-year basis.

An evaluation of effluent monitoring by Small POTWs indicated that large differences in monitoring resources were being expended among facilities with little to no rationale for their disparity. For example, there was a 10-fold difference in the number of effluent measurements made among facilities in 2000 due largely to differences in the frequency of sampling. Regardless of effort, it appeared that the vast majority of measurements were well below effluent permit limits and that altering the frequency could greatly increase the efficiency of effluent monitoring. The model program recommended that the frequency for this core monitoring element should be set on the likelihood of exceeding a permit limit using statistical-based tools such as power analysis. Approaches described in recent Ocean Plan amendments that address reasonable potential analysis use this type of an approach.

Fish and sediment monitoring effort was similar among the Small POTWs, but the transect-based sampling designs used by all of the agencies were inefficient at answering the primary management questions. Transect-based sampling designs commingle both spatial extent and temporal trend questions, wasting effort attempting to answer both questions simultaneously. In this case, the model monitoring program recommended separating these two sampling designs. Trend sites should be located near the outfall in an area of most likely impact. If an impact is observed, then additional spatial sampling is triggered as part of the core program. Regardless, all facilities should become part of an integrated regional monitoring program, with effort relative to their respective contribution of potential pollutants, to assess cumulative impacts in the environment. In order to maximize the comparison to regional conditions, the Small POTWs should adopt the indicators, constituent lists, and methods used in the regional monitoring program.

Water quality monitoring effort at the Small POTWs was sufficient to answer the original management question, but that new questions were being asked of the monitoring program and the current designs were too inflexible to answer them. Originally, the primary water quality questions were about compliance with Ocean Plan requirements. The long history of compliance has answered this question repeatedly for more than two decades. However, answers to new questions about plume location remain almost completely unmonitored. The model program recommended a special study to assess plume location that included examining the wealth of historical data to hindcast where the plume was during certain oceanographic conditions, to nowcast where the plume currently is using new technology such as the Southern California Coastal Ocean Observing System, and to work towards forecasting when conditions are optimal for plume incursions on the beach for protecting public health. This special study is best undertaken as a cooperative among Small POTWs and could include other dischargers including Large POTWs and stormwater agencies that need to answer similar questions about their discharge plumes.

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INTRODUCTION

Small Publicly owned treatment works (POTWs) in the San Diego Region (Table 1) are a source of concern to the public because they discharge treated wastewaters to the ocean. Hence, state and federal regulatory agencies regulate their discharge through the use of National Pollutant Discharge Elimination System (NPDES) permits. These NPDES permits limit the quantity and quality of treated wastewaters they can discharge to the ocean in order to protect the public's use of ocean resources.

In order to ensure that small POTWs do not exceed the recommended quantity or quality of wastewater effluent, the State's Regional Water Quality Control Board (RWQCB) in San Diego mandates each agency to conduct routine monitoring of its effluent. In addition, to ensure that these discharges do not impact the beneficial uses in the ocean, the RWQCB mandates each agency to collect data monitoring the health of the ocean environment.

NPDES permits were originally promulgated in the early 1970's and it was at that time that many Small POTW monitoring programs were developed. Typically, an analysis of variance (ANOVA)-based design was used comparing a site near an outfall to a site(s) distant from the outfall. Much of the monitoring was exploratory because little was known about the marine environment at that time; only the most dramatic of impacts could be differentiated from natural variability among sites or at a site among differing time periods.

Much has been learned about the ocean environment since 1970, yet the design of most Small POTW monitoring programs in San Diego have changed little. The early monitoring designs are sufficient for some management needs, but are not sufficient for all needs. Environmental managers are asking different and more detailed questions about the impacts on ocean resources than 30 years ago including more accurate and complete characterizations of reference condition and natural variability, quantification of the spatial extent as well as magnitude of impact, establishment of rates of improvement (or degradation), determination of cumulative impacts from multiple sources that commingle, and establishment of cause/effect mechanisms for identifying sources of problems.

The goal of this document is to review the ocean monitoring programs of the six Small POTWs in the San Diego Region and make recommendations for improving effectiveness and efficiency, while at the same time maintaining scientific rigor. This is not meant to be a prescriptive methodological document. Instead, it is meant to be a guidebook for regulators and permitted dischargers to use when evaluating or modifying their NPDES ocean monitoring programs.

This review and subsequent recommendations follow similar efforts undertaken for Large POTWs (Schiff et al. 2001) and municipal stormwater permittees (Bernstein and Schiff 2004). Large POTWs are differentiated from Small POTWs in their volume of discharge. Large POTWs discharge over 250 million gallons per day (mgd) while small

POTWs from the San Diego region discharge less than 50 mgd. For nearly two years, scientific staff from all of the large POTWs in southern California, US EPA Region IX, the State Water Resources Control Board (SWRCB), and the Los Angeles, Santa Ana, and San Diego RWQCBs used a consensus driven process to define a model monitoring program for Large POTW NPDES permits. Stormwater discharges differ substantially from small POTWs in the fact that stormwater is not designed to commingle with sanitary waste and is discharged largely without treatment. The SWRCB asked the southern California Stormwater Monitoring Coalition (SMC) to prepare a model monitoring program similar to the Large POTWs, but for Phase I Municipal stormwater NPDES permitees. The SMC also used a consensus driven approach to define its model monitoring program that included staff from all eight of the lead municipal stormwater NPDES permittees and all three of the RWQCBs in southern California. In both the Large POTWs and the SMC, the model monitoring programs have been used, either in part or in whole, to revise existing permit monitoring and reporting requirements.

Table 1. Flow rates for Small POTWs in the San Diego Region during 2000.

Small POTW Name	Average Effluent Flow (mgd)
Aliso Wastewater Management Agency (AWMA)[1]	17.6
South East Regional Reclamation Authority (SERRA)[1]	18.7
City of Oceanside (Oceanside)	12
Encina Wastewater Authority (Encina)	22.9
City of Escondido (Escondido)[2]	14.3
San Elijo Joint Powers Authority (San Elijo)[2]	3.0

[1] These facilities are now operated by the South Orange County Wastewater Agency (SOCWA)
[2] These facilities share the same ocean outfall for a combined average effluent flow of 17.3 mgd in 2000

METHODS

Small POTW monitoring programs were evaluated in five steps. First, a framework was constructed for guiding recommendations for changes in the NPDES monitoring programs. Second, a list of monitoring questions was developed for guiding the designs of the monitoring program (Appendix A). Third, the effort for each monitoring program was summarized using monitoring and reporting program specifications stipulated in their NPDES permits, Annual reports of waste discharge (WDR), and intensive receiving water monitoring reports. Fourth, based on the effort and a review of available results, the ability of the current monitoring designs was evaluated for their respective ability to answer each of the monitoring questions. Fifth, a list of recommendations for altering existing designs was provided to enhance efficiency and/or effectiveness of the existing monitoring programs.

After initial review of the monitoring programs and discussions with regulatory and permitted agency managers, it was apparent that ocean monitoring falls into five main elements:

- effluent
- water quality
- sediment
- fish

Therefore, the document was divided into five sections based on each of these elements.

FRAMEWORK AND MONITORING QUESTIONS

Four fundamental principles guided our ideas for each monitoring element. The first principle focused on the need to monitor. Our premise was that discharge to the ocean is a privilege, not a right. NPDES permits are issued to grant the privilege for discharging to public waters predicated on demonstration that the discharge does not result in environmental degradation or impacts to beneficial uses. Monitoring is necessary to develop this demonstration and is part of exercising the privilege.

Our second principle is that while discharger permittees have monitoring responsibilities, monitoring should be focused on activities that directly relate to management questions that need to be answered, rather than gathering data for data's sake (See Appendix A for a detailed list of management questions and how they were developed). The answer to these monitoring questions should have decision value, with managers being prepared to take one action if the answer is "yes" and a different action if the answer is "no". In some cases, the action can be as simple as conducting more sampling to better understand the problem (or less sampling if there appears not to be a problem), but the link between data collection and potential actions should be explicit.

The third principle is that monitoring programs need to address questions posed at different spatial scales by a variety of different audiences. Discharge monitoring has traditionally focused on the impact in the immediate vicinity of the discharge to address regulatory issues. Monitoring also needs to address public concerns about the health of the environment, which are often regional in scale. An example might include the publics' perception about the health of fish. While they might be concerned about the health of the fish community in the immediate vicinity of an outfall, they often take a more holistic view by asking "are the fish communities in the San Diego area healthy", or "are fish communities in the southern California area healthy"? It is the cumulative responsibility of all NPDES dischargers to answer both the site-specific questions regarding the impact of their discharge as well as the more regional questions to address the publics concerns.

The fourth principle stipulates that the level of monitoring should be proportional to the level of concern about the question to be addressed. The greater the potential for environmental impact, the more monitoring that is necessary to address regulatory and public concerns. Similarly, the less the potential impact, the less monitoring that is necessary. As a corollary to this principle, the level of monitoring should be adaptive to the findings. One of our greatest criticisms of existing monitoring programs is that they are inflexible; monitoring continues regardless of what is learned, needed, or relevant. Throughout this document, references are made to "adaptive monitoring". These references indicate events or thresholds that can serve as triggers to additional (or lesser) monitoring effort based on findings within the monitoring programs.

Framework for Model Monitoring

To integrate the site–specific monitoring regulatory mandates with the publics' more holistic issues, we have designed an over-arching framework for the model monitoring program. The framework has three components that comprise a range of spatial and temporal scales: (1) core monitoring; (2) regional monitoring; and (3) special studies (Figure 1).

Core monitoring consists of the basic site-specific monitoring necessary to address individual discharger limits and impacts. It is mostly conducted in the immediate vicinity of the discharge examining small-scale spatial effects. It is also used extensively for trends analysis because it has been a routine part of all programs since their inception.

Regional monitoring provides the information necessary to make assessments over large areas and addresses the holistic questions posed by the public. It also serves to establish regional reference conditions used to help interpret alterations found as part of the core program. Regional questions need not be answered frequently, but rather at periodic intervals (we recommend five year intervals). Trend information can be deduced from regional monitoring after enough regional surveys are conducted, though there has only been three comprehensive survey conducted by dischargers in the southern California Bight at the time of this writing.

Special studies are the last type of monitoring and are focused on short time and small spatial scales. Special studies are directed monitoring to assist managers in answering specific management or research questions. Often they are used to help managers understand core or regional monitoring results where a specific environmental process is not well understood or to address unique issues of local importance. A good example might include directed studies to measure currents in the vicinity of a discharge. Regardless of the need, special studies have a well-defined beginning, middle, and end.

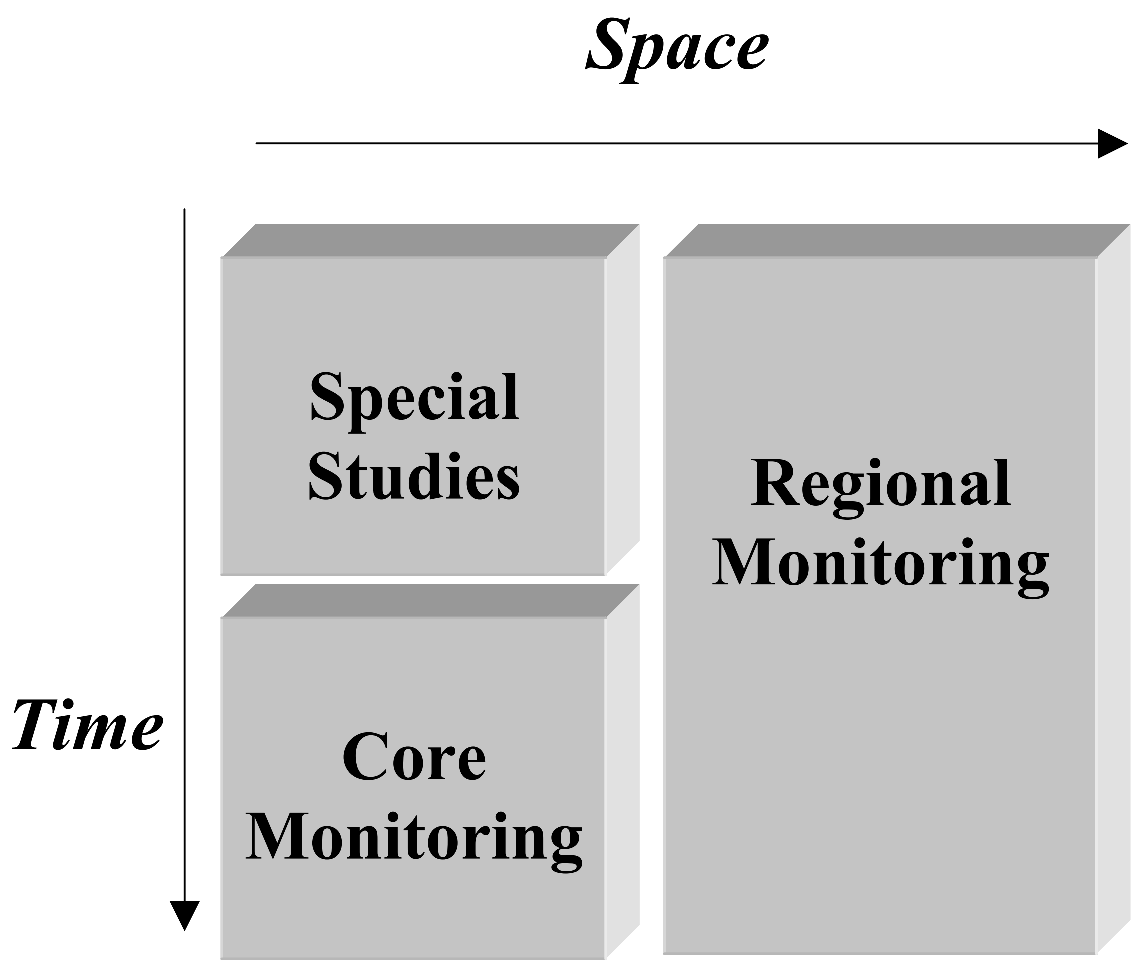


Figure 1. Model monitoring framework.

EFFLUENT

Compare and Contrast Among Agencies

The six small POTWs in the San Diego region discharged a cumulative 88.5 mgd of secondary treated effluent in 2000 (Steinberger and Schiff 2003). For comparison, this is half the discharge flow at the City of San Diego's Pt Loma Wastewater Treatment Facility (174 mgd in 2000), which currently receives only advanced primary treatment. However, it is nearly 15 times the flow rate of small POTW treatment plants as defined by the US EPA nationwide (1 mgd).

The level of effort expended by small POTWs in the San Diego region was not similar among agencies (Table 1). For example, the range in effort for general constituents, metals, and organic constituent vs. varies by a factor of two among agencies. Even where agencies share an outfall (i.e., Escondido/San Elijo), the effort is dissimilar. The differences in measurements among facilities are a reflection of differences in measurement frequency and target analytes(Table 2). For example, the City of Oceanside measures ammonia, nitrate, nitrite, and phosphate whereas the remaining San Diego Small POTWs only measure ammonia. In a similar fashion, San Elijo measures most trace metals semiannually whereas the remaining San Diego Small POTWs measure these constituents quarterly. Finally, Escondido measures organic constituents (DDTs, PCBs, PAHs) quarterly, whereas the remaining San Diego Small POTWs measure these analytes semiannually.

Evaluation of Existing Effort

The management question "*Is the effluent concentration of selected constituents below levels that will ensure public safety and protect aquatic life?*" is effectively being answered by all four dischargers for most effluent constituents. The vast majority of effluent constituent concentrations and toxicity test results are consistently below California Ocean Plan objective-based effluent limits (Table 3).

While dischargers may be answering the management question for the majority of constituents, they may not be answering the question in the most cost-efficient manner. Daily data are currently not required to ensure compliance with water quality thresholds. The minimum frequencies defined in the Ocean Plan are also not being utilized (semiannually for Table B constituents). In our review, little or no justification is evident in the current sampling designs to validate the required frequencies for most of the analytes. Most of the frequencies were set at pre-determined intervals some time in the past without considering the risk of exceeding the threshold. A risk-based approach assumes that a greater number of samples should be required when there is a greater chance of a threshold being exceeded. This would occur when the data are highly variable, or when effluent concentrations are close to exceeding their prescribed limit (Figure 2). Conversely, when there is less risk of exceeding a threshold, such as when data are not variable or are distant from the threshold, frequencies may be decreased.

Risk-based approaches are contingent upon statistical predictions of likelihood of exceedence. Our ability to predict the likelihood of exceedence, or in statistical terms "confidence," is evaluated using power analysis. Power analysis can determine the optimal number of analyses required for a desired amount of confidence that an exceedence has not occurred by examining the variability associated with historical data. This method is essentially the reverse of predicting a confidence interval. Confidence intervals (i.e., 95% confidence interval) are determined from sample size and the associated variability of the data. For power analysis, one determines the sample size based on the associated variability and desired level of confidence.

In the case of normally distributed and independent samples, the sample size necessary for the risk-based approach is given by:

$$n \approx \frac{z_{1-\alpha_1}^2 \sigma^2}{\left(T-\theta_0\right)^2}$$

where
n = number of samples per year,
T = the threshold value,
θ_0 = the estimated current concentration, and
σ^2 = the sample variance (s^2)

The ability of the risk-based approach to yield sample size appropriate to achieve desired level of confidence depends on the accuracy of estimates, θ_0 and σ^2.

Power analysis has not been conducted with historical effluent concentration data from the Small POTWs in the San Diego region. As an example, this exercise has been completed for the large POTWs in southern California to determine the optimal number of samples necessary to be confident that California Ocean Plan objective-based effluent limits or permit performance goals will not be exceeded (Schiff et al. 2001). Analysis using this risk-based approach demonstrated that all large POTWs typically analyzed samples more frequently than necessary to maintain an acceptable level of confidence that they are not exceeding a threshold of concern. In this example, most constituents required less than two samples per year to be 99% confident the effluent is below permit limits. The most notable exception was total DDT (although most large POTWs routinely report below reporting limits for this constituent). The divergence stems from the reporting limit being so close to the respective permit limit. When reporting limits were close to, or above the permit limit, power analysis is not able to resolve appropriate frequency regardless of desired confidence.

Most managers rely upon two criteria when assessing desired levels of confidence. The first criterion hinges upon the importance of the management action that follows from answering the monitoring question. If the action is dramatic or costly, managers often need a high level of confidence before they proceed. For example, if large infrastructure expenditures are required based upon the monitoring results, then managers will expend additional resources to collect more samples to be sure that the construction is necessary. If the management action is small, for instance triggering additional sampling periods, then a lower level of confidence is required. The second criterion for assessing desired confidence is cost efficiency. Power curves are the main tool to demonstrate that effort and confidence are not linear. Power analysis has been completed for some Large POTW effluent measurements (Figure 3). The inflection point of this power curve represents the most efficient frequency for monitoring. It is at this point where maximum confidence is obtained for the fewest number of samples. More samples do not buy significantly greater returns in confidence, and a disproportional amount of confidence is lost when fewer samples are collected. We used these two mechanisms to select the 99% confidence level. There was a need to be strongly confident that concentrations remained below water quality thresholds to minimize risk, while significantly more samples obtained only marginally greater confidence that thresholds were not exceeded.

While the risk-based approach has many advantages, it also has some limitations. First, one must assume that the variability in effluent quality measured historically will continue. Therefore, variability in effluent quality should be re-evaluated at least once per permit cycle or if significant changes in effluent quality are expected. Second, a risk-based approach relies heavily on the quality of the historical data. Managers must be cognizant of artificially decreased variability such as a large frequency of samples with nondetectable quantities. Large POTWs opted to use the maximum estimated variability for historical data sets with largely nondetectable samples. When the detection limit was distant from the water quality threshold, this made little difference, but when the detection limit was at or near the threshold, sampling frequency increased significantly. One remedy to this situation would be a special study with lower detection limits to quantify discharge concentrations that can be used to set nominal sampling frequencies. Third, this approach will not effectively address isolated spills or illegal discharges of potentially toxic compounds into the waste stream because these spills are typically not part of the historical data set. Existing monitoring programs are also poorly designed for this type of an event. Based upon discussions with POTW personnel, however, illegal discharges are often discovered either through more frequent monitoring of routine measurements (i.e., oil and grease, BOD, etc.) or by plant upsets.

The next management question for effluent monitoring pertains to mass emissions. Each agency has effectively addressed this management question within their facility by demonstrating that, despite increases in discharge volume, mass emissions in 2000 were the lowest in 30 years for nearly every constituent assessed (Steinberger and Schiff 2003). This management question also has a regional component, however, wherein managers want to know the cumulative and relative mass emissions for all facilities. The current programs are less effective at assessing regional mass emissions. This is primarily due to a number of constituents that are below reporting limits; hence, mass emissions cannot be accurately evaluated from the existing data. Constituents below the reporting limit can either be considered not present in the effluent and therefore assigned a value of zero, or they can be handled in a more conservative approach by considering them equal to the reporting limit. Certainly, using estimated values would greatly increase the estimated load. Many programs, including SCCWRP's annual summaries of effluent characteristics, treat non-detectable quantities as zero.

The problems associated with assigning non-detectable quantities as zero for estimating mass emissions are compounded by the fact that most of the constituents monitored by the POTWs have dissimilar reporting limits (Table 4). The result is that the agencies that work harder at lowering their limits of detection are penalized. Agencies with higher reporting limits result in non-detectable quantities; hence, their mass emissions are zero. Agencies with lower reporting limits find trace quantities and report some level of emissions. We did note that most facilities had similar or lower reporting limits in 2000 compared to 1995.

The effect of treating non-detectable quantities as zero or the reporting limit for regional mass emission estimation is exemplified by the trace metals zinc, silver, and chromium (Table 5). In this instance we compare the combined mass emissions discharged by Small POTWs to the combined mass emissions discharged by Large POTWs. In the case of zinc, Small POTWs contributed an estimated 11% of the mass emissions to the SCB compared to large POTWs when non-detectable quantities are treated as zero. The result was exactly the same when nondetectable quantities were treated as the reporting limit because virtually every zinc measurement was detectable in both the Large and Small POTW effluent monitoring programs. For silver, Small POTWs accounted for 2% of the mass to the SCB when nondetectable quantities were treated as zero. In contrast, Small POTWs accounted for 20% of the mass emissions for silver when nondetectable quantities were treated as the reporting level. This order of magnitude difference resulted because silver was largely nondetectable in Small POTW programs, but were consistently detected in Large POTW programs. Finally, Small POTWs discharged an estimated 84% of the cadmium to the SCB compared to 16% from Large POTWs when nondetectable quantities were treated as zero. This relative contribution changed to 39% Small POTW, 61% Large POTW, when nondetectable quantities were treated as the reporting level. This differential resulted from the reverse circumstance of silver; there were a greater number of non-detectable quantities from Large POTWs relative to Small POTWs.

The third management question for effluent monitoring pertains to trends. Similar to the effluent evaluation, however, we have not observed a justification for the frequency that is currently used to track trends. While current programs have been effective at tracking trends in effluent quality, particularly for tracking changes in mass emissions, the efficiency of the effluent monitoring program could be improved for detecting trends. The ability to detect trends in mass emissions is a function of sampling frequency, amount of change, and confidence. Likewise, a consistent level of change or confidence has not been expressed by POTWs or regulators during our interviews and discussions.

Recommendations

The effluent monitoring programs at all of the San Diego Small POTWs are, for the most part, effectively answering the management questions concerning effluent. Constituents are routinely below California Ocean Plan objectives and permit limits. Effluent monitoring has demonstrated mass emissions from small POTWs are the lowest in the last 30 years despite significant increases in flow. Now that levels are currently low, improvements in effluent monitoring design are appropriate to improve efficiency and lower costs within facilities, as well as maximize comparability among programs to provide integrated assessments. These recommendations are given below.

- *Frequency of monitoring should be proportional to the potential risk of exceeding a water quality threshold. Power analysis to assess potential risk can dramatically improve efficiency of effluent monitoring.*

Comparing effluent concentrations or toxicity to thresholds such as water quality objectives and permit limits is a useful management tool to assess potential risk. Our evaluation of current monitoring programs, however, indicated that many agencies might be sampling more frequently than is necessary to maintain an acceptable level of confidence (i.e., 99% confidence) that they are not exceeding a threshold of concern. Our recommendation is that the frequency of effluent sampling should be proportional to the potential risk of exceeding that threshold. We further recommend that the potential risk of exceeding a threshold be defined using power analysis and historical performance of effluent concentrations. In this way, the greatest sampling frequency is allocated to those constituents or facilities that have the greatest potential of exceeding a threshold. Agencies that are unlikely to exceed a threshold because they are so far below the limit or their variability is so small should sample less frequently.

- *Develop a common list of reporting limits so that mass emission estimates among facilities are comparable.*

Mass emissions are an important element of effluent monitoring because they enable resource managers to compare the contribution of constituents among different facilities or groups of facilities. Our evaluation of monitoring programs, however, indicated that many facilities have dissimilar reporting limits. The dissimilarities in reporting limits lead to inconsistencies in estimating mass emissions when concentrations are below reporting limits.

Our recommendation is that a common list of maximum reporting limits be developed so that mass emission estimates among facilities would be comparable. This list of reporting limits need not include every constituent, but only those that are of concern due to their toxic or bioaccumulative nature, particularly on large regional scales. The reporting limits that are developed should be achievable with the current technology. This has already begun to be implemented through the State's minimum level program.

Table 2. Number of effluent constituent measurements in 2000.

Agency	General (e.g. pH, D.O.)	Metals	Organics	Acute toxicity	Chronic toxicity
AWMA	1589	40	94	12	12
SERRA	1589	40	94	12	12
Oceanside	1744	40	94	12	12
Encina WTP	912	46	120	12	12
Escondido	1484	48	102	12	12
San Elijo	1482	24	52	4	4

Table 3. Frequency of analyte measurements from effluent in 2000.

Constituent	AWMA	Encina	Escondido	Oceanside	San Elijo	SERRA
Suspended Solids	Monthly	Daily	Monthly	Daily	Daily	Monthly
Settleable Solids	Monthly	Daily	Monthly	Daily	Daily	Monthly
BOD	na	Daily	Monthly	Monthly	Monthly	2/month
CBOD	Monthly	Daily	Monthly	Daily	Daily	Monthly
Oil/Grease	Monthly	Daily	Monthly	Monthly	Monthly	Monthly
Ammonia-N	Monthly	Daily	Monthly	Monthly	Monthly	Monthly
Nitrate-N	na	na	na	Quarterly	na	na
Nitrite-N	na	na	na	Quarterly	na	na
Organic-N	na	na	na	na	na	na
ortho-Phosphate	na	na	na	Quarterly	na	na
Cyanide	Quarterly	Quarterly	Quarterly	Quarterly	Semiannually	Quarterly
Turbidity	Monthly	Daily	Monthly	Daily	Monthly	Monthly
Acute Toxicity	-	-	Monthly	-	-	-
Pimephales promelas (survival)	Monthly	Monthly	-	Monthly	Quarterly	Monthly
Chronic Toxicity	-	-	Monthly	-	-	-
Dendraster excentricus (fertilization)	-	-	-	Monthly	-	-
Macrocystis pyrifera (germination/growth)	-	-	-	-	-	Monthly
Menidia beryllina (growth)	-	Monthly	-	-	-	-
Menidia beryllina (survival)	-	Monthly	-	-	-	-
Mytilus edulis (development)	-	-	-	-	Quarterly	-
Strongylocentrotus purpuratus (fertilization)	-	-	-	Monthly	-	-
Strongylocentrotus purpuratus (growth)	Monthly	-	-	-	-	-
Arsenic	Quarterly	Quarterly	Quarterly	Quarterly	Semiannually	Quarterly
Cadmium	Quarterly	Quarterly	Quarterly	Quarterly	Semiannually	Quarterly
Chromium	Quarterly	Quarterly	Quarterly	Quarterly	Semiannually	Quarterly
Chromium,III	Semiannually	na	Quarterly	na	Annually	Semiannually
Chromium,VI	na	na	na	na	na	na
Copper	Quarterly	Quarterly	Quarterly	Quarterly	Semiannually	Quarterly
Lead	Quarterly	Quarterly	Quarterly	Quarterly	Semiannually	Quarterly
Mercury	Quarterly	Quarterly	Quarterly	Quarterly	Semiannually	Quarterly
Nickel	Quarterly	Quarterly	Quarterly	Quarterly	Semiannually	Quarterly
Selenium	Quarterly	Quarterly	Quarterly	Quarterly	Semiannually	Quarterly
Silver	Quarterly	Quarterly	Quarterly	Quarterly	Semiannually	Quarterly
Zinc	Quarterly	Quarterly	Quarterly	Quarterly	Semiannually	Quarterly
Phenols	-	-	-	-	-	-
Nonchlorinated Phenols	Semiannually	Quarterly	Quarterly	Quarterly	Annually	Semiannually
Chlorinated Phenols	Semiannually	Quarterly	Quarterly	Quarterly	Semiannually	Semiannually
Total DDT	Semiannually	Semiannually	Quarterly	Quarterly	na	Semiannually
Total PAH	Semiannually	Semiannually	Quarterly	Quarterly	Annually	Semiannually
Total PCB	Semiannually	Semiannually	Quarterly	Quarterly	Annually	Semiannually

Dash = Not applicable.

na = Not analyzed.

nr = Not a required analysis.

Table 4. Average flow weighted mean concentrations for effluents in 2000.

Constituent	AWMA	Encina	Escondido	Oceanside	San Elijo	SERRA
Flow (mgd)	18	23	14	12	3.0	19
Flow (L x 10^6/day)	66	87	54	47	11	71
Suspended Solids (mg/L)	8	9.0	14	4.7	11	11
Settleable Solids (mg/L)	0.07	0.07	0	0.13	0.26	0.42
BOD (mg/L)	na	31	17	9.4	na	23
CBOD (mg/L)	5.3	9.6	11	3.1	8.0	7.1
Oil/grease (mg/L)	0.49	0.95	1.1	17	1.2	2.8
Ammonia-N (mg/L)	12	23	23	18	21	23
Nitrate-N (mg/L)	na	na	na	4.1	na	na
Nitrite-N (mg/L)	na	na	na	0.98	na	na
ortho-Phosphate (mg/L)	na	na	na	< 5	na	na
Cyanide (ug/L)	< 200	0.48	< 50	18	nd	< 20
Turbidity (NTU)	4.4	6.2	6.8	4.0	4.5	5.6
Acute Toxicity (TUa)	-	-	0.99	-	-	-
Pimephales promelas (survival)	0.44	0.56	na	1.12	0.59	0.51
Gasterosteus aculeatus (survival)	na	na	na	na	na	na
Menidia beryllina (survival)	na	na	na	na	na	na
Chronic Toxicity (TUc)	-	-	< 58	-	-	-
Dendraster excentricus (fertilization)	na	na	na	< 33.3	na	na
Macrocystis pyrifera (germination/growth)	na	na	na	na	na	< 50
Menidia beryllina (growth)	na	17.9	na	na	na	na
Menidia beryllina (survival)	na	17.9	na	na	na	na
Mytilus edulis (development)	na	na	na	na	< 31.3	na
Strongylocentrotus purpuratus (fertilization)	na	na	na	< 33.3	na	na
Strongylocentrotus purpuratus (growth)	9.8	na	na	na	na	na
Arsenic (ug/L)	< 20	< 15	1.9	< 9	< 4[b]	< 20
Cadmium (ug/L)	< 20	13	< 2	< 0.6	nd	< 20
Chromium (ug/L)	< 10	< 100	< 1.8	< 3	< 3[b]	< 10
Copper (ug/L)	< 30	< 50	9.3	< 2	nd	< 30
Lead (ug/L)	< 20	< 50	1.2	0.98	nd	< 20
Mercury (ug/L)	< 1	< 0.1	< 0.5	0.08	< 0.4[b]	< 5
Nickel (ug/L)	< 20	< 50	18	5.0	nd	< 20
Selenium (ug/L)	< 30	< 15	1.3	< 10	< 4	< 30
Silver (ug/L)	< 20	< 25	< 1	< 5	nd	< 20
Zinc (ug/L)	30	79	69	17	25	41
Phenols[a] (ug/L)						
Nonchlorinated Phenols	< 20	< 100	< 50	< 50[b]	< 50[b]	< 20
Chlorinated Phenols	< 10	< 20	< 10	< 20[b]	nd	< 10
Total DDT (ug/L)	< 0.03	< 0.1	< 0.1	< 0.06[b]	na	< 0.03
Total PAH (ug/L)	< 10	< 10	< 10	< 23[b]	< 23[b]	< 10
Total PCB (ug/L)	< 0.5	< 1	< 5	< 1.2[b]	< 1.2[b]	< 0.5

[a] Phenols represents the measurement for total phenols, for facilities which did not measure individual phenols.
[b] Value provided is the MDL for the measurement, RL not provided in reports
na = Not analyzed nd = Measurement was below detection level, however RL/MDL not provided or not found Dash = Not applicable
< = Less than the reporting level; where more than one RL was used during the year, the higher of the two was reported here

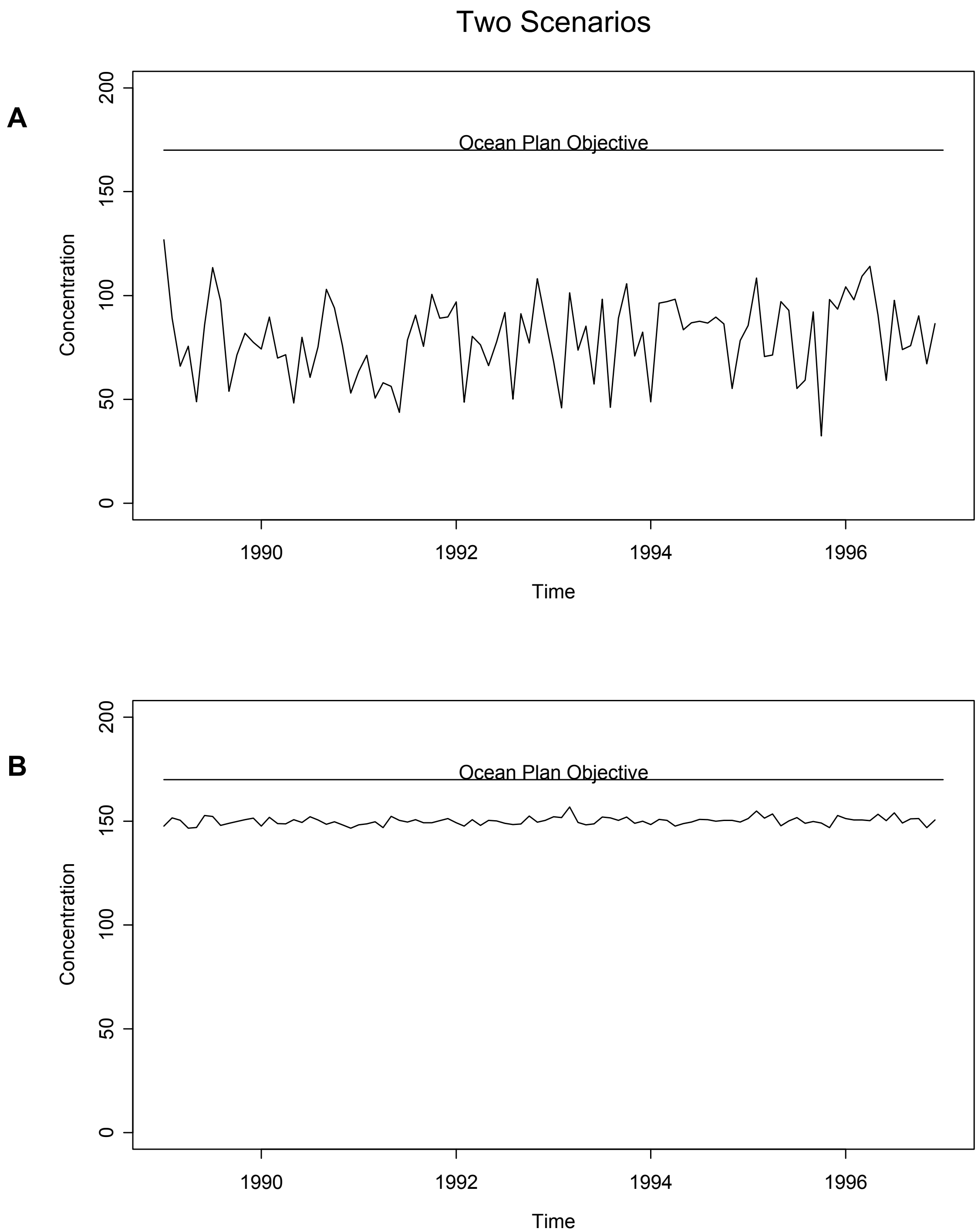


Figure 2. Hypothetical effluent constituent variability relative to California Ocean Plan objective based effluent limits. Proximity to the objective is tolerable as long as variability is small (A). Increases in variability are more tolerable with distance from the objective (B).

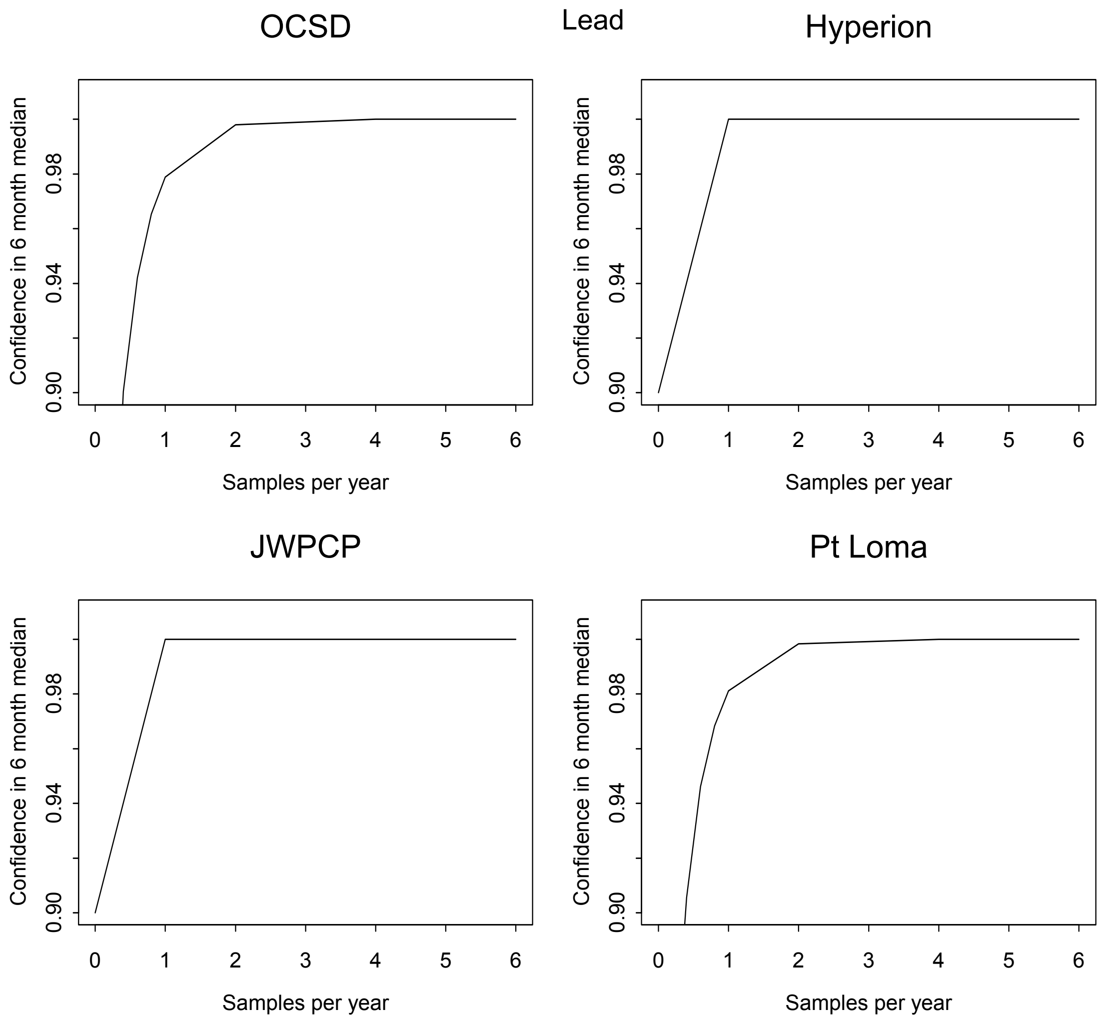


Figure 3. Sampling effort required to achieve an acceptable level of confidence for lead effluent concentrations. Power analysis was used with the historical discharge data from 1989-1996 for each of the four dischargers.

Table 5. Bias in relative mass emissions between small and large POTWs treating quantities below the detection limit (DL) as 0 or as the reporting limit/method detecting limit (RL/MDL).

	DL = 0			*DL = RL/MDL*		
Constituent	Total Mass Emissions	Small POTWs (%)	Large POTWs (%)	Total Mass Emissions	Small POTWs (%)	Large POTWs (%)
Volume (L x 10^9)	1683	12	88	1683	12	88
Suspended Solids (mt)	66,450	3	97	66,450	3	97
Settleable Solids (L x 10^3)	330,289	7	93	365,555	6	94
BOD (mt)	100,626	3	97	100,630	3	97
CBOD[a](mt)	977	-	-	996	-	-
Oil/Grease (mt)	15,516	4	96	15,747	6	94
Ammonia-N (mt)	45,968	7	93	45,969	7	93
Nitrate-N (mt)	430	35	65	432	35	65
Nitrite-N (mt)	479	9	91	480	9	91
Organic-N (mt)	4,620	2	98	4,620	2	98
Total Phosphorus[b] (mt)	1,899	0	100	1,902	0	100
Cyanide (mt)	10	4	96	13	19	81
Arsenic (mt)	4	5	95	5	27	73
Cadmium (mt)	1	84	16	2	39	61
Chromium (mt)	5	2	98	39	56	44
Copper (mt)	52	2	98	57	7	93
Lead (mt)	1	12	88	13	20	80
Mercury (mt)	0	6	94	1	16	84
Nickel (mt)	32	2	98	43	7	93
Selenium (mt)	9	3	97	10	15	85
Silver (mt)	4	2	98	8	20	80
Zinc (mt)	74	11	89	74	11	89
Phenols (mt)	113	0	100	113	0	100
Nonchlorinated phenols	4	0	100	27	18	82
Chlorinated phenols	58	0	100	97	8	92
Total DDT (kg)	2	0	100	93	16	84
Total PAH (kg)	739	0	100	31,393	5	95
Total PCB (kg)	0	-	-	2,279	13	87

[a] CBOD only measured by select small POTW facilities.

[b] Total phosphorus calculated from phosphate and phosphorus results.

Dash = Not applicable.

nd = Not detected.

WATER QUALITY MONITORING

Compare and Contrast Among Agencies

The level of effort expended on receiving water quality monitoring moderately differed among agencies (Table 6). In 2000, the number of water quality sites ranged from seven to 10 and all were sampled monthly. All of the agencies have a similar sampling design consisting of a longshore transect typically at outfall depth. Several sites are located near the outfall diffuser, with the spacing between sites increasing with distance from the outfall, and at least one reference site furthest from the outfall. The number of water quality parameters analyzed by each agency was also similar consisting of transmissivity, dissolved oxygen, temperature, salinity, and pH all of which are measured by an *in situ* device with probes called CTD. None of the agencies measured nutrients, chlorophyll, or other water column parameters.

Evaluation of Existing Effort

Water quality monitoring addresses two basic management questions: 1) *Do the receiving waters near the outfall meet Ocean Plan water quality objectives?* and 2) *What is the fate of the discharge plume?* The first question is intended to assess ecosystem protection, while the second question primarily addresses a human health issue (the likelihood of the plume reaching water contact zones).

The historical programs have effectively addressed the management question about ensuring protection of the [water column] ecosystem. Most programs have demonstrated for more than 15 years that they consistently meet Ocean Plan objectives for pH, dissolved oxygen (D.O.), and transmissivity. When local alterations in these parameters have been noted, they have been attributable to natural phenomena unrelated to outfall discharge (e.g., storms, upwelling), or are identified to be within the range of natural variability (Conversi and McGowan 1994, OCSD 1995a, OCSD 1997). Since the loads of TSS and BOD in small POTWs have decreased over time (Steinberger and Schiff 2003), impacts to D.O. and transmissivity are even less likely.

While historical monitoring designs have effectively determined that D.O., pH, and transmissivity consistently do not exceed water quality objectives, they are not designed to address nutrient impacts as a potential stimulator of phytoplankton growth. With reduced discharges of BOD and TSS, nutrient enrichment becomes the most likely mode of potential water quality impact from POTW outfalls. Several studies during the 1970's suggested that upwelling was a larger source of nutrient enrichment than POTWs (Eppley 1986), but little routine nutrient or phytoplankton monitoring has been conducted since that time by any of the four agencies. Large POTWs have recently begun to address this issue by adding fluorescence (an estimator of chlorophyll) measurements as part of their monitoring and indicate that eutrophication is still minimal as a result of their discharges. Measurements during the Bight '98 regional monitoring program also indicated that eutrophication near Small POTWs was minimal if even perceptible, but this was a one-time survey.

Our evaluation of the question concerning where the discharge plume goes addressed three temporal scales, including the ability of monitoring programs to: 1) hindcast (where has the plume been), 2) determine where the plume currently is (near real-time), or 3) predict where the plume will go under certain conditions (forecasting). Given the importance the public places on this question, particularly with regards to beach closures, a successful program should be able to address all three temporal scales.

To date, none of the programs have attempted to address either of the latter two time scales. With regards to the hindcasting, most of the programs have effectively demonstrated that under typical oceanographic conditions, POTW plumes remain submerged and appear not to encroach upon the shore (Conversi and McGowan 1992). This is particularly true for large POTWs where special studies have been conducted (MEC and Applied Ocean Science 2001). However, the historical monitoring programs at small POTWs have not been effective at assessing where the plume is located in the offshore environment, or under what conditions the plume is likely to move towards shore.

The primary reason that managers are unable to answer questions about where the plume is located under typical oceanographic conditions is because the existing data are under analyzed. Tremendous effort has been expended to collect spatial information over the last 15 to 20 years, but most analysis has focused on a spatial description of single events; the data have not been integrated to create a map that delineates isoclines of plume occurrence (e.g., Figure 4). The problem is exacerbated at small POTWs because their monitoring grids are often too sparse to sufficiently describe the spatial extent of the discharge plume. Finally, little data analysis has been attempted to link correlative variables (i.e. wind, waves, tide, temperature, barometric pressure, etc.) to assess when conditions exist that move the plume in atypical directions.

The primary reason that managers cannot predict where a POTW plume goes during atypical oceanographic conditions is because these conditions have not been well sampled. Episodic events are not well characterized by a monitoring strategy that samples at infrequent, preset intervals. An alternative strategy would be to recognize the success in demonstrating that the plume is typically submerged and to reallocate effort towards periods when the plume is most likely to move towards surface or shore. Doing so would require switching the sampling schedule from calendar-driven to event-driven.

Recommendations

Our recommendations focus on exchanging inefficient effort from historical monitoring towards producing a predictive water quality model that managers need. Our recommendations for achieving that goal follow a four-step path: 1) reduce monitoring frequency and reallocate the effort more effectively; 2) analyze existing data; 3) promote the use of new technology to improve monitoring in a test case application; and 4) find cooperative interactions among POTW programs, other monitoring agencies, and researchers to develop a predictive model.

- *Reduce the frequency of monitoring that addresses questions regarding water quality impairments and reallocate that effort to address questions regarding plume location.*

The monthly water quality monitoring that has been conducted by all of the small POTWs was providing redundant information regarding water quality impacts; more than 15 years have effectively demonstrated that discharge plumes rarely cause exceedences in water quality thresholds. A more efficient reallocation of effort would be to reduce the monthly frequency in favor of monitoring designs that address other questions, such as plume location. This has already begun to occur as part of the large POTW programs where the monitoring frequency has been reduced to quarterly sampling. The tradeoff in effort has been an increase in spatial extent to assess the spatial impact of plumes, including land-based sources. Linking to this effort in a collaborative fashion would be a cost-effective choice for maximizing information and placing the small POTWs in context of regional-scale oceanic circulation patterns that are the forcing functions for plume dynamics.

- *Analyze existing data to create isocline maps of plume occurrence*

The first step in our recommendation is to analyze existing data to improve hindcasting ability. A tremendous quantity of data has been accumulated over the years that could be used to create maps of plume occurrence; contours would represent the proportion of time a plume may occur within its boundaries (Figure 4). Spatial statistics will likely play a role in this mapping component. For example, key data sets will need to be identified so that spatial covariance can be assessed and interpolations between data points can be verified. Separate maps might be produced depending upon prevailing oceanographic conditions such as thermocline present or absent. Similar maps could also be created in vertical space (e.g. water column cross-section) or even three dimensions. This recommendation could be undertaken immediately as a special study and accomplished in a relatively short time frame of one to three years.

- *Promote the use of new technology to capture data regarding episodic events that are not well-characterized with existing monitoring, but are likely important oceanographic driving factors influencing plume movement towards shore. The new technology should be applied in a test case to demonstrate its effectiveness and improved efficiency prior to becoming routine monitoring.*

The second step in our recommendation is to promote the use of new technology to improve monitoring of plume location. The timing for this type of recommendation is perfect since the State of California is beginning to implement the Southern California Coastal Ocean Observing System (SCOOS). SCOOS, which is being led by the Scripp's Institute of Oceanography, is constructing a $20M network of remote sensing tools specifically designed to measure surface water currents from Mexico to Point Conception. These remote sensing tools will include radar, codar, and/or microwave land-based sensors, supplemented with satellite imagery. The purpose of these types of tools is to ascertain real-time data on surface water movement and identifying those times and locations when plumes may surface and move towards shore. However, these systems do not measure subsurface movements and this is one component that Small POTWs may wish to collaborate with Scripp's. Several examples of new technology that could be applied during a collaborative special study include moorings of current meters and/or thermisters, autonomous profiling vehicles (APVs), or autonomous underwater vehicles (AUVs). They're advantageous because each of these new technologies are *in-situ* sampling devices that can record water quality information in near-continuous modes enabling Small POTWs to capture the atypical, episodic events that are not well-characterized now, but without having to deploy field crews in continuous, costly and perhaps unsafe conditions. These new technologies have been used in southern California for these purposes near a large POTW (Noble and Xu 2004)

- *Find cooperative interactions among POTW monitoring programs, other monitoring programs, and researchers to effectively develop predictive models of plume dynamics.*

The third step in our recommendation is to find cooperative interactions among small and large POTW programs and other researchers to develop a predictive model. The predictive model is the ultimate goal managers need to answer questions regarding where the POTW plume is going. Applications for such a model might include chlorination schedules, awareness of plume intrusions to water contact zones, and assessing proposed increases in discharge volume. However, developing such a model requires unique experience and expertise that is rarely found in the oceanographic community and typically beyond the expectations of monitoring program personnel. In fact, this type of model is beyond the scope of a single facility and will likely require integration of many facilities to understand the large-scale processes that drive oceanographic forcing. This integration has already begun for several large and small POTW agencies to the north and should incorporate San Diego POTWs, local research institutions, and National Programs. Several local research institutions exist within the SCB with such expertise and desire including UC Santa Barbara, University of Southern California, UC San Diego (Scripps Institute of Oceanography), and the US Geological Survey. Moreover, these institutions have ongoing research projects that may overlap, or may launch off of existing effort, to better understand ocean dynamics, plume dispersion, and transport. Other monitoring agencies also exist within the SCB that need to address plume dynamics. In particular, stormwater management agencies need to assess the fate of their discharges in the marine environment. Finally, there are a series of National Programs that are being developed on the east coast of the U.S. that desire local participation to become effective tools for decision-making purposes.

Table 6. Water quality monitoring effort at Small POTWs.

Agency	Frequency	# Stations	Total # casts	Parameters measured
AWMA	Monthly	7	84	D.O., pH, salinity, temp, transmissivity
SERRA	Monthly	7	84	D.O., pH, salinity, temp, transmissivity
Oceanside	Monthly	7	84	D.O., pH, salinity, temp, transmissivity
Encina WTP	Monthly	10	120	D.O., pH, salinity, temp, transmissivity
San Elijo/Escondido	Monthly	7	17	D.O., pH, salinity, temp, transmissivity

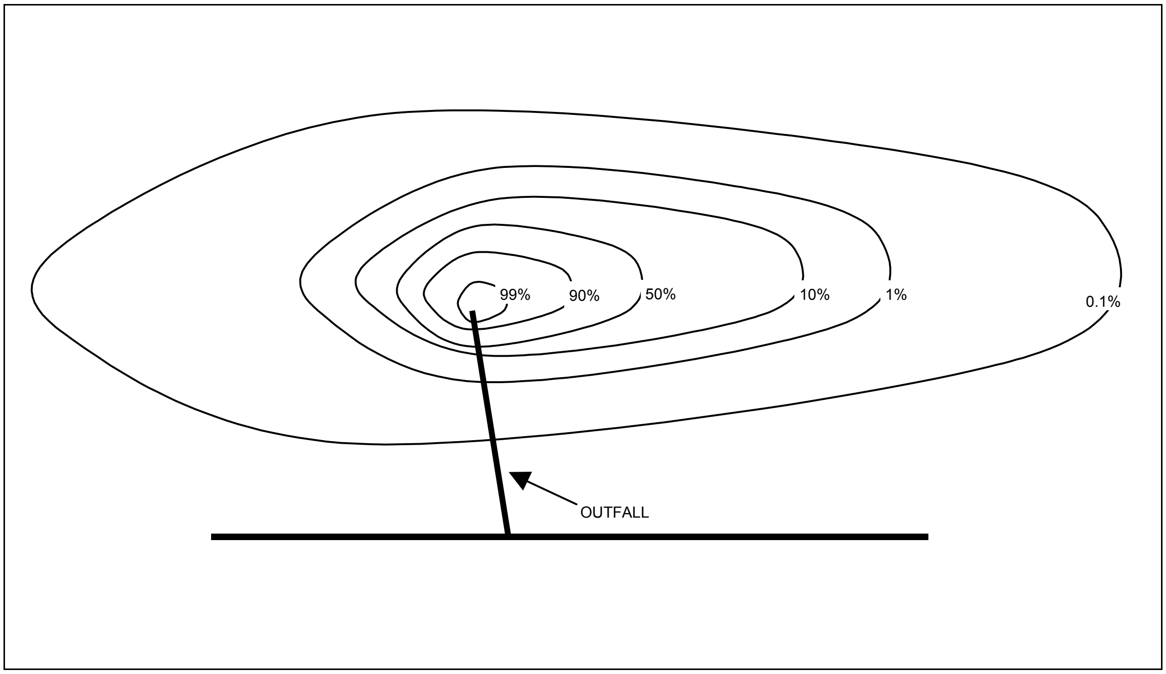


Figure 4. Hypothetical isocline map of plume occurrence. Each isocline represents the proportion of time that the plume may occur at that location. Separate maps could be constructed for varying oceanographic conditions.

SEDIMENT MONITORING

Compare and Contrast Among Agencies

Moderate differences were found among the facilities in the level of effort expended on sediment monitoring. The number of sediment chemistry samples conducted during a permit cycle differed by 50%. The number of benthic infaunal analyses conducted during the same period differed by 100% (Table 7, 8). The biggest differences observed were for sampling frequency and replication. AWMA collects the most samples at the most sites including 3 replicates for sediment chemistry and 5 replicates for infauna. SERRA samples the same number of sites, but collects only one replicate for sediment chemistry and three replicates for infauna. SERRA, Oceanside, and San Elijo all sample sediment chemistry twice per permit cycle (once in summer and once in winter) while AWMA and Encina WTP only sample once (in summer) per permit cycle. A different set of frequencies is also seen for infauna with AWMA, SERRA, and Oceanside sampling twice per permit cycle compared to Encina and San Elijo only sampling infauna once per permit cycle.

The sediment chemistry constituents analyzed among the agencies differed considerably (Table 9). Of the 21 different compound classes identified, only BOD, Cyanide, chlorinated hydrocarbons, phenols, radioactivity, and metals were analyzed in common among all Small POTWs. Even for these compounds, there were observable differences. For example, Encina measures 23 different metals while Oceanside only measures 15.

Evaluation of Existing Effort

Sediment monitoring has been a part of each agency's monitoring program since its inception and has proven to be moderately effective. Each of the agencies has been able to demonstrate discharge effects on sediment chemistry and infauna is negligible. For example, Small POTWs have been shown to have sediment quality at or near reference conditions during the 1998 Regional Monitoring survey (Figure 5). Sediment monitoring data, thus, have demonstrated the effectiveness of effluent control programs through improvements in the benthic communities and decreases in sediment chemical concentrations.

While sediment sampling programs have been effective for addressing several management questions, they have been inefficient for addressing the two primary questions that Small POTW managers have indicated during interviews should be addressed: 1) *is the sediment condition (i.e. contaminant concentration and bioeffects) altered near the outfall?* and 2) *is the sediment condition changing over time?* Present sampling designs fail to distinguish these objectives, which have different design needs, resulting in inefficient allocation of effort.

Describing the spatial pattern of impact requires gathering data from as many sites as possible. To describe a spatial pattern efficiently, the number of replicates collected at a site and the number of repeated visits to the site (e.g., seasonal sampling) should be minimized in favor of sampling more sites. In contrast, trend assessments are more efficiently accomplished through numerous repeated visits to a site and replication during each visit.

At present, most programs commingle these two questions in a common sampling design. A transect of sampling sites are visited one year every permit cycle, but many programs sample seasonally and often with replicates. Revisiting sites every five years hinders trends assessments. Given that little impact is observed in these programs suggests that reduced trend detection is appropriate. The second element of inefficiency is in the site transects. It appears that many of the sites sampled along the transect provide redundant information, which is only amplified with replicate and seasonal sampling.

The practice of measuring replicates at every site appears to be an artifact of the historical approach of using an ANOVA model for spatial assessment. In an ANOVA design, the condition at each site is evaluated relative to a reference site(s) and replication is necessary to determine whether sites differ statistically. More recently, though, regional reference conditions and indices that quantify condition of an individual sample relative to regional reference condition (e.g., the Benthic Response Index for benthic infauna, iron normalization curves for metals) have been developed through a cooperative regional monitoring program. This has reduced the need for replication to characterize the condition of individual sites, allowing more efficient allocation of effort toward description of spatial patterns at sites where replication is not needed for trend analysis.

A more efficient design would involve dedicating a subset of sites to trend monitoring with replication, while dedicating a distinct set of sites to spatial descriptions that do not involve repeated visits or replication. This design would allow managers to assess specific sites near the outfall with increased confidence, while at the same time getting a better spatial distribution of potential impacts in the outfall area.

An opportunity also exists to improve efficiency through the use of power analysis. Large POTWs have performed this analysis and demonstrated that the number of samples allocated to trend analysis could be reduced by more than 50% with minimal loss of trend detection capability; these samples were reallocated to enhancing their detection of spatial pattern. Two types of power analysis might yield additional efficiency for Small POTW monitoring programs. The first is in assessing the desired frequency and replication for trend monitoring. Power analysis would provide needed guidance on whether effort is most efficiently allocated to increased replication on each sampling visit or more visits to the site; it would also provide information about the value/loss of increasing or decreasing total effort at individual sites. The second type of power analysis involves spatial modeling. Accurate depiction of spatial patterns requires samples that are close enough together to allow meaningful interpolation, but not so close together as to yield duplicative information. Power analysis is currently being developed at Point Loma that can be used to define the optimal sampling distance among points to develop cost-effective maps.

The emphasis of the sediment program evaluation is on sampling design, because that is where the greatest gains in efficiency can be achieved. However, the differences in sediment chemical parameters and sediment collection methods among agencies should be eliminated. For the most part, agencies are measuring a common set of chemicals that encompasses most of the parameters measured by the regional and national monitoring programs. More importantly, the State of California is currently developing sediment quality guidelines. The Small POTWs should ensure that their constituent lists mirror the lists used in the regional monitoring and sediment quality objective programs to ensure that comparisons with these programs will occur. Likewise, the methods dictated in the current NPDES permit monitoring programs for sediment collection are not equivalent with regional, state, and national monitoring programs. NPDES permits offer a variety of methods and strict standard operating procedures are used in the regional monitoring surveys.

Recommendations

- *Disaggregate the spatial and trend components of the current sediment monitoring sampling designs. Reallocating sampling sites dedicated to addressing each of these distinct management questions will improve efficiency and cost-effectiveness.*

The present programs have a single sampling design intended to address both spatial and temporal trend questions, which leads to inefficiency in sample allocation. A more cost-effective program would involve dedicating a subset of sites that receive repeated visits to assess trend monitoring, while dedicating a distinct set of sites that do not involve repeated visits to achieve description of spatial pattern.

The number and location of sampling sites dedicated to assessing trends is a facility-specific decision, but one that should focus on the area most likely to be affected. For example, many Small POTWs have a long history documenting conditions near the outfall and these sites should be continued to maintain the historical record. A dedicated effort should also be made to assess trends in reference conditions in similar habitats unaffected by the discharge. Pooling of effort among dischargers may be an efficient technique for accomplishing some of this reference condition assessment. The desired frequency and replication for sampling all of these trend sites should be assessed through power analysis.

If impact is observed at trend sites near the outfall, then additional sites should be monitored to assess the spatial extent of the impact. Ultimately, a map of impacted area is the preferred product for showing management and the public. The difficulty in recommending this adaptive trigger for a core monitoring program is determining how many sites need to be sampled to ascertain spatial extent and draw a map with confidence. Preliminary analysis of chemistry data in Santa Monica Bay suggested that spatial covariance is lost over distances smaller than 4 km. Thus, constructing a defensible map probably requires that all areas within the map boundaries be within 2 km of a measured location, with a more desirable distance being less than that. A special study to define the relationship between distance and confidence in derived maps of condition is being conducted near City of San Diego's Pt Loma Ocean outfall and this may provide more insight into optimal sampling distances.

- *Look for opportunities to incorporate measurements of sediment toxicity to increase the number of thresholds for evaluating impairment. Sediment toxicity will become especially useful when sediment toxicity identification evaluations (TIEs) become routinely available, enabling managers to assess which constituents are responsible for toxicity.*

Currently, no Small POTW programs in the SCB measure sediment toxicity as part of their routine monitoring programs. Sediment toxicity would be a useful addition because of its value in interpretation of sediment quality. Sediment quality objectives being developed by the State will likely rely on sediment chemistry, benthic infauna, and sediment toxicity for assessing sediment impairments. The reliance on multiple indicators as a weight of evidence for impairments is more costly, but provides greater certainty in an environmental impact.

Sediment toxicity measurement also provides assurance that unmeasured chemicals are not causing a problem, reducing the need to measure a larger array of contaminants in the sediment. Much as water column toxicity measures are used to screen for unmeasured chemicals in effluent, sediment toxicity screens for unmeasured chemicals accumulated in sediment. Sediment toxicity will become even more valuable when sediment toxicity identification evaluations (TIEs) are further developed because TIEs provide a mechanism for identifying the causative toxic agents, if toxicity is encountered. Sediments near wastewater discharges contain a variety of chemical constituents. The advantage of the sediment TIEs is that it narrows the list of chemicals to only those which are responsible for toxicity, enabling resource managers to focus their actions on effective remedies.

Resource managers should begin to look for opportunities to integrate sediment toxicity into their ocean monitoring programs while sediment TIEs are being developed. Some opportunities exist for accomplishing this integration. The first is regional monitoring which will also serve as a good testing ground for sediment TIEs. A second opportunity might be special studies. Special studies will be particularly valuable at those sites where sediment chemistry and benthic infauna data disagree (e.g. chemistry exceeds sediment quality guidelines and benthic infauna data indicated a health community).

Table 7. Sediment chemistry sampling effort for Small POTWs.

Agency	# Stations	# Replicates	Frequency	# Samples
AWMA	7	3	1/permit	21
SERRA	7	1	2/permit	14
Oceanside	7	1	2/permit	14
Encina WTP	7	3	1/permit	21
Escondido/ San Elijo	7	1	2/permit	14

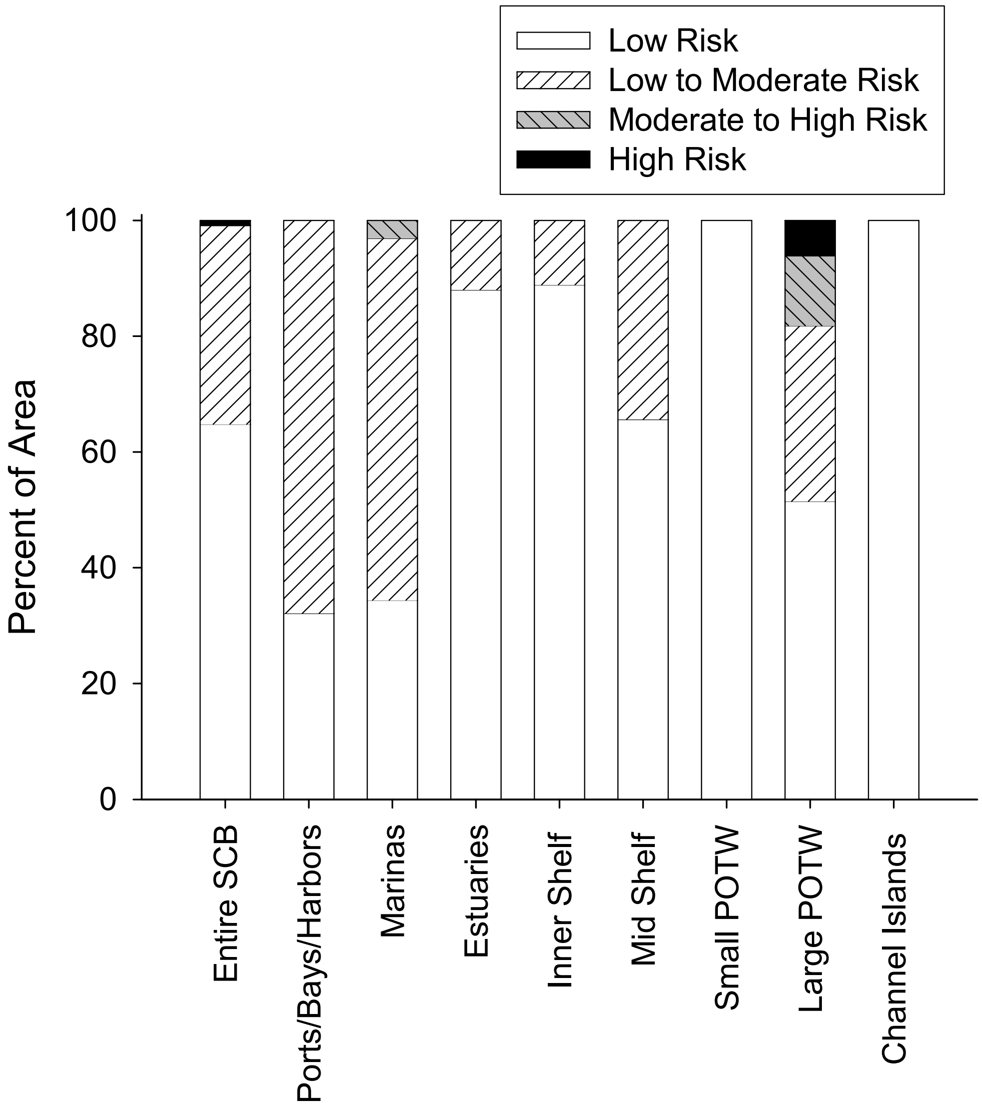
Table 8. Benthic infauna sampling effort for Small POTWs.

Agency	Sample type	# Stations	# Replicates	Frequency	# Samples
AWMA	Grab	7	5	2/permit	35
SERRA	Grab	7	3	2/permit	21
Oceanside	Grab	7	3	2/permit	21
Encina WTP	Grab	5	3	1/permit	15
San Elijo/Escondido	Grab	7	3	1/permit	21

Table 9. Similarities in sediment chemistry analysis for Small POTWs.

Analyte	% Wastewater agencies that measure analyte	% Wastewater agencies that measure at same frequency
BOD	100	67
COD	83	67
Temperature	17	0
Grain size	17	0
Particle size	83	67
Oil and grease	17	0
Sulfides	50	50
Dissolved sulfides	33	33
Total sulfides	17	0
TOC	17	0
VOC	17	0
Radioactivity	100	100
Cyanide	100	100
Base/Neutral/Acid extractables	17	0
Chlorinated hydrocarbons	100	67
PAH	17	0
PCB	83	50
Pesticides	17	0
Phenols	100	100
Dioxins	17	0
Metals	100	100

Figure 5. Risk of biological impact (i.e., sediment toxicity) based on sediment chemistry concentrations from different habitats sampled during the Southern California Bight Regional Monitoring Study in 2003. 100% of the area near Small POTWs was considered a low risk of biological impact (Noble et al. 2002).



FISH AND EPIBENTHIC INVERTEBRATE MONITORING

Compare and Contrast Among Agencies

The total effort for fish assemblage monitoring varies considerably among agencies (Table 10). All of the small POTWs only collect fish once per permit cycle. The methods for fish collection vary widely from diver transect surveys to trawls. In addition, the number of surveys varies from 10 to 36, based largely on number of sites and replication. No samples are collected by any of the Small POTWs as part of the routine monitoring program for fish bioaccumulation either for the protection of human health or the protection of wildlife consumers.

Evaluation of Existing Effort

Three management questions address fish-related beneficial uses in the SCB. The first question pertains to fish community health, whereby managers examine populations and assemblages of fish (and epibenthic invertebrates) that have proved to be useful indicators. This monitoring is conducted by examining bottom fish rather than pelagic fish because of their increased exposure to outfall particulates. The second question pertains to wildlife protection, whereby managers examine concentrations in fish tissues, in particular liver and muscle tissues that might bioaccumulate up the food chain in higher order predators such as birds and mammals. This monitoring is also conducted by examining bottom fish species that are not necessarily caught by sport or commercial fisheries. The third question addresses human health issues examining concentrations in fish tissues that might be consumed by the public. This monitoring is also conducted by examining bottom fish species, but focuses on muscle tissue and targets species caught by sport and commercial fishermen.

Based on the monitoring data from Bight'98, impacts to fish assemblages near Small POTWs, and especially those in the San Diego region appear minimal (Allen et al. 2002). Fish assemblages in 1998 were similar to those found in reference locations at the same depth.

The differences in methodology preclude comparisons among facilities and over time. The diver transect surveys called for in the NPDES permits are appropriate for rocky substrate, especially that with kelp. However, all of the Small POTWs in the San Diego Regional discharge to soft bottom habitat that is universally monitored using trawls by all other permittees in the SCB including Point Loma. Diver surveys are prone to imprecision and strong bias whereas trawl surveys provide repetitive quantifiable data on fish communities.

Current designs by all of the small POTWs commingle spatial extent and trend monitoring. The spatial extent monitoring is inefficient, however, because it provides very little information for decision-making. This is partly due to the lack of observable effects. In addition, variability from haul to haul is naturally high, making differences from site to site difficult to detect on a local scale. Large-scale changes in fish populations, however, are important for environmental decision-making. This is particularly so when managers try to assess the effect of cumulative discharges or attempt to evaluate local changes in relation to widespread changes in abundance that are occurring throughout the SCB.

The lack of seafood monitoring prevent finding an answer to what should be a regional question. *Is the seafood safe to eat?* is a question that needs to be addressed not just near Small POTW outfalls, but at all locations where fish are caught for consumption. For example, no routine monitoring program has been established for fish that are caught by sport fishermen off commercial passenger fishing vessels, piers or beaches. Not only is seafood monitoring a regional question, but the sources of seafood contaminants need to be more broadly defined and costs appropriated.

One reason there is not a regional seafood monitoring program, however, is because Small POTWs and RWQCBs are not the managers that make decisions about seafood for human consumption. It is CalEPA's Office of environmental Health Hazard Assessment (OEHHA) that post fish advisories or closures. Moreover, these primary decision-makers are not mandating integrated monitoring design. This has begun to change in Santa Monica Bay, where OEHHA assisted in the development of the new seafood monitoring design for Large POTWs there.

Recommendations

- *Consolidate methods for fish (and epibenthic invertebrates) into those comparable with regional monitoring programs*

This simple recommendation will provide tremendous value for Small POTW managers. Assessment of fish assemblage data requires regional context because of the naturally large extent of fish populations. Without comparable methods, this comparison cannot occur.

- *Focus fish population and community monitoring on trend sites since spatial extent questions are inefficiently addressed through local monitoring. Spatial extent questions for answers to fish population and community impacts should be addressed through regional monitoring.*

Significant effort has been expended in an effort to answer spatial extent questions at local scales. We recommend that monitoring programs focus fish population and community monitoring on addressing management questions regarding trends and that the spatial extent effort be redirected towards large, regional-scale designs that can capture large portions of a species range in the SCB.

Although we recommend that the spatial monitoring effort be reduced, we do not recommend that all fish monitoring be eliminated at local scales. Fish monitoring provides important information that managers need to report to the public. Maintaining a reduced number of core trend sites will fulfill this need. The frequency of this monitoring should be optimized based upon power analysis using historical data. Managers can evaluate whether population or community parameters are increasing, decreasing or remaining stable over time. Similar to our recommendations for sediment monitoring, we propose that different habitats be monitored in areas that could potentially be affected, such as depth-related habitats . Most programs already monitor these types of habitats; we recommend that this practice be continued as a means to increase their value in trend analysis. The remaining sites should be in the same habitats, but located in reference areas unaffected by the discharge. Pooling of effort among dischargers may be an efficient technique for accomplishing some of this reference condition assessment.

- *Fish tissue monitoring for wildlife protection should be considered only as part of a regional program.*

Small POTWs have not been conducting fish tissue monitoring for wildlife protection. However, Small POTWs do contribute some mass of pollutants and should therefore be part of a large-scale monitoring program to assess these impacts. Therefore, we recommend that fish tissue monitoring for wildlife protection address the spatial extent of fish concentrations at regional scales. We recommend that Small POTWs integrate into the existing regional monitoring program that examines these factors. This will provide tremendous value and valuable context for sites that are located in areas affected by Small POTW discharges.

Regional monitoring can provide answers such as "percent of area with concentrations above thresholds for wildlife consumers" to resource managers. Unfortunately, no single species has a range that covers the entire area of the SCB. Therefore, we recommend that fish guilds be used to gain the necessary large spatial coverage. Fish guilds are a set of fish species that perform similar ecological roles, but live in separate habitats (e.g., depth zones). Recent SCCWRP research suggests that sanddab guild species bioaccumulate chlorinated hydrocarbons at similar rates because of their similarities in exposure to sources such as sediment and sediment-dwelling prey. Secondly, we recommend that whole fish be used for regional assessments. The goal of wildlife protection assessments is to assess whether chemicals present at lower trophic levels endanger consumers that swallow prey whole.

- *Seafood monitoring for public health is a regional question and should be integrated with CalEPA's Office of Environmental Health and Hazard Assessment (OEHHA). This monitoring should be shared equitably among all dischargers to the ocean.*

Resource managers for Small POTWs need to know if their discharges, in combination with other discharges, are accumulating in seafood and presenting a public health risk. Unfortunately, the resource managers from Small POTWs are not the main users of data on seafood concentrations. Instead, OEHHA has the jurisdiction for issuing advisories and closures of commercial and recreational harvesting areas. Moreover, Small POTWs are not the only source of inputs to the ocean of contaminants that can accumulate in seafood; therefore, their resource managers are in no position to take all the actions that need to be taken. We recommend that the current monitoring programs be integrated with OEHHA's monitoring designs to address the management needs for closures and advisories. Furthermore, we recommend that other sources that contribute to accumulations in seafood share in the burden of this monitoring effort. The share of monitoring each discharger should be responsible for should be proportional to the amount of constituent that they have discharged to the ocean.

Table 10. Comparison of effort for sampling fish and epibenthic invertebrates.

Agency	Method	# Stations	# Replicates	Frequency
AWMA	Dive	12	3	1/permit
SERRA	Dive	12	3	1/permit
Oceanside	Dive	12	3	1/permit
Encina WTP	Trawl	5	2	1/permit
Escondido/ San Elijo	Dive	12	3	1/permit

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APPENDIX A – MANAGEMENT QUESTION DEVELOPMENT

Introduction

The first step in creating any monitoring program is to identify why monitoring is needed. In the context of our Model POTW Monitoring Program, we established this need by asking questions. These questions embody the information that resource managers need to make decisions. If the answer to a specific monitoring question is "yes," then the manager makes one decision. If the answer is "no," then an alternative decision is made. If there is no answer, or the answer does not trigger a decision, then the need for that information should be critically evaluated. A monitoring question should always have some decision value.

The audience for monitoring programs is widely varied and so are the questions they ask. At one end of the spectrum are upper level resource managers who typically ask very general questions. These questions include: Is it safe to swim? Is it safe to eat the seafood? Is the ecosystem being protected? The questions are general at this level because they reflect the concerns of the public to whom the managers are ultimately responsible. At the opposite end of the spectrum are scientists who ask very specialized questions. They ask detailed questions because they have a need to define the specifics of how, when and where they will collect and analyze physical, chemical and biological data. One challenge in developing a model monitoring program is to ensure a connection among the questions being asked by the different levels of participants in the monitoring process.

We've made the connection between policy-level and scientist-level needs by creating **Management Questions.** Management questions are those typically asked by mid-level managers who use monitoring information to make decisions. These mid-level managers often serve as the interface between the scientists that collect and analyze monitoring data and the upper level resource managers that must interact with regulatory boards and the public. In most cases, there will be many management questions associated with each policy question and many scientific questions associated with each management question.

Goals of This Document

The goal of this document is to generate a list of management questions for a Model POTW Monitoring Program. Monitoring questions are the single-most important aspect of designing a model monitoring program. The monitoring question, which implies a lack of knowledge, provides the need for a monitoring program. None of the other design or implementation steps that follow can be accomplished if we do not first produce adequate monitoring questions that enable us to focus our effort and resources. If we do not develop the correct questions, or they are framed improperly, the sampling design may not be optimal for the results needed to make important management decisions. This would result in an unnecessary allocation of monitoring effort, eventually increasing the overall cost of a monitoring program.

Undoubtedly, many management questions will need to be answered. However, it will be important to identify the most important questions that the statistical design should address in the next steps of model program development. Our objective, therefore, is to identify the common elements in the monitoring questions and prioritize these for further model program development. Some management questions are site-specific or apply to unique agencies. By focusing on the most universal management questions, we will be able to incorporate designs that all agencies can utilize.

Approach To Developing Monitoring Questions

We spent over one year with upper and mid-level managers, including regulatory and regulated agencies, and have developed the most important management questions to be answered in a Model Monitoring Program. The questions were derived using three techniques. First, we reviewed existing literature to assess what important monitoring needs have already been identified and what significant findings current monitoring programs have already addressed. Second, we reviewed each of the large and small POTW monitoring permits in the SCB and distilled this information into a series of monitoring questions. Third, we interviewed monitoring specialists from the largest POTW dischargers in southern California and the NPDES permit writers from each of their respective regulatory boards. In these meetings, we asked what the most important policy questions were, what the greatest monitoring information needs were for management and what scientific details were most relevant to their monitoring programs. Finally, we discussed these questions, as a group, on a quarterly basis from 1998 to 1999.

One of the most important attributes of a proper management question is to ensure that the question has decision value. That is, once the monitoring has been accomplished, the results should feed directly into a decision-making process. Therefore, as we developed the list of management questions, we focused on four types of information for each:

- **Management Information Need** - Why does the manager need to know the answer?
- **Decision Criteria** - What criteria will be used for deriving an answer to the question?
- **Expected Product** - How should the answer be expressed?
- **Possible Management Actions** - What actions will be potentially influenced by the answer?

By focusing on these four "decision value" criteria, we ensured that monitoring would provide the information necessary to communicate scientifically technical data to upper management and satisfy the public's need to know.

Design of This Document

We have designed this document to correspond to the five different media that are monitored in the SCB. These media include:

- Effluent
- Receiving Water Quality
- Microbiology
- Sediment chemistry and benthos
- Fish

Within each programmatic element, we list the most important management questions refined through our development process, providing justification, rationale, and decision value for each.

Other media are monitored in the SCB including programmatic elements such as kelp, rocky sub-tidal and rocky intertidal areas, birds and mammals. While these media were partially addressed during our development process, we do not focus on them in this document due to the fact that these media are not held in common among all agencies.

Effluent Monitoring

The most important management questions for effluent monitoring are:

- *Is the effluent concentration of selected constituents below levels that will ensure public safety and protect aquatic life?*

- *What are the mass emissions of selected constituents that are discharged annually?*

- *Is the effluent concentration or mass emissions changing over time?*

- *Is the plant operating efficiently?*

The primary reason for monitoring final effluent concentrations prior to discharge is to assess the potential risk to the receiving water, especially in the water column. Measuring trace quantities of constituents in the water column after discharge has been very challenging technically. However, trace quantities that cannot be measured still have the capability to induce impairments to beneficial uses. Therefore, regulatory agencies have placed water quality objectives on final effluents where concentrations are much higher and are technically easier to sample and measure. Regulatory policies, such as the California Ocean Plan (Ocean Plan) (SWRCB 1997) apply risk-based models to predict harmful concentrations in the environment. The risk-based models are designed for beneficial uses including seafood consumption (public safety) and protection of aquatic life. The local Regional Water Quality Control Boards then apply these water quality objectives using a credit for dilution to back-calculate what concentrations in effluent should be for writing specific discharge permits. In this way, resource managers now have the decision-making tool to evaluate if the concentrations in their discharge have the capability to impair beneficial uses. These monitoring data can be used to trigger source tracking or initiate receiving water monitoring for the potential effects, among other actions.

A second method that is used for predicting risk to aquatic life is the use of toxicity tests. These tests expose sensitive life stages of marine organisms to final effluent (after salinity adjustment) to assess their acute or chronic impact (U.S. EPA 1995). The advantages of these tests are two-fold. First, the risk is directly measured instead of modeled. Second, the toxicity tests can capture toxicity that occurs from unmeasured constituents or from synergistic effects of multiple constituents below their individual water quality objectives. Resource managers can use toxicity monitoring to assess if their discharge is toxic, trigger toxicity identification evaluations (TIE) and track sources or modify the treatment process to reduce environmental risk.

Mass emissions are an important contributor to the effluent monitoring program because they provide resource managers with the tool to compare contributions of constituents from different facilities or groups of facilities (e.g., one POTW versus another POTW or all POTWs versus urban runoff). Identifying which facilities contribute the greatest mass emissions helps managers effectively utilize their resources to reduce inputs. Smaller contributors, where even severe management actions will result in minute changes to the total load, should become a lower priority for concern. Finally, as mass-based regulations become more important, such as total maximum daily loads (TMDLs), mass emission monitoring will become critical in evaluating compliance.

Both mass emission and effluent concentration monitoring enable resource managers to track discharges from a single facility over time. If effluent concentrations or mass emissions from a facility are increasing over time, especially if they are associated with changes in effluent volume, then resource managers can use this information to carefully consider if management actions are necessary. On the other hand, if a more drastic management action is taken, monitoring for trends in mass emissions of effluent concentration can enable that resource manager to document the improved discharge and reduction in risk to beneficial uses.

Monitoring of effluents for plant performance is another useful program for facility performance. Measurements of common POTW constituents such as suspended and dissolved solids (TSS, TDS), biological oxygen demand (BOD) and others provide invaluable information to facility managers on how well their plant is functioning. Plant performance, however, is not within the scope of this document. Instead, this document focuses on potential impacts to receiving waters in the coastal oceans of the SCB. In reality, facility managers will measure these general constituents at frequencies that address internal operations, regardless of what regulatory agencies may request. Therefore, this document does not address the monitoring question regarding plant performance.

Receiving Water Quality Monitoring

The most-important management questions for receiving water quality monitoring are:

- *Are water column physical and chemical parameters within the ranges that ensure protection of the ecosystem?*

- *What is the fate of the discharge plume?*

POTWs design their outfalls to quickly mix and diffuse with receiving waters in the SCB. Most POTWs conduct water quality monitoring to assess if their plume has been sufficiently mixed to maintain protection of the ecosystem in receiving waters. Many water column ecosystems are particularly susceptible to reductions in light or alterations in pH and dissolved oxygen (D.O.). Light reduction can contribute to a decrease in primary production that will have a ripple effect through the ecosystem may eventually leading to reductions in fish abundance and assemblage parameters. Alterations in pH and D.O. can have acutely toxic effects on fish and other invertebrates; D.O. reductions have been responsible for fish kills in other affected ecosystems around the nation.

The California Ocean Plan stipulates numerical water quality objectives for attainment in the receiving waters near the vicinity of a discharge. The water quality objectives are for light transmittance, pH, and D.O. One of the primary management questions is to assess if the levels near the discharge are meeting Ocean Plan objectives and that the ecosystem is being protected.

An equally important, but distinctly different question that managers need to know is where their plume is going. Although light transmittance, pH, and D.O. may be within acceptable limits, there are concerns beyond water column ecosystem health. First, most managers need to know if their plume is moving towards shore where it may encroach upon water contact zones. In this case, human health concerns are of interest and additional water quality thresholds exist for bacteria (*see microbiological monitoring*). Second, plume direction and mixing has a direct effect on sediment loading. Although, light transmittance may be within acceptable levels for water column assessments, the direction of the plume determines where the discharged particles will eventually settle. Years of accumulations may affect sediments in locations where the plume direction is most consistent. In this case, ecosystem health issues are primary concerns in terms of habitat quality and impairments of benthic communities (*see sediment monitoring*).

Microbiological Monitoring

The most-important management questions for microbiological monitoring are:

- *Does sewage effluent reach water contact zones?*

- *Are densities of bacteria in water contact zones below levels that will ensure public safety?*

The primary motivation for measuring bacteria in receiving waters is for managers to determine if POTW discharges are encroaching upon beneficial use areas such as body-contact recreation zones (i.e., swimming, surfing, diving) and shellfish harvesting grounds. Bacteria are conservative tracers of fecal contamination and are often measurable when other indicators, such as salinity or turbidity, are not sensitive measures. Resource managers can use microbiological monitoring to evaluate if fecal sources are present and, if sampled across a spatial gradient, monitoring can be used to infer sources and/or transport of bacteria.

Resource managers need to assess whether contamination is present and if the levels are high enough to be a public health risk. In the case of three bacteria (total coliform, fecal coliform, and enterococcus), water quality thresholds have been established that set levels of acceptable risk for body-contact recreation and shellfisheries (SWRCB 1997, AB411). By using these thresholds, resource managers have the tool they need, in conjunction with microbiological monitoring, to assess if unacceptable risk is present and whether beach warnings or closures need to occur.

Sediment Monitoring

The most important management questions for sediment monitoring are:

- *Is sediment in the vicinity of the discharge impaired?*
- *If so, what is the spatial extent of sediment impairment?*
- *Is the sediment condition changing over time?*

Sediments integrate constituents that are discharged to the ocean. The particles that come from POTW discharges, and any associated contaminants, will eventually settle to the seafloor where they are incorporated into the existing sediments. Sediments accumulate these particles over the years until the point where sediment quality has degraded and beneficial uses are impaired. The beneficial uses most often associated with sediment quality are aquatic life and public safety (seafood bioaccumulation). Public safety is addressed in the chapter on fish monitoring (although bioaccumulation in invertebrates can also occur). Impairment of sediment quality that can affect aquatic life is monitored by assessing habitat quality such as grain size and organic carbon content, sediment contamination such as anthropogenic constituents, biological communities such as balanced indigenous populations, and interactions among all three components such as sediment toxicity.

Resource managers can utilize sediment monitoring to assess if discharges are affecting receiving waters. Resource managers can use sediment monitoring as a means to evaluate if effluent concentrations or mass emissions are accumulating in receiving water environments, especially if they exceed water quality thresholds. An assessment of magnitude and/or spatial extent of impairment enable resource managers to rank sites and evaluate which locations are most critical for immediate action. Finally, sediment monitoring can be used for beneficial use assessments in other program elements, particularly assessments of impairment to fish.

Answering the management question "*Is sediment near the discharge impaired and, if so, how much is impaired?*" is a two-step process. Resource managers will first want to establish that there is an impact near their discharge before extending their monitoring to greater distances. Alternatively, if there is no impact near the discharge, then additional sampling is unwarranted. This example of adaptive monitoring, whereby resource managers can use the monitoring to establish further need, is an efficient mechanism for minimizing costs and increasing effectiveness of a program.

One of the most effective means for communicating spatial extent is a map. Maps have the capability to add context to interpreting results that long tables of data cannot convey. Maps are easily understood by non-technical audiences. Maps can be especially useful for transmitting magnitude and spatial extent information by the addition of contours. Contours of increasing sediment concentration, contours of numbers(s) of indicators that exceed thresholds, and contours of previous year(s) extent are all insightful tools to relay detailed information in a meaningful format that will provide the appropriate context to decision-makers.

Resource managers can utilize trends in sediment condition to make decisions regarding the need for additional actions. If the trend in sediment condition is improving, then the manager can utilize this information to demonstrate that the actions already undertaken have been effective at reducing risks to beneficial uses. If the trend in sediment condition is getting worse, then little or no action may be necessary if the trend is small or the condition of sediment is already very good. However, if the trend is getting worse and the level is near or above some action level, then the need to take action increases. If there is no trend, then little or no action may be required.

Fish Monitoring

The most important management questions for fish monitoring are:

- *Is the health of fish communities changing over time?*
- *Is the population of selected species changing over time?*
- *Is fish tissue contamination changing over time?*

- *Are seafood tissue concentrations below levels that will ensure public safety?*

Fish monitoring helps to assess impacts to two beneficial uses. The first is aquatic life and the second is public safety (seafood bioaccumulation). The monitoring questions above fall into three categories for resource managers. The first two questions are in response to managers' needs to assess whether populations and assemblages of fish are normal and not degraded. The third question addresses wildlife protection; contaminants can bioaccumulate in fish and harm the fish or its predators after consumption. The fourth question addresses public health; contaminants that bioaccumulate in fish that can harm humans after consumption.

Protection of fish communities and recreational/commercial fishing are among the greatest public concerns of all the receiving water monitoring elements. Managers need to be able to address the public's concern, which is most effectively accomplished by trend analysis. Alterations in communities of fish and important species are easily assessed and communicated to the public by comparing current years to previous years. Moreover, fish populations and community structure can be related to water quality variables such as temperature. Since fish populations extend over wide areas, and water quality variables such as temperatures are wide-scale phenomenon (i.e., El Niño), this essentially becomes a regional question.

Similar to the community and population questions, resource managers can assess wildlife protection questions by assessing fish tissue concentrations over time. Unlike the community and population questions, however, tissue concentration thresholds exist (Ridgeway et al. 2000). This is extremely important because this enables resource managers to answer new questions regarding changes in area and proportion of fish that exceed limits of concern. Assessing the percent of fish or percent of fishing area that exceeds thresholds of concern adds tremendous context to management decisions, especially if these measures of extent are increasing over time. Resource managers should be concerned about contaminants that bioaccumulate in fish because they can induce harm in the fish itself by making them more susceptible to disease or predation. Also, contaminants that bioaccumulate in fish can be passed up the food chain to biomagnify in the higher order wildlife consumers such as birds and marine mammals.

Fish tissue concentrations are a priority for many managers to answer questions regarding human consumption and public health. Strict thresholds have been established by state (CalEPA) and federal (FDA) governments for tissue concentrations of several constituents. Fish tissue monitoring will address managers' needs by assessing if the levels are above or below these thresholds. We phrased the public health question in terms of trends because managers need to know not only if the levels are above or below thresholds, but if they are increasing or decreasing over time. If they are increasing, and near the threshold, then management action may be imminent. If they are increasing, but well below the threshold, then only continued monitoring may be necessary. If they are increasing and above the threshold, then management action is necessary.

Summary of Decision Value Criteria for Priority Management Questions

Management Question	Information Need	Decision Criteria	Expected Product	Potential Action
Effluent Monitoring				
Is the effluent concentration of selected constituents below levels that will ensure public safety and protect aquatic life?	Managers needs to know if effluent concentrations are high enough to represent a potential risk to public or ecosystem health. Risk assessors can estimate the potential for bioaccumulation or toxic exposure in the receiving waters based upon effluent concentrations and predicted dilution. These are the tools used to set numerical criteria for effluent.	Ocean Plan objectives and permit limits, toxicity tests.	Table of constituent concentrations, water quality threshold, and indication of exceedence. Toxic unit summaries.	Examine toxicity test data, look for constituent in ambient monitoring elements, examine trends question. Use an adaptive trigger to increase frequency to reassess data distribution and frequency of exceedence. Use an adaptive trigger to begin a Toxicity Identification Evaluation (TIE). If severe, source ID program.

What are the mass emissions of selected materials that are discharged annually?	Managers need to know the total mass emission of their respective discharge, and what percentage of the total mass emission to the Bight this represents.	Relative to other agencies and sources, relative to influent. Compared to performance goal or waste load allocation for TMDL.	Bar chart or pie chart of combined loads from all sources.	If large piece of pie, then trigger adaptive strategy to improve confidence in load estimate. Examine sediment questions.
Is the effluent concentration or mass changing over time?	A manager wants to know if increases in effluent mass or concentration is an environmental problem they need to address, or alternatively, if the mass is decreasing, have the management actions already been effective.	Historical performance.	Graph of concentration or mass over time.	The relationship between the trend in effluent mass and the total mass emission limit will alter the amount of response required to comply with the limit. If increasing, examine sediment questions.

Management Question	Information Need	Decision Criteria	Expected Product	Potential Action
Receiving Water Quality Monitoring				
Are water column physical and chemical parameters within the ranges that ensure protection of the ecosystem?	Managers need to demonstrate that the discharge is not adversely affecting the physical and chemical characteristics of ocean waters within the waste field where initial dilution occurs. In order to protect the ecosystem, managers must verify that the POTW is meeting the numerical and narrative water quality objectives.	Ocean Plan Objectives for light transmittance, pH, dissolved oxygen. Levels relative to reference condition.	Table of number of days that exceeded thresholds by parameter.	If exceed threshold, assess spatial extent and frequency of exceedences.
What is the fate of the discharge plume?	Is the plume moving towards shore. Managers should be able to tell public where the plume goes. What is the extent of water column alterations.	Use conservative tracer of plume such as salinity or indicator bacteria for determining where the plume is going. Use Ocean Plan criteria for exceedences.	Plume map with isoclines estimating the frequency of occurrence at different distances. Table of volume-days that exceed water quality thresholds.	If large area, trigger adaptive strategy to assess biological impacts and incorporate other measures (i.e. nutrients and chlorophyll). If moving into water contact areas, trigger additional microbiological monitoring

Management Question	Information Need	Decision Criteria	Expected Product	Potential Action
Microbiological Monitoring				
Does sewage effluent reach water contact zones?	Water-contact zones adjacent to POTWs are often influenced by more than one anthropogenic source. Therefore, the POTW manager must know if the effluent is contributing to the degraded water quality at water-contact zones. The manager needs information not only concerning effluent incursions from the discharge zone, but also about sewer line breaks and overflows into the stormwater system.	Comparison of bacteria levels to reference condition.	Plume location map. Table or map of affected sites.	If there is an indication that the plume is reaching the water-contact zone, this justifies the need for further management action such as triggering an adaptive strategy to increase frequency or spatial extent
Are densities of bacteria in water contact zones below levels that will ensure public safety?	Once a plume intrusion has occurred, the manager needs to know if the severity, both in magnitude and duration, represents a potential health risk.	Ocean Plan Objectives, AB411 Standards.	Table or map of densities at specific locations, Table of number of days that exceed thresholds.	If above standards, contact Public Health Agencies. If near drain, notify stormwater agencies. If chronic, trigger a special study to track upstream sources.

Management Question	Information Need	Decision Criteria	Expected Product	Potential Action
Sediment Monitoring				
Is sediment in the vicinity of the discharge impaired?	A manager needs to know if the discharge has accumulated in the environment and is impairing ecological health.	Comparison of indicators to reference condition.	Table or chart of chemistry, biology, toxicity relative to reference conditions for sites near the outfall.	If impaired, trigger spatial extent questions. Examine mass emissions question. Examine Fish question.
If so, what is the spatial extent of sediment impairment?	Once the sediment is known to be impacted, the manager needs to know how big of an area is affected. The severity in the spatial distribution will guide the extent of possible management actions.	Comparison of indicators to sediment quality guidelines/criteria, Biological indices/criteria, and magnitude of toxicity endpoints.	Map of impacted area. Contours can add context.	Examine trends question. Examine plume extent question. Trigger special studies to examine cause-and-effect.

Is the sediment condition changing over time?	Increases in the area or magnitude of sediment impairment justifies the need for action. Alternatively, if the area or magnitude of concentrations are decreasing, the manager will know that previous actions have been effective. The relationship between the trend of sediment contamination near the outfall, and conditions at a reference site will alter the amount of response required.	Relative to magnitude or spatial extent over time.	Graphs of various indicators over time. Maps with shrinking/growing contours.	If getting bigger and worse, examine effluent mass and fish question. Trigger special studies to address fate-and-transport including other potential sources.

Management Question	Information Need	Decision Criteria	Expected Product	Potential Action
Fish Monitoring				
Is the health of fish communities changing over time?	Communities of indigenous species need to be balanced.	Ocean Plan Narrative Standards. Assemblage parameters, guidelines/biocriteria	Table of assemblage parameters relative to regional condition. Graph of assemblage parameters at discharge location and reference condition over time.	If communities are declining relative to reference condition, trigger adaptive strategy to assess spatial extent. Evaluate tissue accumulation.
Is the population of selected species changing over time?	Selected populations need to be healthy and sustainable.	Ocean Plan Narrative Standards. Density and catch per unit effort for selected species. Gross external pathologies.	Table of population parameters relative to regional condition. Graph of population parameters at discharge location and reference condition over time.	If populations are declining relative to reference condition, trigger adaptive strategy to assess spatial extent. Evaluate tissue accumulation. Trigger special studies to assess cause-and-effect.

Management Question	Information Need	Decision Criteria	Expected Product	Potential Action
Fish Monitoring (Cont.)				
Is fish tissue contamination changing over time?	Fish tissue contaminant concentrations are to be below levels that would adversely affect the fish or their consumers. Numerical quality objectives are not available in the Ocean Plan, but predator protection limits are available in the scientific literature.	Ocean Plan narrative standards. Predator protection limits. Ecological risk assessment benchmarks from Cal EPA or others.	Table of tissue contaminant concentrations at POTW site, reference condition, and predator protection limit. Estimate of percent of area and percent of fish that exceed limit. Create map showing locations of exceedences and magnitude.	If increasing, examine population and community structure. Evaluate sediment levels. Trigger an adaptive program that evaluates biomarker or biochemical impairment. Trigger special study to assess accumulation mechanisms and evaluate if higher-order consumers are being affected.
Are seafood tissue concentrations below levels that will ensure public safety?	Fish tissue contaminant concentrations are to be below levels that would adversely affect human consumers.	FDA action limits.	Table of tissue contaminant concentrations at POTW site, reference condition, and action limit. Create map showing locations of exceedences and magnitude.	If near or above limits, contact CalEPA. Increase trend monitoring program. Trigger a special study for sources.