Regional Monitoring Program
for Water Quality
in the San Francisco Estuary

The Regional Monitoring Program: Science in Support of Managing Water Quality in the San Francisco Estuary

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I. INTRODUCTION

The Regional Monitoring Program for Water Quality in the San Francisco Estuary (RMP) is an innovative model for providing the scientific foundation needed for managing water quality in a treasured aquatic ecosystem. In the ten years since its inception, the RMP has matured into a multifaceted, sophisticated, and efficient program that has demonstrated the capacity for considerable adaptation in response to changing management priorities and advances in scientific understanding. The RMP is a novel partnership that has combined shared financial support, direction, and participation by regulatory agencies and the regulated community in a model of collective responsibility. The RMP has produced a high quality body of knowledge on estuarine contamination that is allowing managers to develop sophisticated, rational approaches to solving the Estuary's water quality problems. The RMP has established a climate of cooperation and a commitment to participation among a wide range of regulators, dischargers, industry representatives, community activists, and scientists. This climate has carried over into other activities related to the development of Total Maximum Daily Loads (TMDLs) and other water quality attainment strategies for the Estuary.

This report will describe the characteristics of the RMP that have allowed it to achieve all of these positive outcomes. The RMP is a collaborative effort of regulators, the regulated, and scientists. The perspectives of each of these groups on the benefits of the Program are presented. One key to improvement is the capacity to respond to constructive criticism. In this regard, challenges or areas for improvement are also discussed throughout the report and by each of the three major participant groups.

Establishment of the Program

The San Francisco Bay Regional Water Quality Control Board (Regional Board) is the implementing agency of the federal Clean Water Act and the State of California's Porter Cologne Water Quality Control Act (California Water Code) in the San Francisco Estuary. The Regional Board adopted numerical water quality objectives in 1986, yet at that time there was no monitoring program to determine if water quality objectives were being met or if beneficial uses were being protected. Starting in 1989 the Regional Board implemented a series of pilot studies in order to develop information to determine if the Estuary was impaired. Studies were funded through U.S.EPA grants and the State's Bay Protection and Toxic Cleanup Program (BPTCP), which has since been discontinued. These studies were designed to determine if numerical water quality objectives were being met and if water or sediment was toxic. Since 1979, additional studies to measure the accumulation of contaminants in bivalves had also been taking place in the Estuary through the State Mussel Watch Program. The BPTCP brought these studies together to form the basis of a Regional Monitoring Plan.

In 1987, the San Francisco Estuary Project (SFEP), a State/Federal cooperative endeavor mandated by the National Estuary Program under the Clean Water Act, initiated the development of a Comprehensive Conservation and Management Plan (CCMP) for the San Francisco Estuary. The CCMP was developed with the assistance of over 100 stakeholders. The CCMP called for establishment of the San Francisco Estuary Institute and a Regional Monitoring Program. In 1992 the Regional Board passed Resolution No.

92-043 directing the Executive Officer to send a letter to regulated dischargers requiring them to implement a regional multi-media pollutant monitoring program in San Francisco Bay. The Regional Board's regulatory authority to require such a program comes from California Water Code Sections 13267, 13383, 13268 and 13385. The Regional Board offered to suspend some effluent and local receiving water monitoring requirements to provide cost savings to implement baseline portions of the RMP, although they recognized that additional resources would be necessary. The Resolution also included a provision that the requirement for a RMP be included in discharger permits.

The SFEP developed a Regional Monitoring Strategy and assisted in developing institutional arrangements with the Aquatic Habitat Institute's (AHI) Board of Directors. In 1992 the Aquatic Habitat Institute was reconstituted as the San Francisco Estuary Institute (SFEI) and the Regional Monitoring Program was formed. In 1993 the Program commenced. The RMP used the pilot studies conducted by the Regional Board to form the basis of the monitoring and assessment component of the RMP.

II. ANATOMY OF A SUCCESSFUL LONG-TERM MONITORING PROGRAM

Over the past thirteen years, the organizational and funding structures created in 1992 have proven to be viable over the long-term. In this thirteenth year of monitoring the participants in the RMP remain satisfied with the Program, and the Program is meeting the information needs of managers as well as ever, even though those needs have changed and increased considerably since 1993. Over the course of its development, the RMP has demonstrated the ingredients that are necessary to sustain a long-term water quality monitoring program that meets management needs.

A. Stable Funding

Stable funding is obviously essential to sustaining a long-term monitoring program. The funding mechanism established by the Regional Board in 1992 has proven to be very effective. At its inception in 1993, the RMP was a $1.2 million program focused on measuring spatial and temporal trends in contaminant concentrations and toxicity in the main channel of the Estuary. The budget steadily increased for the first six years, and has remained relatively constant for the past 8 years (Figure 1). After thirteen years the RMP has matured into a multifaceted $3 million program of study that evaluates spatial and temporal trends in chemical contamination and toxicity in a more comprehensive and representative manner, and also assesses contaminant effects, contaminant loading, and performs broad-scale synthesis of information from RMP and other programs. In 1997, in response to a comprehensive programmatic review, sweeping recommendations were implemented without the need for significant budget increases – this required a great deal of deliberation and prioritization, and many difficult choices.

Stable funding provides many benefits to a long-term monitoring program. Maintaining the long-term time series of indicators of condition is of course the primary benefit. However, there are other significant benefits that are less obvious. Most

importantly, stable funding has allowed the RMP to develop an efficient organizational structure and processes that enable the Program to adapt to changing management priorities and advances in scientific understanding (described further below under "Adaptation"). Another benefit of stable funding is continuity of the personnel involved. Staff turnover is inevitable, but the stability of the RMP has allowed staff at all participating institutions to develop professionally and maintain enough continuity to provide the institutional memory that prevents the inefficiency of reinvention or repeating mistakes of the past.

The local funding of the RMP has largely insulated the Program from the waxing and waning cycles of the State and Federal budgets. The participants of the RMP do sometimes face fiscal challenges, however. Keeping the Program as cost-effective as possible and maximizing efficiency through close coordination with other related programs will be a particular priority in future years. Fulfilling the objectives of a multifaceted, adaptive monitoring program like the RMP requires continual evaluation and prioritizing of competing uses of limited funds. This is one of the principal challenges of managing the RMP.

Maintaining the satisfaction of the Program participants is an obvious requirement of continued funding. This depends on several factors. One is providing products that the participants value and that answer management questions. The dredging sector has recently questioned the value of the RMP in meeting their needs, and steps are being taken to improve in this regard. Demonstrating efficient use of contributed funds is also important; this is done through keeping the Program focused on high priority projects and ensuring that the Program is managed efficiently.

The establishment and maintenance of an equitable distribution of the costs among the participants is essential to the long-term fiscal stability of the Program. At the outset of the Program, the proportions that each sector would contribute were established (Figure 2). By mutual agreement among the groups, the proportions have remained fixed since the beginning of the Program. Within each discharger category, mechanisms have been developed to allocate the costs of the Program in proportion to the magnitude of their discharge. For example, for the municipal dischargers, the fee for each facility is the sum of a relatively small base charge and a fee that is proportional to the emissions of four selected trace elements during the previous year. Recent developments, such as the decline of in-Bay disposal of dredged material and the restoration of thousands of acres of tidal wetlands, may require reevaluation of the mix of participants included in the RMP and the distribution of costs among participants.

B. Collaboration

The RMP provides a forum for an innovative and highly valued collaboration among the regulators, the regulated, and scientists. This forum is largely provided by an organizational structure with committees (Figure 3) that meet quarterly to track progress and plan future work. The Steering Committee consists of management representatives from the Regional Board and each of five categories of discharger (municipal, industrial, stormwater, dredger, and cooling water), with administrative support from SFEI. The Steering Committee determines the overall budget, allocation of program funds, tracks

progress, and provides direction to the Program from a manager's perspective. Oversight of the technical content and quality of the RMP is provided by the Technical Review Committee (TRC), which consists of technical representatives from the Regional Board, discharger groups, and SFEI. The four workgroups report to the TRC and address four main technical subject areas covered by the RMP. Workgroups consist of regional scientists and regulators and invited scientists recognized as leaders in their field. The workgroups directly guide planning and implementation of pilot and special studies. Shared interest in the success of the RMP has created an atmosphere of cooperation among these groups.

RMP meetings also provide a forum for communication with other Estuary stakeholders, including environmental organizations and scientists. All RMP committee and workgroup meetings are open to the public. Input from all parties is given consideration as consensus is sought on the issues at hand.

C. Clear Objectives

Careful articulation of a monitoring program's objectives and the questions it is intended to answer are essential to effective design and execution of the program. The original objectives of the RMP were somewhat imprecise and were not adequately articulated. The 1997 Review recommended that the Program objectives be re-evaluated and supported by a framework of focusing questions and management questions to provide a more precise focus for the Program. Through broader objectives, the scope of the Program was also broadened to include subject areas that had not been part of the original design: sources, pathways and loadings; effects; and synthesis.

The RMP is presently guided by a framework of objectives and management questions developed after the 1997 Review and revised and updated in 2004 (Hoenicke 2005) (Appendix 1). The objectives succinctly define the Program's six general areas of activity. The management questions, developed collaboratively by RMP participants, provide a more detailed elaboration of information needs under each Program objective. The management questions point to specific quantitative monitoring endpoints. The management questions provide a detailed basis for developing and implementing the RMP during each five-year period between Program reviews.

One challenge facing the Program is to keep the objectives framework updated. In particular, management priorities can change significantly over a five or ten year period. For example, at the time of the 1997 Review, TMDLs were not a focus of regulatory activity. This changed shortly after that Review, and significantly altered the regulatory landscape. The current emphasis on TMDLs has heightened the need for information on contaminant loads from different pathways and the need for models to predict the response of the Estuary to different management actions. As another example, the recent development of plans to restore vast acreages of tidal marsh has intensified the need for information on methylmercury concentrations and cycling in the Estuary. Based on changes observed in the course of the RMP, revisiting the objectives framework on a five-year cycle appears appropriate.

D. Sound Science

It is essential that all stakeholders with an interest in monitoring the ecosystem accept the data and information generated by a monitoring program as unbiased, high quality science. The RMP achieves this goal through several mechanisms.

Objectivity is assured at an institutional level by having the Program administered by an independent, non-profit scientific organization – the San Francisco Estuary Institute (SFEI). SFEI is governed by a politically balanced Board of Directors comprised of Bay Area scientists, environmentalists, regulators, local governments, and industries. All of these sectors participate in review of SFEI products and accept their objectivity.

Scientific objectivity and quality are also achieved through multiple levels of peer review, inclusion of leading scientists in the Program, and a rigorous and proactive quality assurance program. Peer review occurs at many levels in the Program. For specific projects peer review is incorporated from the planning stages through implementation and the completion of final reports. Peer review at all of these stages is accomplished primarily by the RMP workgroups, which include invited members from outside the RMP. The invited members are selected as authoritative leaders in their field of expertise, and this raises the quality of RMP science to the highest level. Regional scientists also are members of the workgroups and contribute significantly to peer review. Regional scientists on the Technical Review Committee also provide general oversight on RMP studies from planning through completion. Anonymous peer review of final reports completes the review process of each project. For reports authored by SFEI, an independent scientist coordinates the peer review.

At a programmatic level, peer review is performed on approximately a five-year cycle by assembling a panel of prominent experts on environmental monitoring. The first Program Review occurred in 1997 (Bernstein and O'Connor 1997) and resulted in many fundamental changes to the Program (discussed further below). The second Program Review was initiated in 2003 and resulted in additional fine-tuning of the Program (Schubel et al. 2004).

A rigorous and proactive quality assurance (QA) program is essential to obtaining high quality monitoring data. Data quality objectives that ensure that RMP data are sufficiently reliable to answer the relevant management questions have been established and documented in a Quality Assurance Program Plan (QAPP) (Lowe et al. 1999). The QAPP covers all aspects of sampling and analysis in the many components of the RMP. Measures taken to evaluate quality of chemical data include both assessment of performance relative to data quality objectives for accuracy, precision, and completeness, and also comparison of the concentrations and patterns present in reported data with previously reported data. For example, for PCB congener data the reported values can be compared to prior data both in terms of the magnitude of reported concentrations and the fingerprint of congeners within each sample. The latter step screens out many data that satisfy data quality objectives, but fail a reality-check against actual field data. Only data which are considered to have a high degree of reliability are included in the data archive for unrestricted use. Data for which any question of reliability exists are either included in the data archive with qualifiers attached or not included at all. These data are still

available for data users who wish to delve deeply with the awareness that reliability is in question. Careful and attentive screening of data and supporting QA information is the key to accumulating an archive of high quality data.

Another way in which the RMP has a high standard of scientific quality is through inclusion of leading scientists as RMP investigators. Many of the RMP contractors are recognized nationally or internationally as leaders in their fields. Other contractors are less prominent regional scientists that also conduct high quality work. These investigators have made the Estuary a laboratory for advancing understanding of water quality in a coastal ecosystem.

E. Adaptation

Key elements of a monitoring program must remain constant over the long-term in order to effectively track long-term trends in contamination. However, a purely static monitoring program would become less and less relevant over time as management priorities change, as understanding increases, and as technology advances. The RMP has undergone considerable evolution in its thirteen year existence in response to these forces.

Adaptive management is achieved through several mechanisms in the RMP. One of these is the institutional structure with committees and workgroups that meet regularly to track progress and plan future work. This structure allows for continual adjustment of the Program. Each year Committee deliberations culminate in a Program Plan for the coming year, which provides an overview of planned activities and documents the incremental evolution of the Program.

Another important mechanism by which the Program adapts is periodic Program Reviews, where independent, prominent experts in environmental monitoring evaluate the Program as a whole. Program Reviews are conducted on approximately a five-year cycle, with the most recent one occurring in 2003. The first Program Review in 1997 resulted in a major course correction for the RMP. The major recommendations of the 1997 Review and how the Program responded to each is summarized in Appendix 2.

Pilot and special studies are the third major mechanism by which the Program adapts. These studies constitute a mechanism for responding quickly to new information or concerns, assessing new technical approaches, investigating particular questions that have defined endpoints, and evaluating new directions for status and trends monitoring. RMP pilot and special studies have been keys to both the refinement of status and trends monitoring and the success of the RMP in meeting its objectives related to effects, loading, and synthesis. Collectively, these Program characteristics have allowed for adaptation in response to changes in the regulatory landscape, advances in understanding of the Estuary, and a continual drive to adjust the Program to better meet its objectives.

Pilot and special studies have been included in the RMP every year, and have lead to significant additions and refinements to status and trends monitoring. A pilot study is a monitoring study conducted on a trial basis in order to determine whether it is suitable for inclusion in status and trends monitoring. A special study is a study that helps

improve monitoring measurements or the interpretation of monitoring data, in particular by elucidating cause-effect relationships, or that serves to meet RMP objectives through activities other than monitoring. Pilot and special studies currently account for 16% of the annual budget. The major elements added to Status and Trends monitoring in the past 10 years that originated from pilot studies include hydrography and phytoplankton, suspended sediment dynamics, and fish contamination. Some of the refinements resulting from special studies include ongoing development of mass budget models, an updated list of target chemicals, an optimized bivalve monitoring program, and incorporation of surveillance monitoring and interlaboratory quality assurance exercises (Table 1).

Given the importance of pilot and special studies to the success of the Program, it is essential to have an effective process for generating new study ideas and deciding which studies to fund. One of the main products of the first Program Review was a Pilot and Special Study Selection Procedure (PSSSP). The PSSSP clearly lays out the responsibilities of the parties involved in the decision-making process: the Steering Committee, Technical Review Committee (TRC), Regional Board, and SFEI. The PSSSP also lays out the steps that begin with the generation of ideas and culminate in the implementation of a well-planned study. One of the valuable features of the procedure is that it establishes a wide funnel to channel potentially useful ideas into the process. Many ideas originate from within the committees and workgroups of the Program. However, input from scientists from outside the Program is also encouraged. These outside scientists may also end up implementing the proposed work, providing a means of broadening the scientific horizons and skills of all parties to the RMP. Ideas for new studies are solicited on the RMP web site.

F. Communication

Effective communication at many levels is another key to the success of a monitoring program. Internal communication among Program participants is one crucial form of communication. The success of the collaboration of the parties involved in the RMP depends on active participation and communication in the regular committee and workgroup meetings. These meetings also provide a forum for communication with stakeholders in general.

The other essential form of communication is dissemination of the findings of the Program to managers, scientists, and the public. Providing needed information to water quality managers is the fundamental mission of the RMP. Consequently, the timely delivery of reports and other informational products tailored to the needs of managers is imperative.

One primary way in which the RMP accomplishes this is through SFEI's technical report series and annual reports on the RMP. SFEI technical reports provide detailed documentation of the findings of RMP pilot and special studies. The scientific quality of these reports is assured through extensive peer review. Annual RMP reports include the *Pulse of the Estuary* and the *Annual Monitoring Results*. The *Pulse of the Estuary* (SFEI 2005a) provides a concise, accessible, largely pictorial summary of RMP information that is targeted toward managers and the public. The *Pulse of the Estuary* is

distributed via hard copy and the web, with a hard copy circulation of several thousand copies. The *Annual Monitoring Results* (SFEI 2005b) includes brief narrative summaries and comprehensive data tables and charts of the most recent monitoring results, and is distributed via the SFEI web site.

The RMP Annual Meeting is another mechanism for providing information to water quality managers and Estuary stakeholders. Speakers at the Annual Meeting address topics of current interest and summarize the latest RMP findings. The Annual Meeting also provides an opportunity for the diverse groups involved in the Program to interact. Presentations by RMP scientists at numerous other meetings and symposia throughout the year are another important channel for communicating information about the Estuary to managers and the public.

Data management is a major component of a successful monitoring program. Maintaining a reliable and accessible archive of data requires considerable effort, particularly for a multi-faceted monitoring program that generates many different types of data. RMP data are stored in an actively-maintained database that is accessible via the RMP web site. The web site also provides comprehensive access to RMP technical reports, Powerpoint presentations, posters, program information, and links to other sites relating to water quality of the Estuary.

RMP findings are communicated to the scientific community through the RMP web site, journal publications, and presentations at technical symposia. RMP scientists frequently produce journal publications based on RMP data (Table 2). An increased emphasis was placed on this in 2005 and 2006, with a Special Study to synthesize data from the first ten years of the Program. This Study will produce a series of articles published in a special issue of *Environmental Research* summarizing the findings of the first ten years of the RMP and other programs evaluating Bay water quality during this period. The RMP has produced a wealth of data; the information content of these data has not yet been fully extracted.

Public outreach is not presently an explicit objective of the Program. Nevertheless, some effort is made to provide information that the public can use. Some major RMP products are intended to be accessible to the public, such as the *Pulse of the Estuary* and the RMP website. Efforts are also made to provide information to the public through the media, primarily newspapers. With the 2003 Annual Meeting celebrating the tenth anniversary of the Program, a consultant was hired to provide outreach to the media, and this generated extensive coverage in newspapers and on television. This media coverage, in turn, generated thousands of visits to the RMP web site. The goals of the RMP with respect to public outreach need to be clarified and formalized.

Figure 1. RMP annual budgets (total revenue) from 1993 - 2005. The annual budget has grown from $1.2 million in 1993 to $3.1 million in 2005. The revenue for 2003 was higher due to the inclusion of reserves set aside in previous years. Spending is slightly more cyclic in response to Program elements that occur less frequently than once a year.

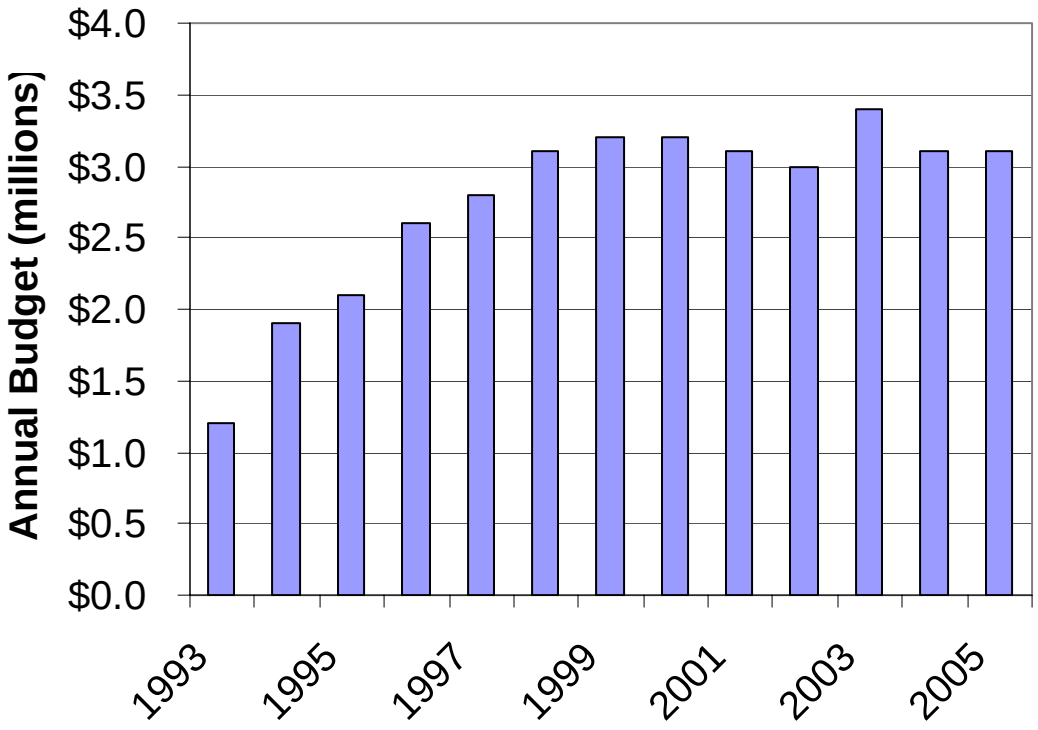

Figure 2. RMP contributions by each category of discharger. By mutual agreement among the groups, the proportions have remained fixed since the beginning of the Program.

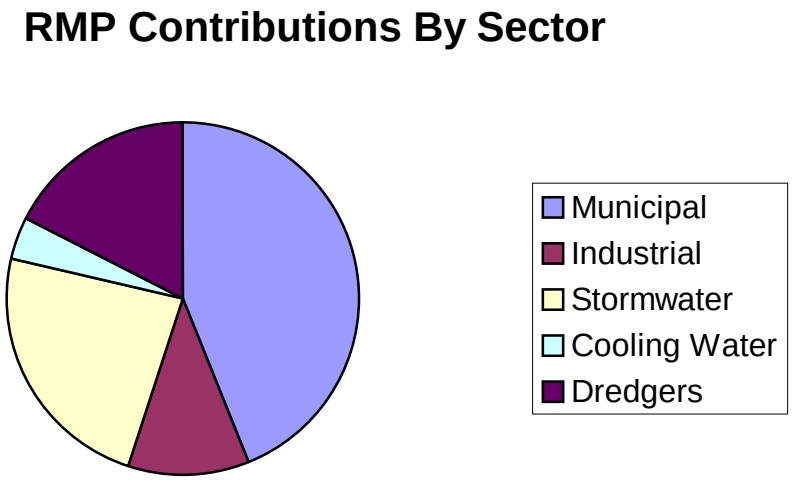

Figure 3. RMP committee organization chart.

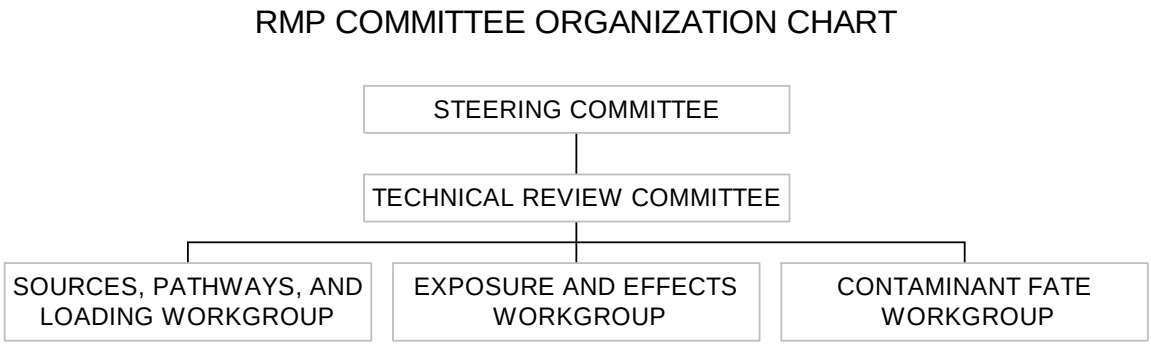

Table 1. RMP pilot and special studies from 1993-2005. I = year incorporated into the RMP.

Pilot Studies

Hydrography and phytoplankton	93	I											
Suspended sediment dynamics	93	I											
Benthic macrofaunal assemblages		94	95	96	97	98							
Wetlands monitoring			95	96									
Estuary interface				96	97	98	99	00	01				
Fish contamination					97			00			I		
Episodic toxicity						98	99	00	I				
Atmospheric deposition						98	99	00	01				
Mercury deposition network									01	02	03	04	
Exposure and effects									01	02	03	04	05

Special Studies

Comparison of local effects monitoring and the RMP		94											
Optimal water quality sampling strategy		94											
Development of a chronic Ampelisca abdita bioassay		94	95										
Methods for analysis of spatial and temporal patterns (trace elements)			95										
Workshop on ecological indicators			95										
Interlaboratory comparison exercises			95										
Sediment contamination indicators				96									
Review of bivalve monitoring				96									
Sediment information synthesis						98							
Sources, pathways, and loadings literature reviews						98	99	00	01	02	I		
Mass budget models									01				
Contaminant transfer from sediment to biota									01				
Surveillance monitoring									01	02			
CTR monitoring										02	03		
Loads from rivers										02	03	04	
10 year synthesis											03	04	

Table 2. Journal publications by RMP scientists, 2002 - 2006.

AUTHORS	TITLE	**JOURNAL**	**PUBLICATION DATE**
McKee et al.	*Estimates of suspended sediment entering San Francisco Bay from the Sacramento and San Joaquin Delta, San Francisco Bay, California*	Journal of Hydrology	2006
Greenfield and Davis	*A PAH fate model for San Francisco Bay*	Chemosphere	2005
Greenfield et al.	*Seasonal, interannual, and long-term variation in sport fish contamination, San Francisco Bay*	Science of the Total Environment	2005
Oros and Ross	*Polycyclic aromatic hydrocarbons in bivalves from the San Francisco estuary: Spatial distributions, temporal trends, and sources (1993–2001)*	Marine Environmental Research	2005
Oros et al. 2005	*Levels and Distribution of Polybrominated Diphenyl Ethers in Water, Surface Sediments, and Bivalves from the San Francisco Estuary*	Environmental Science & Technology	2005
Cloern and Dufford	*Phytoplankton community ecology: principles applied in San Francisco Bay*	Marine Ecology Progress Series	2005
Cloern et al.	*Heat wave brings a red tide to San Francisco Bay*	Eos Transactions of the American Geophysical Union	2005
Cloern et al.	*Climate anomalies generate an exceptional dinoflagellate bloom in San Francisco Bay*	Geophysical Research Letters	2005
Davis	*The long term fate of PCBs in San Francisco Bay*	Environmental Toxicology and Chemistry	2004
Ross and Oros	*Polycyclic aromatic hydrocarbons in the San Francisco Estuary water column: Sources, spatial distributions, and temporal trends (1993–2001)*	Chemosphere	2004
Oros and Ross	*PAH in SF Estuary sediments (1993 – 2001)*	Marine Chemistry	2004
Thompson and Lowe	*Assessment of macrobenthos response to sediment contamination in the San Francisco Estuary*	Environmental Toxicology and Chemistry	2004

Sanudo-Wilhelmy, Flegal, et al	*Examining Dissolved Toxic Metals in U.S. Estuaries*	Environmental Science & Technology	2004
Conaway, Flegal, et al.	*Mercury deposition in a tidal marsh of south San Francisco Bay downstream of the historic New Almaden mining district, California*	Marine Chemistry	2004
Ganju et al.	*Tidal oscillation of sediment between a river and a bay: a conceptual model*	Estuarine, Coastal and Shelf Science	2004
Luengen, Flegal	*Evaluation of immune responses as indicators of contamination in San Francisco Bay, Using a novel phagocytosis and phagocytic index method developed for mussels*	Marine Environmental Research	2004
Chauvaud, Cloern et al.	*Clams as CO2 generators: The Potamocorbula amurensis example in San Francisco Bay*	Limnology and Oceanography	2003
May, Cloern et al.	*Effects of spatial and temporal variability of turbidity on phytoplankton blooms*	Marine Ecology Progress Series	2003
Davis et al.	*Mercury and tidal wetland restoration*	San Francisco Estuary and Watershed Science	2003
Oros et al.	*Surveillance for previously unmonitored organic contaminants in the San Francisco Estuary*	Marine Pollution Bulletin	2003
Hoenicke et al.	*Effective application of monitoring information: the case of San Francisco Bay*	Env Mon and Assessment	2003
Lee, Thompson, and Lowe	*Estuarine and scalar patterns of invasion in the soft-bottom benthic communities of the San Francisco Estuary*	Biol. Invasions	2003
Conaway, Flegal.	*Mercury speciation in the SF Estuary*	Marine Chemistry	2003
Ndung'u, Flegal	*Organic complexation and total dissolved trace metal analysis in estuarine waters…*	Analytica Chimica Acta	2003
Phillips, et al.	*Causes of Sediment Toxicity to* Mytilus galloprovincialis *in San Francisco Bay, California*	Arch. Environ Contam. Toxicol	2003
May, Cloern, Schoellhamer	*Effects of spatial and temporal variability of turbidity on phytoplankton blooms*	Mar Ecology Progress Series	2003
Davis et al.	*Contaminant concentrations in sport*	Marine Pollution	2002

	fish from San Francisco Bay, 1997	Bulletin	
Tsai, Yee et al.	*Atmospheric Concentrations and Fluxes of Organic Compounds in the Northern San Francisco Estuary*	Environmental Science and Technology	2002
Steding and Flegal	*Mercury concentrations in coastal California precipitation*	Journal of Geophys Res	2002
Roitz, Flegal	*The biogeochemical cycling of manganese in San Francisco Bay: Temporal and spatial variations*	Estuarine, Coastal and Shelf Science	2002
Spinelli, Flegal	*Groundwater seepage into northern San Francisco Bay: implications for dissolved metals budgets*	Water Resources Research	2002
Squire, Flegal	*Decadal trends of silver and lead contamination in San Francisco Bay surface waters*	Environmental Science and Technology	2002
Thomas, Flegal	*Mercury Contamination from Historic Mining in Water and Sediment, Guadalupe River and San Francisco Bay, CA*	Geochemistry	2002
Cloern	*Stable carbon and nitrogen isotope composition of aquatic and terrestrial plants of the San Francisco Bay estuarine system*	Limnology and Oceanography	2002
Guarini, Cloern	*Microphytobenthos potential productivity estimated in three tidal embayments of the San Francisco Bay system*	Estuaries	2002

III. PERSPECTIVES ON THE RMP: BENEFITS AND CHALLENGES

A. The Regulator Perspective

Karen Taberski
San Francisco Bay Regional Water Quality Control Board

The San Francisco Bay Regional Water Quality Control Board (Regional Board) is the implementing agency of the federal Clean Water Act and the State of California's Porter Cologne Water Quality Control Act (California Water Code) in the San Francisco Estuary. Under the California Water Code the Regional Board is required to protect beneficial uses in the Estuary. Beneficial uses are primarily designed to protect aquatic life, wildlife and human health. In order to protect beneficial uses the Regional Board has adopted water quality objectives in their Water Quality Control Plan (Basin Plan). Water quality objectives include numerical water quality objectives for individual contaminants and narrative objectives that prohibit toxicity due to contaminants, as well as any detrimental increase of bioaccumulative contaminants.

1. Benefits

Regional Board activities to manage water quality in the Estuary can be divided into two broad categories. One is impairment assessment, which is performed to determine whether any contaminant is impairing a beneficial use. Water bodies affected by chemicals that are determined to be impairing beneficial uses are placed on a 303(d) list of impaired water bodies, as required by Section 303(d) of the Clean Water Act. The second broad category is the development of Water Quality Attainment Strategies. TMDL development is a subset of this category. The Clean Water Act requires that TMDLs be developed for all water bodies identified on the 303(d) list. In TMDLs, all contaminant inputs to the water body are identified, the total input that can be accommodated without impairment is determined, and ways to reduce inputs to the acceptable level are identified. Other types of water quality attainment strategies include public outreach and pollution prevention. RMP information is contributing significantly to both impairment assessment and water quality attainment strategy development by the Regional Board.

Impairment Assessment and 303(d) Listing

The RMP has provided the Regional Board with information to focus on water quality problems; to determine what is and what is **not** a problem. This enables the Regional Board to develop management priorities so that environmental problems can be addressed and resources can be used efficiently. An early example of the focus that the RMP provided was apparent in the 1998 303(d) "impaired waterbodies" listing process. Prior to 1998, the San Francisco Estuary was listed as impaired by "metals". In the 1998 303(d) list, the Regional Board staff determined that there was sufficient evidence to show that only copper and nickel exceeded water quality objectives to a level that required listing, and all other metals, except mercury and selenium which cause

bioaccumulative problems, were removed from the list. This allowed for a focused effort to take place, which included the efforts of the regulated industries and municipalities, environmental groups, scientists, and the Regional Board to concentrate on this specific problem. Out of that process came site-specific water quality objectives for copper and nickel in South San Francisco Bay, south of the Dumbarton Bridge, that are fully protective of aquatic beneficial uses; a Water Quality Attainment Strategy featuring pollution prevention, source control and monitoring activities; and the removal of copper from the 303(d) list.

In 1994, the Regional Board, through the BPTCP, conducted a study to measure contaminant concentrations in fish that people consume from San Francisco Bay. This study resulted in a health advisory for consuming San Francisco Bay fish. The fish advisory was primarily based on high levels of mercury and PCBs. In addition, several banned chlorinated pesticides including DDT, chlordane, and dieldrin, as well as dioxins, exceeded screening values. The health advisory for consuming fish from San Francisco Bay caused the Regional Board to list San Francisco Bay as "impaired" by mercury and PCBs on the 303(d) list. Currently, the Regional Board is developing TMDLs (see next section) for both of these chemicals in the Estuary.

Following up on the 1994 study, in 1997 the RMP started to measure contaminants in Bay fish every 3 years to determine temporal trends of contaminants in fish that people consume. Based on data from 1994, 1997 and 2000 there has been no measurable change in mercury or PCB concentrations in Bay fish. However there may be a decline in banned chlorinated pesticides, and chlordane concentrations have fallen below screening values in all fish tested. The continued monitoring of contaminants in fish will allow the Regional Board to determine the effectiveness of water quality attainment strategies (includingTMDLs), whether legacy contaminants such as chlorinated pesticides remain a concern, and whether contaminants that are only recently being measured, such as the flame retardant compounds polybrominated diphenyl ethers (PBDEs), have become a significant problem.

The measurement of aquatic toxicity has been a core component of the RMP since the beginning and is one of the best examples of adaptation in the Program. From 1989 to the present toxicity tests have been conducted on waters from the Bay and its tributaries. Results in 1996 and 1997 indicated that most of the observed toxicity was episodic, coming from the Sacramento/San Joaquin Delta during winter runoff events. As a result of this information, the Program was adapted to concentrate more on the potential sources of toxicity. The RMP started to measure the severity of toxicity, as well as the temporal extent, where these two rivers come into the Estuary. Thus, the episodic toxicity component of the Program was born. At the same time as the RMP studies, other studies were being conducted upstream of the RMP stations. The combined result of these studies indicated that toxicity was due to the organophosphate (OP) pesticide diazinon. These data resulted in 303(d) listing of diazinon for San Francisco Bay. In recent years (1999 to present) it started to become apparent that toxicity was decreasing, apparently due to the decreased use of diazinon. Since 1998 very little toxicity has been found in Bay waters.

With declining toxicity in the Bay itself, the episodic toxicity component of the RMP took a new focus to measure toxicity in other smaller tributaries to the Bay. The

new focus was driven by the fact that toxicity due to diazinon and chlorpyrifos had been detected in creeks around the Bay, and a TMDL was being developed for these pesticides in urban creeks. These studies also showed that there was currently very little aquatic toxicity in other tributaries. However, there was one incidence of toxicity in the Napa River that seemed to be associated with suspended sediment. Since pesticide usage, in general, has switched from OP pesticides, which are water soluble, to pyrethroids, which adhere to sediment, the episodic toxicity portion of the Program is again being revised to determine if this change in pesticide use pattern is causing sediment toxicity. This effective use of adaptive management has enabled the Regional Board to track the decline in aquatic toxicity associated with the decline in OP pesticide use and focus on potential future impairments with the increased use of pyrethroids. The RMP is extremely important in tracking toxicity to determine: 1) if toxicity is occurring; 2) if it is increasing or declining; 3) what is causing the toxicity; and 4) if management efforts are being successful. The development of methods to measure new pesticides, as well as the development and use of more sophisticated Toxicity Identification Evaluation (TIE) methods, are extremely important in linking toxicity to a particular contaminant. This linkage is critical if effective management efforts are to be taken that will result in measurable improvements in water quality.

In 1999 the RMP made a decision to proactively identify emerging contaminants of concern before they reach concentrations at which beneficial uses are impacted and regulatory action is necessary. In 2000 and 2001 the RMP conducted a special study to determine if contaminants that have recently become a concern have been detected in RMP samples. This study identified peaks on archived chromatograms that had previously been unknowns, to determine if they could be chemicals of concern. Chemicals were evaluated based on their potential to be persistent, bioaccumulative, and toxic. A list of chemicals came out of this study that was added to the analyte list for the Status and Trends Program for two years A preliminary review of the data suggested that many of the compounds were below thresholds of concern or were not dectected. The RMP has developed an Emerging Contaminant workgroup to review these data and to decide which emerging chemicals should be included in future monitoring. Screening for new chemicals of concern will be conducted on a periodic basis since new chemicals are always being introduced into the ecosystem. The Regional Board considers that surveillance monitoring for emerging contaminants is necessary as a means of identifying potential impairments in their early stages before they become a threat to beneficial uses.

One group of chemicals that has emerged as chemicals of concern from this process, as well as studies by the California Department of Toxic Substances Control, are the flame retardants polybrominated diphenyl ethers (PBDEs). These chemicals have been banned in Europe and a 2003 state law banned the use of two types of PBDEs in California by 2006. Despite the future ban, PBDEs are currently in the environment and used in furniture foam, computers, and other business equipment. This information led the Regional Board to list PBDEs on the 2002 303(d) “watch” list to encourage increased monitoring and studies to determine how PBDEs are getting in to the aquatic food chain. Determining pathways could help to identify management actions that would decrease the input of these and similar chemicals to the Estuary. These chemicals seem to be increasing exponentially in the tissues of estuarine organisms, such as harbor seals. Tracking the trends in these chemicals is extremely important to determine if

management actions are necessary and what effect the ban will have on concentrations in the future.

The 1997 Program Review resulted in redesign of the Status and Trends monitoring program. A stratified random sampling design, similar to U.S. EPA's Environmental Monitoring and Assessment Program (EMAP) design, was adopted. This new design will develop data that will be statistically representative of the Estuary and segments of the Estuary and enable the Regional Board to better evaluate whether water or sediment quality in the Estuary is impaired. This design will allow the Regional Board to better evaluate: 1) spatial patterns of contamination; 2) whether the Estuary or segments of the Estuary exceed water quality objectives; and 3) the proportion of the Estuary that is contaminated.

In order to afford this type of sampling design within a fixed budget the number of sampling events was reduced to one sampling event per year, during the dry season, since this is the least variable time period. Although there are sources and loadings and episodic toxicity studies being conducted during wet weather, some wet weather data gaps have been identified by Regional Board staff and RMP scientists. Evaluation of waterbodies for 303(d) listing, as well as the calculation of background conditions for permits requires seasonal data. In addition, since sediment toxicity in the Bay is highest in the wet season it would be easier to identify causes with winter sampling. The RMP is currently developing a program to directly measure impairment associated with contaminants in the Estuary. The RMP has set up a workgroup to develop an Exposure and Effects Pilot Study to: 1) measure contaminants in target species (i.e., bird eggs) that would be a better indicator of long- term trends in contaminants in the Estuary and 2) directly measure effects associated with contaminants. The goal of this pilot study is to develop a "toolbox" that will be incorporated into the RMP core program to accomplish these two objectives. Measuring contaminants higher in the food chain makes it easier to detect contaminants that tend to biomagnify in higher trophic levels, providing an "integrator" for food webs in the Estuary. Higher trophic levels, particularly cormorant eggs, may also provide a better indication of trends than other matrices measured in the Program. Impairment measurements, such as bird egg viability, that directly measure effects associated with contaminants, give a more direct determination of impacts on beneficial uses. The challenge is to be able to determine a direct association between a contaminant and an effect in the field. Using laboratory toxicity tests the RMP has funded the development of sediment Toxicity Identification Evaluations (TIE) that has helped evaluate the cause of sediment toxicity. This connection between cause and effect is necessary in order to take effective regulatory/management actions that will result in measurable improvements in water quality.

The measurement of contaminant concentrations in water, sediment, and tissue in the Estuary, as well as continuing efforts to measure effects, provides a more comprehensive view of the Estuary that enables Regional Board staff to evaluate data using a weight of evidence approach. The fish contamination study pointed out the importance of a weight of evidence approach and the choice of an appropriate indicator to assess water quality impairments by specific pollutants. The accumulated database on mercury in water, sediment, and bivalve tissue did not reflect the degree of impairment that was evident from measuring fish tissue. Mercury concentrations rarely exceeded

water quality objectives in the Estuary, and bivalves are poor accumulators of mercury. Targets associated more closely with possible effects of mercury (fish tissue for human health and birds eggs for wildlife) provide a more sensitive indication of beneficial use impact. The RMP, through peer-reviewed workgroups, is working to identify appropriate indicators of impairment to assist the 303(d) listing and TMDL process.

Total Maximum Daily Loads (TMDLs)

A Total Maximum Daily Load (TMDL) is required for waterbodies on the 303(d) list. A TMDL is the pollutant load level necessary to attain the applicable water quality standard. TMDLs include: 1) a problem statement; 2) a source assessment that quantifies the contribution of various sources and describes the uncertainties associated with them; 3) numeric targets to protect the beneficial uses that are impaired; 4) a linkage analysis that summarizes knowledge about the fate and transport of the contaminant, including within the food web; 5) load allocations that allocate loads among the sources to attain the proposed targets; and 6) an implementation plan listing specific actions intended to reduce loads to meet targets, monitoring to refine load estimates and evaluate progress, and special studies to address uncertainties.

The 1997 Review provided the impetus for a redesign of the Program. This redesign resulted in: 1) a refinement of RMP objectives to include an increased emphasis on pollutant effects measurements, sources and loadings, and data synthesis; 2) a clearer definition of management and scientific questions to focus studies; 3) the development of mass budget models to provide a context for RMP results and to identify data gaps; and 4) a redesigned base program with a probabilistic design. Coincident with the RMP redesign was an increased emphasis in the regulatory arena to develop TMDLs for contaminants on the 303(d) list. Therefore, the RMP was poised to provide the data synthesis, model development, studies to validate mass budget models and information on target species (fish contamination for human health and effects on bird reproduction) that is providing valuable information for the development of TMDLs. Since that time the Clean Estuary Partnership (CEP) was set up between wastewater agencies, stormwater agencies, industrial dischargers and the Regional Board to provide more specific collaborative assistance to the Regional Board in order to complete water quality attainment strategies, including TMDLs.

Data integration, synthesis, and analysis conducted through the RMP are proving to be instrumental in the development of the TMDLs for mercury and PCBs in the Estuary. Sediment concentrations have been mapped to determine sources and hot spots of contaminants. A mass balance model was developed for PCBs that allowed the Regional Board to: 1) identify the relative significance of sources; 2) determine the approximate time it would take to meet targets based on various input scenarios; and 3) to identify data gaps. A food web model was also developed to help determine how far concentrations of PCBs need to decline in the sediment to bring fish concentrations down to levels that are protective of human health.

RMP measurements of mercury on suspended solids, in bedded sediment, and in fish were used to develop a mercury sediment target in the mercury TMDL. These targets are intended to be protective of human health (through fish consumption) and wildlife (by protecting the most sensitive receptor, bird reproduction). A special study to measure air deposition of mercury and PCBs funded by the RMP and the City of San Jose helped

Regional Board staff determine the relative contribution from that source. A study currently being funded by the RMP and CEP to measure mercury loadings from small tributaries will enhance understanding of transport of sediment bound pollutants, improve load estimates, and assist with development of feasible and effective implementation plans. Continued monitoring of mercury and PCBs by the RMP in water, sediment, and tissue will allow the Regional Board to evaluate the success of TMDL implementation plans and to make adjustments if necessary.

Implementing Other Water Quality Attainment Strategies

Water Quality Attainment Strategies are development and implementation actions associated with attaining water quality standards. These Strategies include TMDLs, public education, pollution prevention, scientifically valid water quality guidelines/objectives, appropriate permit limits, sediment cleanups, and better scientific methods for evaluating whether water quality standards are being attained. The RMP has made a significant contribution to the Regional Board's ability to develop TMDLs and generate scientifically valid sediment guidelines and permit limits. The RMP has also provided the impetus and information necessary to foster public education programs that are being carried out by other agencies and has provided information that is being used in monitoring estuaries and developing standards statewide.

The health advisory on fish consumption that was issued as a result of the 1994 studies, led the RMP to fund a study of fish consumption in the Bay that was conducted, and partly funded, by the California Department of Health Services (DHS). This study was designed to: 1) gather information on San Francisco Bay anglers and their fish consumption practices; 2) identify anglers who are at risk due to their fish consumption habits; and 3) gather information to aid the development of effective educational messages about the consumption of fish from the Bay. Over 1300 San Francisco Bay anglers participated in the study. Study results indicated that: 1) about one in ten fish-consuming Bay anglers eats over the advisory level; 2) among those eating above the advisory level, about two-thirds are eating twice the advisory level or more; 3) anglers' likelihood of eating over the advisory limit varied with ethnicity, with Asians (particularly Filipinos) and African Americans more likely than other ethnic groups to eat over the limit; 4) differences in income, education, or fishing mode did not markedly change anglers' likelihood of eating over the limit; 5) the most commonly eaten fish were striped bass, halibut, jacksmelt, sturgeon, and white croaker (all fish monitored by the RMP); 6) of those interviewed, 61% had some knowledge of the advisory, and 7) although about one-third of those who had some knowledge of the advisory said that they changed their behavior because of this awareness, no significant difference was found between the overall consumption rate of those who were aware of cautionary information and those who were not.

The study interviewed anglers to determine how they preferred to receive information regarding fish consumption advisories for further outreach. Using these results, DHS has developed an appropriate outreach and education program to inform the public about the health advisory and about ways to prepare fish that minimize exposure to contaminants. This effort, which has included state, county and city agencies and environmental and community groups, has resulted in the posting of signs in 6 different languages describing the advisory, as well as outreach presentations to communities that

are most at risk. In an ecosystem where recovery from contamination will take decades, educating the public is the best way of providing short-term reductions in exposure to the contaminants found in Bay fish.

Another outreach and education program that grew out of information provided by the RMP, as well as many others, is "Our Water Our World". Due to the increased awareness of the impact of pesticide usage on aquatic organisms, stormwater and wastewater agencies have developed outreach and education efforts to minimize the use of pesticides and encourage integrated pesticide management. This pollution prevention program develops information targeted at the general public to prevent future pesticide toxicity.

RMP data have been and continue to be used by Regional Board staff to develop regulatory guidelines for the Estuary and to support permit conditions. Knowledge of Bay-specific fish consumption rates allows regulatory agencies to develop screening values that reflect the Bay population that they are trying to protect. The results of the RMP consumption study enabled the Regional Board to calculate target values for mercury in Bay fish in the mercury TMDL that would protect 95 percent of all Bay fish consumers. In 1998 the Regional Board developed ambient sediment guidelines, using RMP and BPTCP data, to determine "background" concentrations of contaminants in the Estuary. These guidelines assist regulators in determining when sites may have high concentrations of contaminants and can trigger an investigation of sources. The calculation of Estuary-specific background concentrations allows the Regional Board to determine when concentrations of contaminants at a particular site are "high" due to a possible contaminant source, or because of natural geologic conditions. The RMP also provides data that are used in writing NPDES permits for discharges to the San Francisco Estuary. RMP data are used to determine background concentrations that are used in determining effluent limits. Recently, the RMP has conducted a special study to determine, based on ambient data, whether the 126 contaminants listed in the California Toxics Rule (CTR), promulgated in 2000, should be listed in permits.

On a statewide basis, the RMP has given the State Water Resources Control Board and the other Regional Boards methods to better understand their bays and estuaries. RMP data are currently being used to develop statewide sediment quality objectives. RMP efforts in measuring sediment chemistry, conducting toxicity tests and TIES, and performing a pilot study on benthic invertebrates to understand the relationship between benthic communities and contaminants, are an important component of this statewide process.

2. Challenges

There are many complex technical issues concerning contaminants in the Estuary that are not currently being adequately addressed. Studies that would provide a better understanding of food web transfer are needed to determine how best to regulate concentrations of contaminants in sediment and water to protect humans, aquatic organisms, and wildlife. Studies in wetlands that are crucial to the understanding of processes linking contaminant concentrations in sediment to concentrations in wildlife need to be conducted. Especially during this time, when extensive wetland restoration is planned, it is extremely important to understand the mechanisms by which contaminants,

particularly mercury, become bioavailable in order to minimize the potential for creating wetlands that increase methylmercury accumulation in the food chain.

In this time of severe financial resource limitations it is crucial to reconsider how programs could better cooperate and coordinate to develop this needed information. Therefore, some of the biggest challenges in the future will be institutional.

Although studies from the RMP have been very helpful in the development of TMDLs, the dischargers and the Regional Board have recognized that additional studies and assistance is needed in order to collaboratively complete scientifically sound TMDLs. Because of this the Clean Estuary Partnership (CEP) was initiated. The mission of the CEP is to use sound science, adaptive management, and public collaboration to develop and implement scientifically valid and cost-effective strategies including TMDLs that result in identifiable, sustainable water quality improvements for SF Bay. Currently, there is an overlap in the objectives and studies conducted by the RMP and the CEP. Both are involved in: 1) evaluating sources and measuring loadings; 2) developing models to assist in understanding the mass budget for particular contaminants in the Bay; 3) filling in data gaps to determine the relative contribution of particular sources; and 4) developing data to determine target concentrations in the appropriate media. From an institutional perspective and for the purposes of consistency, efficiency and cost-effectiveness it may be advantageous to merge these two programs in some way.

Another institutional challenge is the coordination and synthesis of large-scale environmental programs that monitor and assess the San Francisco Estuary. CALFED, as well as the Interagency Ecological Program (IEP), are two large programs that are also involved in monitoring and special studies in the Estuary. CALFED is conducting studies in the Delta, in primarily freshwater environments, to better understand the processes by which mercury becomes bioavailable in wetlands. Although these data can be used to help guide restoration efforts in the South Bay, South Bay wetlands have a different salinity regime as well as other characteristics that need additional evaluation. The IEP primarily conducts ecological studies. These studies might be better coordinated with RMP studies to understand how contaminants interact with food web dynamics. Better coordination, cooperation, and synthesis of data are needed to develop a more comprehensive view of the Estuary and to provide a better understanding of the underlying processes that create impairment so that better management decisions can be taken.

One example of successful coordination of the RMP and another large program is the partnership between the U.S. Geologic Survey (USGS) and the RMP. Since the inception of the RMP, USGS has been funded by the Corps of Engineers as their contribution for dredging activities, making USGS an integral partner. As part of larger programs to characterize the Estuary, the USGS has provided important information on basic water quality parameters such as dissolved oxygen and nutrients, as well as explaining the relationship between the fluctuation of suspended solids and concentrations of contaminants that have provided an essential context to understanding contaminants in the Estuary. USGS programs have been taking place over a longer timeframe than the RMP. However, measurements are taken on a smaller temporal and spatial scale. This has allowed the RMP to put contaminant data, collected one to three times a year, in a context with chemical, physical and biological data collected on a much

more intensive spatial and temporal scale, providing a better perspective and understanding of processes. Information from USGS studies has enabled the Regional Board to determine if the Bay is impaired by basic water quality parameters such as oxygen and nutrients. Understanding the relationship between suspended solids and contaminants has provided an explanation of why certain areas of the Bay are high in contaminants. Data from studies relating suspended solids to chemical concentrations may also enable us to predict, for certain chemicals, concentrations on small timescales throughout the year, putting RMP results in context. This information allows the Regional Board to make more informed decisions on impairment and assists in the understanding of processes for TMDLs.

Better coordination could be accomplished through shared funding of programs (this is currently being done with the RMP and the Fish and Wildlife Service on a study of contaminants and bird egg mortality), coordinating grant funding, creating a forum for data synthesis such as an environmental report card for the Bay, and having more participation by other agencies and programs on RMP committees. This type of collaboration would enable the RMP to put their data in a broader context, to better understand the processes that work in the Estuary, and to ultimately assist the Regional Board in better assessing impairments and protecting beneficial uses.

The Regional Monitoring Program is a testament to the importance of maintaining the institutional and monetary commitment to measuring meaningful indicators of water quality, and linking them to programs of action. In the past thirteen years the credibility of the Regional Board and local implementing agencies in preventing pollution to the Bay has dramatically increased and managers have become reliant on the scientific information consistently provided by the RMP. We now have answers to water quality attainment questions. We can advise the public on how to consume fish from the Bay and remain healthy. We have seen the decline in toxicity in tributaries to the Bay, associated with a change in pesticide use patterns. We have started educational programs on alternatives to pesticide usage. We have raised local scrutiny of the use of copper, nickel, and mercury in industrial processes. With diverse participation, a foundation in scientific principles, and a continual commitment to improvement over time, the RMP has become a model for water quality monitoring programs around the world.

B. The Regulated Community Perspective

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The regulated community involved in the RMP includes 34 municipal dischargers, 10 industrial dischargers, 9 stormwater management agencies, a variable number of dredgers depending on what projects are active in a given year (18 in 2003), and two cooling water dischargers. Each of these entities possesses a National Pollution Discharge Elimination System (NPDES) permit to discharge to the Bay. These permits include a provision for the permit-holder to participate in the RMP. An equitable distribution of the costs of the Program is achieved as described in Section II, with the larger dischargers contributing a larger share of the funds.

The regulated community actively participates in the RMP through membership on the committees that guide the Program. Each sector (municipal, industrial, stormwater, dredger, cooling water) is represented. Management representatives from the dischargers are members of the Steering Committee, and technical representatives are members of the Technical Review Committee. The perspectives of the regulated community on the value of the RMP and challenges facing the program have been the subject of group discussion in 2003 and were also the theme of presentations at the 2003 RMP Annual Meeting. This section summarizes these discussions and presentations.

1. Benefits

The dischargers consider the RMP to be a very valuable program, and are strongly committed to continued participation and involvement in it. The value to the dischargers can be described by four general areas: enhanced collaboration, regional efficiency, high quality technical information, and credibility that facilitates informed decisions.

Enhanced Collaboration

Perhaps the most highly valued aspect of the RMP for the dischargers is the forum that the Program provides for communication and collaboration. RMP committee meetings, workgroup meetings, workshops, and the Annual meeting all provide opportunities for the dischargers to communicate with each other, with the Regional Board, with environmental organizations, and with other stakeholders. The enhanced interaction occurs at multiple levels, including the leaders of these organizations and their technical staff. Shared interest in the success of the RMP has created an atmosphere of cooperation among these groups. The diverse groups of dischargers have developed a closer working relationship as a result of their participation in the RMP. The dischargers and the Regional Board have also developed an effective collaborative relationship through their joint participation in the RMP. The success of this collaboration in the RMP assisted in the development and implementation of the Clean Estuary Partnership, another major innovative collaboration of these organizations (www.cleanestuary.org). All RMP committee and workgroup meetings are open to the public, and this facilitates communication and coordination with other

Estuary stakeholders, including environmental organizations and scientists. Input from all parties is given consideration as consensus is sought on the issues at hand. Dischargers benefit from the channels of communication that have been established with all of these groups.

Efficiency

The dischargers also consider the efficiencies created by the RMP to be very beneficial. The pooling of resources, both intellectual and financial, that occurs in the RMP allows for efficient monitoring of water quality in the Bay. Prior to the RMP, isolated monitoring of individual discharges prevailed. Pooling of resources has provided the opportunity to perform comprehensive, consistent monitoring across the ecosystem with minimal administrative costs, and several benefits resulting from economies of scale: coherent data management system, an overarching quality assurance program, effective reporting, and others. Large-scale efforts, such as fish contamination monitoring, can be effectively implemented. Pooling of resources also allows the Program to identify and respond to problems in an adaptive manner, as exemplified by the evolving aquatic toxicity monitoring element. Other ingredients to the efficiency achieved by the RMP are the clear articulation of the management questions that the Regional Board needs answered and the objectives of the monitoring program, and the continual adjustment of the Program by workgroups and committees based on changes in management priorities and new knowledge. These adjustments allow the Program to maintain a focus on the highest priority issues. Another aspect of the efficiency created by the RMP is the improved regulatory decisions that can be made based on the wealth of reliable information generated by the Program - the decision to remove copper from the 303(d) list is a prime example.

High Quality Technical Information

Another general category of benefits to the dischargers is reliable and objective technical information. The dischargers benefit from the large amount of high quality data produced by the Program. The RMP has established many accepted concepts and facts about the condition of the Bay, contaminant loads, and how the Bay will respond in the future. TMDLs and other regulatory actions for the Bay – permit limitations, 305(b) reporting, 303(d) listing – can be developed with a foundation of sound scientific information. RMP data help provide clear justification for solutions that are proposed for Bay water quality problems. Bay Area dischargers have demonstrated through the RMP and the CEP that they are quite willing to participate in solving water quality problems that have been defined with objective and reliable scientific information.

Credibility

Finally, the dischargers value the credibility they have gained and accountability they have demonstrated by sponsoring and participating in the RMP. The regulated community in the Bay Area has demonstrated their interest in protecting and tracking water quality in a technically sound, cost-effective, and transparent manner. The RMP has provided a foundation for data-driven regulatory decisions that are based on a conceptual understanding of contamination in the Estuary, indicate whether water quality is improving or deteriorating, and are less susceptible to legal challenge.

2. Challenges

Improved Collaboration and Communication

The discharger community has identified several areas for future improvement. The first area is coordination and collaboration. The sector of the discharger community that is least satisfied with the RMP is the dredgers. Better linkage of the RMP with the Long Term Management Strategy (LTMS) for the Placement of Dredged Material in the San Francisco Bay Region (USACE 2001) and the Dredged Material Management Office (DMMO) is desired. The LTMS and DMMO are products of interagency collaboration for management of dredged material disposal in the region. The DMMO is a joint program of the many agencies involved in regulating dredging and dredged material disposal in the Bay region (San Francisco Bay Conservation and Development Commission, San Francisco Bay Regional Water Quality Control Board, State Lands Commission, the San Francisco District U.S. Army Corps of Engineers, the U.S. Environmental Protection Agency, the California Department of Fish and Game, the National Marine Fisheries Service, and the Fish and Wildlife Service). In the DMMO these agencies cooperatively review sediment quality sampling plans, analyze the results of sediment quality sampling, and make suitability determinations for material proposed for disposal in San Francisco Bay. Closer linkage of the DMMO and the RMP from a planning perspective could be achieved through meeting participation by appropriate staff.

Continued improvement in the mutual understanding of the perspectives of regulators and the regulated is also desired, with a goal of agreeing on a rational perspective on subjects such as in-bay disposal or TMDL development and implementation. The interaction of regulators and dischargers facilitated by RMP committee and workgroup meetings can be an effective vehicle for this dialogue.

Another coordination challenge identified by the dischargers is obtaining broader agency involvement in the RMP. Specifically, it has been suggested that the U.S. Fish and Wildlife Service and the California Department of Fish and Game could be more involved. Another institutional challenge will be coordinating the RMP and the Clean Estuary Partnership. These two programs have different areas of primary focus, but also considerable areas of overlap. Furthermore, many of the same people sit on committees for both programs. Integration of these two programs would enhance efficiency from both technical and organizational perspectives. Improved coordination and collaboration with outside researchers and agencies in general would possibly identify ways to optimize the use of RMP funds.

Environmental Information Clearinghouse

A second area for improvement that has been identified is addressing the information needs of the different sectors of dischargers in an equitable manner. Concerns in this regard have been expressed primarily by the dredging sector, which has suggested several ways in which the Program could be more beneficial. Two of them have been mentioned above (closer linkage with the LTMS and DMMO and management of dredged material testing data). Another would be to identify ways in which RMP data collection could result in reduced dredger data collection needs (e.g., if the existence of

RMP data could reduce the need for reference site data in the dredged material testing program). A concern expressed by a Suisun Bay industrial discharger is that the RMP may be biased toward South Bay and Central Bay. These concerns should be addressed so that all of the dischargers are satisfied that they receive their fair share of value from the Program.

Communication and Outreach

A third area for improvement identified by the dischargers is information dissemination and outreach. There is a general perception among the RMP participants that the Program could do a better job of getting the word out. The Pulse is considered to be a useful product of the RMP, but it would be nice if it reached more readers. A formal strategy for conducting outreach for the Pulse and other RMP products has not been developed.

Technical Challenges

Some technical challenges have also been noted by the dischargers. A major technical question managers are facing is how to restore wetlands in the Estuary, which is planned on a massive scale, without exacerbating the existing problem of methylmercury accumulation in the food web. Addressing this difficult question will require collaboration of the RMP with mercury researchers and restoration ecologists from several other programs and projects. Food web accumulation continues to be a concern for other contaminants as well, such as selenium. Managing selenium and mercury will require improvements in the sensitivity of analytical methods and studies of the speciation of these elements in inputs to the Bay and in Bay water and sediment. As our understanding of contaminant loadings to the Bay has improved in recent years, appreciation of the importance of loads from stormwater runoff has grown. Assessing the magnitude of these loads and tracking them over time as management actions are taken will be a major challenge with the highly variable flow regimes found in the Bay-Delta watershed.

RMP Funding

There are two issues related to funding of the RMP. First, the last few years have included a general economic downturn and RMP participants have generally experienced reduced budgets. As a result, the RMP budget has seen a slight reduction on an inflation-adjusted basis. At the same time, TMDL development and implementation, recommendations from the 2003 Program Review, and other factors are placing increased demands for new types of information from the RMP. The RMP therefore faces the challenge of providing more information with essentially a fixed budget. To meet this challenge, the Program will have to keep a sharp focus on high priority elements to ensure that as much useful information as possible is obtained for the money spent on the Program. In this regard, in 2006 the Program began a process of thoroughly evaluating the elements of RMP Status and Trends monitoring in order to replace lower priority elements with higher priority ones.

The second issue is the need to reevaluate the funding structure of the Program. This is a difficult topic that needs to be addressed. As we have learned more about water

quality in the Estuary and as discharges to the Estuary have changed over time, the existing funding structure (Figure 2) may not still be equitable for all of the participants. Another related issue is the possibility of a new group of "discharger" – wetland restoration projects – being included in the RMP. In response to these changes there may be a need to evaluate the existing allocation scheme or perhaps other funding scenarios. Addressing this issue will require facilitation and leadership.

C. The Scientific Community Perspective

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The RMP is a large, multi-faceted program that involves scientists from many organizations, including SFEI, academic institutions, government agencies, and consulting firms. Many are involved directly in the Program as contractors performing field sampling or laboratory analysis. Others serve as representatives on the Technical Review Committee, participants in RMP Workgroups, or as peer reviewers of RMP products. In addition to this large group of scientists directly involved in the Program, the influence of the RMP extends to the broader international community of environmental scientists through the publications, presentations, and other interactions of RMP scientists.

1. Benefits

The RMP has benefited the scientific community in many significant ways. One of the most important technical contributions of the RMP is the creation of an extensive, comprehensive, and high quality repository of data on long-term trends of many important parameters describing water quality in the Bay. Contaminant monitoring in San Francisco Bay is as thorough and of as high a caliber as for any other estuary in the world. The dataset that has been generated on concentrations of contaminants in water is particularly noteworthy. Advanced sampling and analytical methods with unusual sensitivity have been employed to obtain reliable measurements of extremely low concentrations of trace elements and organic contaminants in the Bay water column, with concentrations down to the parts per quintillion range. High quality, long-term datasets have also been generated for the other parameters measured in the RMP, including chemical contamination of sediment, bivalves, and fish, toxicity in water and sediment, and basic water quality parameters (salinity, dissolved oxygen, chlorophyll a, temperature, and suspended sediment). RMP monitoring data constitute an extremely valuable frame of reference for comparison of data from other water quality studies.

RMP results are illustrating the value of long-term monitoring. One recent example is the fundamental shift that has been documented in seasonal cycles of the Estuary's food supply. Chlorophyll monitoring has revealed a change in the annual pattern in South Bay from a spring bloom cycle, which prevailed for 21 years of monitoring prior to 1999, to a spring and autumn-winter bloom cycle from 1999 to the present. Long-term chlorophyll monitoring has also shown that a summer phytoplankton bloom that was an annual occurrence in Suisun Bay prior to the invasion of the Asian clam (*Potamocorbula amurensis*) in the late 1980s has been absent ever since the invasion. These trends in phytoplankton have tremendous ecological implications as phytoplankton are the most important energy supply to the Estuary's food webs. Long-term monitoring of suspended sediment concentrations has allowed a trend toward declining sediment loads to the Estuary to be identified in spite of the extremely noisy

signal that characterizes these data. Declining sediment loads to the Estuary are a concern with regard to both water quality (increased erosion of relatively contaminated buried sediment will likely delay improvements in water quality) and habitat restoration (suspended sediment in Bay waters is a primary source of sediment needed for tidal wetland restoration). For contaminants, long-term trends in concentrations in water, sediment, and the food web are key indicators of progress toward reducing impairment. For example, trends of organic contaminant concentrations in bivalves are the best indicator of change in these chemicals over the past 20 years, and have been used in combination with mass budget models to forecast recovery of the Bay in decades to come. In an ecosystem that exhibits a high degree of variability on time scales ranging from hours (tides), to seasons (wet season versus dry season), to years (drought versus El Nino), long-term monitoring is essential to confidently establishing long-term trends in water quality.

In addition to generating valuable long-term time series, RMP studies have resulted in many advances in methods and pioneered in the application of monitoring approaches to estuarine ecosystems. For example, many advances have been made in the field of trace element geochemistry of estuarine waters. The first accurate measurements of silver and mercury in waters of an estuary were made in San Francisco Bay. The first reliable measurements of many other trace elements (including cadmium, cobalt, copper, iron, manganese, nickel, lead and zinc) in the Bay were in the RMP. The RMP has also developed one of the world's most extensive datasets on concentrations of organic contaminants in water. Many of these chemicals are present in the Estuary at parts per quadrillion concentrations, and the analysis of several suites of chemicals at these low concentrations requires the use of sophisticated high-volume sampling and sensitive analytical techniques. Methods developed for the RMP have been adopted by scientists studying other ecosystems. Many of the analytical methods for trace elements developed or applied in the RMP were a major influence on standard methods promulgated by U.S. EPA (1995a-j) for analysis of trace elements in ambient waters. At the time these methods were being developed, U.S. EPA filmed RMP sampling of San Francisco Bay and used it in national and regional workshops to illustrate their new methods.

The scientific community at large benefits from publications and presentations by RMP scientists that document RMP methods and lessons learned about our Estuary. The high quality science conducted in the RMP is reflected in many peer-reviewed journal publications. Publications from the past two years are listed in Table 2. RMP findings have also been presented at innumerable symposia over the past ten years, including annual meetings of national scientific organizations such as the Society of Environmental Toxicology and Chemistry, the Estuarine Research Federation, and the American Geophysical Union, and many other local and national meetings. RMP scientists also share their expertise through participation on advisory panels for other programs, including national programs such as NOAA's National Status and Trends Program and U.S. EPA's Environmental Monitoring and Assessment Program, and many state and local programs (the State Water Resources Control Board's Surface Water Ambient Monitoring Program, the San Francisco International Airport Runway Expansion Project, the Interagency Ecological Program, and others).

RMP scientists value the forum the RMP provides for communication with water quality managers. RMP workgroup and committee meetings provide opportunities for direct dialogue between scientists, regulatory agency staff, and other stakeholders. All of these groups benefit from these interactions, which have the net effect of integrating high quality scientific information in public decision-making. The RMP has allowed high quality science (both the scientific method and the data generated) to drive water quality policy (e.g., Hoenicke et al 2003 and the mercury TMDL final project report).

Research groups that are able to join the RMP team of investigators benefit from the stable, long-term funding associated with long-term monitoring. This is best exemplified by the three principal research groups that have participated in the RMP since the beginning: Russ Flegal's group at U.C. Santa Cruz (UCSC); Jim Cloern's group at USGS, Dave Schoellhamer's group at USGS, and RMP staff at SFEI. These institutions have been able to combine RMP funding with funding from other sources to maintain stable, productive research programs for the past 10 years. One major benefit of these long-term programs is that they are a fertile training ground for young scientists and students, who have opportunities to learn about environmental science while performing meaningful applied research. Russ Flegal's group, for example, has produced 13 doctorates and six master's degrees, and these scientists have gone on to positions in universities, government agencies, and consulting firms. Eleven graduate theses based wholly or in part on RMP work have been produced by Dr. Flegal's group alone. Ten years of the RMP have resulted in a legacy of a large number of well-trained productive scientists.

Another benefit that these institutions derive from stable, long-term funding is the opportunity to build broader research programs that are integrated and have synergy with RMP work. This benefits the RMP and the other sponsors of the work. For example, UCSC augments their RMP funding with an estimated $200,000 to $500,000 per year of support from other sources. This has enabled UCSC to perform a large body of innovative work on trace elements in sediment pore waters, speciation in estuarine water and atmospheric deposition, and isotopic composition of estuarine waters. Another example is the continuous suspended sediment monitoring network that has been assembled by Dave Schoellhamer of USGS, which is partially supported by RMP with additional support from many other agencies. This network has yielded many important insights into sediment dynamics in the Estuary, and as understanding of contaminant fate in the Estuary increases so does appreciation of the influence of sediment dynamics on water quality.

2. Challenges

The need for long-term monitoring of the San Francisco Estuary is as great as ever. The Estuary is naturally a highly complex and dynamic ecosystem, and ten years of monitoring is only enough to begin to characterize this complexity. Humans also place an unusual amount of stress on this ecosystem, making it one of the most highly altered large coastal ecosystems in the world. Several major alterations to the Estuary are

looming. Restoration of wetland habitat on a grand scale is planned; while this will greatly benefit wildlife, some negative side-effects on water quality may occur through increases in the amount of methylmercury that is produced and accumulated in the food web and through creation of a more erosional sediment regime that exposes contaminated buried sediment. Major construction projects have been under consideration, such as the expansion of the San Francisco International Airport, which would have a major impact on water and sediment movement in the Bay. Biological invasion of the Estuary continues to occur, with the potential for impacting water quality through fundamental alterations in food web structure, as observed with *Potamocorbula*. The human population of the Bay Area also continues to grow, bringing the threat of increased human pressure on the Estuary water quality through larger volumes of sewage effluent and more highly contaminated stormwater runoff. Counterbalancing population growth and other negative pressures, TMDLs are being implemented to reduce water quality impairments and restore beneficial uses. Long-term monitoring is needed to determine the net effect of all of these influences on water quality in the Estuary.

Given this dynamic setting, the primary challenge facing the RMP is maintaining the basic long-term monitoring that has been established so the impact of changing human influences on the Estuary can be measured. Commitment to the long-term goals of the Program should be maintained, as should key features of the Program such as the high quality of the data generated. Continued financial support will be the key to maintaining the Program over the long term, and sustaining investment in the RMP through fluctuating economic conditions and with competing demands for funds is a major challenge for the Program.

One way to help meet this challenge is to draw other sources of funding for water quality research to the Estuary. RMP investigators have done this to some extent. However, other prominent coastal ecosystems such as Chesapeake Bay and the Great Lakes have received far more federal investment than San Francisco Bay. Broader communication of the significance of the Estuary ecosystem, the magnitude of the stresses on it, and the existing foundation of long-term scientific investigations may help in this regard.

There are many technical areas in which the RMP can continue to grow; a few important ones are briefly mentioned here. Mercury accumulation in the Estuary food web is perhaps the highest priority water quality problem, posing a concern for the health of humans that consume Bay fish and a potentially affecting Bay wildlife, including endangered species, at the population level. Mercury has a very complex biogeochemical cycle, however, so our present monitoring techniques are still evolving and our ability to predict the impact of management actions on mercury impairment is rudimentary at best. Development of effective monitoring and management approaches for mercury poses a challenge that will require interdisciplinary teams of scientists, programmatic coordination with the California Bay-Delta Authority and other organizations conducting mercury research, and interdisciplinary coordination with scientists involved in habitat restoration, which has the potential to significantly increase mercury accumulation in the Estuary food web. Another technical area for improvement is identification and

monitoring of emerging contaminants. Surveillance monitoring for these chemicals was recently added to the Program. Continued refinement of this component will help managers take action to stop contaminant loading before long-term problems are created. A third area for continued development is applying effective new tools to Bay monitoring. Sampling and analytical methods will continue to improve and offer the potential for providing new information, more information, better information, or less expensive information. Lastly, the RMP has begun to develop a capability to predict the future course of recovery of the Estuary from water quality impairments. Continued development of this predictive capability will be important in deciding on how aggressively to pursue load reductions. However, model development should proceed thoughtfully, with care taken to avoid the potential for wasting effort by creating models that are more elaborate than necessary to answer the management questions at hand.

Another major challenge from the scientific perspective is improved integration and coordination of the RMP with other research and monitoring programs for the Estuary. From its inception, the RMP was envisioned as one part of a comprehensive monitoring program for the Estuary. Other aspects of Baywide monitoring have not been established, such as monitoring of plankton, benthos, birds, marine mammals, nutrients, and primary production. The monitoring elements that do exist, such as the Interagency Ecological Program and long-term studies of the USGS, could be better integrated with the RMP. As mentioned above, coordination of the RMP with habitat restoration and mercury research programs is going to be imperative to address the mercury problem. As these programs become coordinated and gaps in monitoring of the Estuary are filled, there is going to be a clear need for cross-program data synthesis and integration.

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APPENDIX 1

RMP OBJECTIVES FRAMEWORK

RMP OBJECTIVES AND MANAGEMENT QUESTIONS: 2004

The specific management questions listed below are intended to provide a basis for developing and implementing both the Base Program and Pilot/Special Studies. This development should address the Regional Board's information needs, reflect a coherent perspective on the Estuary and its management, and fit within the RMP's mission and objectives.

These specific management questions also incorporate key agreements among all parties about the future direction of the RMP. These include maintaining a viable Base Program to track patterns, continuing and expanding the commitment to Special Studies that can elucidate important processes, and making better use of available data by expanding SFEI's role in data syntheses and interpretation.

1. Describe the distribution and trends of pollutant concentrations in the Estuary

1.1 Which pollutants should be monitored in the Estuary, in what media, and at what frequency?

1.2 Are pollutants of concern increasing, decreasing, or remaining the same in different media?

1.3 How are contaminant patterns and trends in the Estuary over time affected by remediation and source control or pollution prevention in the watersheds?

1.4 Do pollutant concentration distributions indicate particular areas of origin or regions of potential ecological concern?

1.5 What effects on beneficial uses or attainment of Water Quality Standards will occur due to large-scale habitat restoration in the Estuary in decades to come?

2. Project future contaminant status and trends using current understanding of ecosystem processes and human activities

2.1 Can reasonably accurate recovery forecasts be developed for major segments and the Estuary as a whole under various management scenarios?

2.2 Can potential impairment and degradation be better anticipated in the face of projected changes in land and water use and management, as well as product use and disposal?

2.3 Which pollutant categories are predicted to accumulate in the Estuary faster then they can be assimilated?

2.4 Do pollutant trends reflect historical changes in use patterns, transport and transformation processes, or control actions?

2.5 How will the importance of each pathway change through time under various management and development scenarios?
2.6 What is the projected future loading of pollutants of concern under various management and development scenarios?
2.7 What are the likely consequences of various management actions or risk reduction measures?
2.8 Do pollutants show existing distributions that fit our current understanding or models of their origin, loads, and transport?
2.9 What changes in loadings or ecosystem characteristics (e.g., extent of restored tidal marsh, Estuary circulation and flushing, food web shifts) would reduce or increase pollutant exposures and effects?
2.10 How are distributions and long-term trends in pollutants affected by current and predicted estuarine processes (e.g. sediment erosion, deposition, river inflows)?

3. Describe sources, pathways, and loading of pollutants entering the Estuary

3.1 Where are/were the largest pollutant sources, in what context are/were these pollutants applied or used, and what are/were their ultimate points of release into the aquatic environment?
3.2 What are the circumstances and processes that cause the release of pollutants from both internal and external source areas?
3.3 Once released, how do pollutants travel from source areas to the Estuary, what are the temporal and spatial patterns of storage, and are they transformed along the way or after deposition?
3.4 What is the annual mass of each pollutant of concern entering the Bay from each pathway?
3.5 Can data with high temporal resolution from a few watersheds be projected to other watersheds and the Basin as a whole?
3.6 For each pollutant of concern, what forms are released from each pathway and what are the magnitude and temporal variation of concentrations and loadings?
3.7 How do loads change over time in relation to management activities?
3.8 What is the relative importance of pollutant loadings from different sources and pathways, including internal inputs, in terms of beneficial use impairment?

4. Measure pollution exposure and effects on selected parts of the Estuary ecosystem (including humans)

4.1 How are emerging problems reflected in exposure and effects measurements?
4.2 Which (co-)factors (e.g., food web structure) influence exposure and effects of specific pollutants on biota?
4.3 What ecological risks are caused by pollutants of concern?
4.4 What human exposure to pollutants of concern results from consumption of fish and game?
4.5 To what extent does exposure to multiple pollutants lead to effects?
4.6 Which forms of pollutants cause impairment?

4.7 To what extent do factors other than specific pollutants (invasive species, flow diversions, land use changes, toxic algal blooms) contribute to beneficial use impairment?

5. Compare monitoring information to relevant benchmarks, such as TMDL targets, tissue screening levels, water quality objectives, and sediment quality objectives

5.1 What percentage of the Estuary is supporting beneficial uses?

5.2 Which segments should be considered impaired and why, and how do segments compare in terms of recovery targets?

5.3 How can specific source limitations, controls, and mitigation be best linked to appropriate beneficial use endpoints and recovery targets?

6. Effectively communicate information from a range of sources to present a more complete picture of the sources, distribution, fate, and effects of pollutants and beneficial use attainment or impairment in the Estuary ecosystem.

This objective applies to all of the questions listed under objectives 1 – 5.

APPENDIX 2

Summary of Recommendations of 1997 Review and Responses

Table 1. Recommendations and suggested implementation approaches from the 1997 Review and progress as of 2003, part 1: Recommendations that suggest more fundamental activities to be undertaken by the RMP.

Recommendation	**Responsible Party**	**Implementation Approach**	**Financial Impact**	**Progress and Comments**
3b Document aims of the RMP	All	Agreement on roles and responsibilities of parties; definition of data needs/usage by parties	?	•1 Objectives framework developed that documents aims of the Program as recommended •2 Roles and responsibilities agreed on in "Final RMP Pilot/Special Study Selection Procedure"
3c Expand core objectives/questions	All	Agreement on scope and direction of RMP; develop five year plan	?	•3 Done – major changes to Program objectives implemented •4 Five year plan updated annually
3a Evaluate design issues	All	Definition of data needs/usage by parties; integration with other studies; statistical analyses	?	•5 Design recommendations generated by several topical Workgroups •6 Workgroup recommendations integrated by Design Integration Workgroup •7 Fundamental changes to Status and Trends monitoring, including change from fixed station to spatially randomized sampling of water and sediment •8 Pilot and special studies explicitly linked to Program objectives and management questions

Table 2. Recommendations and suggested implementation approaches from the 1997 Review and progress as of 2003, part 2: Recommendations for gradual implementation.

Recommendation	**Responsible Party**	**Implementation Approach**	**Financial Impact**	**Progress and Comments**
2a Integrate other data for holistic appraisal	SFEI, Reg. Bd., Subs	Develop study plan/work plan by RMP workgroup; new subcontract or increased effort by SFEI	substantial	•9 Data integration subtask added to Program Management task •10 Mass budget model development a major integration tool •11 Literature reviews performed under workgroup guidance •12 Non-RMP information integrated into *Pulse* •13 Ten Year Synthesis Special Study in progress a major data integration effort •14 Database development in support of integration
2b Assess sources; develop mass balance inventory	SFEI, Reg Bd	Develop work plan by RMP workgroup; subcontract or increased effort by SFEI	substantial	•15 Sources, Pathways, and Loadings Workgroup established •16 SPLWG has developed and implemented a long-term workplan •17 Field studies of loading from atmospheric deposition, small tributary loads, river loads •18 Contaminant Fate Workgroup established •19 Mass budget model developed for PCBs. Manuscript accepted for publication in ET&C. •20 Mass budget models in development for PAHs, and organochlorine pesticides

Table 2. Continued.

2c Define impacts on resources and beneficial uses	SFEI; Steering Comm, Reg Bd	Develop work plan by RMP workgroup; increased effort by SFEI, RB, and SC	substantial	•21 Exposure and Effects Workgroup and Pilot Study initiated •22 Advisory Panel for Workgroup established •23 Five year study plan developed with substantial Reg Bd input •24 Studies initiated on multiple indicators of exposure and effect
3g Use TSS measurements to define exceedances	SFEI; Subs	Develop study plan/work plan by RMP workgroup; new subcontract or increased effort by SFEI	substantial	•25 Not implemented •26 Long-term monitoring of suspended solids concentration (SSC) has yielded many insights •27 Field studies implemented based on contaminant:SSC relationships
3i Test seasonality of RMP data	SFEI; Subs	Develop study plan/work plan by RMP workgroup; increased effort by SFEI and subs	substantial	•28 Design Integration Workgroup examined seasonality and considered importance of this information; decision made to drop most seasonal sampling in order to provide better spatial characterization
3j Determine rates of particle burial	SFEI; Subs	Develop work plan by RMP workgroup; subcontract or increased effort by SFEI	substantial	•29 This issue was examined in the PCB mass budget. Recent USGS studies indicate net erosion in the Bay. Rather than reducing concentrations, this represents a form of contaminant input and slows recovery of the Bay.

Table 3. Recommendations and suggested implementation approaches from the 1997 Review and progress as of 2003, part 3: Recommendations expected to be implemented simply and directly.

Recommendation	**Responsible Party**	**Implementation Approach**	**Financial Impact**	**Progress and Comments**
2e Make RMP information more widely available	SFEI	WWW, publications, presentations	slight	•30Web site established - could be improved •31*Pulse of the Estuary* a major improvement •32RMP Newsletter distribution improved
3f Use more sophisticated data presentation	SFEI, Chapter authors	Evaluate presentation methods	slight	•33Progress embodied in *Pulse* •34Reevaluation needed with new Status and Trends design
4b Document fully the data management system	SFEI; Subs	Descriptive writing	slight	•35Comprehensive set of SOPs developed
4d Develop computer-assisted quality checks	SFEI	Software development	moderate	•36Partially done – room for improvement
4e Conduct recommended lab intercomparisons	SFEI; Subs	Expand intercomparison program	moderate	•37Current efforts include participation in SCCWRP intercomparison, PBDE exercise •38Room for improvement
4g Store data backups off site weekly	SFEI	Procure storage site	slight	•39Done
4h Provide for development of data management staff	SFEI	Courses; workshops	moderate	•40Done
4j Increase citation of contributions	SFEI	Descriptive writing	slight	•41Not implemented

Table 3. Continued.

4k Analyze citations of RMP data	SFEI	Accounting	slight	•42 Not implemented
4l Analyze web site usage statistics	SFEI	Software added to web site	slight	•43 Data are periodicially compiled but not distributed
4m Develop specific list of PCB congeners	SFEI	Evaluate data	slight	•44 Done
4n Describe laboratory analysis methods in more detail	SFEI; Subs	Descriptive writing	slight	•45 Done
4o Describe accuracy measurements in more detail	SFEI; Subs	Descriptive writing	slight	•46 Done
4p Automatically calculate derived values	SFEI	Software development	slight	•47 Done
4q Add citation information to RMP Annual Report	SFEI	None	slight	•48 Done
4r Word newsletter titles more judiciously	SFEI	None	none	•49 Done
5a Clarify Regional Board responsibilities	Regional Board	Policy statement	none	•50 Done (in "Final RMP Pilot/Special Study Selection Procedure")
5b Request from Executive Officer for 5-year plan	Regional Board	Official letter	none	•51 Five year plan is updated annually in the Annual Program Plan

Table 3. Continued.

6a Develop procedure for reviewing direct charges internal to SFEI	SFEI	Accounting	slight	•52Done
6b Define in-kind contributions from SFEI staff and contractors	SFEI	Evaluations; interviews, accounting	slight	•53Not done
6c Create technical/logistics manager	SFEI	Talent search	substantial	•54New RMP Associate Manager position fills this role
6d Schedule changes in contractors when possible at beginning of year	SFEI	Planning	slight	•55Done
6e Implement competitive bidding where possible	SFEI	Planning	slight	•56Done
6g Prepare Steering Committee agendas early	SFEI	Done	none	•57Done
7a Accept Five Year Review report and recommendations	Regional Board, Steering Committee	Done	none	•58Done