

Development of an Integrated Environmental Monitoring and Research Program

Introduction

On November 24, 1997, the Interagency Ecological Program (IEP) proposed to the CALFED Policy Group that the IEP and the San Francisco Estuary Institute (SFEI) develop a comprehensive monitoring^{1*} and research* program for CALFED. The Policy Group approved the proposal on December 19, 1997, and authorized \$25,000 for SFEI's participation. Also on December 19, the U.S. Geological Survey (USGS), a member agency of IEP, made a similar proposal to the Policy Group in response to a request by Bruce Babbitt, Secretary of the Interior². The Policy Group requested that IEP, SFEI, and USGS work together to produce a final proposal for developing a comprehensive monitoring and research program for CALFED.

The simultaneous proposals to develop a comprehensive monitoring and research program reflect a widely felt need to improve efficiency and coordination among the CALFED agencies. The CALFED Bay/Delta Planning Effort has proposed a wide range of actions to solve diverse problems in the Delta, many of which are interconnected. CALFED and its member agencies are involved in an unprecedented change in infrastructure and environmental rehabilitation. These efforts, although largely uncoordinated, have been underway for several years as a result of water rights decisions, biological opinions, and mitigation agreements. More recently, attention has intensified on efforts to improve and rehabilitate the system with passage of the 1992 Central Valley Improvement Act, the 1994 Delta Accord, Proposition 204, and subsequent federal appropriations. In total, these activities will allocate several hundred million dollars to rehabilitate and improve many aspects of the

¹ The IEMRP Steering Committee has found that many terms are used by different parties to mean different things. The Committee has attempted to use certain terms consistently throughout this report and in our discussions with other parties. Appendix A is a glossary of these terms. The first occurrence of a term included in the glossary is denoted with an *.

² In response to the request from Secretary Babbitt, the USGS produced a report entitled, *USGS CALFED Science Support Initiative*. Special Report (98-01). January 1998. U.S. Department of the Interior. U.S. Geological Survey. This report describes several recommended actions to strengthen the role of science in CALFED Bay-Delta rehabilitation efforts.

Bay/Delta system. Aside from Bay/Delta Planning efforts, member agencies of CALFED are also responsible for managing and protecting resources outside the Bay/Delta, but actions affecting those resources may be essential in addressing environmental problems within the delta. Solving the environmental problems of the delta in a way that is consistent with management and protection of resources throughout the watershed requires an integrated environmental monitoring and research program.

The Issues

The CALFED program is proposing numerous and substantial changes to many aspects of the Bay-Delta/Central Valley system. In addition, many of the member agencies are currently charged with activities and programs directly affecting this system (e.g., SWRCB regulation of water rights, DWR/BOR export of water from the Delta, FWS/NMFS/DFG protection of threatened and endangered species, etc.). Further, CALFED and its member agencies have adopted an adaptive management* strategy as a process for implementing many of the proposed changes and ongoing activities (e.g., actions in the Ecosystem Restoration Program Plan, or the Vernalis Adaptive Management Program).

In addition to implementation of the various actions and programs, CALFED and its member agencies are also responsible for the implementation of monitoring and applied research that provide the data and information necessary to evaluate the performance of completed actions and ongoing programs. A recent facilitated scientific review of the Ecosystem Restoration Program Plan by a panel of nationally recognized scientists emphasized the need for improved scientific support as CALFED begins to implement rehabilitation actions in 1998. The panel called for creation of an integrated monitoring and research program characterized by: (1) explicit, quantifiable rehabilitation goals; (2) use of models to link physical and biotic ecosystem processes; (3) an integrated and comprehensive monitoring program based on testable hypotheses; (4) improved emphasis upon environmental function; and (5) creation of a standing science organizational body to link science to long-term management.

CALFED is developing a long-term program, based on adaptive management principles, that has a maximum likelihood of achieving desired rehabilitation. The incremental approach of adaptive management (taking action, evaluating the benefits of the action, and modifying subsequent actions as necessary) requires extensive data collection and analysis with feedback to resource managers and decision-

makers. Equally important, CALFED will need to prepare for Congress, the California Legislature, government agencies, stakeholders, and the general public a "report card" describing its effectiveness in achieving the stated program goals. An integrated environmental monitoring and research program (IEMRP) is the most effective means of providing the information necessary for this reporting.

Many institutions, both within and outside of the CALFED partnership, are involved in monitoring and applied research that can contribute to the design and assessment of environmental rehabilitation programs (see Appendix B). The scope, coverage, and coordination of existing monitoring and applied research, however, are admittedly fragmentary. When viewed together, these programs do not provide a coherent, overall picture of what is being monitored, how the environment is changing over large spatial scales, or a clear sense of how the monitoring data might be used by resource managers and decision makers. The lack of coherent and complete coverage is especially important because the geography of this ecosystem is complex, as are the associated physical and ecological processes.

Purpose of this report

The initial planning for the development of an IEMRP has largely been the work of a steering committee (referred to as the IEMRP Steering Committee), consisting of representatives from the USGS, SFEI, USEPA, CALFED, and DWR. DWR also allocated one full time staff person to support this effort. The committee is developing IEMRP in two phases. The first phase, to be completed by March 20, 1998, defines the relevant issues, the initial scope of effort, and presents proposed tasks and associated funds recommended for the completion of Phase II. The goal of the Phase II effort, to be completed nine months after the Policy Group approves the Phase I study plan and allocates the necessary funding, is development of the initial IEMRP. This report summarizes the work and recommendations of the Phase I effort.

Scope and Goals of an Integrated Environmental Monitoring And Research Program

Overall Goals of the IEMRP

Monitoring Program. The goals of the proposed monitoring program are to:

1. Describe conditions in the Bay/Delta, and its watershed on appropriate temporal and spatial scales. Determination of appropriate scales requires precise statements of management goals.
2. Evaluate trends in the measures of environmental condition.
3. Identify the major factors that might explain the observed trends.
4. Provide information to management on the effectiveness of actions.

Research Program. The goals of the applied research program are to:

1. Test causal relationships among environmental variables identified in conceptual models*.
2. Reduce areas of scientific uncertainty regarding management actions.
3. Interpret results of project-effect monitoring as tests of presumed relationships
4. Incorporate relevant new information from academic research
5. Revise conceptual models as scientific understanding increases.

The scope of the IEMRP includes all of the CALFED Bay/Delta Program elements that address environmental conditions (i.e., ecosystem restoration, water quality, water supply reliability, levee stability, and some elements of water use efficiency), as well as the environmental monitoring needs of the CALFED member agencies.

Geographic Scope

The geographic scope of the IEMRP is dictated by attributes of the chemical, biological, and physical environment. For example,

monitoring Chinook salmon can necessitate some form of sampling from the headwaters, down the rivers, through the Bay/Delta and into the ocean. Conceptual models of the life histories of salmon (as for other species), will determine which of the almost limitless possibilities of chemical, biological, and physical attributes will be used to help set the geographic scope for monitoring the various attributes, and ultimately, the entire monitoring program.

Programmatic Scope

IEMRP intends to provide an umbrella structure to ensure that environmental monitoring needed by CALFED agencies is: (1) identified, (2) coordinated to provide comprehensive system-wide coverage, (3) performed by the most appropriate party, (4) completed in a comparable manner by all parties, (5) accomplished with minimum redundancy and maximum effectiveness, and that the results from the monitoring are (6) readily available to all interested parties and (7) incorporated as feedback to facilitate adaptive management.

The scope of the recommended program must include both institutional and environmental considerations. For example, CALFED agencies presently monitor the abundance of several key species and environmental attributes such as streamflow and fish salvage at the State and federal diversion facilities in the Delta. Thus, the recommended program must have a broad basis so that the information obtained will lead to a better understanding of factors controlling the abundance and distribution of these same key species.

Institutional Considerations. The Phase II planning effort will include consideration of the specific needs of CALFED agencies as well as all of the elements of the CALFED Bay/Delta Program. For the Bay/Delta Program this includes the goals and objectives of the ecosystem restoration, water quality, water supply reliability, and levee stability components, as well as some elements of water use efficiency. From an agency perspective, the comprehensive program may include such disparate activities as real-time monitoring of fish distribution, compliance monitoring, the Vernalis Adaptive Management Program, levee integrity evaluation, and a host of special monitoring and research related to each agency's mission.

A special institutional case is the need for monitoring associated with Category III projects funded through CALFED. A requirement for Category III funding is that project proposals contain monitoring elements to determine if stated objectives have been met and to provide guidance for assessing future rehabilitation needs. It will be necessary for the

recommended program to ensure that monitoring data from all these projects is technically sound, broadly usable, and provides meaningful information to guide future actions.

Environmental Considerations. The IEMRP Plan will be designed to take into consideration the broad variety of factors that can affect the environment, its physical structure, chemical makeup and biotic communities. The recommended program will necessarily be limited to monitoring only a small fraction of the possible chemical, biological, and physical attributes of the ecosystem. Conceptual modeling, as described more fully in a subsequent section, plays a key role in helping decide which attributes to monitor.

As an example, a simplified listing of some of the factors that influence the abundance and distribution of a generalized Chinook salmon run (Figure 1) illustrates the ecological, geographical, and temporal scope which must be considered in developing a useful salmonid monitoring and research program (similar listings could be made for other species of interest). This listing points out that:

1. broad geographic coverage is required - from the upper stream reaches to the ocean - in order to understand the run's life history, environmental requirements, and stressors;
2. broad temporal range is needed because the time between egg deposition and adult return can vary from 2 to 6 years; and each factor listed, in turn, has an additional list of factors influencing it. For example, air temperature, reservoir operation, amount of riparian habitat, and streamflow can all affect water temperature; food supply is influenced by streamflow, water temperature, riparian habitat (insect drop), contaminants, competition, and turbidity. The relative importance of each factor in the early life stages may be stream specific, i.e., their effects will be considerably different on the mainstem Sacramento River as compared to streams like Mill and Deer creeks; and
3. many factors that may affect salmon also must be part of monitoring programs for other environmental issues of CALFED agencies, including sediment transport, reservoir operations, water quality, water level, levee condition and bank erosion. Thus, an integrated monitoring program may allow better overall management at lower cost.

Approach to Preparing the Program

The approach recommended for Phase II, is completion of a several specific tasks (described further below), involving the following activities:

1. Work with CALFED partners to define and clarify the overall goals and specific objectives of the CALFED programs;
2. Develop a conceptual framework for understanding the factors controlling significant biological and environmental characteristics of the bay-delta and its watershed;
3. Design an integrated environmental monitoring program based on an inventory of existing programs that involves identification of gaps; selection of monitoring elements; development of a process for data management, interpretation, and reporting; and establishment of a process for monitoring approved Category III projects.
4. Identify primary research questions and develop a focused research program and review process.
5. Develop a recommended institutional structure necessary for effective implementation of the IEMRP.

Stakeholder and Agency Staff Involvement

Since much of the technical knowledge about the Bay/Delta and Central Valley system is in the minds, data files, and reports of many agency and stakeholder scientists and engineers, it is critical that they be involved in developing the IEMRP. The Phase I effort has been coordinated with several other groups dealing with related topics and similar needs. The CALFED Indicators Group is developing broad conceptual models and ecosystem indicators to guide implementation of the Ecosystem Restoration Program Plan (ERPP). The IEMRP will include the development of more specific conceptual models consistent with broader models developed by the Indicators Group and will ensure that the monitoring program includes the critical ecosystem indicators identified by the other group. The Steering Committee for development of a Strategic Plan to Implement the ERPP has identified a science-driven process to implement the ERPP that is expected to rely heavily upon adaptive management, and thus the environmental monitoring program will need to be able to encompass whatever data needs the adaptive management program identifies.

Completion of the IEMRP Phase II goal of developing detailed recommendations for the monitoring and research program will require

a broader and more coordinated base of knowledge than presently exists. Following approval of the Phase I report, the IEMRP Steering Committee, will be joined by others to develop the IEMRP through completion of specific tasks during Phase II.

Stakeholder parties sensitive to gaps in all the current monitoring programs are expected to play a large role in the development of the Phase II. This involvement will occur in several arenas, including:

1. seeking the Bay-Delta Advisory Council's assistance in forming a stakeholder advisory committee for the Phase II project;
2. actively interacting with CALFED's Indicators Group and Integration Panel;
3. giving presentations, as appropriate, to CALFED's Ecosystem Roundtable and Bay/Delta Advisory Council;
4. coordinating with a strategic planning team established to work with CALFED staff in revising the ERPP; and
5. working with representatives of major ongoing monitoring programs (such as those of the Regional Water Quality Control Boards, the Sacramento Watershed Program, DWR's Municipal Water Quality Investigations Unit, DWR and U.S. Bureau of Reclamation's Water Project Monitoring Units, the USGS, the VAMP technical team, watershed conservancies, and similar organizations and units) to ensure the IEMRP incorporates specific agency needs.

Need for Long-term Commitment

As Phase II concludes, the collective efforts of the previous nine months will have resulted in the development of the first iteration of an IEMRP. The inventory of existing monitoring programs combined with efforts to develop conceptual models of system properties, processes, and biological components, and identification of the key indicators, will guide the IEMRP Steering Committee in the development of this first version of the integrated environmental monitoring strategy. Identification of research requirements to support this initial monitoring strategy will also be an important by-product of this work. At the conclusion of Phase II, a report will form the baseline from which the IEMRP will evolve.

The first version of an IEMRP for CALFED is only a beginning. As data are collected, and particularly as they are analyzed from a

system-wide perspective, results will feed back to managers and scientists who can, as needed, initiate improvements in the IEMRP. More efficient and effective data collection protocols will evolve as we learn more from the results we have gathered. Any initial recommended monitoring and research program will itself be subject to adaptive management. A program as complex as this one will undoubtedly require modifications for improvement over time.

It will be important to sustain continuity in the team charged with developing the first iteration of this program. The experience accumulated by this team will be crucial in designing subsequent refinements of the research requirements and monitoring strategy. We expect that additional funding will be requested to support the effort anticipated in a subsequent Phase III that will address needed refinements of the IEMRP developed in Phase II. To this end we recommend preserving the continuity in the monitoring and research program management, to enhance the continued development of the highest quality program. At the conclusion of a three-year period the entire program should be reviewed by an independent scientific panel.

Recommended Phase II Program

This section summarizes the structure and tasks recommended to develop an integrated environmental monitoring and research program for the Bay/Delta and its watershed/. The core program includes five tasks to be completed over nine months at a cost of approximately \$1.9 million. The details of each task are described below.

Phase II will be managed by a Steering Committee similar to that in Phase I. The Steering Committee will establish direct links with stakeholders through the Bay-Delta Advisory Council, and stakeholders will be invited to Steering Committee meetings and be included on electronic mailing lists. With the exception of a representative from SFEI, Steering Committee members' salaries and expenses will be covered by their agencies.

A three-person staff will be assigned to assist the Steering Committee in conducting its activities. Individual agencies will appoint a staff member who can dedicate full time effort to this work over the next nine months. The estimated cost for this three-person staff is \$270,000.

Task 1-Define Expectations, Goals, and Objectives

The fundamental mission of the CALFED Bay-Delta Program is to "... develop a long-term comprehensive plan that will restore ecological health and improve water management for beneficial uses of the Bay-Delta system." The specific objectives of this program, still under development, currently include the following four primary considerations:

1. to provide good water quality for all beneficial uses;
2. to improve and increase aquatic and terrestrial habitats and improve environmental functions in the Bay-Delta to support sustainable populations of diverse and valuable plant and animal species;
3. to reduce the mismatch between Bay-Delta water supplies and current and projected beneficial uses dependent on the Bay-Delta system;
4. to reduce the risk to land use and associated economic activities, water supply, infrastructure, and the ecosystem from catastrophic breaching of Delta levees.

Activities during Phase II will begin with review of the established CALFED goals and objectives and work with agency staff and stakeholders to further refine these goals and objectives so they can direct the development of an IEMRP.

The ultimate goal of any monitoring program is to produce information that is useful in making management decisions ... enabled by two-way communication between scientists responsible for designing monitoring programs and the users of the monitoring information³. Bridging this gap is a crucial task that will be addressed during Phase II. The IEMRP Steering Committee will work with the agencies/stakeholders and the relevant scientific community to further define expectations and goals of the efforts to collect monitoring information, which will feed back to the development of the monitoring strategy. These interactions will give decision-makers and managers an understanding of the limitations of the monitoring program and simultaneously provide the technical experts who are designing the monitoring program with an understanding of what particular questions need answers.

The process for identifying the specific questions to be addressed by an IEMRP would be achieved through the following activities:

1. review information already collected during previous CALFED problem identification workshops;
2. consult with agency staff and stakeholders to specify the problems already identified and to define expectations and goals for information necessary to determine the state of each problem, in priority order;
3. identify expectations and goals of various restoration efforts (e.g., ERPP) and other core program changes;
4. identify relevant laws, regulations, and permit requirements that require monitoring;
5. form a focused review group composed of stakeholders, managers, and technical experts for facilitated discussions aimed at synthesizing information in items 1-4 to develop clear goals and objectives for the IEMRP.

³ National Research Council. 1990. *Managing Troubled Waters - The Role of Marine Environmental Monitoring*. National Academy Press.

This process, as with all components of the IEMRP, will be iterative. Initially it is expected that specification of goals and objectives will be addressed over the first three months of Phase II. The results of this initial specification will drive the development of the preliminary IEMRP with completion anticipated at the conclusion of Phase II.

Timeline: Three months
Funds: \$ 50,000
Lead: IEMRP Steering Committee

Task 2 - Developing a Conceptual Framework

Conceptual models are needed to incorporate current thinking by Bay-Delta scientists about how the ecosystem is structured and how it functions, about the effects of environmental stressors on relevant ecosystem processes, and about the influences of specific rehabilitation actions. The importance of conceptual models in ecosystem monitoring and assessment has been aptly described in a report issued by the National Research Council, *Managing Troubled Waters - The Role of Marine Environmental Monitoring* (National Academy Press 1990):

A description (i.e., a conceptual model) of the cause-effect links between human activity and anticipated environmental change is the central feature in developing specific questions to be answered [in a monitoring program]. It is the conceptual model that is the means of predicting environmental change and the results of management action -predictions that efficiently direct and focus monitoring efforts.

Conceptual models describe links among the resources at risk: the physical, chemical, and biological attributes of the ecosystem; and human and natural causes of change. The understanding that results permits testable questions to be clearly stated and ultimately evaluated. By providing a context for organizing existing scientific understanding, a conceptual model also identifies important sources of uncertainty.

Although many of the questions arising from a review of existing programs and CALFED documents were developed from implicit conceptual models of how the system works, many of these models need to be made explicit. Explicit conceptual models are not only useful in

designing a future monitoring program, but are also useful to document the basis for earlier decisions. Providing an objective basis through explicit conceptual models for both the design of a monitoring program and documentation of earlier decisions is a feature essential to development of an IEMRP using an iterative approach.

The CALFED Indicators Group has undertaken construction of broad ecosystem models, based on the interconnections among the issues of water quality, hydrology, sediment supply, nutrients, and migrating species as they bear on habitats, ecosystem processes and interactions, and stressors.

The IEMRP Steering Committee will work with the CALFED Indicators Group and use local expertise to refine the broad models into appropriately detailed conceptual models to address the following objectives:

1. identify the highest priority issues to be addressed in the monitoring program (from system-wide and restoration-project-specific);
2. clarify both the goals and expectations of a monitoring program;
3. develop specific, testable questions for further research;
4. identify presumed cause-effect relationships;
5. develop predictions i.e., how a particular environmental perturbation is expected to affect a monitored parameter and/or how a specific management action might affect an important resource; and
6. help identify gaps in knowledge where further research is needed.

During Phase II the IEMRP Steering Committee, in collaboration with the CALFED Indicators Group, would accomplish the following:

1. Facilitate a review of existing conceptual models drafted by the Indicators Group, with the objective of developing a consensus about the key processes, linkages, and the information gaps and spatial coverage affecting the development of a comprehensive monitoring program.

Timeline: Two months

Funds: \$ 2,000 (Travel and meeting expenses)

Lead: IEMRP Steering Committee

2. Organize a workshop in May or June 1998 to hear presentations from one or more experts about how monitoring, assessment, and research programs have been successfully developed elsewhere; to summarize the status of Bay/Delta, and watershed conceptual modeling, including the work of the CALFED Indicators Group; to begin listing and prioritizing the major issues to be addressed in both system-wide and restoration-project-specific monitoring programs; and to develop recommendations about the next steps that should be taken in developing conceptual models that will facilitate achieving the above objectives. A written summary of the workshop proceedings and recommendations will be prepared and distributed to CALFED participants.

Timeline: Two months

Funds: \$ 8,000

Lead: DWR and USGS

3. Organize several working panels of scientists to summarize our current scientific understanding of specific aspects of ecosystem structure and function (e.g., regarding individual species, habitat types, or geographic regions), and to develop the conceptual model framework necessary to design effective monitoring programs and to identify data and information gaps that need to be the focus of additional research efforts. The workshops will include both local and national scientists with experience in other systems, and stakeholder technical specialists. Each of these workshops would culminate in the preparation of a "white paper" discussing the state of knowledge in the workshop subject area, posing testable hypotheses and unanswered questions, and recommending appropriate strategies for both monitoring and research programs.

Timeline: Six months

Funds: \$300,000

Lead: USGS

4. Produce an overall report describing the conceptual framework of the Bay/Delta ecosystem upon which the CALFED monitoring, assessment, and performance measurement programs will be based. This report will include conceptual models, text to summarize the known structure and function of the ecosystem, description of scientific questions and hypotheses upon which monitoring and focused research will be based; and specific recommendations applicable to monitoring design, such as identification of key parameters and functional linkages.

Timeline: Three months

Funds: \$30,000

Lead: IEMRP Steering Committee

Task 3-Monitoring Program Design

This section addresses two subjects. The first is initial development of a long-term IEMRP, which is the major focus of Phase II. The second is the development of an institutional process designed to work in the short-term (1-3 years) specifically addressing Category III project monitoring.

Successful design of a long-term integrated environmental monitoring program depends upon the identification of focused questions, which are based on clear goals and objectives. Preliminary work, including definition of goals and objectives, conceptual model review, knowledge of existing programs and pilot monitoring are often necessary to refine questions and technical aspects of monitoring designs. Some of this work (e.g. defining goals and objectives, conceptual model development) is described above in Tasks 1 and 2. The remaining work necessary is described here.

A. Inventory Existing Monitoring Programs

The goal of this task is to identify and assess existing monitoring programs in the Bay/Delta and its watershed. Monitoring needs determined through Tasks 1 and 2 can then be matched with efforts in existing monitoring programs to identify redundancies, as well as gaps in need of augmentation.

This task will build on efforts conducted by CAMP, SFEI, and DWR's Municipal Water Quality Investigations program. The product will be a metadata information system providing program-specific information on program objectives, questions addressed through

monitoring, spatial coverage, attributes monitored, location of sampling sites, frequency of monitoring, primary contact, reporting scheme, and funding. The system will be designed for continuous use for ongoing coordination, information on program status, and program gap analysis.

Process: SFEI will take the lead in development of the monitoring metadata system. Stakeholders, CALFED and CALFED agency staff will review a prototype design of the product and provide input as necessary until development is completed.

Timeline: Six months

Funds: \$200,000

Lead: SFEI

B. Develop Monitoring Elements

The goal of this task is to narrow the focus of monitoring from the vast number of questions and parameters that could be examined to those that will produce the specific information needs. This task will run in conjunction with Tasks 1 and 2, addressing currently known needs of CALFED and CALFED agencies. Additional information derived from Task 2 and the previous tasks (inventorying existing monitoring programs) will be used to subsequently modify monitoring elements to ensure their effectiveness.

Based on information described in Tasks 1 and 2 an integrated environmental monitoring program that focuses on CALFED's needs (ecosystem restoration, water quality, levee stability, water storage and conveyance and water use efficiency) and CALFED agency needs will be developed. The strategy will be to identify current needs, identify existing programs, identify monitoring gaps and recommend modifications of programs to fill those monitoring gaps. Quality control and assurance programs will be reviewed to ensure consistent data collection and storage protocols. Individual databases will be linked together to facilitate comprehensive data assessment. The product will result in a document identifying monitoring objectives, focused questions, specific monitoring elements to address the questions, and will include a recommended integrated environmental monitoring program.

Process: Technical work teams comprised of program managers of existing programs will meet with the IEMRP Steering Committee to determine how best to coordinate their programs and add missing components, as needed. Such a strategy has already been proposed for

water quality monitoring (Inquiry Proposal for CALFED Category III funding) , by which IEP's water quality monitoring program, SFEI's Regional Monitoring Program, the Sacramento Watershed Program, DWR's Municipal Water Quality Program, the USGS' estuarine and river-basin monitoring program and the Central Valley and San Francisco Regional Boards water quality programs would be coordinated and augmented to meet CALFED's needs. The technical work teams would be responsible to the IEMRP Steering Committee and all work would be reviewed periodically by a focused group of stakeholders, CALFED staff and agency staff. The IEMRP Steering Committee will be responsible for organizing and collating all work into a useable product that will constitute recommendations for an integrated environmental monitoring program.

Timeline: Nine months

Funds: \$225,000

Lead: IEMRP Steering Committee and CALFED Agency
Program Managers

C. Develop a process for data management

Data management is an effort important to all aspects of the IEMRP data collection and dispersal processes. Data/information will need to be made accessible to agency staff and stakeholders and CALFED Bay/Delta staff in time to meet program time-lines, and provides information for adaptive management plans. Data will also need to be updated regularly to meet the different program reporting time-lines in a way that allows information from one program to be related to another.

The purpose of an integrated database system is to allow for comprehensive, integrated data management that will permit broad access to biological, water quality, hydrodynamic, and physical data from the Bay/Delta and its watershed. The intent of the IEMRP database project is not to duplicate or replace the efforts of any entity involved, but to provide a comprehensive, integrated source of data for scientists and decision-makers. This will yield a "level playing field" for all parties by providing data for all types of analyses, reports, studies, and models concerning the Bay-Delta and tributary regions. Important features of such a database include:

1. The data can be spatially referenced through a Geographic Information System.

2. The data include available, accessible data from public agencies, municipalities, and larger private companies and consultants.
3. Simple queries may be conducted "on-the-fly" by scientists through menu-driven or graphical user interfaces, while more complex queries can be generated by each entity's database programmers.

The IEMRP will ultimately include numerous data providers whose data management capability will vary substantially. A major cost of managing data from different groups will be developing a mechanism for obtaining or providing access to this data, in a standardized format, with adequate QA/QC and in time to meet program objectives. To manage this very large and diverse volume of information, a data management "infrastructure" will need to be developed. This infrastructure will provide the ability for the data providers to manage their data locally, integrate data with other data collected in the system, and provide comprehensive access to all needed data.

Process: A committee of technical experts, managers and stakeholders will meet to review current data management systems, develop the components necessary to provide the best system for managing IEMRP data, and develop a prototype upon which to base a complete system. Specific tasks include:

- develop a list of data providers and their current information technology capability;
- determine the cost associated with obtaining and providing access to these data sources;
- determine how comprehensive data access existing data systems should occur;
- develop a mechanism and cost estimate for obtaining data from data providers;
- determine the cost of computer applications that are necessary to turn data into information; and
- evaluate GIS needs.

At the end of Phase II we will demonstrate an expandable system capable of managing data from a remote data provider where data management is conducted locally by the provider, with comprehensive data access.

Timeline: Nine months

Funds: \$100,000

Lead: IEMRP Steering Committee and CALFED Agency
Program Managers.

D. Develop a Process for Data Interpretation and Reporting

Easily understood reports released in a timely manner provide the all-important feedback about monitoring results to managers, regulators, and stakeholders. Appropriate interpretation and display must accompany monitoring data. Annual monitoring reports are envisioned, which include both data analyses and interpretive graphs and text.

Process: A committee of managers responsible for monitoring programs, stakeholders and regulatory representatives will meet to design an interpretation and reporting plan that provides for timely and objective interpretation of all monitoring data.

Timeline: Within the ninth month period identified in Task 3B

Funds: \$100,000

Lead: IEMRP Steering Committee and CALFED Agency
Program Managers.

E. Category III Monitoring Institutional Process

A short-term institutional process is needed now to coordinate monitoring of Category III projects approved over the last two years, and for projects that will be approved this year (1998). To make Category III monitoring more effective, CALFED is awarding a grant to develop guidelines and protocols to ensure that:

- monitoring plans associated with Category III projects are sufficient to identify whether or not project goals and objectives are being met; and
- a process is established for the orderly flow of data collection to information from all Category III project monitoring to provide resource managers with information on individual project effectiveness and cumulative project impacts (both positive and negative).

Process: The Category III monitoring project began in Phase I with funding from a Category III grant to establish a dedicated chair/coordinator position. The chair is assembling a workgroup to review existing and proposed monitoring elements of Category III projects and develop recommendations for standardized monitoring protocols. The workgroup will also prepare recommendations for data management and information dissemination. Additional funding will be needed in Phase II to support the efforts of the workgroup for a one-year period to implement this important activity.

Timeline: Three months for process development

Funds: \$200,000 (not including the \$100,000 previously granted by CALFED).

Lead: IEMRP Steering Committee and CALFED Category III Staff

Task 4 - Design a CALFED Focused Research Program

This task includes design of a focused research program and resumption of a research enhancement program. As previously stated, the goals of the focused research program are to reduce areas of scientific uncertainty affecting the achievement of management goals, to identify cause and effect relationships, and to corroborate relationships in conceptual models. The goal of the research enhancement program is to enhance the involvement of the academic community in expanding our understanding of this complex system

Focused research program. CALFED needs a focused research program to support implementation of the common programs, particularly for adaptive management of implementation uncertainties. As suggested by the example uncertainties in Appendix C, the common programs face a number of unresolved questions that impede large-scale actions. Although this list is not intended to be comprehensive, it illustrates the breadth of uncertainties, many of which are not being addressed by current study programs. If uncertainties are left unresolved, some CALFED actions could lead to irreversible environmental consequences.

The IEMRP Steering Committee would design a focused research program to meet CALFED's needs for adaptive management of program implementation. The approach would be to develop and maintain a list of study questions, to objectively select a group of focused research projects, and annually to evaluate and present new

study findings to CALFED. The design would be subjected to scientific and stakeholder review and summarized in a report during Phase II. Information for designing the initial list of study questions would come primarily from:

- an assessment of study needs of CALFED's common programs;
- the conceptual models designed in Task 2;
- the body of scientific literature on the estuary and Central Valley (such as the technical report series of IEP, the Status and Trends reports of the San Francisco Estuary Project, the USGS bibliography of publications for the bay and delta, the State of the Estuary conference proceedings, and the RMP annual reports); and
- the collective knowledge of scientists working in the estuary and Central Valley.

The list of study questions would be generated and prioritized by assessing the most serious impediments to implementing CALFED program elements. Much work would be necessary during and subsequent to Phase II to focus and refine the management questions as well as to develop appropriate study questions that would permit timely answers to outstanding management questions.

The list of questions would become the basis for soliciting proposals from the scientific community. An anonymous review process of the proposals would be designed to rank the proposals, and a list of the highest-ranking proposals within budget limitations would be provided to the CALFED integration panel. The integration panel would continue to construct a recommended list for funding.

The annual evaluation and presentation of new study findings would be constructed and published from:

- an annual presentation of progress by principal investigators of funded proposals at a CALFED science conference each September;
- presentations at the IEP annual conference in February; and
- new literature published during the year.

Research enhancement program. This program was begun by EPA's San Francisco Estuary Project and IEP about 10 years ago. The program funded about 20 graduate students to work on problems judged relevant to the management problems of the bay-delta estuary. Although this program was less directed at management questions than the focused research program will be, it generated many worthwhile findings before it was discontinued for lack of funding. Given availability of CALFED funds, the IEMRP group would perform necessary staff work to resume this program with an appropriately expanded geographical extent and problem scope.

Phase II activities. The IEMRP group would undertake the following tasks during the 9 months of Phase II:

1. A preliminary assessment of CALFED needs would be performed for each of the common programs. Program documents would be reviewed and program managers would be queried about the actions proposed and management questions associated with their programs. Based on these queries and on the existing literature, a preliminary list of management and study questions would be created. Agency scientists and stakeholder technical specialists would be asked to review the preliminary lists, and then the lists would be finalized.

Timeline: Six months

Budget: \$250,000

Lead: IEMRP Steering Committee

2. One or more request for proposals (RFPs) would be designed to solicit proposals for addressing the identified study questions and would be presented for approval to the Ecosystem Roundtable, BDAC, and the CALFED Management and Policy Teams. Similarly, the brochure for the research enhancement program would be revised to address CALFED's geographic extent and problem scope.

Timeline: Three months

Budget: \$25,000

Lead: IEMRP Steering Committee

3. An anonymous peer review process, similar to that used by NSF, would be designed to judge the technical merit and relevancy of

the proposals, and to provide these results to the CALFED integration panel. A process for identifying reviewers would be designed in consultation with appropriate academic institutions. A process for paying reviewers would be devised.

Timeline: Three months

Budget: \$25,000

Lead: IEMRP Steering Committee

4. An agenda for a first CALFED science conference would be devised, session chairs would be selected, and a preliminary program of invited presentations would be developed. The focus of the initial conference would be the state of scientific knowledge in the areas pertinent to CALFED's proposed actions, and presentations of early results of research projects funded with Category III funding. This draft program would be submitted to BDAC and the CALFED Policy Team for review, approval, and funding. If approved, the conference would be held in 1999, and would be timed to coincide with release of the first RFPs.

Timeline: Three months

Budget: \$25,000

Lead: IEMRP Steering Committee

5. Results of these four tasks would be summarized in a report or in a section of the IEMRP Phase II report.

Timeline: Three months

Budget: \$25,000

Lead: IEMRP Steering Committee

Task 5-Develop an Institutional Structure for the IEMRP

An extraordinary amount of coordination, collaboration and integration will be required for effective implementation of a system-wide IEMRP that meets the needs of CALFED and other resource management mandates of the CALFED agencies. The institutional structure that is built to address monitoring and research for CALFED should be constructed in such a manner as to best facilitate this coordination, collaboration and integration.

Much of the monitoring required to fulfill the adaptive management needs of CALFED is ongoing. In other cases, adjustments or expansions to existing programs will be needed, and in some cases, new programs will need to be established. Because of the immense size of the system and the large number of monitoring programs already in existence, numerous agencies at the federal, state, regional, and local levels, academic institutions, and non-governmental organizations will all need to be involved.

In reality, it is currently impossible for any one organization to implement an IEMRP over such a large amount of geography and sociology as the entire Bay/Delta watershed ecosystem and its water management infrastructure. What is envisioned instead, is an 'umbrella' structure that would draw substantially on the structure of existing monitoring programs of numerous agencies and organizations, and assist those agencies and organizations in filling the gaps identified in the current system. The goal of this umbrella structure would be to ensure that an integrated program emerged from a myriad of inter-organizational coordination and collaboration efforts, that information for decision-making was reported from these programs in a timely manner, and that this information was clearly communicated to decision-makers and the public.

During Phase II, the IEMRP Steering Committee will develop recommendations for creating an institutional structure to implement the IEMRP over the long term. Because the actual program configuration will continue to evolve over the next several years, an emphasis will be placed on flexibility, insuring that new players can become fully involved as needed, and additional monitoring and research questions can be addressed as they are identified. The committee recommendations will be developed after examining the strengths and weakness of current cooperative working relationships, considering the information needs of the CALFED participating agencies, consulting with organizations that will be involved as partners in the IEMRP, and consulting with stakeholders.

Timeline: Six months

Budget: \$50,000

Lead: IEMRP Steering Committee

Figure 1. Listing of Some Factors Influencing Distribution and Abundance of Generalized Central Valley Chinook Salmon Stock

Life Stage	Factors		
Spawning/egg deposit	Barriers and effects of delays		Water temperature
	Flow (stability and rate)		Predation on adults and eggs
Incubation	Gravel permeability		Flow
	Water temperature		Dissolved oxygen
	Sediment/turbidity		Contaminants
	Egg quality		Disease
Early Rearing	Water temperature		
	Food supply (amount and quality)		
	Diversions		
	Availability of escape habitat		
	Competition and compensatory mechanism		
Active Migration to Ocean	Fishing	Predation	Contaminants
	Diversions	Competition	Disease
	Water temperature	Barriers	Streamflow
	Delta hydraulics		
Ocean Rearing	Food	Water temperature	El Nino/La Nina
	Harvest	Predation	Disease/parasites
Return to Freshwater	Food reserves	Harvest	Barriers
	Availability of migratory areas		Streamflow

Appendix A

Glossary of Specific Terms Used in this Report

Adaptive management: Adaptive management consists of undertaking an action (or set of actions), evaluating effectiveness of achieving the goal, modifying the action if it is not achieving its intended results and to plan to use the information from early efforts to guide later efforts. Adaptive management presupposes goals, competing theories about the most effective way to achieve the goals, and a monitoring or research program that identifies changes to the environment and the response of the intended target.

Conceptual models: Explicit statements of the hypothesized functional relationships underlying management decisions regarding environmental resources. Conceptual models are essential tools for effective monitoring, research, and management because they highlight the significant environmental parameters, important data gaps, and the expected linkages among actions and effects. Conceptual models vary greatly in their level of specificity and complexity.

Monitoring: Development of data sets that report the distribution, condition, abundance or other aspects descriptive of status and trends of environmental features of interest. Monitoring includes, for example, standardized biological surveys, water chemistry, measurements of river flows, and assessment of levees for compliance with federal standards.

Research: Data collection, analysis, and interpretation intended to test hypotheses about functional relationships among environmental parameters. Research includes studies of the relations among uncontrolled variables as well as experimental manipulations of environmental variables.

Appendix B

Initial Summary of Existing Monitoring and Applied Research Programs

Information about several existing monitoring and applied research programs was gathered through literature searches and direct contact with the organizations or program leaders. The summary information is displayed in a metadata format that may be used in Phase II, Task 3. A table at the end of the summary shows overall budget information for the programs

This summary shows that over \$22 million a year is currently spent on monitoring and applied research in the Bay/Delta and Central Valley. Although the list includes some of the largest programs, many other programs exist in the area. For example, USBR (in conjunction with other federal, state and local agencies) conducts the Grassland Bypass Project adjacent to the San Joaquin River, south of Oristamba Creek. This program monitors flow, water quality, sediment, and biological factors. Local colleges and universities conduct research on a variety of topics in the Bay/Delta, however, information regarding these studies was not pursued for this summary.

It is important to note that IEP and CAMP are listed as individual monitoring programs. However, both are representative of numerous projects within the Bay/Delta and Central Valley. Summary information about the individual programs under CAMP was published in March 1997, in the U.S. Fish and Wildlife Service's CAMP implementation plan. This document lists metadata summaries of the existing adult and juvenile monitoring programs in the Central Valley, in a format suitable for use in a Geographic Information System (GIS).

Two additional sources for information on existing monitoring programs are DWR's Compendium of Water Quality Investigations and SFEI's coastal water quality monitoring program inventory. The compendium covers the Sacramento River watershed from the Bay/Delta region to the Oregon border and will be published in April 1998. Each sampling site is mapped and has corresponding metadata summaries gathered from surveys of federal, state and local agencies. This project is a good source of information, particularly about the smaller, local water quality monitoring programs. Funds have been designated to expand this program to the San Joaquin River watershed. SFEI's coastal inventory work will include metadata summaries on permit water quality programs and should be finished by mid-summer 1998.

Agency: Interagency Ecological Program (IEP)

Program Contact: Chuck Armor
Address: Department of Fish and Game, Bay Delta Division
4001 North Wilson Way
Stockton, CA 95205

Phone: (209) 948-7800
(209) 946-6355 fax
carmor@delta.dfg.ca.gov

Program Objectives:

- To provide for the collection and analysis of data needed to understand fa Sacramento-San Joaquin estuary controlling the distribution and abundanc wildlife resources and make the data readily available to other agencies and
- To comply with permit terms requiring ecological monitoring in the estuar
- To identify impacts of human activities on the fish and wildlife resources.
- To interpret information produced by the program and from other source possible, recommend measures to avoid and/or offset adverse impacts of operation and other human activities on these resources. To seek consens recommendations, but to report differing recommendations when consens
- To provide an organizational structure and program resources to assist in and integration of estuarine studies by other units of cooperating agencies

Start Date: IEP formed in 1972. Inception date of individual programs v

Attributes Measured:

1. Hydrodynamics
2. Water quality
3. Lower trophic organisms (e.g. zooplankton, phytoplankton)
4. Fish & macroinvertebrates

General Area: Between and including San Pablo Bay and the Delta

Number of Sampling Sites: Numerous

Frequency: Hydrodynamics: continuous
Water quality: both continuous and discrete monthly meas
Lower trophic organisms: both continuous chlorophyll sampl
zooplankton sampling.
Fish and macroinvertebrates: varies between bimonthly samp
collection.

Budget: Monitoring: \$4.9 million
Special Studies: \$6.3 million
Program Management: \$1.5 million

Agency: Sacramento River Watershed Program

Program Contact: Tom Grovhoug
Larry Walker Associates

Address: 509 Fourth Street
Davis, CA 95616

Phone: (916) 753-6400
(916) 753-7030 fax
lwa@davis.com

Program Objectives:

- To ensure that current and potential uses of the watershed's resources are and, where possible, enhanced while promoting the long-term social and e region.
- In coordination with other subcommittees and the larger stakeholder grou efficient and well-coordinated long term monitoring program within the the causes, effects and extent of constituents of concern that affect the ben and to measure progress as control strategies are implemented.
- To assess conditions in the main stem of the Sacramento River through th information, with an emphasis on examining the degree to which beneficia potentially impaired.

Start Date: Spring 1998 (some elements began in 1997)

Attributes Measured:

- Mercury, PCB's and chlorinated pesticides in fish tissue
- Trace metals in water (arsenic, cadmium, copper, chromium, lead, mercury sliver and zinc)
- Aquatic life toxicity in water and sediment
- Pathogens in water (*Cryptosporidium*, *Giardia*, coliforms)
- Organic carbon in water
- General constituents (minerals, nutrients, solids, turbidity, hardness) in wat
- Benthic invertebrates
- Algae (attached and planktonic)

General Area: Sacramento River watershed from above Shasta dam to near including several major tributaries.

Number of Sampling Sites: 63 total sites; number varies according to attr

Frequency: Basic chemical characteristics: varies between monthly and se
Pathogens: varies between monthly and quarterly
Chronic aquatic toxicity in water: varies between monthly and
Sediment toxicity: twice annually
Fish tissue analysis: once annually

Budget: Monitoring: \$500,000 for the first year.
Other: \$500,000

Agency: Department of Water Resources
Municipal Water Quality Investigations Program

Program Contact: Rich Breuer
Address: 1020 9th Street, 3rd Floor
Sacramento, CA 95814
Phone: (916) 327-1726
(916) 227-1648 Fax
rich@water.ca.gov

Program Objectives:

1. To determine and evaluate the source of contaminants that affect the of the Sacramento - San Joaquin Delta
2. Alert water agencies about current and potential contaminants in Delt
3. Assist water supply agencies in planning, protecting, and improving dr and water supply facilities
4. Document water quality under a variety of hydrologic conditions for s alternatives, water quality standards and predictive modeling capabiliti

Start Date: 1983

Attributes Measured:

Varies by site; includes: Standard mineral, turbidity, UVA, TOC, DOC, Bro THMFP, reactivity-based THMFP and HAAFP, Ammonia, MTBE.

General Area: Delta

Number of Sampling Sites: 13 (varies yearly)

Frequency: Varies between weekly and monthly measurements

Budget: Monitoring: \$350,000
Applied Research: \$1,175,000
Other: \$325,000 (Program Management)

Agency: Comprehensive Assessment and Monitoring Program (CAMP)

Program Contact: Larry Puckett
Address: U.S. Fish and Wildlife Service
3310 El Camino Avenue
Sacramento, CA 95821
Phone: (916) 979-2760
(916) 979-2770 fax
larry_puckett@fws.gov

Program Objectives:

1. To assess the **overall** (cumulative) effectiveness of actions implemented p Section 3406(b) in meeting AFRP production targets and
2. To assess the **relative** effectiveness of categories of Section 3406(b) actio management modifications, structural modifications, habitat restoration, a toward meeting AFRP production targets.

Start Date: CAMP was developed in 1997. Inception date of individual prog began in 1952).

Attributes Measured:

Varies according to program. Juvenile and adult surveys of Chinook salmon, s bass, white sturgeon, green sturgeon and American shad. Monitoring includes: spatial and temporal spawning distribution, length frequency, sex ratio, fish ma clarity and water temperature. Ladder counts, snorkel surveys and carcass surv

General Area: Central valley watersheds

Number of Sampling Sites: Numerous

Frequency: Varies according to program from daily (continuous) to annua

Budget: \$2.5 million
The \$2.5 million budget shown for CAMP reflects the amoun monitoring, either for new monitoring programs or to subsidi
The total budget, which now stands at about \$5 million, inclu agencies pay and can fluctuate greatly from year to year with t short-term monitoring projects.

Funding summary for several existing monitoring and applied research programs

Organization	Monitoring	Applied Research	Other*	Total
San Francisco Estuary Institute (SFEI)	\$2.5 Million	\$1.5 Million	\$388,000	\$4.4 Million
Interagency Ecological Program (IEP)	\$4.9 Million	\$6.3 Million	\$1.5 Million	\$12.7 Million
Comprehensive Assessment and Monitoring Program (CAMP)	\$2.4 Million	\$0	\$132,000	\$2.5 Million
Sacramento River Watershed Program (SRWP)	\$0.5 Million	\$0	\$0.5 Million	\$1 Million
Municipal Water Quality Investigations Program (MWQIP)	\$0.4 Million	\$1.2 Million	\$0.3 Million	\$1.9 Million
Total	\$10.7 Million	\$9 Million	\$2.8 Million	\$22.5 Million

*Note: "Other" includes administrative costs, quality assurance/control, coordination of monitoring, and stakeholder activities.

Appendix C

Examples of CALFED management uncertainties.

1. **Wetland restoration.** Significant amounts of the land in the delta have subsided by more than 10 feet below sea level, with some islands as much 25 feet below sea level. Restoring these subsided peat islands poses a particular challenge to wetland restoration efforts in the delta.
 - Restoring land-surface elevation of subsided lands is a necessary step for developing tidal aquatic habitat. Options for accreting land surface (e.g. application of dredge material, biomass accretion, suspended sediment deposition) all have serious limitations to overcome to accomplish this task in a reasonable period of time.
 - Delta channel waters currently form high levels of disinfection by-product (DBP) carcinogens from DOC when treated for use as drinking water. Peat soils in the delta are currently thought to be the largest source of DOC in delta channel waters. All CALFED alternatives include a substantial continuing contribution of delta channel water to the California drinking-water supply. Wetland restoration on peat soils may increase the DOC released to the delta channel waters and thus the DBP carcinogens in drinking water.
2. **Introduced species.** The role of introduced species as contributors to the ecological problems in the estuary is not well understood. In particular, the degree to which habitat restoration will encourage exploitation by exotic species that might prey on or compete with species of concern is not known. Thus, pilot restoration projects are needed to carefully monitor species-habitat relationships before large-scale restoration is undertaken.
3. **Contaminant effects.** The role of contaminants as contributors to the environmental problems of the delta and bay is not well understood. If a monitoring program is to assess the effects of habitat restoration on population changes, the deleterious effects of contaminants at least need to be ruled out:
 - More than 200 pesticides (10% of total U. S. usage) are used in the Central Valley. During winter runoff events insecticide

concentrations in the Sacramento and San Joaquin Rivers, the Delta, and Suisun Bay have been shown to be acutely toxic to test organisms. Effects of pesticides on resident organisms need to be assessed.

- Limited data suggest that methyl mercury is already contaminating several species in the Bay-Delta (sturgeon, striped bass, sharks). Many of the areas being considered for wetland restoration contain hydraulic mining debris deposited during the late 1800s. Methylation of the mercury contained in these sediments may significantly increase the contamination problem.
 - A high probability exists that selenium is affecting diving ducks and sturgeon, and perhaps other bottom-feeders such as dungeness crab. Changes in water conveyance could increase the amount of San Joaquin River water and selenium that enters the estuary. Documenting current conditions is a necessary step in evaluating the effects of CALFED actions.
4. **Delta hydrodynamics.** A hydrodynamic model that is validated with continuous flow data is needed to evaluate the effects of CALFED actions on flow and water quality in the delta. A primary missing component for such a model to be successfully applied is adequate channel bathymetry data in portions of the delta.
 5. **Levee stability.** More than 1000 miles of levees in the delta are made of poor quality materials, and surround more than 500,000 acres of farmland that continue to subside at a rate of 2 to 4 inches per year. Early estimates of the potential costs of delta levee rehabilitation exceed \$2 billion. Given that phasing of repairs will be necessary, additional characterizations of levee stability are needed to set priorities for rehabilitation. For instance, collection and analysis of ground motion potential data that ranks levee seismic vulnerability are needed.
 6. **Land subsidence potential.** Proposed increased conjunctive use of surface and ground water in the Central Valley lacks an adequate recognition of the potential for renewed land subsidence and aquifer destruction. A well monitoring program and groundwater model of the Central Valley has yet to be constructed that incorporates aquifer properties needed to assess subsidence potential. In addition, no program presently exists to develop tools to optimize conjunctive use while avoiding subsidence and water-quality problems.