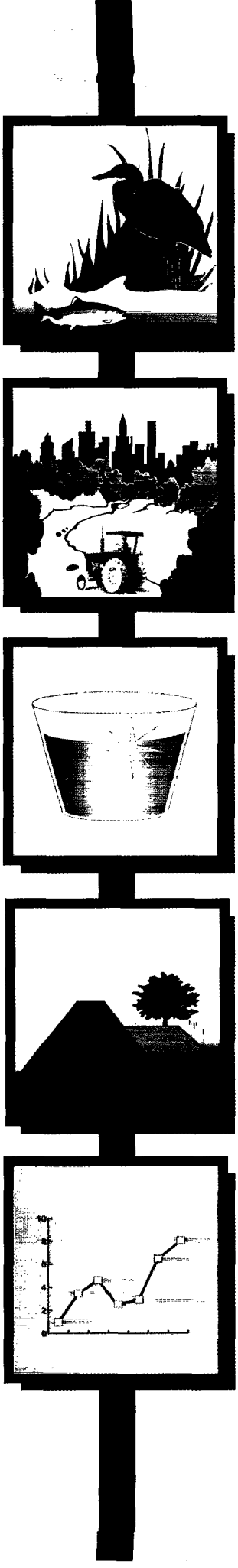

CALFED
BAY-DELTA
PROGRAM

Comprehensive Monitoring, Assessment and Research Program

Draft Programmatic EIS/EIR Technical Appendix
June 1999

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C-021836

CALFED
BAY-DELTA
PROGRAM

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March 8, 1999

To Interested Parties:

The enclosed report describes the initial efforts to design CALFED Bay-Delta Program's Comprehensive Monitoring, Assessment, and Research Program (CMARP). The purpose of CMARP is to provide those facts and scientific interpretations necessary for the CALFED Program to be fully implemented and for the public to judge the program's success. The report summarizes results of a 9-month process involving 30 teams and about 300 people, and facilitated by a steering committee. The teams and steering committee were composed of people from agencies, academia, and the stakeholder community. The Interagency Ecological Program, the San Francisco Estuary Institute, and U. S. Geological Survey proposed and jointly led the effort for CALFED.

The report describes the efforts undertaken to

- Summarize CALFED goals and objectives,
- Use conceptual models in designing monitoring and research,
- Propose monitoring and focused research questions for all of the CALFED programs,
- Propose data management, assessment, and reporting, and
- Recommend organizational ingredients necessary to implement CMARP.

The report concludes by proposing refinement of the program and early implementation of high-priority program elements. Supporting the report are 50 technical appendices produced by the teams, which can be found on the World Wide Web at http://www.calfed.ca.gov/programs.html under the heading CMARP.

The report has been reviewed by the CALFED Bay-Delta Program, CALFED agencies, and the public, and has been modified in response thereto. However, major issues such as prioritization of research needs, recognition of scientific uncertainty, and the role of conceptual models require significant work prior to completion of the CALFED EIS/EIR.

CALFED Agencies

California
The Resources Agency
Department of Fish and Game
Department of Water Resources
California Environmental Protection Agency
State Water Resources Control Board

Federal
Environmental Protection Agency
Department of the Interior
Fish and Wildlife Service
Bureau of Reclamation
U.S. Army Corps of Engineers
Department of Agriculture
Natural Resources Conservation Service
Department of Commerce
National Marine Fisheries Service

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Sincerely,

Lester A. Snow
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Enclosure

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March 10, 1999

RECOMMENDATIONS FOR THE IMPLEMENTATION AND CONTINUED REFINEMENT OF A COMPREHENSIVE MONITORING, ASSESSMENT AND RESEARCH PROGRAM

SUMMARY

On May 1,1998, the CALFED Policy Group approved a joint *San Francisco Estuary Institute, Interagency Ecological Program, U.S. Geological Survey* proposal to develop a Comprehensive Monitoring, Assessment, and Research Program (CMARP) for CALFED and its member agencies. (See appendix *I* for the complete CMARP proposal.) CALFED allocated $1.8 million to complete the project, with a final report due by January 31, 1999. The proposed CMARP addresses eight CALFED program elements and actions to be implemented over the next 30 years. The program elements are Long-term Levee Protection, Water Quality, Ecosystem Restoration, Water Use Efficiency, Water Transfer Framework, Watershed Management Coordination, and Delta Conveyance and Storage.

CMARP STRUCTURE

The three parties responsible for developing CMARP established a15-person Steering Committee consisting of agency and stakeholder scientists, co-chaired by Interagency Ecological Program, San Francisco Estuary Institute, and U.S. Geological Survey representatives. The Steering Committee appointed a Chief of Staff and a small staff to facilitate the work. Most of the technical work was accomplished by 30 technical teams, which included more than 250 agency and stakeholder representatives.

CMARP

The CALFED program evolved considerably from the time the Policy Group approved the proposal until completion of this report. For example, a report, "Developing a Draft Preferred Program Alternative," (August 5, 1998) solidified the concept of a 30-year project completed in stages. The first stage would begin in 2000 and last for seven years. The December 1998 revised CALFED Phase II report expanded on the staging concept and narrowed the options for the preferred alternative. The evolving definition of the preferred alternative and actions to be taken in Stage I have resulted in this report being more of a programmatic overview rather than a specific plan. The report recommends some interim implementation actions and proposes a process to develop a specific monitoring and research program for CALFED's Stage I.

CMARP TASKS

The proposal to develop CMARP was based on completion of five tasks. The activities under each task are discussed and include, where appropriate, references to likely interim implementation and Stage 1 actions.

Task 1. Refine the Goals, Objectives and Needs of CALFED Programs and Major Agency Goals and Objectives. The overall mission of CALFED is to develop a long-term comprehensive plan to restore ecological health and improve water management for beneficial uses of the San Francisco Bay-Delta system. The CMARP team compiled goals and objectives from numerous CALFED documents to define specific program objectives that could be used to help determine the program's information needs. Some of the documents studied for this review are from the CALFED Common Programs. Others include:

C—021840

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- CALFED Revised Phase II Report
- Species and Habitat Conservation Strategy
- Storage and Conveyance Refinement Process Overview
- Strategic Plan for the Ecosystem Restoration Program
- Water Transfer Program Technical Appendix

Individual program goals and objectives (Chapter 2 and Appendix *IV*) were provided to the workteams for their consideration in developing proposals for monitoring and research strategies within each program.

Task 2. Develop a Conceptual Framework for the CMARP Program. Conceptual modeling is the first step in the adaptive management process. Adaptive management is an integral component of all CALFED actions. If adaptive management is "learning by doing" (Walters, 1997), conceptual modeling is an explicit summary of what we know before we begin. Conceptual modeling is an essential tool to help managers and scientists select projects and actions having the greatest potential of achieving the desired goals and objectives.

The CMARP Steering Committee sponsored a two-day conceptual modeling workshop (see Appendix *V* for the final report) and encouraged CMARP workteams to include conceptual models in their reports describing monitoring and research needs. At the workshop, representatives from Puget Sound, South Florida, and Chesapeake Bay monitoring programs described their experiences with conceptual models in monitoring/research program design.

Several conceptual models are described in Chapter 4 and in many of the technical appendices. From their variety and complexity, it is clear that conceptual models take many forms and that some models have better scientific support than others. However, the process of conceptual model development has helped participants to

- articulate their understanding of key ecosystem relationships and presumed stressors, and
- identify major issues that need to be addressed and questions that need to be answered.

The articulation of explicit conceptual modeling into a multitude of existing monitoring/research programs is a significant interim accomplishment of the CMARP development process.

Task 3. Design a Monitoring Program Monitoring is conducted for many purposes and the terminology used to describe each purpose varies considerably among agencies and programs. For this report, we use terms suggested by the National Research Council (NRC) (1990), with definitions slightly modified for the CALFED program.

- Compliance monitoring provides information needed to determine if activities are meeting permit or other regulatory requirements.
- Model verification monitoring provides information to evaluate management alternatives, e.g., for adaptive management.
- Trend monitoring helps identify long-term changes occurring as a result of human and natural factors.

Although not mentioned by the NRC, a fourth monitoring category, Operations Monitoring is used in the San Francisco Bay-Delta. This provides near real-time data to biologists and water project operators for use in adjusting project operations to help protect fish and maintain water supply reliability.

The NRC emphasized that monitoring is an integral component of environmental management and can include modeling, time series measurements, indicators research, and collection, analysis,

C-021841

C-021841

information. For CALFED, the synthesized information will be used to prepare a "report card" to Congress, legislators, public, stakeholders, etc. on progress towards achieving CALFED goals.

The following are elements within the monitoring program development task.

Inventory Existing Monitoring Programs. The inventory of existing monitoring has been particularly important in identifying the scope and content of ongoing programs and exposing the gaps in coverage and content remaining because of differing objectives among individual programs. The inventory (Chapter 2 and Appendix *VI*) identified 622 monitoring and research programs with a total budget approaching $30 million annually. (The inventory can be used interactively at http://www.sfei.org/cmarpinv/). Almost $28 million is currently budgeted for the following seven existing large programs:

- Interagency Ecological Program
- CVPIA Comprehensive Assessment and Monitoring Program
- DWR Municipal Water-Quality Investigations
- SFEI Regional Monitoring Program for Trace Substances and SFEI Wetlands, Watersheds, and Invasive Species Programs
- Sacramento River Watershed Program
- USGS National Water Quality Assessment Program
- USGS Bay/Delta Ecosystem Project

Monitoring under CMARP will incorporate data collected by many of these existing activities and will, as necessary, augment these programs to ensure complete coverage in time and space and add critical variables.

Develop Specific Monitoring Elements. The CMARP Steering Committee charged the workteams to:

- review their (and other related) monitoring needs and research,
- develop conceptual models,
- recommend monitoring and research needed to respond to CALFED actions, increase understanding and provide for long-term trend monitoring, and
- list indicators that could be used by CALFED and others to evaluate the success of their actions.

The results of these work team efforts are summarized in Chapter 4 and are in the technical appendices of this report.

Most teams identified specific variables to be included in trend monitoring and some general research questions. CMARP is unable to recommend more specific monitoring until the CALFED preferred alternative and Stage 1 actions are better defined. The monitoring and research items have not been ranked by priority, and any cost estimates are very rough. During CMARP interim implementation (essentially calendar year 1999 and early 2000, see below).

The CMARP Steering Committee and staff will work with CALFED program managers, stakeholders, and agency staff to set priorities and refine cost estimates for the high priority projects. Priorities will depend in part on the preferred alternative and accompanying actions.

The CMARP Steering Committee will work with the ERP Strategic Plan Core Team to develop a suite of indicators to allow CALFED to assess progress toward meeting its goals and objectives. These efforts will build on the work of the CALFED-ERP Indicators Group and the Environmental Defense Fund.

Develop a Process for Data Management. CMARP is proposing a relational database-management system that will allow individual data collectors and data providers to manage their own data locally, while providing a centralized means of uploading the data into a larger database. These data

C-021842

C-021842

will be fully protected by the data management structure; only the data provider will be permitted to change their data. Collected and uploaded data will be subject to a strict quality assurance/ quality control protocol. Data in the centralized database can be used for comprehensive analysis and reporting by agency and stakeholder scientists.

Develop a Process for Data Assessment and Reporting. Raw data are of little use in making management and policy decisions. A common problem of many monitoring and research programs is the failure to sufficiently analyze collected data and to make the information available to other scientists, managers, stakeholders, and the general public in a timely manner. Often, this failure results from program budgets that do not allocate sufficient staff time for data analysis and interpretation. The CMARP data assessment and analysis element identifies the means of interpreting and reporting collected information to decision-makers. External peer review will ensure that field and laboratory techniques are appropriate and that interpretations are scientifically defensible. The final CMARP budget will provide adequate staffing to ensure timely data analysis, interpretation, peer review, and reporting.

Task 4. Develop a CALFED Focused Research Program. Monitoring data can describe what happened; research is often needed to help explain why and how it happened. Focused research (also called problem-solving research or targeted research) simply means that the research will be done in areas specifically of interest to CALFED and will be essential in making adaptive management decisions. In a sense, adaptive management is focused research in that selected management actions are framed as hypotheses and data are collected and analyzed to test those hypotheses for other purposes.

The CMARP focused research program will be developed to facilitate the CALFED adaptive-management process and provide answers to critical research questions identified by CMARP teams, CALFED, and stakeholders. CMARP research will be funded through three distinct processes.

- Directed research—A specific entity, such as a university researcher, will be asked to submit a proposal for a well-defined project. The proposal will be peer reviewed and, if found acceptable, will be funded.
- Request for Proposal—A general solicitation will be made for proposals in one or more areas of interest to CALFED. Only those proposals that meet the scrutiny of anonymous peer review will be funded.
- Agency research—Agency scientists will continue to be involved in independent research. Much of this research will be conducted for purposes other than CALFED. Many of their results will be of interest to CALFED.

Appendix *VII.J* of this report includes a proposed proposal-solicitation process and an example solicitation package. This package and the research questions identified by the workteams have been forwarded to CALFED staff for possible use by the CALFED Integration Panel in identifying key research questions and developing a possible interim request-for-proposal package.

Task 5. Recommend an Institutional Structure for CMARP. Because of the uncertainty of CALFED's institutional structure, CMARP provides recommendations on interim and long-term structure/organization.

Interim (calendar year 1999 and early 2000) Organization and Management of CMARP. A CMARP Steering Committee will continue to manage the program until the Record of Decision and a final decision on CALFED

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C-021843

structure are available. The Steering Committee will report to the CALFED Management and Policy groups, through the CALFED Executive Director, and will designate a scientist, with appropriate staff support, to direct the program during this interim period. The Program Director and Steering Committee members will coordinate CMARP activities with CALFED program managers and deputy directors. Interim operation of CMARP, i.e., prior to full implementation of monitoring data collection activities, will cost about $400,000 annually. The CMARP Steering Committee recommends that CALFED funding be allocated for some interim implementation projects in 1999. The proposals and funding requirements will be developed in early 1999.

Examples of some possible interim implementation actions under CMARP (Chapter 7) include:

- Develop a better understanding of three Delta water-quality constituents - bromides, dissolved solids, and dissolved organic carbon.
- Evaluate "flexible operations" as being discussed by the CALFED Diversion Effects on Fish Team. Flexible operations will probably involve an expanded version of IEP's real-time monitoring program, perhaps with statistically valid estimates of the numbers of fish salvaged at the Central Valley Project and State Water Project intakes.
- Determine feasibility of using new technology to map topography and bathymetry of the delta, set up a continuing process to update locations and elevations of new high-accuracy benchmarks, and extend the elevations of these benchmarks to delta streamflow gages.
- Use existing IEP Delta Fish Facilities Technical Team to develop and implement monitoring and research programs to provide CALFED management with information needed to determine how to evaluate proposed Stage 1 fish screens.
- Take an active role in documenting introductions of non-indigenous species and determine the effects and control of these introductions. These efforts will be closely coordinated with CALFED's non-native invasive-species team, which will have an implementation plan in early 1999.
- Design a constant fractional marking program at Central Valley chinook salmon hatcheries to help evaluate hatchery contribution to spawning escapement and ocean and inland recreational fisheries. These data are essential to understanding the effect of restoration actions on chinook salmon.

Long-term structure. In the long-term, CMARP must

- have a structure to ensure that the program remains responsive, credible, and accountable
- design and direct the scientific program
- collect, manage, and distribute data
- analyze and interpret data
- report findings
- provide for extensive scientific review
- collaborate with CALFED managers on adaptive management, and
- find a way to effectively use data from existing programs that are not under the direct control of CMARP.

To accomplish this, CMARP should be directed by a Chief Scientist and an Executive Officer supported by appropriate technical staff, with all activities subject to structured scientific review. CMARP must be a partnership among agencies, stakeholders, universities, and non-profit and private contractors. The actual field and laboratory technicians, scientists, and computer specialists doing the work cannot be identified until the CALFED and CMARP structures are better defined. During the upcoming year, CMARP will develop a process to recruit a chief scientist, and will collaborate with others to develop a

permanent organizational structure to implement CMARP.

FUNDING REQUIREMENTS

Given CMARP's present programmatic level of detail, it is not possible to provide a useful estimate of the amount of funding required. Existing monitoring and research programs contribute about $33 million per year; much of the data collected from these existing programs is already useful to CALFED. Some program restructuring may allow these existing programs to better meet CALFED needs.

C-021845

C-021845

TABLE OF CONTENTS

SUMMARY S1-S6

LIST OF TABLES iii
LIST OF FIGURES iv
LIST OF ACRONYMS v
LIST OF APPENDICES AVAILABLE ON THE WORLDWIDE WEB vii

Chapter I. INTRODUCTION 1-7

- Background 1
- Purpose of CMARP 2
- Scope of CMARP 3
- Approach to Design 5
- Purposes of the Report 6
- Topics Covered in this Report 7

Chapter II. INITIATING THE CMARP EFFORT 9-14

- Identification of CALFED Goals and Objectives and Agency Goals and Objectives 9
- Refinement of CALFED Proposed Actions 10
- Inventory of Current Monitoring and Research Programs 11

Chapter III. USES OF CONCEPTUAL MODELS IN MONITORING AND RESEARCH DESIGN 15-23

- Introduction 15
- Development of Conceptual Models in CMARP 15
- Monitoring Program Design 16
- Research Program Design 22
- Adaptive Management 23

Chapter IV. MONITORING AND FOCUSED RESEARCH PROGRAM DESIGN 25-96

- Part A. Introduction and Reader's Guide 25
- Part B. Ecosystem Restoration Program Plan 31
- Part C. Water Quality 51
- Part D. Delta Levee System Integrity 63
- Part E. Subsidence on Delta Islands 69
- Part F. Storage and Conveyance 71
- Part G. Water Transfers 73
- Part H. Water Use Efficiency (Conservation and Water Recycling) 78
- Part I. Watershed Management Coordination 84
- Part J. Category III Project Monitoring and Data Review 91
- Part K. Integrating CMARP Monitoring 95

C-021846

C-021846

Chapter V. DATA MANAGEMENT, ASSESSMENT AND REPORTING 97-117

Introduction 97
Information Requirements 97
Coordination Between CALFED and Existing Programs 99
Information Gathering and Organization 102
CMARP Quality Assurance 104
Indicator Selection 105
Analysis and Integration 106
Reporting 108
Conclusions 110
Examples and Tables 110

Chapter VI. INSTITUTIONAL STRUCTURE TO IMPLEMENT CMARP 119-132

Introduction 119
Attributes of a CMARP Institutional Structure 119
Functions of the CMARP Institutional Structure 120
Elements of the Institutional Structure 121
Processes 124
Questions to Resolve in Developing the Organizational Structure 130

Chapter VII. IMPLEMENTATION OF CMARP 133-140

Managing CMARP during the Development of a CMARP Implementation Structure... 133
Implementation Tasks for 1999 133
Refinement of CMARP Elements during 1999 136
Estimating Program Costs 140
Financing CMARP 140

LITERATURE CITED 141

C-021847

C-021847

LIST OF TABLES

Table 1-1. CMARP Steering Committee Tasks 2

Table 2-1. Programmatic actions given in CALFED Revised Phase II Report 11

Table 2-2. Number of existing monitoring programs compiled in the Inventory and sorted by CALFED Common Program and geographic region 13

Table 2-3. Summary of information about the largest existing monitoring and research programs in the CALFED region 14

Table 4-1. Summary of monitoring elements recommended by CMARP Workteams and merged with indicators proposed by the CALFED ERP Indicators Group 26-30

Table 4-2. Water-Quality Program Actions 52

Table 4-3. Water-Quality Monitoring Objectives 53

Table 4-4. Drinking Water Contaminants and Potential Health Effects 57

Table 4-5. Drinking Water Constituents of Concern 58

Table 4-6. Major Existing Water-Quality Monitoring Programs 62

Table 4-7. An outline of information expected to be in the monitoring/data-collection methods plan 93

Table 4-8. Joint information needs of the CALFED Common Programs 96

Table 5-1. Examples of periodic and non-periodic reports from agencies and programs in the CALFED Bay-Delta solution area 115

Table 5-2. Examples of real-time monitoring web-page reporting from agencies and programs in the CALFED Bay-Delta solution area 116

Table 7-1. Summary of CMARP's ERP work team accomplishments and tasks needing further development for implementation of recommended monitoring elements 138

C—021848

C-021848

LIST OF FIGURES

Figure 1-1. Elements of understanding and managing the natural resources of the Bay-Delta and Central Valley 3

Figure 3-1. Some potential mechanisms underlying the relationship between Bay-Delta species and X2, the degree of uncertainty about the relationships, and the assumed relative importance of the mechanisms 17

Figure 3-2. Potential causative pathways underlying the fish-X2 relationships 18

Figure 3-3. Conceptual model of the relative influences of water flow (both river and tidal flows) on the movement of water and salt in the estuary 19

Figure 3-4. Conceptual model of the fish-X2 gravitational circulation mechanism 20

Figure 3-5. Conceptual model of the annual life cycle of Delta smelt, the potential important mechanisms regulating smelt abundance, and proposed areas for the focus of monitoring and research 21

Figure 4-1. Category III Monitoring Workgroup Process 92

Figure 5-1. Level of Detail Desired by Different Audiences of CMARP Information and Reports 97

Figure 5-2. Providing Information to Managers and Decision-Makers 100

Figure 5-3. Conceptual Model of Information Flow and Feedback Loops between CMARP and CALFED 101

Figure 5-4. Relationship between management of water pumping in south Delta and corresponding effects on water supply reliability and the salmon population 111

Figure 5-5. CALFED Ops Group Decision Process 112

Figure 5-6. Plot of Chinook salmon incidental take at the SWP & CVP Delta Fish Facilities 113

Figure 5-7. Time series for mysids, X2, and clams, annual means for sampling seasons for stations in Grizzly Bay and San Pablo Bay 114

C—021849

C-021849

LIST OF ACRONYMS

ARFE	CALFED ERP Indicators Group, Alluvial River-Floodplain Ecosystem
BDAC	Bay-Delta Advisory Council
BDT	Bay/Delta and Tributaries
BMP	Urban Best Management Practices
BOD	Biological Oxygen Demand
C	Carbon
CAMP	Comprehensive Assessment and Monitoring Program
CARA	California Rivers Assessment
CDFG	California Department of Fish and Game
CERES	California Environmental Resources Evaluation System
CII	Commercial, Industrial and Institutional customers
CIMIS	California Irrigation Management Information System
CMARP	Comprehensive Monitoring, Assessment and Research Program
CUWCC	California Urban Water Conservation Council
CUWA	California Urban Water Agencies
CVAP	Central Valley Aquifer Project
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
CVPWA	Central Valley Project Water Authority
CY	Calendar Year
DART	CMARP Data Analysis and Reporting Workteam
DAT	CALFED Operations Group Data Assessment Team
DBP	Disinfection By-product
DBPP	Disinfection By-product precursor
DE	CALFED ERP Indicators Group – Delta Ecosystem
DEFT	Diversion Effects on Fish Team
DFG	California Department of Fish and Game
DHS	California Department of Health Services
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
DOE	Department of Energy
DU	Irrigation Distribution Uniformities
DWR	California Department of Water Resources
EC	Electrical Conductivity or Specific Conductance
EDF	Environmental Defense Fund
EBMUD	East Bay Municipal Utility District
EIS/EIR	Programmatic Environmental Impact Statement/Environmental Impact Report
EPA	United States Environmental Protection Agency
EPT Index	Ephemeroptera, Plecoptera, Trichoptera Index
ERP	Ecosystem Restoration Program
ERPP	Ecosystem Restoration Program Plan
ESA	Endangered Species Act
ET	Evapotranspiration
EWA	Environmental Water Account
EWMP	Agricultural Efficient Water Management Practices
FEAT	Governor's Flood Emergency Action Team
FEMA	Federal Emergency Management Agency
FY99	Fiscal Year 1999
FY2000	Fiscal Year 2000
GIS	Geographic Information Systems
GMI	Green Mountain Institute for Environmental Democracy
GPS	Global Positioning System
GUI	Graphical User Interface
HMP	Flood Hazard Mitigation Plan for the Delta (1986)
HBI	Modified Hilsenhoff Biotic Index

LIST OF ACRONYMS – CONT.

ICE	UC Davis' Information Center for the Environment
IEP	Interagency Ecological Program
Kc	Crop Coefficients
LWA	Larry Walker & Associates
MARO	Monitoring, Assessment and Research Organization
MCL	Maximum Contaminant Level
MTBE	Methyl Tertiary-Butyl Ether
MWD	Metropolitan Water District
N	Nitrogen
NAWQA	National Water Quality Assessment Program
NOAA	National Oceanographic and Atmospheric Administration
P	Phosphorus
PDT	Percent Dominant Taxon
PEIR	Programmatic Environmental Impact Report
PEIS	Programmatic Environmental Impact Statement
PRBO	Point Reyes Bird Observatory
PSP	Proposal Solicitation Packages
PSU	Practical Salinity Units
PL 84-99	Public Law 84-99
QA/QC	Quality Assurance/Quality Control
QWEST	Net flow of the San Joaquin River near the confluence with the Sacramento River
RASA	Regional Aquifer System Analysis Program
RDBMS	Relational Database Management System
RMP	Regional Monitoring Program
RWQCB	Regional Water Quality Control Board
SCMP	Sacramento Coordinated Monitoring Program
SCT	Science Coordination Team (Future CMARP)
SFBE	CALFED ERP Indicators Group, Greater San Francisco Bay Ecosystem
SFEI	San Francisco Estuary Institute
SFEP	San Francisco Estuary Project
SJVDP	San Joaquin Valley Drainage Program
SLMWA	San Luis and Delta Mendota Water Authority
SRWP	Sacramento River Watershed Program
STORET	Storage and Retrieval Database of the U.S. Environmental Protection Agency
SWP	State Water Project
SWRCB	State Water Resources Control Board
TDS	Total Dissolved Solids
THM	Trihalomethane
THMFP	Trihalomethane Formation Potential
TIE	Toxicity Identification Evaluation
TOC	Total Organic Carbon
TTHM	Total Trihalomethane
URFE	CALFED ERP Indicators Group, Upland River-Floodplain Ecosystem
USACE	United States Army Corps of Engineers
USBR	United States Bureau of Reclamation
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
VAMP	Vernalis Adaptive Management Program
WUE	Water Use Efficiency
WUECP	Water Use Efficiency Common Program
X2	The distance in kilometers up the axis of the estuary to where the tidally-averaged near-bottom salinity is 2 practical salinity units.
ZOI	Zone of Influence

LIST OF APPENDICES AVAILABLE ON THE WORLDWIDE WEB
http://calfed.ca.gov/programs.html

Appendix I. Proposal for the Development of a CMARP
Appendix II. Glossary of Terms
Appendix III. Membership of CMARP work teams
Appendix IV. CALFED Goals and Objectives
Appendix V. Conceptual Framework
Appendix VI. List of existing monitoring programs
Appendix VII. Monitoring Program Design
- A. Ecosystem Restoration
  1. Bay-Delta Fish X-2
  2. Shallow Water Habitats- Geomorphology Emphasis
  3. Fishes in Shallow-Water Habitats
  4. Hydrodynamics and Sediment Transport
  5. System Productivity- Small Invertebrates
  6. System Productivity- Fish and Large Invertebrates
  7. Delta Smelt
  8. Bay-Delta Salmon
  9. Chinook Salmon and Steelhead in the Central Valley Rivers
  10. Resident Fish
  11. Central Valley Steelhead
  12. Fluvial Geomorphology and Riparian Systems
    - a. Floodplain Research and Monitoring Objectives
    - b. Habitat Characterization Protocol for Gravel-Bed Reaches of Lowland Rivers
    - c. Substrate Particle Size Sampling Protocol
    - d. Protocol for Sampling Surface Water-Groundwater Interactions in Spawning Reaches of Lowland Rivers
    - e. Floodplain habitats
    - f. Fish Use of Floodplain habitats
    - g. Bird Monitoring, Assessment and Research
    - h. Central Valley Riparian Vegetation Inventory
    - i. Monitoring Riparian Arthropod Assemblages
  13. Benthic Invertebrates
  14. Monitoring for Non-indigenous Organisms
- B. Water Quality
  1. Contaminants
  2. Drinking Water
  3. Sacramento Region
  4. San Joaquin Region
- C. Water Transfers
- D. Water Use Efficiency
- E. Water Recycling
- F. Watershed Management
- G. Delta Levees
- H. Data Management Process
- I. Data Analysis and Reporting
- J. Focused Research Program
- K. Subsidence of Delta Islands

Appendix VIII. Integration Workshop Report

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Chapter 1. INTRODUCTION

BACKGROUND

CALFED mission and principles. The 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 CALFED Mission Statement is supported by a set of **Primary Objectives** and **Solution Principles**, as cited in the Executive Summary of the CALFED Bay-Delta Program Programmatic EIS/EIR, March 1998.

The **Primary Objectives** are:

- Water Quality – Provide good water quality for all beneficial uses.
- Ecosystem Quality – Improve and increase aquatic and terrestrial habitats and improve ecological functions in the Bay-Delta to support sustainable populations of diverse and valuable plant and animal species.
- Water Supply – Reduce the mismatch between Bay-Delta water supplies and the current and projected beneficial uses dependent on the Bay-Delta system.
- Vulnerability of Delta Functions – Reduce the risk to land use and associated economic activities, water supply, infrastructure, and the ecosystem from catastrophic breaching of Delta levees.

The **Solution Principles** are to:

- reduce conflicts in the system,
- be equitable,
- be affordable,
- be durable,
- be implementable, and
- have no significant redirected impacts.

To fulfill its mission, the CALFED Bay-Delta program is proposing substantial changes to many aspects of the Bay-Delta/Central Valley environmental and water-management system. In addition, many member agencies of CALFED are currently charged with activities and programs directly affecting this system.

Mandate for CMARP. In November 1997, the Secretary of the U.S. Department of the Interior, Bruce Babbitt, requested that U.S. Geological Survey (USGS) assist him in meeting a Congressional mandate to monitor the success of CALFED restoration efforts. Also during November, a proposal to develop a monitoring and research program for CALFED was sent to the CALFED Policy Group by the Interagency Ecological Program (IEP) and the San Francisco Estuary Institute (SFEI), USGS presented its proposal (USGS, 1998) to the CALFED Policy Group on December 19, 1997. On that day, the Policy Group directed IEP, SFEI, and USGS to develop a joint proposal to design a Comprehensive Monitoring, Assessment, and Research Program (CMARP) for CALFED.

A steering committee was formed by IEP, SFEI, and USGS to prepare a joint proposal. The CMARP Stage I Report, April 24, 1998 (Appendix *I*), was reviewed by agencies and stakeholders and presented to the Policy Group on May 1, 1998. The Policy Group accepted the proposal, provided $1.8 million to finance the effort, and directed that the work be completed by the end of January 1999.

The CMARP Stage I report proposed development of a monitoring, assessment, and research program for CALFED programs and related agency programs. It called for an expanded steering committee to be composed of agency personnel and stakeholders (listed in Stage I report, Appendix *I*), and the performance of five tasks (Table 1-1).

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Table 1-1. CMARP Steering Committee Tasks

- **TASK NUMBER ONE – Refine the Goals, Objectives and Needs of CALFED Programs and Agency Major Program Goals and Objectives** – Maintain a continuing and iterative process to:
  A. Identify goals, objectives, and needs of CALFED Programs (Ecosystem Restoration, Water Quality, Water Transfers, Water Use Efficiency, Watershed Management Coordination and Delta Levees System Integrity) and related programs (Category III, Conservation Strategy, and Indicators);
  B. Compile Agency major program goals and objectives;
  C. Develop CMARP monitoring elements and a research program based on identified goals and objectives.

- **TASK NUMBER TWO – Develop a Conceptual Framework for the CMARP Program** - Develop explicit conceptual models for use in designing monitoring and research programs, and for documenting the basis of earlier decisions on program design. This task is being accomplished, in part, by taking advantage of experience gained in the development of monitoring and research programs in Puget Sound, Chesapeake Bay, and South Florida.

- **TASK NUMBER THREE – Design a Monitoring Program** – Carry out five sub-tasks to:
  A. Inventory Existing Monitoring Programs;
  B. Develop Monitoring Elements;
  C. Develop a Process for Data Management;
  D. Develop a Process for Data Analysis and Monitoring;
  E. Institute a Category III Monitoring Process.

- **TASK NUMBER FOUR – Develop a CALFED Focused Research Program**- Define a process to identify and conduct research that is focused on addressing critical uncertainties about causes of ecosystem variability, change, and long-term trends.

- **TASK NUMBER FIVE – Recommend an Institutional Structure for CMARP** - Identify functions of a CMARP institutional structure and its relationship to CALFED. Recommend how it should operate, how it should be funded, and to whom it should be accountable.

PURPOSE OF CMARP

Monitoring, assessment, and **research** are three parts of an interactive process to understand and manage a natural resource system (figure 1-1).

Monitoring involves measuring and sampling physical, chemical, and biological attributes of the resources and social and economic attributes of associated human activities.

Assessment involves organizing and evaluating incoming information from monitoring and research activities, for example examining correlations between the abundance of a fish species and a physical factor, such as river flow, that might affect abundance.

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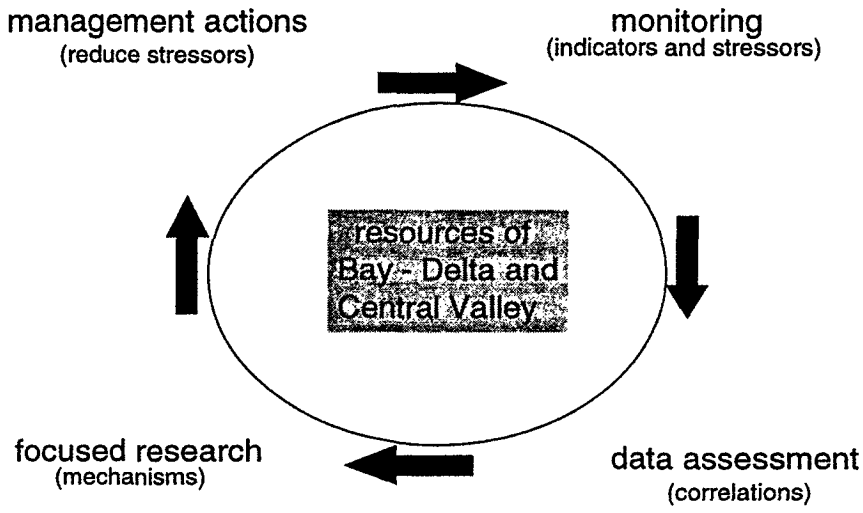

Figure 1-1. Elements of understanding and managing the natural resources of the Bay-Delta and Central Valley.

Research involves analysis or experiments to elucidate mechanisms that explain observed correlations, such as documenting fish distributions and mortalities for different flows.

The information generated from monitoring, assessment, and research provides resource managers with understanding needed to design actions, to detect responses to their actions, and to provide the public with information about the success of these actions.

CALFED needs a monitoring and research program for at least four reasons:

1. CALFED needs monitoring data and information to assess baseline conditions, resolve questions regarding the preferred alternative, and to carry out its related programs in the context of an adaptive management strategy.
2. CALFED needs to satisfy the Congressional mandate for indicators and performance measures with which to judge the success of restoration efforts.
3. CALFED needs data and information with which to assure stakeholders that the actions being taken are having desired results.
4. CALFED needs to reduce the scientific uncertainty associated with the management and protection of valued natural resources.

Thus, the purpose of CMARP is to provide those new facts and scientific interpretations necessary for CALFED to implement fully its preferred alternative and related programs and for the public and government to evaluate the success of CALFED actions.

SCOPE OF CMARP

Challenges – In developing the scope of CMARP, the Steering Committee recognized that the CALFED programs and the preferred alternative were not yet

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C-021856

completely defined. Moreover, no comprehensive list of ongoing monitoring programs existed. Therefore, for most issues, the Steering Committee relied on information available during late summer/ early fall, 1998, and incorporated the objectives of existing monitoring programs into the development of a comprehensive monitoring and assessment program.

Because of the broad geographic range and scientific scope of the required program, the CMARP Steering Committee recognized the necessity of subdividing the task of developing monitoring and research strategies into manageable components. Thus, numerous smaller committees (work teams) were needed to review existing information in specific subject matter areas and to prepare recommendations.

Organization – The CMARP organizational structure (Appendix *III*) was developed to maximize the flow of information and interaction between the Steering Committee, agency staff, stakeholder groups, and program managers for the CALFED programs. Thirty technical work teams developed recommendations for research and monitoring, the basis of which were the CALFED programs and tasks to be completed by the CMARP (Appendix *VII*). About 250 individuals representing stakeholder groups, agency staff, CALFED staff, CALFED program managers, and other area scientists, served on these work teams (Appendix *III*). Representatives from major monitoring programs (Sacramento River Watershed Program, San Francisco Estuary Institute Regional Monitoring Program, DWR's Municipal Water Quality Investigations Unit, Interagency Ecological Program, CVPIA Comprehensive Assessment and Monitoring Program, USGS National Water Quality Assessment Program, and similar organizations) ensured that the CMARP will utilize existing monitoring programs and incorporate specific agency and stakeholder needs.

In seeking advice on the creation and refinement of the CMARP design, the Steering Committee worked with the Green Mountain Institute for Environmental Democracy (GMI) to gather details about institutional structures, decision-making processes, and monitoring and research programs in twelve large, ecosystem-level management projects across the United States. This information was gathered through interviews with key individuals and from program documents of Chesapeake Bay, South Florida/Everglades, Puget Sound, the Southern Appalachian Assessment, the Mid-Atlantic Integrated Assessment, the Interior Columbia Basin Ecosystem Management Project, Great Lakes, Gulf of Mexico, Prince William Sound, Gulf of Maine, the Forest Ecosystem Assessment, and the Greater Yellowstone Ecosystem. Additionally, the regional monitoring program of the Southern California Coastal Waters Project was reviewed. GMI is compiling the information into a summary of the key findings that will be available as an appendix *VII.I.1* to this report. Meanwhile, the information from the interviews was used in the development of recommendations contained in the Institutional Structure and Data Management, Assessment, and Reporting Chapters and Appendices (Chapters 5 and 6, Appendix *VII.H*).

Geography—The geographic scope of the CMARP is determined by attributes of the chemical, biological, and physical environment associated with implementation of CALFED Stage 1 actions. For example, monitoring of chinook salmon necessitates 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 were used to determine the specific variables that will be monitored and to identify when and where monitoring should occur. Monitoring associated with other program elements, such as water transfers, will also have wide geographic scope.

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Monitoring Objectives—Principal CMARP monitoring objectives include:

- documenting conditions,
- recognizing trends,
- assessing causes of observed changes,
- partnering with agency/ecosystem management for adaptive management, and
- reducing scientific uncertainties.

CALFED will need to assure the regulatory community and stakeholders that certain actions specific to project development are carried out. Examples include implementing mitigation measures that address project impacts and complying with standards and objectives required as permit conditions to construct and operate projects. Terms of the National Resource Council (NRC) (1990) are used, with definitions slightly modified for the CALFED program. Different types of monitoring will be implemented to address these objectives:

Compliance/Mitigation Monitoring – Determines whether and to what degree specified objectives, standards or mitigation measures are being met. A permitting authority usually requires this type of monitoring as a result of project development and operation.

Model Verification or Validation Monitoring – Determines whether and to what degree a specified practice has achieved its immediate objectives. (Did the project do what it was supposed to do?) Monitoring is used to validate hypotheses and conceptual models that predict relationships among variables. It validates theories on the effectiveness of certain actions in the context of adaptive management.

Trend Monitoring – Provides consistent data through time for evaluating, identifying, and quantifying longer-term changes in key indicators or conditions (including physical, chemical, and biological variables such as fish populations, streamflow, temperature, salinity, area of habitat restored) that are most likely associated with changes in key conditions and/or human activities. Trend monitoring addresses the questions "what", "when" and to some extent, "why" things have changed.

Operations Monitoring – Supports specified project operations. Although not mentioned by the NRC, Operations Monitoring is useful in San Francisco Bay-Delta. It is intended to provide up-to-date (within 24 to 48 hours) information to managers and operators on effects of project operations for specified environmental variables, or provide specified environmental information to determine how projects should operate. This monitoring is a tool that allows for flexibility in project operations. Examples include real-time fishery and water-quality monitoring.

These monitoring types are not mutually exclusive and some are interdependent. They require coordinated and integrated data-collection efforts. The objectives and plans of each monitoring program will be clearly specified, and the overlaps in data needs among programs will be identified and eliminated, where possible, to achieve cost savings.

APPROACH TO DESIGN

Principles – Prior to developing the monitoring and research recommendations, members of the Steering Committee, agency staff, and CALFED staff agreed to several principles that formed the basis for the CMARP tasks and provided the direction necessary for completing the work products. The principles are:

- Recommendations for monitoring and research are based, in part, upon development of conceptual models that incorporate current thinking about how the physical, chemical, and biological systems are structured and how they function (see Chapter 3).
- CMARP is to be built upon coordination and integration, where feasible, of

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existing monitoring programs, resulting in reduced capital and operation costs (see Chapters 2 and 4).

- Emphasis of CMARP will be on data evaluation and use. Evaluative reports, subject to peer review, will be published on a regular basis (see Chapter 5).
- CMARP is to be fully coordinated with similar assessment activities of other local, State, Federal, and regional organizations. Through the active cooperation and participation of all organizations, duplication of effort will be minimized (see Chapter 5).
- Through a quality-assurance and quality-control program, CMARP will encourage standardization of sampling equipment, sampling methodologies and analytical methodologies.
- CMARP's data-management structure will ensure that the data collected are available to public agencies and the public on a timely basis (see Chapter 5).

Development of Recommendations– Initial activities to develop monitoring and research recommendations began with a review of the established CALFED goals and objectives for all programs, including the Conservation Strategy and Category III elements. Participants worked with agency staff and stakeholders to identify CALFED agency goals and objectives for existing monitoring and research programs. However, because of the short time frame for the development of this report, the details on which particular element should be monitored and how (e.g., gear type/methodology), and who will do the monitoring, were postponed pending approval to work on implementation of specific CMARP elements.

PURPOSES OF THE REPORT

This report describes the initial design of the monitoring, assessment, and research program, and proposes early implementation tasks and additional program refinement prior to a Record of Decision on CALFED's programmatic environmental impact report. In addition, a number of specific issues presently important to CALFED and its stakeholders are addressed. These include:

A need for indicators (see Chapter 5) – In addition to the congressional mandate to develop indicators of ecosystem health, a need exists to agree on water supply, water quality, and levee-reliability indicators, and perhaps to agree on social and economic indicators of associated human activities. The development and use of indicator values in turn need to be conducted in an unbiased and clearly defined way, based on sound monitoring and research data, and provided to the public in a timely fashion.

Adaptive management (see Chapter 3) – Recognizing the level of uncertainty about the resources, CALFED proposes to use an adaptive approach to managing the natural resources. Adaptive management involves designing and executing actions, monitoring and assessing the responses of the natural resources to these actions, and thereby learning how actions affect the resources. At issue is the type of adaptive management to be employed - traditional passive adaptive management or a more active adaptive management recommended by the ERP Strategic Plan (1998). Appropriate and timely assessment of monitoring and research data is critical to effective adaptive management.

Questions raised by Diversion Effects on Fish Team (DEFT) (see Chapter 7) – Information and assumptions about the effects of delta exports and diversions on the abundance and distribution of fish species, particularly threatened species, are the foundation of biological opinions that constrain operation of the Central Valley and State Water Projects to deliver water south of the delta. The Diversion Effects on Fish Team (DEFT) has assessed available information to recommend how to use flexible operations of the water projects to

C—021859

C-021859

improve the welfare of salmon, delta smelt, and striped bass in the delta. DEFT recognized the need for improved information to help refine and judge the efficacy of its recommendations during Stage I of CALFED program implementation.

Drinking-water quality of exports and diversions (see Chapter 7) – As drinking-water regulations for disinfection by-products are revised and water-treatment technology evolves, and as more blending and recycling of delta water are needed to meet increasing municipal water demands, an increasing need exists to reduce concentrations of bromides, organic carbon, and dissolved salts in delta exports and diversions. CALFED has recognized the need to investigate and implement measures to effect these reductions during Stage I, and these activities will need strong monitoring and research support.

Implementing CMARP – An underlying issue for CALFED and CMARP is what organization or organizations will implement the monitoring, assessment, and research programs. This issue is particularly important because of the expressed intent to use an adaptive management approach to implement the CALFED programs. As the debate continues, necessary ingredients for a CMARP organizational structure need to be defined.

TOPICS COVERED IN THIS REPORT

The following chapters contain discussions and summaries of key topics relevant to the implementation of CMARP:

Chapter 2 – refinement of goals and objectives and inventory of existing monitoring programs.

Chapter 3 – development and use of conceptual models in CMARP.

Chapter 4 – recommended monitoring and research programs and proposed indicators for all of the CALFED programs, including DEFT-related work in the ecosystem restoration section and drinking water-related work in the water quality section. More detailed descriptions of the design work are presented in the numerous appendices to this document.

Chapter 5 – a data assessment and reporting process to provide information derived from the monitoring data to decision makers, resource managers, and the public.

Chapter 6 – organizational ingredients needed to implement CMARP.

Chapter 7– proposed interim-implementation tasks (including DEFT and drinking-water-related tasks), program refinements during 1999, clarification of active adaptive management issues, and suggestions regarding potential costs and financing mechanisms for CMARP.

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Chapter 2. INITIATING THE CMARP EFFORT

IDENTIFICATION OF CALFED GOALS AND OBJECTIVES AND AGENCY GOALS AND OBJECTIVES

The CMARP steering committee began design of the monitoring and research program by identifying CALFED and agency goals and objectives that would direct the scope and content of monitoring and research activities. The ultimate goal of monitoring and research must be to produce information that is useful in making management decisions. Thus, it was important to base the monitoring and research program on management objectives. Communication between scientists responsible for designing monitoring programs and the users of the information is essential (National Research Council, 1990). It must be clear to both scientists and managers what purposes the monitoring and research data are intended to support. The first step of this effort was, therefore, to define the goals and objectives of CALFED and member agencies, as specifically and quantitatively as possible.

The CMARP steering committee began with an evaluation of existing goals and objectives from CALFED programs and agency programs. Goals and objectives from the following programs are compiled in Appendix *IV*:

CALFED Common Programs

- Long-Term Levee Protection Plan
- Water Quality Program
- Ecosystem Restoration Program
- Water Use Efficiency
- Water Transfer Policy
- Watershed Management Coordination

CALFED Variable Programs

- Storage
- Conveyance

Interagency Programs

- Comprehensive Assessment and Monitoring Program (CAMP)
- Interagency Ecological Program
- Sacramento River Watershed Program
- San Francisco Estuary Institute

The six CALFED common programs are in varying stages of development; thus, designation of program goals and objectives is more specific for some programs than for others, depending on the progress made within each common program. The goals and objectives for all programs are also still in flux. The Long-Term Levee Protection and Water Quality Common Programs have defined fairly specific targets for certain implementation objectives. We have identified 11 specific targets for the Long-Term Levee Protection Plan program and 25 specific targets for the Water Quality program. The Ecosystem Restoration Program has four main implementation objectives and 64 specific sub-programs; each has accompanying implementation objectives. The Water Use Efficiency, Water Transfer, and Watershed Management Coordination Common Programs have less-developed objectives and actions.

There is overlap among some independent agency program goals and objectives with CALFED program goals and objectives. For example, an implementation objective of the Ecosystem Restoration Program is to "Restore riparian scrub, woodland, and forest habitat along largely nonvegetated, riprapped banks of Delta island levees, the Sacramento and San Joaquin Rivers, and their major tributaries." (CALFED Program Goals and Objectives, p. 8). The Department of Fish and Game Riparian Habitat Joint Venture program has a similar goal "to conserve, increase and improve riparian habitat to protect and enhance California's native resident bird and neotropical migratory birds." Both programs require field monitoring and focused research as part of accomplishing their

respective goals. These areas of overlap provide opportunities for CALFED (and CMARP in particular) to collaborate with such existing programs that are active, independent of CALFED. Attention to these opportunities, through active partnerships between participating scientists, will enable a contribution from cooperating agencies to targeted CALFED actions.

At the agency and program levels, the goals and objectives are of necessity very broad. In addition, CALFED goals and objectives are changing, as the programs become more refined. The CMARP program presented here is designed to address CALFED actions at a more conceptual level. However, in order to implement the proposed monitoring, assessment and research program, details of CALFED actions, such as time, place, and magnitude of the actions must be specified. Specification and prioritization of monitoring and research actions are the next steps for CMARP.

REFINEMENT OF CALFED PROPOSED ACTIONS

The CMARP is designed to meet likely CALFED implementation actions. The following documents were reviewed to provide information on CALFED objectives and likely implementation actions.

- CALFED Revised Phase II Report
- Developing a Draft Preferred Alternative
- Ecosystem Restoration Program Plan. Volume 1. Ecological Attributes of the San Francisco Bay-Delta Watershed
- Ecosystem Restoration Program Plan. Volume 2. Ecological Zone Visions
- Long-Term Levee Protection Plan
- Species and Habitats Conservation Strategy
- Storage and Conveyance Refinement Process Overview
- Strategic Plan for the Ecosystem Restoration Program
- Water Quality Program Plan
- Water Transfer Program Technical Appendix
- Water Use Efficiency Program Plan
- Watershed Program Plan

The CALFED Water Quality Program Plan went beyond listing goals and objectives and possible implementation actions to recommending specific monitoring and research studies. For the problem area of low dissolved-oxygen levels observed in the Stockton Ship Channel, for example, the following monitoring and research recommendations were made:

- Document sources of unpermitted discharge of waste from concentrated animal feedlots and other less-specific industrial sources in the Central Valley and beyond, which result in oxygen demand in the San Joaquin River each fall.
- Develop accurate models to determine substances introduced to the San Joaquin River near Stockton that will produce dissolved oxygen sags downstream and where the sags will be produced.
- Monitor to determine the current biological oxygen demand (BOD) and chemical oxygen demand loads in Stockton tributaries, the associated dissolved oxygen concentrations, and the potential impact of current BOD levels on the ecosystem.
- Conduct special studies in Five-Mile Slough, Mosher Slough, and the Calaveras River to determine if urban storm-water runoff is the cause of low dissolved oxygen concentrations.

As CALFED program actions become more defined, it will be possible to design a monitoring program to this level of specificity. However, even the Water Quality Program retains a Water Quality Technical Group charged with refining the Water Quality Program and recommended actions as the CALFED program changes. The proposed CMARP must be flexible enough to adapt to these changes. Example programmatic actions given in the CALFED Revised Phase II Report are presented in Table 2-1.

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Table 2-1. Programmatic actions given in CALFED Revised Phase II report.

Program	Actions
Water Quality	Agricultural Drainage and Runoff - Reduce selenium (agricultural subsurface drainage), salinity, pesticides, sediment, TOC (discharges from Delta islands), nutrients and ammonia, and pathogens (controlling inputs from rangelands, dairies, and confined-animal facilities).
	Human Health – Water-quality efforts focus on reducing constituents contributing toxicity to the ecosystem and affecting water users (including BOD) and on reducing reducing total organic carbon loading, salinity, and pathogens that degrade drinking water quality.
Ecosystem Restoration Program	Restore, protect, and manage important habitat types, including tidally influenced fresh and brackish-water marsh habitat; seasonal, fresh emergent, and nontidal perennial aquatic habitat; perennial grasslands; agricultural lands managed using "wildlife friendly" techniques; stream meander corridor and riparian land along the Sacramento River; and riparian woodland and shaded riverine aquatic habitat.
	Develop floodways along the lower Cosumnes and San Joaquin Rivers.
Water Use Efficiency	Work with the California Urban Water Conservation Council and the Agricultural Water Management Council to identify appropriate urban and agricultural water conservation measures, set appropriate levels of effort, and certify or endorse water suppliers that are implementing cost-effective feasible measures.
	Expand state and federal recycling programs to provide sharply increased levels of planning, technical, and financing assistance, and to develop new ways of providing assistance in the most effective manner.

INVENTORY OF CURRENT MONITORING AND RESEARCH PROGRAMS

The proposed CMARP program is based on utilizing existing monitoring and research programs where possible. In addition to taxpayer cost savings from elimination of duplicative efforts, existing monitoring and research programs have much of the necessary scientific expertise, years of historical data, and established connections with local groups and landowners.

The initial inventory of existing monitoring activities, conducted by CMARP, identifies existing environmental-monitoring programs in the CALFED regions. Information in the inventory includes program objectives, questions addressed through monitoring, spatial coverage, parameters monitored, and the primary person to contact. The database is searchable by CALFED common program or region. The inventory (Appendix *VI*) may be accessed on the World Wide Web at: http://www.sfei.org/cmarpinv. When completed, the inventory will reside on the CALFED server (http://calfed.ca.gov) and be linked with California Environmental Resources Evaluation System (CERES, http://ceres.ca.gov).

The inventory was prepared to give CMARP a point-of-reference regarding what data are currently being collected. We are keenly aware that an enormous volume of information is already being collected and clearly, to be successful, CMARP must find ways to incorporate these data collection efforts. Just as clear is the fact that these existing data collection efforts are not going to cover all the monitoring and research data needs that CMARP ultimately must

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serve. Subsequent efforts of CMARP, addressed in part in later sections of this report, must identify the gaps in current data collection with respect to overall goals and objectives of CALFED. Upon identification of these gaps, CMARP will be responsible for determining how to fill these gaps with supplementary monitoring and research data-collection efforts.

The inventory includes information from several existing inventories, which are linked from the CMARP inventory site:

- UC Davis' Information Center for the Environment (ICE).
- Watershed Programs Inventory
- Ecosystem Restoration Programs Inventory
- Noxious Weeds Survey
- SFEI's inventory of water-quality-monitoring programs in the Bay-Delta, recently completed for the State Water Quality Control Board.
- DWR's Compendium of Water Quality Investigations (not yet linked to the inventory).

Many other monitoring and research programs have been added, and more are being added as additional request forms are returned. As of mid-January 1999, there are 622 monitoring and research programs in the inventory. These programs include a wide range of Federal, State, municipal, local, and volunteer programs and encompass most of the CALFED program areas.

More than 184 ecosystem restoration programs have been identified in the Sacramento River Watershed (Table 2-2), and more than 125 Water-Quality monitoring programs were identified in San Francisco Bay.

Examples of WWW site information for nine of the largest programs are listed in Appendix *VI* and summarized in Table 2-3. Annual expenditures on monitoring and research in the CALFED regions by those programs is almost $27 million of the approximately $33 million currently spent. This is likely to be an underestimate of the total of all existing programs, and does not include Category III costs.

The WWW site uses database-search procedures to list information about each existing monitoring program. The inventory may be searched by CALFED Common Program and by general geographic area. Information about programs in the inventory includes program objectives, questions addressed through monitoring, spatial coverage, parameters monitored, and primary contact. Currently one can search using any string of words. More sophisticated search capabilities are being designed to allow keyword searching. Sampling-site maps are included for programs if they were made available.

Table 2-2. Number of existing monitoring programs* compiled in the Inventory and sorted by CALFED Common Program and geographic region.

	Ecosystem Restoration	Delta Levees	Watershed Management	Water Quality	Water Transfers/ Use Efficiency**	Totals
San Joaquin River	76	0	37	21	0	134
Sacramento River	184	0	12	39	0	235
Bay	15	0	1	128	0	144
Delta	53	2	3	51	2	111
Totals	328	2	53	239	2	624

- Several levee monitoring programs and sources of water transfer monitoring information have been identified but are not yet included in the inventory.

** Some water transfer monitoring information on ground- and surface-water levels is categorized under "Watershed Management"

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Table 2-3. Summary of information about the largest existing monitoring and research programs in the CALFED Region. Costs are annual estimates.

Organization	Areas	Time Frame	Monitoring	Applied Research	Management & Administration	Total
San Francisco Estuary Institute (SFEI)	Bay Region	1993 - present	$2.5 M	$1.5 M	$0.4 M	$4.4 M
Interagency Ecological Program (IEP)	Bay and Delta Region	1996 - present	$4.9 M	$6.3 M	$1.5 M	$12.7 M
Comprehensive Assessment and Monitoring Program (CAMP), CVPIA-FWS	Sacramento and San Joaquin River Regions	1997 - present (1952 earliest subprogram begun)	$2.4 M	$0	$132,000	$2.5 M
Sacramento River Watershed Program (SRWP)	Sacramento River Region	1996 - present	$0.9 M	$0.1	$0.5 M	$1.5 M
Municipal Water Quality Investigations Program (MWQIP)	Delta Region	1982 - present	$0.4 M	$1.2 M	$0.3 M	$1.9 M
Sacramento Coordinated Monitoring Program (SCMP)	Sacramento and San Joaquin River Regions	1992 - present	$0.4 M	not reported	$0.1 M	$0.5 M
USGS San Francisco Bay and Delta Ecosystem Program	San Francisco Bay and Delta Regions	1995	$0	$1+ M	$0	$1+ M
USGS National Water Quality Assessment Program	Sacramento and San Joaquin River Regions	1991 - present	$2.2 M	$0	$0	$2.2 M
East Bay Municipal Utility District (EBMUD) Mokelumne River	Central Valley; Mokelumne River	1990 - present	$1.0 M	Active; amount not reported	$0	$1.0 M
DWR-SB 1086 Program	Sacramento River Region	1993 – present	$0.15 M	$0	$0.15 M	$0.3 M
DWR-Northern California Water Management Program	Sacramento River Region	1950 – present	$0.4 M	$0	$0	$0.4 M
DWR-Water and Environmental Monitoring Program	Sacramento and San Joaquin Rivers	1950 – present	$3.0 M	$0	$0	$3.0 M
Grasslands Bypass Program	San Joaquin River Basin	1996 - present	$0.75 M	$0.5 M	$0	$0
Total	---	---	$19 M	$10.6 M	$3.05 M	$32.65 M

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Chapter 3. USES OF CONCEPTUAL MODELS IN MONITORING AND RESEARCH DESIGN

INTRODUCTION

The term "conceptual model," in the context of environmental monitoring, has been generally defined as a "description of causes and effects that define how environmental changes are expected to occur" (National Research Council, 1990). The intention of conceptual modeling is to show how processes may be linked across space, time, and trophic levels (cause-effect relations) to help formulate specific testable questions to be answered through monitoring and research, and to lead to predictions about the effects of environmental perturbations or management actions. In their simplest form, conceptual models can be used to describe complex system processes to policy makers and to the public. Conceptual models do not represent finished products, however. Rather, it is the process of thinking about, developing, and revising conceptual models that provides the greatest benefit to the users. As described in the Strategic Plan for [the CALFED] Ecosystem Restoration Program (1998),

> *"Conceptual models are based on concepts that can and should change as monitoring, research, and adaptive probing provide new knowledge about the ecosystem. When key concepts change, the conceptual models should be updated to reflect these changes, thereby paving the way toward changes in management."*

Despite the importance of conceptual models in environmental management, existing explicit models of the features of the San Francisco Bay-Delta and its watershed are limited to a few species and system functions. Bay, Delta, and watershed scientists, engineers, and resource managers have developed ideas about how particular features of the system function and may be influenced by natural and human-induced stressors, but these ideas have seldom been presented in a format that can be shared with and discussed by others. With the recognition that conceptual models should be the centerpiece of the design of both monitoring and research programs directed toward CALFED needs, the development of explicit models of major features of the estuary and its watershed is an important thrust of CMARP.

DEVELOPMENT OF CONCEPTUAL MODELS IN CMARP

In June 1998, CALFED and agency staff, university researchers, stakeholders, and representatives of restoration and monitoring programs from outside California participated in a workshop to discuss the role of conceptual modeling in developing CMARP research and monitoring programs (see notes from the workshop in Appendix *V*). The participants of the workshop, drawing on experience gained in programs in Puget Sound, Chesapeake Bay, and South Florida, as well as in San Francisco Bay-Delta and its watersheds, concluded that conceptual models must play an important role in the design of CALFED programs. However, workshop participants agreed that existing models are mostly implicit, i.e., not well documented, and are not generally available. Moreover, it was agreed that CALFED and local, state and federal agencies are presently not making good use of conceptual models in developing monitoring/restoration programs, in adaptive management, or in communication with other scientists, managers, and the public.

Subsequent to the June workshop, the CMARP workteams have incorporated conceptual modeling as an integral part of the monitoring and research design process. Using existing knowledge and

theories, the workteams have identified and described the key features or attributes of the system under study, the inter-relations among them, and the important environmental factors (including stressors) that influence them. Existing published versions of these models take a variety of forms, including descriptive texts, complex diagrams, and combinations thereof. Whatever the format or complexity, the intent of these models is to provide the authors' written descriptions of the specific habitat, species, or system attributes and functions and the forces acting upon them. The Fish-X2 and delta smelt conceptual models, as examples, provide two contrasting approaches to ecosystem modeling; the first model (depicted in Figures. 3-1 to 3-4) describes an ecological process, while the second (Figure 3-5) is an example of a species-specific model.

The Fish-X2 model (see Appendix *VII.A.*1 for details) summarizes a broad spectrum of available information (Interagency Ecological Program Technical Report 52). Understanding the underlying mechanisms for the apparent fish-X2 relationships is of great importance because these relationships form the basis for the current X2 salinity standard (the distance in kilometers up the axis of the estuary to where the tidally-averaged near-bottom salinity is 2 practical salinity units [PSU]). The possible mechanisms affected by X2 that are important to the selected fish species are summarized here in a matrix (Figure 3-1). The potential causative pathways underlying the fish-X2 relationships are summarized graphically (Figure 3-2) in a way that serves to illustrate that both trophic and physical processes may be important and that there may be multiple causes of the observed relationships. Two additional graphical displays (Figures 3-3 and 3-4) summarize the complex physical processes that may be involved in the fish-X2 relationships.

The delta smelt conceptual model (Figure 3-5; see Appendix *VII.A.7* for details) adopts a life cycle approach, emphasizing the life stages that appear to be important in understanding the population dynamics of the species. The model presents some of the major questions regarding processes that may be affecting the delta smelt population and includes some of the graphical data relationships that form the basis of major hypotheses. This conceptual model emphasizes the need for continuing or additional monitoring and research on all life stages.

Conceptual models of various physical, chemical, and biological processes and systems are being developed within each of the CALFED program areas (see Appendix *VII*).

In many instances, there is not unanimity of opinion about the described features and linkages in the models that have been developed thus far. However, the point of preparing and presenting these conceptual models is to BEGIN the discussion of the attributes, functions, and linkages described by the models, to undertake the formulation of specific questions and hypotheses, to develop appropriate monitoring and research strategies, and to provide a scientific basis for adaptive management.

MONITORING PROGRAM DESIGN

Conceptual models of individual species (e.g., delta smelt or winter-run salmon), habitat types (e.g., shallow water), physical processes (e.g., sediment transport), or ecosystem functions (e.g., primary productivity) lead naturally to the development of working hypotheses about important linkages and how the system will respond to management interventions. These hypotheses, in turn, suggest the variables that will need to be measured in order to document the status and trends of system properties, and more generalized system indicators that can provide the basis for assessing progress in meeting CALFED's objectives.

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	Species										
	CF	PH	SF	WS	AS	SB	LF	DS	ST	CS	NM
Spawning Habitat Space		○		•	●	○	•	●	○	○	
Spawning Habitat Access				•	○	○			○	○	
Co-occurrence of Food		●		•	•	●	●	●	●	•	•
Rearing Habitat Space	○	●	●	●	●	○	○	●	●	•	•
Predation Avoidance: Turbidity		•			•	○	•	•	•	○	●
Predation Avoidance: Shallow	•	•	•						•	○	
Predation Avoidance: Encounter	•						•	●	•	•	
Reduced Entrainment (CVP-SWP)			•	○	○	○	○	○	•	○	○
Reduced Entrainment (PG&E)	•		•		○	○	●	●	•	○	•
Reduced Entrainment (Agricultural)			•		•	○	•	●	•	•	•
Toxic Dilution	•	•	•	•	•	○	•	•	●	•	•
Transport	•			○	○	○	○	•	•		
Gravitational Circulation Strength	●	○	●			●	●	●			●
Entrapment Zone Residence Time						●	●	●			●
Temperature (As affected by flow)					•	•				○	•
Strong Migratory Cues	•	•	•	●	○	•			•	○	
Higher Production of Food	•	•			●	●	●	●	•		●

Relative Uncertainty

• Higher

○ Lower

Importance

● High

• Low

● Upstream Effect

Figure 3-1. Some potential mechanisms underlying the relationships between bay-delta species and X2, the degree of uncertainty about the relationships, and the assumed relative importance of the mechanisms. Species and abbreviations are: bay shrimp CF, herring PH, starry flounder SF, white sturgeon WS, American shad AS, striped bass SB, longfin smelt LF, Delta smelt DS, splittail ST, Chinook salmon CS, Neomysis NM (see Interagency Ecological Program Technical Report 52, 1997).

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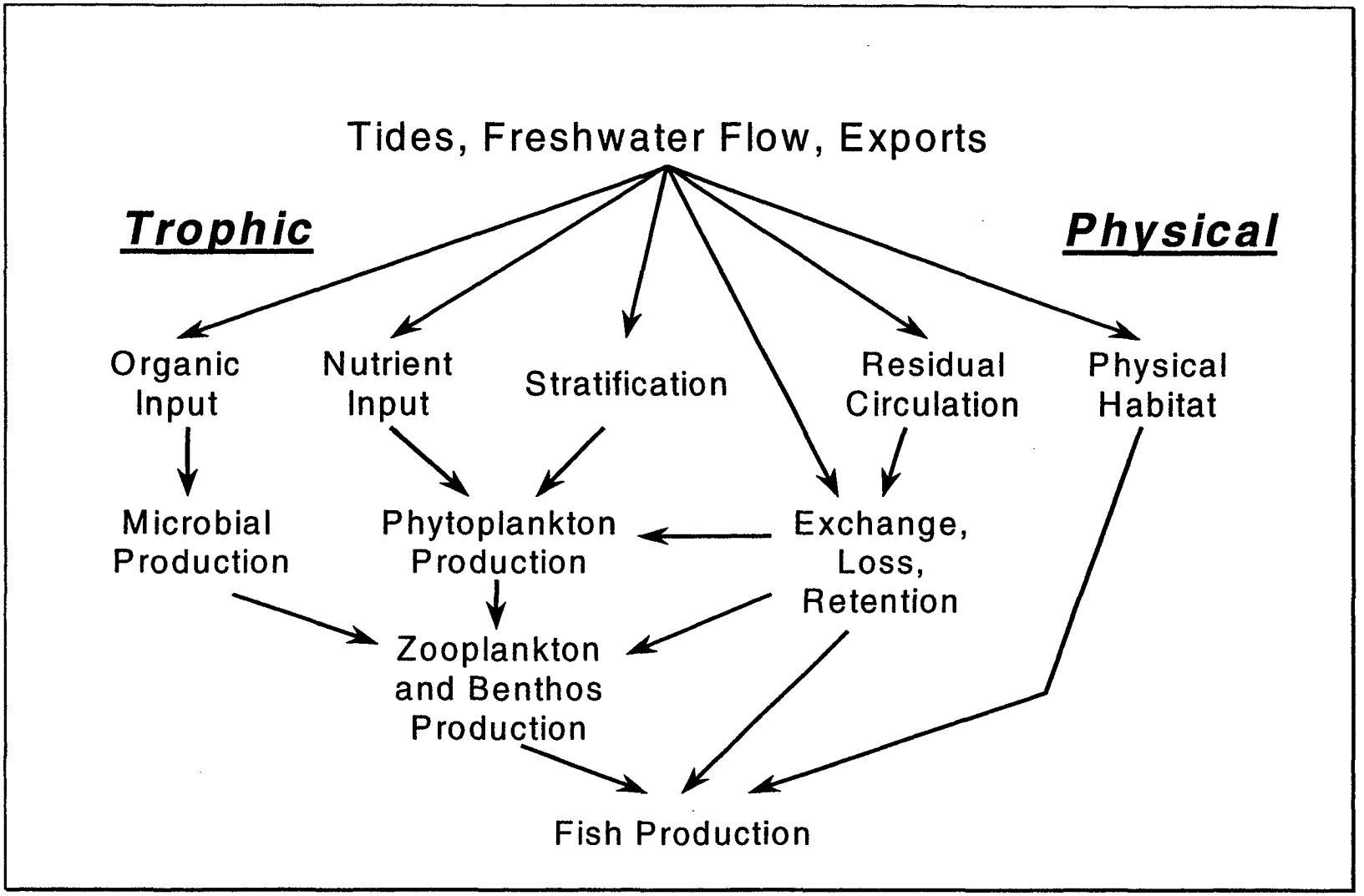

Figure 3-2. Potential causative pathways underlying the fish-X2 relationships. "Trophic" pathways based largely on feeding relationships, "physical" pathways arise through interactions between physical conditions and abundances of species of interest.

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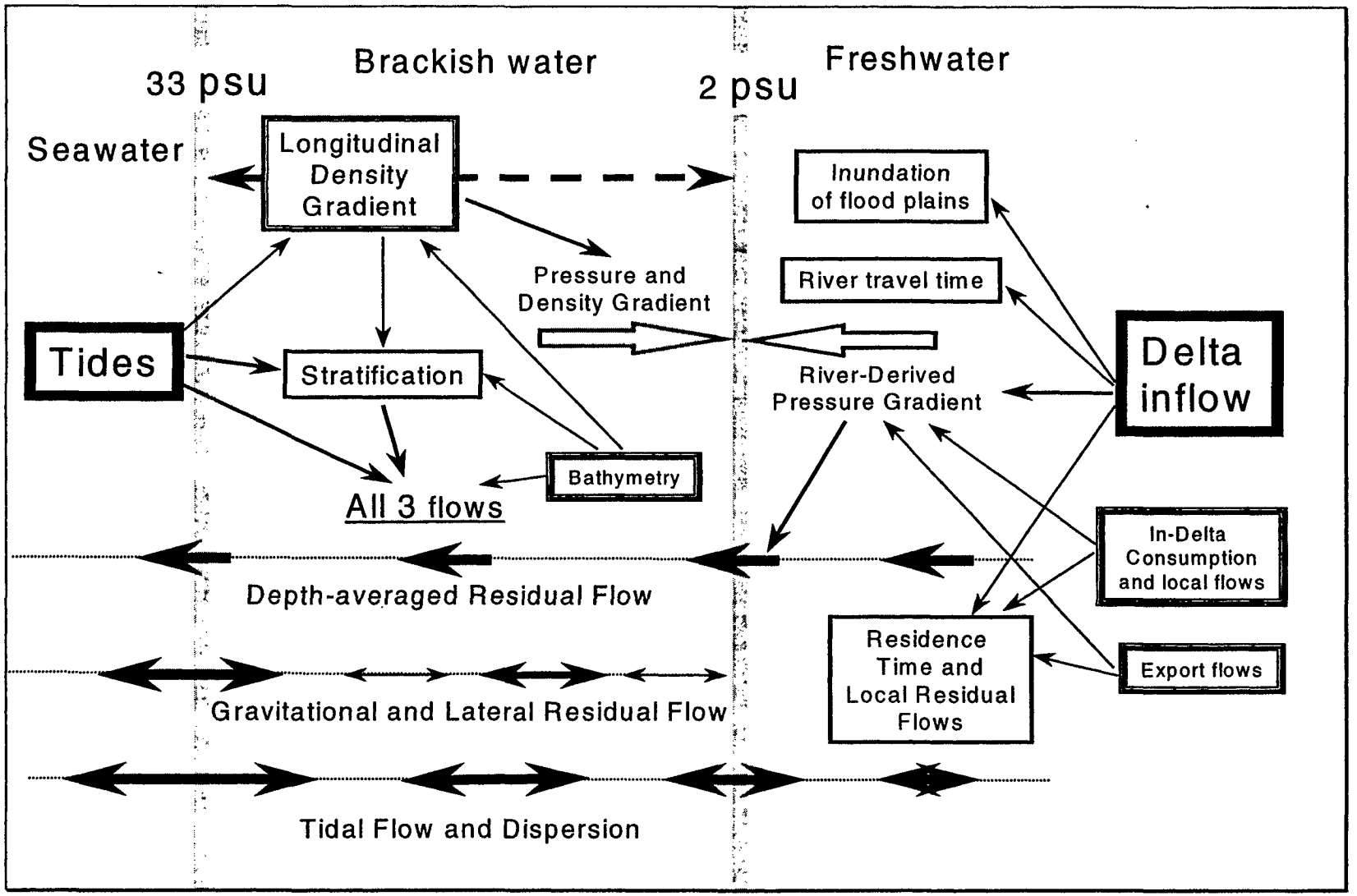

Figure 3-3. Conceptual model of the relative influences of water flow (both river and tidal flows) on the movement of water and salt in the estuary. The principle influence of freshwater flow on the brackish part of the estuary is indirect, occurring through pressure and salinity gradients.

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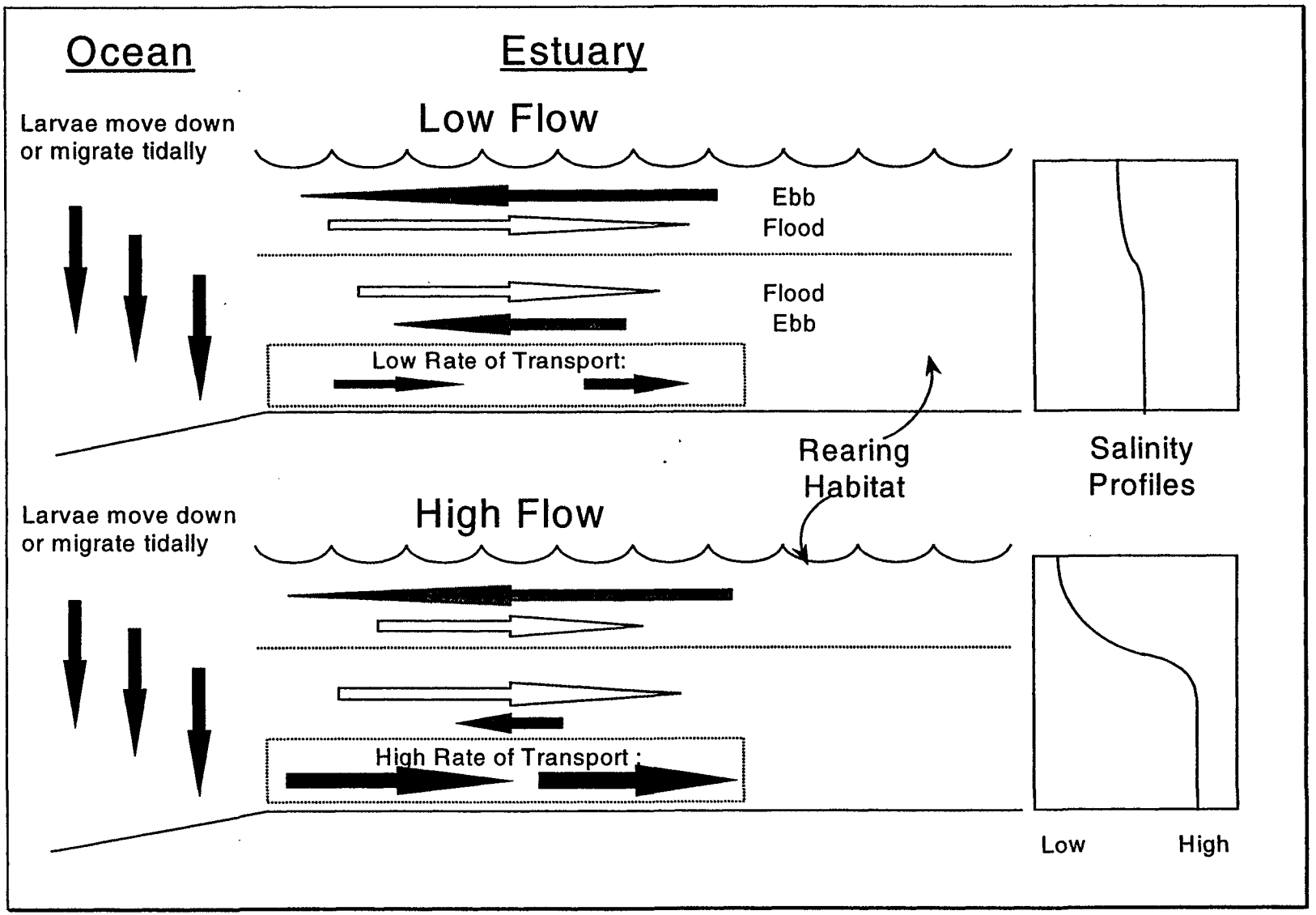

Figure 3-4. Conceptual model of the fish-X2 gravitational circulation mechanism, specifically the effect of the relative strength of gravitational circulation on the movement of fish larvae to rearing habitat in the upper estuary.

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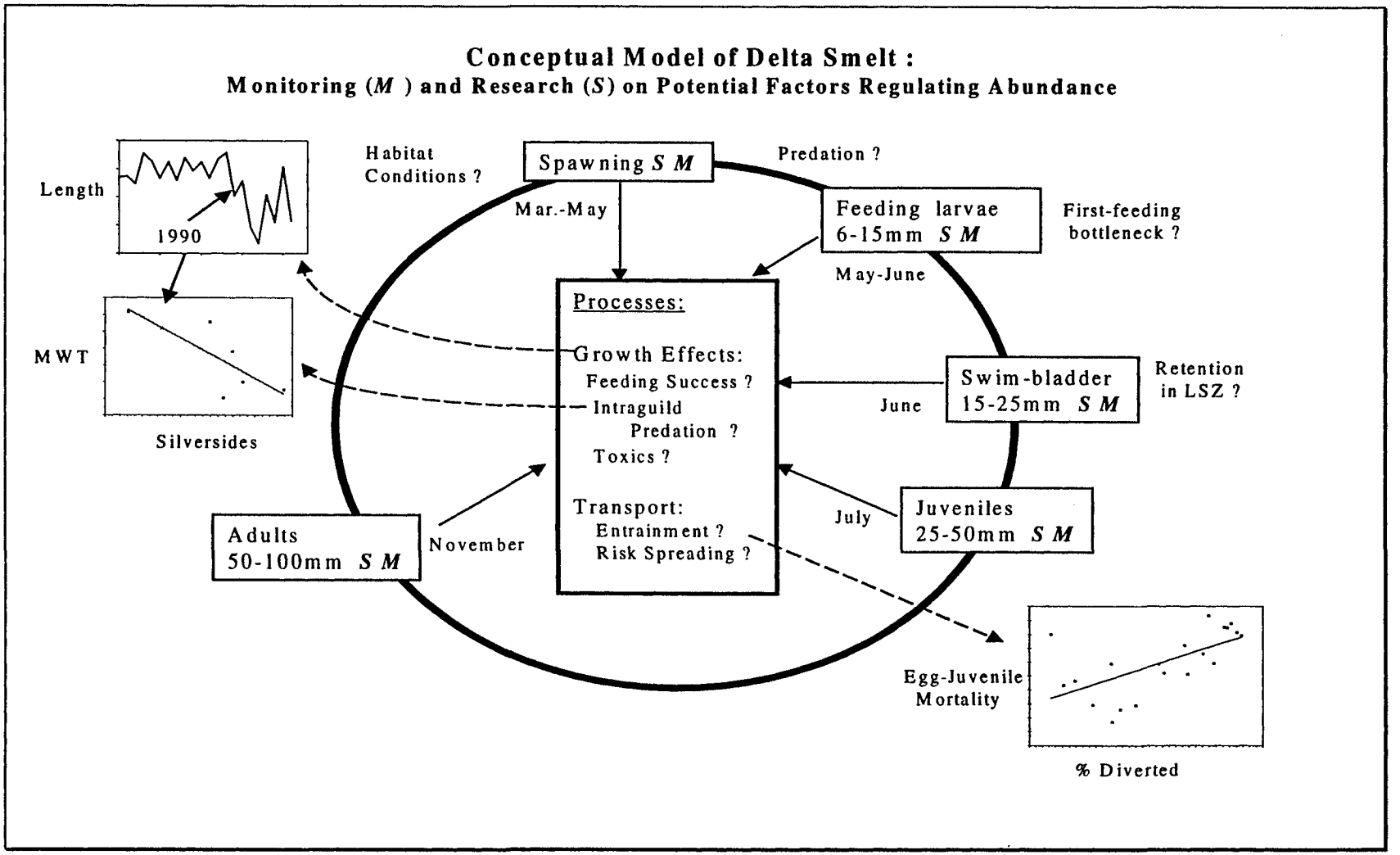

Figure 3-5. Conceptual model of the annual life cycle of Delta smelt, the potential important mechanisms regulating smelt abundance, and proposed areas for the focus of monitoring (M) and research (S).

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A critical role of conceptual modeling is to narrow the list of the many possible monitoring variables to those that, within appropriate space and time scales, will produce the specific information required, i.e., that are focused on the system attributes that are of greatest concern. Some of these variables can also serve as the broader indicators or attributes that are expected to change over time in response to restoration actions. A primary purpose of the CALFED monitoring program will be to measure the status of those indicators, i.e., collecting and reporting on basic information about the critical species, habitats, and system functions and any changes that occur as a result of management actions.

For many attributes of the San Francisco Bay-Delta and watershed system, monitoring programs are already in place that can be used in the formulation and testing of hypotheses. The conceptual models assist in uncovering the gaps in these programs such as the need for more complete spatial or temporal coverage, the need for better coordination, the need for improved standardization, the need for additional variables, or the need for new or more sophisticated interpretation of existing data.

RESEARCH PROGRAM DESIGN

Conceptual models are extremely useful in identifying gaps in our understanding of critical system processes and interactions. Addressing these gaps will require targeted research investigations that can include testing of hypotheses, distinguishing among alternative hypotheses, addressing critical unanswered questions, and quantifying interactions, e.g., through combinations of field and laboratory experimentation and/or quantitative numerical modeling.

Primary goals of the CALFED Focused Research Program are to:

- build upon our existing understanding of physical, chemical, and biological processes in those areas that are relevant to CALFED program actions,
- provide information useful in evaluating the effectiveness of existing monitoring protocols and the appropriateness of monitoring attributes,
- test causal relationships among environmental variables identified in conceptual models,
- reduce areas of scientific uncertainty regarding management actions,
- incorporate relevant new information from non-CALFED-sponsored research, and
- revise conceptual and numerical models as our understanding increases.

To achieve these goals, the CALFED research program will establish clear priorities for research and incorporate peer review of proposals, ongoing work, and finished products.

The conceptual models developed to date suggest a variety of research questions that are very relevant to the fundamental questions being addressed by CALFED and that are critical to the design of "adaptive probing to distinguish among alternative hypotheses about the best management solutions" (Strategic Plan for ERP, 1998).

A major CMARP task during the next six months will be to synthesize and prioritize among the many research ideas and to develop a strategy for undertaking the most critical of these targeted research efforts. The strategy will include two mechanisms for supporting CALFED-targeted research:

1. an annual request-for-proposal process in which the scientific community at large will be asked to submit research ideas that address specific CALFED research needs, and
2. the establishment of a directed research effort, overseen by a CALFED Science Review Board, to undertake a sustained, coordinated, interdisciplinary program of study and experimentation on specific problems.

The CMARP Steering Committee, through its technical workteams, is compiling a list of relevant research questions in each of the common program areas. This list will be used to issue a series of CALFED Proposal Solicitation Packages (PSPs) for research directed toward answering the questions, and for implementing a longer-term, directed research program. Details about the CALFED Research Program are found in the Appendices.

ADAPTIVE MANAGEMENT

Conceptual models provide a means for "link[ing] human activities or management actions to outcomes important to society" (Strategic Plan for ERP, 1998). As described by Walters (1997),

"Adaptive management should begin with a concerted effort to integrate existing interdisciplinary experience and scientific information into dynamic models that attempt to make predictions about the impacts of alternative policies. This modeling step is intended to serve three functions:

- *problem clarification and enhanced communication among scientists, managers, and other stakeholders;*
- *policy screening to eliminate options that are most likely incapable of doing much good, because of inadequate scale or type of impact; and*
- *identification of key knowledge gaps that make model predictions suspect."*

It is the task of the modeling effort to describe the relationships that potentially link management actions, through physical, chemical, or ecological processes, to consequences or outcomes for species or systems.

"[The conceptual] models provide the basis for informed management actions from which a better understanding of [a] system can be derived. The knowledge and hypotheses about [system] responses summarized in conceptual models lead directly to potential restoration actions, although each model is likely to suggest many possible courses of action. Such models, and simulation models developed from them, are essential for conveying why certain management actions are expected to produce desirable effects. Alternative, competing conceptual models can illustrate areas of uncertainty, paving the way for suitably-scaled experimental manipulations designed to both restore the system (according to more widely accepted models) and explore it (to test the models)." (Strategic Plan for ERP, 1998).

The models being developed (see Appendices) will be used to examine alternative hypotheses about how the bay/delta watershed systems work in order to identify and clarify situations in which uncertainties may influence decisions about specific management actions, and consensus understanding suggests where management actions are warranted.

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Chapter 4. MONITORING AND FOCUSED RESEARCH PROGRAM DESIGN

Part A, INTRODUCTION AND READER'S GUIDE

Thirty CMARP Workteams developed conceptual models and monitoring and research recommendations based on the information needs of the eight CALFED programs (Ecosystem Restoration, Water Quality, Delta Levees System Integrity Storage, Conveyance, Water Transfers, Water Use Efficiency, and Watershed Management Coordination) and supporting programs (Category III and Conservation Strategy). This chapter summarizes the CMARP Workteam monitoring and research recommendations for each CALFED program. Details of the conceptual models and associated monitoring and research plans appear as appendices to this report. Each section (Chapter 4.A-K) addresses the following:

- CALFED mission, goals and objectives—Lists relevant CALFED goals and objectives addressed by the proposed monitoring. In some cases, monitoring for one CALFED program may fulfill goals and objectives of other CALFED programs.
- Goals and objectives of monitoring plan—Explains how the monitoring plan addresses CALFED goals.
- Monitoring elements—Summarizes the major monitoring elements for each common program.
- Research recommendations—Lists the most important research recommendations for each common program.
- Linkages among program elements—Identifies the linkages between monitoring for a particular CALFED program and the monitoring proposed for other CALFED programs. Identification of the linkages is important for integration of monitoring elements into a cohesive and coordinated program.

The CMARP workteams recommended 640 monitoring elements and 490 research topics. These recommendations are compiled in two large spreadsheets as sub-appendices to the Data Assessment and Reporting Team Appendix (Appendix *VII.I*) and are available on the CMARP web-page. This list includes existing monitoring programs as well as new monitoring recommendations and has not been prioritized.

To provide a broad overview of the monitoring recommendations from all of the CMARP Workteams, Table 4-1 summarizes the recommended monitoring elements and integrates them with indicators proposed by the CALFED ERP Indicators Group. Some workteams, such as Delta Levees System Integrity, also identified indicators. However, for illustration purposes, only the proposed ERP indicators are included in this table. The monitoring elements in Table 4-1 are organized under eight major headings and thirty-three categories. The eight major headings are:

- Biota
- Energetics and Nutrient Cycling
- Geomorphology
- Habitat
- Human Welfare
- Hydrology
- Land use, Water Use & Resource Management
- Meteorology

The categories range from "Birds" to "Bay-Delta Hydrodynamics" to "Water Transfer Effects."

For example, the first category under the "Biota" heading is "Algae & Plankton." The box to the right contains the specific monitoring elements identified for algae, phytoplankton and zooplankton. The listed CMARP workteams for the Water Quality Program (WQ) and Ecosystem Restoration Program (ERP) recommended various subsets of these monitoring elements. The next box to the right contains related indicators proposed by the CALFED ERP Indicators Group.
Future work will include developing and linking indicators to identified monitoring elements for all programs. Indicator selection and development are discussed briefly in Chapter 5.

Table 4-1. Summary of Monitoring Elements recommended by CMARP Workteams and merged with indicators proposed by the CALFED ERP Indicators Group. The monitoring elements are arranged under the general headings of Biota, Geomorphology, Energetics & Nutrient Cycling, Habitat, Human Welfare, Hydrology, Land use & Resource Management, and Meteorology. Each general heading is further organized into categories. Workteams are organized by CALFED Program (**DL:** Delta Levees System Integrity; **ERP:** Ecosystem Restoration Program; **WMCP:** Watershed Management Coordination Program ; **WQ:** Water Quality; **WT:** Water Transfers; **WUE:** Water Use Efficiency). Indicators Group designations are: ARFE=Alluvial River-Floodplain Ecosystem, DE=Delta, SFBE=Greater San Francisco Bay, URFE=Upland River-Floodplain Ecosystem; No designation refers to all systems.

	Category	Monitoring Elements	CMARP Workteams	Proposed Indicators (ERP Indicators Group)
		BIOTA		
1	**Algae & Plankton**	**Algae:** Community survey; biomass relative to nutrients **Phytoplankton:** Biomass; primary productivity; species composition; assemblages **Zooplankton:** Presence/absence; abundance; community; species abundance; biomass; size composition; secondary production; flux	**WQ:** Sacramento River, San Joaquin River, Contaminants **ERP:** Hydrodynamics, Benthic Macroinvertebrates, Fluvial Geomorphology, Estuarine System Productivity, Shallow Water Habitats,Fish X2, Salmon	Trends in abundance, diversity, composition, and distribution of native phytoplankton and zooplankton assemblages (DE, SFBE); Abundance of zooplankton (DE, SFBE); Primary production rates (DE, SFBE)
2	**Birds**	Abundance; distribution; reproduction; species richness/diversity; percent breeding species; reproductive success; percent migrants, *genetic diversity, guild structure; clutch size; behavior; sign*	**ERP:** Fluvial Geomorphology, Shallow Water Habitats	Trends in abundance, reproductive success, diversity, composition, and distribution of native resident and *migratory birds; Population trends of selected listed species*
3	**Contaminants (Biota)**	**Algae:** Community assessment **Birds:** Organochlorines, Hg, Se in eggs; Contaminant load **Fish:** bioaccumulation of metals, trace elements, organics, Hg, PCBs, chlorinated insecticides; condition indices; bioassessment surveys; exposure effects; contaminant load **Invertebrate-clams, crustaceans:** bioaccumulation of metals, trace elements, organics, condition indices; contaminant load **Invertebrates:** bioassessment, exposure effects **Small mammals:** contaminant load **Plankton:** Phytoplankton & Zooplankton exposure effects **Vegetation:** contaminant load, bioassessment	**ERP:** Estuarine System Productivity (lower), Shallow Water Habitat, Fluvial Geomorphology **WQ:** Contaminants, Sacramento River, San Joaquin River	Toxicity Concentrations in water and sediment Tissue concentrations Bioassays Biomarkers Bioindicators Contaminant loading
4	**Fish**	**General:** striped bass, splittail, white & green sturgeon, American shad, salmon, steelhead, resident fishes distribution & abundance; relative abundance; community survey; species richness; condition indices; diet; feeding success; biomass; health; growth rate; size class distribution; reproductive success; lamprey spawning; flux; secondary production; species of special concern; distribution of larvae,juveniles,adults in floodplains; emigration past fish ladder; exports from bypasses to rivers; fish screening effects- number salvaged & lost by species; ocean abundance of salmon prey; harvest of wild & introduced species **Delta Smelt:** Adult, juvenile, larval, spawning **Salmon & Steelhead:** ***-Adult:*** ocean conditions; migration timing; straying; pre-spawning mortality; harvest (angler survey, creel survey, ocean); survival; escapement (carcass) surveys; age analysis; redd distribution & stranding rates; egg viability; origin determination; percent hatchery fish in escapement; hatchery fish gamete viability; habitat use; steelhead/rainbow trout allelic variation, dietary analysis,distribution ***-Juvenile:*** Outmigration abundance, timing, maturity; distribution vs. streambed complexity; growth; lipid storage; abundance & health indices; stranding rates; smoltification timing; smolt survival; fry emigration	**ERP:** Bay-Delta Productivity (upper), River Resident Fish, Steelhead, Fluvial Geomorphology, Fish X2, Hydrodynamics, Shallow Water Habitats, Delta Smelt, Salmon **WQ:** Contaminants, San Joaquin River, Sacramento River	Trends in abundance, diversity, composition, distribution and trophic structure of natives resident and anadromous fishes; Presence and distribution of native and migratory fish species; Population trends of selected listed species; Number of unnatural barriers interfering with natural movements of native species, flow, sediment & nutrient transport/supply (DE), Cohort replacement & survival rates of selected life stages of certain fish (DE); Invasive introduced species -- Measures of new invasions; Abundance, spatial extent and distribution of selected species; Number of selected species eradicated or exhibiting no net increase in distribution.

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	Category	Monitoring Elements	CMARP Workteams	Proposed Indicators (ERP Indicators Group)
5	**Non-Indigenous Species**	Non-indigenous species (invasive fish, invertebrates, animals, plants)- Percent non-indigenous species; presence; distribution; trends; transport & release; new introductions; monitor floating docks & buoys, shallow water margins, small water bodies, small tributary rivers and sloughs, artificial or altered lagoons, shipping facilities & ship exteriors, ship ballast water discharges & seawater system, baitworm seaweed & water packing; Update species keys;	**ERP:** Shallow Water Habitats, Non-Indigenous Species, Fluvial Geomorphology, Resident Fish **WMCP:** Watershed	Invasive introduced species: -Measures of new invasions -Abundance, spatial extent and distribution of selected species -Number of selected species eradicated or exhibiting no net increase in distribution
6	**Invertebrates**	**Benthic:** taxa richness, diversity, EPT taxa & index; dominant species, percent dominant taxon, Hilsenhoff Biotic Index, biomass; size distribution, species composition and abundance; community analysis; secondary production; **Terrestrial:** abundance, diversity, composition, distribution **Aquatic:** distribution; abundance; harvested species' diet & health; mysid abundance	**ERP:** Salmon, Benthic Macroinvertebrates, Fish X2, Estuarine System Productivity, Bay-Delta System Productivity, Shallow Water Habitats **WQ:** Contaminants, San Joaquin River, Sacramento R.	Trends in the abundance, diversity, composition, and distribution of benthic invertebrate assemblages, by functional group (DE, SFBE); Trends in the abundance, diversity, composition, and distribution of riparian insect assemblages, by functional group (URFE, ARFE); Population trends of selected listed species; Secondary production of zoobenthos (DE, SFBE)
7	**Vegetation**	Canopy cover; productivity; biomass; plant architecture; distribution, abundance, richness; riparian structure, stand attributes; upland land cover and structure; vegetation changes after flooding	**DL:** Delta Levees **ERP:** Fluvial Geomorphology, Shallow Water Habitat **WMCP:** Watershed	Trends in distribution, diversity, and structural complexity of native plant associations; Population trends of selected listed species
8	**Terrestrial & Aquatic Species (General)**	Status, distribution, abundance & population trends by taxa in floodplain, riparian, wetland habitats, bypasses & riparian corridors; Extent, distribution, population trends of commercial/recreational species; reproductive success; individual morphometry; harvest of wild & introduced species; wildlife-incidence of disease & deformities; trophic structure; small mammals (biomass, genetic diversity, sign, species richness, trends in diversity, composition & distribution); water conservation & water transfer environmental effects; mitigation for levee improvements;	**DL:** Delta Levees **ERP:** Fluvial Geomorphology, Shallow Water Habitats **WMCP:** Watershed **WT:** Water Transfers **WUE:** Water Use Efficiency	Trends in the abundance, diversity, composition, and distribution of native mammals (URFE, ARFE, DE); Fish and wildlife health; Population trends of selected listed species
		ENERGETICS & NUTRIENT CYCLING		
9	**Energetics & Nutrient Cycling**	Primary productivity, carbon pools; nitrogen fixation; detritus composition & transport; organic carbon input in brackish estuaries; flux of organic carbon, N, P in freshwater/tidal marshes; planktonic nutrient cycling; chlorophyll; vegetation biomass, carbon content & litter accumulation; carbon & nutrients following flood events; microbial communities & production. Ratio of floodplain to river production; export of organic materials from floodplain to river channel [See also nutrients in Water Quality, Sediment, & Soils]	**ERP:** Fish X2, Fluvial Geomorphology, Shallow Water Habitats, Estuarine System Productivity **WMCP:** Watershed **WQ:** Sacramento River, San Joaquin River	Nutrients from salmon carcasses(URFE); Organic input from grazing animals (URFE); Nutrient loading (DE); Ratios of natural to anthropogenic sources of nutrients (URFE); Ratio of floodplain to river production (ARFE); Export of organic materials from floodplain to river channel (ARFE); Percent increase in dissolved N and P after overbank flows (ARFE); Dissolved N and P in groundwater at selected sites (ARFE); Flux of detrital organic matter (DE, SFBE);
		GEOMORPHOLOGY		
10	**Aquifers**	Boundary delineation & compaction; regional and local mapping of hydrogeologic boundaries; thickness and degree of confinement	**WT:** Water Transfers	
11	**Channel**	Bathymetric surveys; structural complexity; channel & bank stability & erosive resistance; streambed complexity; cross-sectional profile, hydraulic geometry, meander geometry, longitudinal profile, channel density, network order, channel changes after flooding; number freely meandering river miles;	**DL:** Delta Levees **ERP:** Hydrodynamics, Salmon, Benthic Macroinvertebrates, Steelhead, Shallow Water Habitats,Fluvial Geomorphology **WMCP:** Watershed	Mean width of available meander corridor (ARFE); Percent of river length not constrained by constructed levees (ARFE); pool to riffle ratio (URFE); Inter-annual comparison of fluvial geomorphic features (URFE); Percent of river miles exhibiting naturalistic meandering (ARFE); Linear distance of channels per unit area (DE); Proportion of 1st, 2nd, 3rd order channels/ unit area(DE); Bank slope(DE)

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	Category	Monitoring Elements	CMARP Workteams	Proposed Indicators (ERP Indicators Group)
12	**Land**	Subsidence (Delta island, Delta levees, Central Valley); land surface altitude; topographic/geologic characterization; landslides; floodplain features, surface roughness, basin topography	**DL:** Delta Levees **ERP:** Fluvial Geomorphology **WT:** Water Transfers **WMCP:** Watershed	Difference in percent of area flooded during MHHW versus MLLW (DE)
13	**Sediment**	**Chemistry:** ionized ammonia, total sulfides, total organic carbon, total nitrogen; phosphorous; micronutrients; salinity; pH; redox potential; conductivity **Contaminants:** Se, organics, organochlorines, resuspension mercury; toxicity; trace elements & metals; **Physical:** Texture; composition; grain size;particle size distribution; bulk density; deposition & resuspension dynamics; floodplain, bank, & channel deposits; organic matter; depth of detritus; substrate permeability; sediment production background rates; bioturbation depth; [See Water Quality for suspended sediments]	**ERP:** Estuarine System Productivity, Salmon, Fluvial Geomorphology, Shallow Water Habitats, Hydrodynamics, Benthic Invertebrates **WQ:** Contaminants **WMCP:** Watershed	Bedload movement (URFE); Sediment particle size and distribution (URFE, ARFE); Net change in depth per unit time of unconsolidated sediment (URFE, ARFE); Amount of coarse sediment delivered (as a proportion of pre-dam) (ARFE); Lateral exchange: river to floodplain (ARFE); Inter-annual comparison of fluvial geomorphic features (ARFE); Marsh plain & mudflat elevation relative to sea level (DE, SFBE); Change in area of Delta islands and islets (DE); Net sediment accretion rate relative to rate of sea-level rise at subtidal and intertidal sites (SFBE);
14	**Soils**	**General:** stability and erosive resistance; horizontal & vertical accretion & erosion; C, P, N, micronutrients, salinity, redox, pH; moisture; organic matter, particle size distribution; contaminants **Peat & organic:** oxidation; gradation, organic matter content, moisture, void ratio, compressibility, vertical & horizontal extent;	**DL:** Delta Levees **ERP:** Fluvial Geomorphology, Shallow Water Habitat **WMCP:** Watershed Management	
		HABITAT		
15	**Habitat**	**General**: habitat spatial extent, configuration, distribution, connectivity; patch classification, size frequency, diversity, temporal variability; habitat metrics & quality; tidal wetlands with natural flooding; total shoreline length; floodplain habitat proximity to topographic features, e.g. location of the thalweg & littoral zone; aerial extent of wetlands and seasonally wet environments; riparian habitat delineation & areal extent; detritus & debris; **Vegetation**- horizontal cover and vertical structure; canopy cover; riparian forest width, height, density relative to water temperature; changes after flooding **Channel:** river habitat vs. fish assemblage; floodplain inundation, frequency & duration; channel changes after flooding; steelhead & *salmon rearing habitat & spawning habitat investigations &* restoration; flooding effects on salmonid habitat; **Stressors**: impacts due to levee improvements & compensatory mitigation; occurrence of unnatural barriers interfering with movements of native species; water transfer & water conservation environmental effects; response to levee breeches/removal	**DL:** Delta Levees **ERP:** Steelhead, Fluvial Geomorphology, Salmon, Shallow Water Habitats, Benthic Macroinvertebrates **WMCP:** Watershed **WT:** *Water Transfers* **WUE:** Water Use Efficiency	Extent and distribution of patches of all natural habitat types; presence and distribution of species requiring multiple habitats; Abundance, distribution, and recruitment rate of large woody debris (URFE); Shaded riverine aquatic habitat (URFE); Diversity of flow velocity (URFE); Distribution and extent of floodplain habitats (ARFE); *Distribution and extent of littoral zone* (ARFE); *Percent of* river length not constrained by constructed levees (ARFE); Connectivity of riverine channels to wetlands (DE); ; Length of river channel obstructed by artificial barriers; Length of riparian corridor unobstructed by artificial barriers;
		HUMAN WELFARE		
16	**Flood**	levee inspection, high water monitoring & staking; flood emergency response status; flood fighting support; levee technical assessment	**DL:** Delta Levees	
17	**Health**	Risk assessment for Hg, Se; Mitigation of Se inputs into ducks, crabs & fish; drinking water impacts	**WQ:** Contaminants	Toxicity: Concentrations in water, sediment, tissue, bioassays, Biomarkers, Bioindicators, Contaminant loading;
18	**Population/ *Demographics***	Population; population within water service area boundaries;	**WT:** Water Transfers **WUE:** Water Use Efficiency	

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	Category	Monitoring Elements	CMARP Workteams	Proposed Indicators (ERP Indicators Group)
19	**Socio-Economic**	**General**: Income; rural businesses sales & employment; social & economic values related to community involvement, watershed management, recreation, habitat extent & species diversity; third party effects of water transfers and conservation; recycled water expenses & use benefits; delta operations outages, power operations & costs **Agriculture**: Value of agricultural output; agricultural employment; labor force and unemployment; social and economic values related to agricultural practices	**WMCP:** Watershed **WT:** Water Transfers **WUE:** Water Use Efficiency	
		HYDROLOGY		
20	**Bay-Delta Hydro-dyamics**	3D-Hydrodynamic Model; X2; delta export rates; channel tidal flows; historical bay-delta hydrodynamics studies; horizontal current patterns; ocean currents; sea level rise; shallow water hydrology; tidal prism conservation; hydroperiod; tidal regime; tidal prism; tidal time series flow; net tidally averaged flow; upwelling; water depth;	**DL:** Delta Levees **ERP:** Hydrodynamics, Salmon, Shallow Water Habitats, Estuarine System Productivity **WT:** Water Transfers	Water movement and vertical mixing at select locations throughout Bay (SFBE); X2 location (SFBE); Salinity at selected locations in the Bay (SFBE);
21	**Flow**	Adequate streamgage network; Daily flow; depth; diversions & withdrawals; Delta operations flow requirements; Delta inflow & outflow; installation & removal of barriers; flow gate operation; inflow rate; river time series; stage (height); discharge; velocity; velocity profiles; vertical hydraulic gradient; flood frequency & inundation; changes due to setback levees; peak flows; pulsing, flooding regime; floodplain inundation, frequency & duration; characterization of low flows; historic streamflow & stage data; hydroperiod; flow predictions from snowmelt & runoff models-runoff; evaporation; infiltration	**DL:** Delta Levees **ERP:** Fluvial Geomorphology, Estuarine System Productivity, Salmon, Hydrodynamics, Shallow Water Habitat, Benthic Macroinvertebrates, Steelhead **SC:** Storage & Conveyance **WMCP:** Watershed **WQ:** Contaminants, San Joaquin River **WT:** Water Transfers	Minimum base flows (URFE, ARFE); Seasonal shifts in river level (URFE, ARFE); Measures of variability (URFE, ARFE); Geographic distribution of flows (ARFE); Delta outflow (DE); X2 location (SFBE); Salinity at selected locations in the Bay (SFBE); Minimum surface area of floodplain inundated at least once every 2 years and every 10 years (ARFE); Flood duration (mean and variability) (ARFE); Mean annual frequency of floods (ARFE); Composite measures for freshwater flow rates, water residence time, and flow direction for selected channels (DE); Flows of tributaries mimic pattern of unimpaired flow (DE);
22	**Groundwater**	Discharge & recharge; levels; movement; water quality; sources; wetland storage & streambank storage; net infiltration	**DL:** Delta Levees **ERP:** Fluvial Geomorphology **WMCP:** Watershed **WT:** Water Transfers	Depth of water table (ARFE); Soil moisture levels, laterally from banks (ARFE); Characteristic plant communities (ARFE); Width of riparian corridor (ARFE)
23	**Reservoirs**	Conditions; water quality; temperature; storage; suspended sediments deliver & types to impoundments	**ERP:** Steelhead **WMCP:** Watershed **WT:** Water Transfers	
24	**Water Quality**	**Contaminants**: Pesticides & other organic chemicals, MTBE, bromide, dissolved & total organic carbon, THMFP, dissolved & total trace metals including mercury & methylmercury, selenium, pathogens, nutrients. Contaminants & nutrient loading from sources such as dredging operations, wastewater discharge, cannery effluent, urban runoff, dairies, farms & rangeland. Aquatic toxicity to invertebrates, algae, fish. **Chemistry:** Alkalinity; pH; conductivity; dissolved oxygen; hardness; major ions; C, P, N, micronutrients; nutrients-organics; BOD; salinity; TDS; total organic carbon; strontium in steelhead spawning streams; chlorophyll **Physical:** Light attenuation; irradiance; total suspended solids; turbidity;temperature; suspended sediment flux,bedload,solute load	**DL:** Delta Levees **ERP:** Fluvial Geomorphology, Benthic Macroinvertebrates, Fish X2, Salmon, River Resident Fish, Estuarine System Productivity, Steelhead Hydrodynamics; Shallow Water Habitat **WMCP:** Watershed **WQ:**Contaminants, Sacramento River, San Joaquin River, Drinking Water **WT:** Water Transfers	Toxicity: Concentrations in water and sediment, Tissue concentrations, Bioassays, Biomarkers, Bioindicators, Contaminant loading; Salinity at selected locations throughout the Delta (DE); Dissolved oxygen; Turbidity-suspended solids; Nutrients (N, P, C); Salinity/TDS

C-021882
C—021882

	Category	Monitoring Elements	CMARP Workteams	Proposed Indicators (ERP Indicators Group)
		LAND USE, WATER USE & RESOURCE MANAGEMENT		
25	**Land use**	**General:** Land use, trend analysis, history, intensity, management practices; presence & type of human activities near streams, riparian areas & habitats; logging; mining; point sources of sediments & contaminants; urbanization; roads & road-building; wildfire & fire suppression; watershed improvement practices; program personnel turn over & funding; shoreline development; **Agriculture:** Number & size of farms; crop patterns; land use surveys including irrigation method by crop; grazing; management practices; chemical applications; pesticide management effectiveness;	**ERP:** Fluvial Geomorphology, Shallow Water Habitats **WMCP:** Watershed **WQ:** Contaminants **WT:** Water Transfers **WUE:** Water use efficiency	
26	**Levees & Impound-ments**	**Levee:** Levee cross-sections, profiles & maintenance quality inspections; levee miles or islands/tracks meeting minimum PL84-99 standard, with enhanced flooding protection, with seismic upgrades, with subsidence control measures; assessment of set-back levee restoration efforts; [see also Geomorphology] **Impoundments;**	**DL:** Delta levees **ERP:** Fluvial Geomorphology **WMCP:** Watershed	
27	**Water Deliveries & Transfers**	Surface water; recycled water; history of water transfers; water transfers among agencies within the projects	**WMCP:** Watershed **WT:** Water Transfers **WUE:** Water Use Efficiency	
28	**Water Recycling**	Amount produced/used in supplier service area, quality of source water & recycled water; wastewater collected/treated; wastewater discharge; water quality effects on recycled water production & usage	**WUE:** Water Use Efficiency	
29	**Water Use**	**Agriculture:** EWMP implementation; land use/acreage by irrigation methods; irrigation amounts & efficiency; real time Eto; crop coefficients; length of canals & laterals; canal seepage; reduction in applied water & groundwater depletion; surface & subsurface drainage water & ground water reuse; delta water use surveys; **Environmental:** Operational commitments to fisheries; wetland restoration evapotranspiration rates **Urban:** Applied water reduction; BMPs; commercial, industrial, & institutional customer data; landscape irrigation efficiency; groundwater depletion; interior water use; irrigated landscape acreage surveys; water management plans; water use per capita data by customer class, water district, hydrologic region; water use efficiency estimates; seasonal & peak water use; water audits & leak detection	**WMCP:** Watershed **WUE:** Water use efficiency	
		METEOROLOGY		
30	**Air**	Mercury deposition; organochlorine source loading; relative humidity; temperature; wind speed & direction	**ERP:** Estuarine System Productivity **WQ:** Contaminants	
31	**Precipitation**	Amount, timing & form; snow-pack & snow-melt dynamics, sunlight, weather, weathering	**ERP:** Estuarine System Productivity **WMCP:** Watershed	

C-021883
C—021883

Chapter 4, Part B. Ecosystem Restoration Program Plan

Goals of the Ecosystem Restoration Program Plan (ERPP)

The mission of the CALFED Bay-Delta Program is to develop a long-term comprehensive plan for the restoration of ecosystem health and improve water management for beneficial uses of the Bay-Delta system. The ERPP has been developed to address problems related to ecosystem quality. Ecosystem goals developed as part of the Strategic Plan for Ecosystem Restoration (1998) will guide implementation of the program. These strategic goals include:

1. Achieve large, self-sustaining populations of at-risk native species dependent on the Delta and Suisun Bay, support similar restoration of at-risk species in San Francisco Bay and the watershed above the estuary, and minimize the need for future endangered species listings by reversing downward population trends of non-listed native species.
2. Rehabilitate natural processes in the Bay-Delta estuary and its watersheds to support, with minimal ongoing human intervention, natural aquatic and associated terrestrial biotic communities, in ways that favor native members of those communities.
3. Maintain and enhance populations of selected species for sustainable commercial and recreational harvest, consistent with goals 1 and 2.
4. Protect or restore functional habitat types throughout the watershed for public values such as recreation, scientific research, and aesthetics.
5. Prevent establishment of additional non-native species and reduce the negative biological and economic impacts of established non-native species.
6. Improve and maintain water and sediment quality to eliminate to the extent possible, toxic impacts to organisms in the system, including humans.

The CALFED Ecosystem Restoration Program (ERP) proposes to reach these goals through restoration of the physical and ecological processes associated with the formation and maintenance of the habitats required by the diverse species dependent on the Bay-Delta and its associated watersheds. The ERP proposes to achieve this restoration through an ambitious program including a wide variety of actions taken in the context of adaptive management. The core idea behind adaptive management is to treat management actions as scientific experiments. This requires that the effects of each management action be monitored and the data assessed to determine the success of the action and modify subsequent actions to achieve greater success, if possible, in response to the knowledge gained. Also, the ERP recognizes that management of human activities is an integral component of ecosystem management. Thus, actions undertaken as part of other CALFED programs concerned with water quality, water supply reliability, and levee integrity must be closely linked to ERP.

As an initial step in achieving the first goal, CALFED is developing a comprehensive Conservation Strategy (Conservation Strategy, 8 Oct. 1998 draft). The Conservation Strategy addresses all Federal and State listed, proposed, and candidate species that may be affected by the CALFED Program actions and integrates enhancement and mitigation efforts that will benefit the species and the habitats that support them. As part of the conservation and protection of these species and habitats, the Conservation Strategy specifies monitoring and reporting needs that must be met by the broader CALFED monitoring and adaptive management programs. The

C-021884

C-021884

Conservation Strategy is especially important because it will form the foundation for compliance with the California Endangered Species Act, the Federal Endangered Species Act, the Natural Community Conservation Planning Act, and other regulatory requirements. Such compliance will be necessary for the implementation of CALFED programs and associated monitoring and research activities.

OBJECTIVE OF THE ERP PORTION OF CMARP

The complex and ambitious adaptive management program proposed by CALFED, and ERP in particular, requires a significant investment in monitoring and research activities. Long-term, system-wide, baseline monitoring data are needed to determine if the overall goals are being met.

- Monitoring is needed to determine the effects and degree of success of specific actions and projects.
- Focused research is needed to increase understanding of ecological processes and consequently reduce uncertainty regarding the outcome of actions.

As outlined in the Strategic Plan for Ecosystem Restoration (1998), all of these activities should be undertaken within a framework of:

- developing conceptual models,
- developing testable hypotheses,
- testing the hypotheses by conducting focused research, and
- learning from management actions, which would lead to improvement of conceptual models and more refined management actions.

The purpose of the ERP portion of the CMARP (ERP-CMARP) is to present an initial concept of the monitoring and research program required to implement, assess, and improve the ERP as adaptive management proceeds. The plan includes monitoring of physical processes that may change in response to CALFED actions, such as river flow below dams that can affect fluvial geomorphic processes. The plan includes monitoring of habitats affected by those processes, such as channel form and riparian vegetation. The plan also includes monitoring of the species dependent on those habitats, with additional emphasis on species of high concern. The final ERP-CMARP will also be designed to fulfill the monitoring and assessment needs of the Conservation Strategy, once those needs have been finalized.

The plan is programmatic in scope because a sequence of actions has not yet been defined. Thus, the plan is flexible and can be modified as the sequence of CALFED actions is implemented. For example, ongoing discussions in the Diversion Effects on Fish Team (DEFT) include the concept of a comprehensive program of real-time monitoring of fish species of concern to aid in management of an environmental water account. Such a program cannot be designed until the data needs of the entity managing the environmental water account are known. Once the requirements are known, a program can easily be designed and incorporated into the CMARP framework.

Small groups of experts (work teams) were asked to design discrete portions of the plan. Each work team was asked to provide a conceptual model, a monitoring program, and a program of focused research for their topic (Appendices *VII.A1-14*). The short time available for developing the plans precluded the participation of many interested scientists and did not allow for outside review and revision of the plans. The lack of full involvement with the stakeholder community suggests that their reviews will be necessary before proceeding with refinement of the program. Thus, the initial framework for ERP-CMARP presented here will continue to be revised and improved as CMARP moves into the implementation phase. This process will likely involve new work teams with a wider

C-021885

C-021885

range of stakeholder membership. These teams will develop more comprehensive or alternative conceptual models and identify the research needed to test the underlying hypotheses critical to determining which conceptual models should guide development of CALFED management actions.

Work team assignments were made before the Strategic Plan for Ecosystem Restoration (1998) was available, so the goals and objectives listed in individual appendices may not exactly match those presented in the body of this report. The Conservation Strategy (1998) was also unavailable to the work teams and so is not explicitly addressed; however, the need to monitor special-status species was stressed in many of the reports.

The work team assignments included requests for estimated costs, appropriate indicators, and prioritization of monitoring and research elements; however, these items were not required and response was variable. The work teams were instructed not to submit "wish lists" and to be practical with regard to recommendations. Realistically, it is inevitable that logistic and monetary constraints will limit the scope of CMARP from what is proposed in the appendices. Prioritization of the monitoring and research elements within ERP-CMARP and among the portions of CMARP related to other CALFED Common Programs will likely be a sensitive process requiring discussion among the CALFED stakeholders as CMARP implementation proceeds.

The plan components are divided into those concerned with **river systems** and those concerned with the **Bay-Delta system**. This division is arbitrary but does correspond with many changes in issues and monitoring and research methods used to study them. Clearly, the river and Bay-Delta components will be closely integrated in the actual design and implementation of CMARP. The ERP primarily limits consideration of river issues to the stream reaches downstream of the major foothill dams or equivalent elevations on undammed streams. Upstream reaches of rivers are covered by the CALFED Watershed Management Coordination Program; however, several other work teams also included upstream river reaches in their plans to some degree. Terrestrial issues were not adequately addressed in this initial ERP-CMARP. Development of these aspects of the program should continue in close cooperation with the Watershed Management Coordination Program. The major components of monitoring proposed for each type of system are presented below.

ERP-CMARP PROGRAM COMPONENTS

Products of the ERP-CMARP work teams are summarized in the following sections. The content varies but generally includes a brief justification for the particular monitoring and research component, major monitoring and research needs, and a listing of any proposed indicators. Refer to the individual appendices for more detail. Linkages among the various ERP-CMARP plans are discussed below, as are linkages between ERP-CMARP and other Common Programs and linkages between ERP-CMARP and existing monitoring and research programs.

RIVER SYSTEMS

Fluvial Geomorphology, Hydrology and Riparian Issues (Appendix *VII.A.12*)—The objective of many CALFED actions is to re-establish natural flow patterns and associated habitat processes in regulated streams to improve habitat for anadromous fishes, resident fishes, other aquatic organisms, and terrestrial plants and animals. These processes include such things as stream meander, sediment recruitment and transport, floodplain

C-021886

C-021886

inundation, stream hydrology, and riparian forest succession. These processes are understood in a general sense; however, many concepts of fluvial geomorphology are best applied to free-flowing streams and the concepts may have to be adapted for regulated streams. The degree to which natural function can be restored to systems in the CALFED solution area is unknown in some cases because present conditions have been so altered from natural conditions. A monitoring and research program is needed to assess the success of CALFED actions and improve understanding of fluvial geomorphology (which includes hydrologic processes) and riparian processes.

The monitoring recommendations emphasize the gravel-bed reaches of the streams where anadromous fishes spawn and rear and where most other native fishes are found. Additional emphasis on soft-bottomed reaches may be appropriate as the program develops. The monitoring program includes:

- Periodic stereoscopic aerial photography of all significant streams of interest. Photography should be repeated approximately every five years or after significant flows. Fluvial geomorphic processes are largely driven by large flows; thus, floods may result in significant changes that should be documented as soon as possible. Photographic analysis will provide data at scales ranging from the landscape level to the project-specific level, including topography, channel form, stream width, sinuosity, general habitat types at several scales of detail, and riparian vegetation.
- Comparison of aerial photographs taken during high and low flows to define the extent of floodplain habitat available. In addition, new or supplemental photography might be required to document effects of management actions such as levee setbacks or channel modifications.
- Detailed measurements at 40-50 long-term monitoring sites throughout the CALFED solution area. Two types of sites are needed--geomorphic and riparian. Ideally, a single site will serve both functions. The sites will serve as long-term monitoring sites for baseline conditions or as comparison sites for projects within the same or nearby reaches of stream. Geomorphic measurements include detailed channel morphology, stage-discharge curves (the relationship between water level and stream flow), floodplain morphology, and substrate composition as important variables. Riparian measurements include tree species composition and trunk diameter, shrub species composition and basal area, percent cover by herbaceous species, and various other growth and productivity measures.
- Monitoring of geomorphic processes, riparian plants, and animals. A plan for monitoring of birds is provided. General guidelines, compatible with those proposed for the Watershed Management Coordination Program, were also developed for integrated monitoring of habitats, species, and ecological communities. Plans for river resident fishes, including anadromous lampreys, and anadromous salmonids were designed by separate work teams (below).
- Monitoring of physical habitat and biota in floodplain areas and flood bypasses.
- Review and assessment of adequacy of the existing network of stream flow gages. Accurate flow measurements are essential to the calculation of many hydrologic parameters and interpretation of the monitoring data gathered.

Research or assessments of existing data are needed in several areas (see Appendix *VII.A.12* for justifications).

- Test a methodology for assessing the effect of water development on flow regime.

C-021887

C-021887

- Compile and assess temperature data and existing temperature data collection activities.
- Improve understanding of river-groundwater exchange processes.
- Improve understanding of groundwater (hyporheic zone) ecology.
- Improve understanding of riparian vegetation recruitment dynamics.
- Assess the importance of floodplain habitat to fish and other aquatic and terrestrial animal populations.

River Benthic Macroinvertebrates (Appendix *VII.A.13*) – Benthic macroinvertebrates are important as food for various life stages of many anadromous and resident fishes and terrestrial animals. Bioassessments of benthic macroinvertebrate communities are commonly used tools for monitoring of water quality and evaluation of watershed condition. Individual species of benthic macroinvertebrates are sensitive in varying degrees to water temperature, dissolved oxygen, sedimentation, scouring of the streambed, nutrient enrichment, and chemical and organic pollution. Benthic macroinvertebrates also have intrinsic value as an important component of ecological diversity. Benthic macroinvertebrate monitoring is primarily included in CMARP as a bioassessment tool for detection of changes in the stream environment resulting from CALFED actions. Secondarily, changes in the diversity or abundance of this resource could have effects on higher trophic levels, particularly fish.

The monitoring program should have a number of characteristics.

- The suggested scale of monitoring is the watershed, which requires coordination between ERP and the Watershed Management Coordination Program.
- Adopt specific protocols for site selection, sampling methodology, and sampling frequency (see Appendix *VII.A.10* for suggestions).
- Characterize physical and water quality conditions at each site as completely as possible, including at a minimum: water temperature, pH, turbidity, specific conductance, water depth, water velocity, substrate characteristics, and canopy cover.
- Determine relationships between species abundances and biological metrics of community structure with watershed characteristics and physical and chemical parameters.
- Develop appropriate models or indices to provide a standardized measure of the condition of the benthic macroinvertebrate community.

Simultaneously with the monitoring effort, several research topics should be pursued.

- Improve knowledge of the taxonomy and distribution of California benthic macroinvertebrates to better understand the species diversity present in the study area. This research will also provide information on exotic species.
- Determine the sensitivity of western species of benthic macroinvertebrates to various types of environmental degradation. Existing research emphasizes streams in the eastern United States.

Several metrics of benthic macroinvertebrate communities are commonly used as indicators in bioassessments. These metrics may also serve as useful indicators of benthic macroinvertebrate community condition for ERP and include taxa richness, Shannon Diversity Index, EPT taxa (total number of distinct taxa in the insect Orders Ephemeroptera, Plecoptera, and Trichoptera), EPT Index (proportion of total number of individuals in EPT taxa), Modified Hilsenhoff Biotic Index (HBI), and Percent Dominant Taxon (PDT) (the percentage of total individuals represented by the most dominant taxon).

River Resident Fishes (Appendix *VII.A.10*)—The emphasis of the ERP on ecosystem management, ecosystem processes, and preventing the decline of currently unlisted species of fish and other taxa will require monitoring and research on river resident species (including anadromous lampreys). Fish communities, similar to benthic macroinvertebrates, may be used as bioindicators of environmental conditions. Resident fishes, both native and introduced, respond seasonally and annually to environmental conditions including flow regime, physical habitat, water quality, and interactions with other species. The monitoring program will simultaneously build the long-term data base required to assess the affects of CALFED actions on resident fish populations and provide the information needed to continue refinement of the conceptual models and increase understanding of ecological processes.

The work team proposed a long-term, geographically extensive program of monitoring to assess the distribution and relative abundance of native and introduced river resident fish species and to detect new introduced species as they enter the system.

- Monitor river resident fishes in all streams being monitored for anadromous fishes with cooperative sampling whenever possible. Additional monitoring should be conducted on a prioritized set of the remaining streams and will depend, to some extent, on proposed management actions and the ability to locate monitoring sites at locations where other monitoring is occurring.
- Develop specific sampling protocols for site selection, sampling methodology, and sampling frequency (see Appendix *VII.A.10* for suggestions).
- Evaluate additional measurements that will benefit both monitoring and research, including assessment of fish condition/health, aging of fish, diet analysis, in addition to the collection of routine information such as species identification, counts, lengths, and weights.

Several areas of research would be useful in the interpretation of the monitoring data and in understanding the responses of resident fishes to management actions.

- Compile existing data and conduct research as needed on the life history and physiology of resident species to better understand their responses to environmental conditions.
- Clarify the population structure (genetics) of species of concern.
- Evaluate the development of an Index of Biotic Integrity or similar index as an indicator of resident fish community condition.
- Evaluate techniques for assessment of fish condition/health.
- Experimentally test causal relationships suggested by monitoring data and observational studies.
- Document the sources and effects of new exotic species as needed.
- Assess the effects of commercial or recreational exploitation as appropriate for selected native and exotic species.

Several possible indicators were suggested for resident fishes. An Index of Biotic Integrity or similar multimetric index could be developed. Percentage of native fish and percentage of intolerant fish (species sensitive to environmental stress) are other possible general indicators. Measurements of fish health/condition can also serve as good general indicators. Map presentations of the geographic distribution of the various fish communities can provide a useful summary of complex fish community data.

Chinook salmon (Appendix *VII.A.8-9*) – Chinook salmon are probably the most studied fish in the Central Valley. Thus, the conceptual models, monitoring, and research proposed for this species are the most detailed of any presented for the monitoring elements concerning river

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C-021889

systems. The high level of concern reflects the recreational, commercial, and aesthetic value of the species and the Federal or State listing of the various runs. The chinook salmon work team considered steelhead needs in their plan but a separate steelhead plan (below) was also prepared to highlight the needs for proper understanding of steelhead needs. Restoration of salmon runs is a major objective of CALFED. Monitoring and assessment of the effectiveness of CALFED actions is essential to evaluating success.

The conceptual model focuses on the major life stages of the fall-run chinook salmon and is based on an extensive review of the existing literature and other information on Central Valley chinook salmon. The conceptual model identified key issues for each life-stage.

- Upstream migration of adults – straying, delayed migration, egg viability, migration barriers, and prespawning mortality.
- Spawning – altered flows, degraded channel complexity, high water temperatures, gravel recruitment, harvest and harassment, and altered genetics due to hatchery fish.
- Incubation and emergence – elevated water temperatures, fine sediment intrusion, gravel recruitment and instream gravel mining, intrusion of oxygen-poor groundwater into redds (nests), excessive gravel mobilization during high flows, and reduced habitat complexity.
- Juvenile rearing – stream flow and interactions with floodplains, elevated water temperatures, contaminants, food supply, and disease.
- Juvenile migration – stream flow, predation, unscreened diversions, stranding, and water temperatures. Juvenile migration through the Bay-Delta is covered by a separate monitoring element below. The work team also noted that ocean residence can have very important effects on chinook salmon populations.

The suggested monitoring elements were extensive and covered each life stage separately.

- Adult monitoring using carcass surveys on streams not included in existing programs, evaluation of new or additional methods for estimating adult abundance, and analysis of scales and otoliths to verify age structure of the runs.
- Monitoring of spawning activity should include documentation of the distribution of redds within and between riffles so the extent of spawning habitat can be determined and under-utilized habitat identified.
- Where spawning habitat restoration projects are funded and unsuitable intragravel water quality exists, monitor intragravel dissolved oxygen concentration, intragravel water temperatures, substrate permeability, and vertical hydraulic gradient.
- Assess the overall abundance and health of juvenile salmon annually, using a variety of techniques at monthly intervals from February through June in cooperation with existing programs.
- Monitor juvenile survival in both the river and the Bay-Delta system. Techniques suggested to monitor river survival include mark-recapture studies of hatchery and (if available) wild fish. Several different group sizes should be used for releases and, in streams where outmigrants of appropriate size are available, radio tagging should be used.
- Monitoring of ocean conditions such as ocean harvest, ocean currents, and prey abundance, was also mentioned as an important activity.

Research topics derived from the assumptions and hypotheses forming the basis of the conceptual models are summarized under the following general categories:

C-021890

C-021890

- effects of fluvial geomorphology,
- effects of predation,
- effects of water temperature,
- factors effecting smolt survival,
- instream flow studies,
- genetic evaluations of stock structure,
- adult tagging studies,
- creel surveys,
- effects of contaminants, and
- factors affecting egg incubation.

Five possible indicators were identified as trends in:

1. naturally-produced salmon and steelhead measured as sport harvests and escapement to rivers and the ocean,
2. the number of "crashes" (catastrophic loss of a brood year) due to unsuitable environmental conditions,
3. the egg-to-fry survival of naturally-produced salmon and steelhead,
4. the number of naturally-produced juvenile salmon and steelhead migrating out of rivers, and
5. the survival of naturally-produced juvenile salmon and steelhead migrating through the rivers and Delta.

Steelhead (Appendix *VII.A.11*) – Compared to chinook salmon, Central Valley steelhead have received relatively little study. In the past, it has been assumed that steelhead respond to environmental stresses in the same way as chinook salmon. The conceptual models prepared by the chinook salmon teams apply generally to steelhead because the species share an anadromous life history but there are some significant differences, especially in population structure and dynamics. Most importantly, however, are differences in the severity of impacts of stressors common to the two species (particularly those dealing with flow and temperature), which can be greater for steelhead because of the longer period of freshwater rearing by juveniles. The primary stressor identified for steelhead was large-scale loss of spawning and rearing habitat. Juvenile steelhead must rear in fresh water for one year or longer; therefore, water temperatures must remain in the tolerable range for the entire year. This is often not the case during late-summer and fall below the major dams. The status of steelhead populations and their response to CALFED actions must be monitored because the species, a member of the native fish community, is Federally listed as threatened and supports a valuable recreational fishery.

Six major knowledge gaps require either new monitoring and assessment programs or enhancements to ongoing anadromous fish monitoring programs:

- Current distribution and abundance of naturally-spawning populations.
- Specific spawning and rearing habitat requirements and assessment of existing habitat.
- Genetic and population structure of Central Valley steelhead.
- Feasibility of providing access and restoration of potential habitat currently above impassable dams.
- The degree of straying of hatchery steelhead and the effects of straying on naturally-spawning populations. Assessing these effects may require documentation of straying in natural populations as well.
- Effects of water project operations in the delta/estuary.

The suggested comprehensive monitoring plan, for application in the tributary streams, mainstem rivers, and the Delta, as appropriate, has two primary components--habitat monitoring and population monitoring. Specific recommendations include:

- habitat typing and mapping,
- stream flow and temperature monitoring,
- identification of other stressors important in specific situations (e.g., sedimentation), and
- population monitoring for several life stages, including spawning adults, rearing juveniles, and emigrating juveniles.

C-021891

C-021891

Changes in abundance, timing of life stage, and habitat availability, at each life stage, were identified as indicators by the work team. A detailed list of specific monitoring questions to be addressed by the program was also provided. In many respects the monitoring program proposed by the work team also serves as a research component because so little is known about Central Valley steelhead.

BAY-DELTA SYSTEM

Hydrodynamics (Appendix *VII.A.4*) – In recent years, workers in the Bay-Delta system have come to recognize that understanding hydrodynamics, the movement of water through the system, is central to understanding how sediments, salts, nutrients, contaminants, other chemicals, and organisms are distributed. This task is complicated by the physically complex and tidally driven nature of the estuary. In essence, hydrodynamics encapsulates the physical processes essential to the creation, maintenance, and evolution of Bay-Delta habitats that are used by and determine the distribution of organisms. Monitoring and understanding Bay-Delta hydrodynamics is essential to assessment and refinement of CALFED actions affecting the physical structure of existing channels and water management.

The conceptual model for Bay-Delta hydrodynamics must consider two pivotal concepts that account for the complexities involved in hydrodynamic monitoring and research.

- Various temporal scales--include the tidal (about daily) time scale, the fortnightly spring-neap tidal cycle, and annual and longer time scales.
- Spatial variability--Sources include the physical complexity of Delta channels, the interaction between shoals (shallows) and deep channels, longitudinal salinity structure, horizontal stratification in Central Bay, semi-isolation of South Bay, and the interaction of shoals and channels with marshes and intertidal mud flats.

A variety of new monitoring programs were suggested in addition to ongoing programs.

- Deploy bottom salinity/temperature sensors to accurately define X2 (X2 is a regulatory tool defined as the distance in kilometers up the axis of the estuary to where the tidally-averaged near-bottom salinity is 2 psu).
- Deploy various sensors to estimate fluxes (movements) of water and other materials at key points in the Bay-Delta system.
- Monitor water flow with a before and after monitoring design linked to CALFED actions and choice of the preferred alternative.
- Deploy various sensors in selected shallow-water regions to determine interaction of deep and shallow-water regions.
- Monitor deposition and resuspension of sediments.
- Conduct periodic measurements of bathymetry (channel geometry).
- Continually utilize and update hydrodynamic models to improve understanding of the system.

Research topics stress specific issues important to improving the ability of models to confidently predict changes in hydrodynamics that might occur in response to CALFED actions.

- Determine net transport through major cross-Delta connections (e.g., Georgiana Slough).
- Resolve the hydrodynamic basis and accuracy of the concepts supporting QWEST and carriage water.
- Determine the dependence of water residence time on tidal and flow conditions in shallow water regions (e.g., Franks Tract).
- Quantify the degree of cross-sectional mixing in channels and the influence of size, shape, and connections with other channels.

C-021892

C-021892

- Conduct research into all aspects of the hydrodynamics of shallow water areas, including processes within shallows and between shallows and deeper channels.
- Determine transport processes and flow structure in Suisun Bay and areas downstream.
- Determine fluxes of materials and organisms in areas of interest.
- Determine processes of sediment deposition and resuspension.
- Conduct numerical modeling.

Several possible indicators were identified for hydrodynamic processes. The proposed calculations of fluxes of material and organisms at various points in the system might serve as indicators, especially the fluxes in waterways of high interest (e.g., Delta Cross Channel or various points in Old River). Inferred mass fluxes similar to QWEST or cross-Delta flow might be possible. Water level at the Golden Gate or X2 could also serve as indicators. The usefulness of these indicators to ERP will depend on linking them to important ecosystem process such as primary productivity or transport of larval fish to favorable nursery areas.

System Productivity at Lower Trophic Levels (Appendix *VII.A.5*) – This work team addressed a number of issues including physical processes, primary production by phytoplankton and benthic plants, the microbial food web, zooplankton and macrozooplankton (mysid shrimp and amphipods), benthic macroinvertebrate communities, exotic species, and variation in the relative importance of issues among geographic regions. This program element serves a dual purpose in this report appearing here and in the discussion of the Water Quality Program (Chapter 4-C). However, this repetition does not imply a request for dual monitoring and research programs. In the context of ERP, the processes considered determine the productivity of the food web in the Bay-Delta system. Understanding these processes is critical to assessing the effects of CALFED actions on the Bay-Delta ecosystem. This section deals primarily with the deep-water pelagic system. Shallow-water systems are discussed below and the interchange between them mentioned in hydrodynamics.

The work team identified existing monitoring programs and provided a list of monitoring needs (see Appendix *VII.A.5* for details). A short list of general considerations for ongoing and new sampling programs includes:

- conduct continuous monitoring at established stations for physical and chemical variables in preference to, or supplemented by, shipboard monitoring,
- continue to use conductivity-temperature-depth sensor packages with additional sensors as needed,
- conduct studies to determine the effects of alternative sampling frequencies and schemes with regard to daily and spring-neap tidal cycles,
- develop a standard policy for storage and archiving of biological samples,
- incorporate new techniques of data acquisition and analysis as they prove their utility, and
- design a program to detect and track newly introduced species.

Another general consideration not included in the list but implicit in much of the plan was that monitoring had to be extended into more shallow-water areas than are currently monitored by ongoing programs. Shallow-water issues are discussed below and in Appendix *VII.A.6*.

The list of monitoring needs was very detailed, presenting specific recommendations for variables to be monitored under more generic topics. The more general topics include:

- measure basic physical variables ranging from precipitation to light attenuation in the water column,
- measure flow variables,

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- measure chemical variables including nutrients and organic carbon,
- measure biomass and primary production of phytoplankton, benthic algae, and submerged aquatic vegetation,
- monitor microbial communities,
- monitor zooplankton species composition, biomass, and production,
- monitor sediment quality, and
- monitor species composition, abundance, biomass, and size distributions of benthic macroinvertebrates.

Twenty research topics were presented with a detailed justification for each. The research is needed to understand the processes underlying ecosystem responses observed in the monitoring data. This understanding is necessary to assess the contribution of CALFED actions to observed changes.

Bay-Delta System Productivity at Upper Trophic Levels (Appendix *VII.A.6*) – Declines in populations of many Bay-Delta fishes and larger macroinvertebrates (i.e. crabs and crayfish) have been observed in recent years. Many of these species support recreational or commercial fisheries with significant economic value. Others have been listed as threatened or endangered. CALFED goals emphasize increased populations of such species; therefore, monitoring and assessment is required. Three management activities were defined to guide design of the monitoring and research program:

1. management of harvested populations,
2. monitoring of status and trends species, and
3. assessment of general trophic dynamics among estuarine species.

Delta smelt and chinook salmon are mentioned in the plan but are addressed in more detail in single-species plans. This work team concentrated on the open-water pelagic system and emphasized aquatic species. Additional work on other organisms, particularly birds, may be needed. Most ongoing monitoring is conducted through the Interagency Ecological Program (IEP). Proposed new sampling to supplement ongoing IEP sampling was presented in the context of these three management activities.

Management of harvested species emphasized monitoring for striped bass, American shad, white and green sturgeon, various catfishes, Dungeness crab, and crayfish. Suggestions for additional monitoring included:

- determine catch per unit effort of adult American shad from the recently initiated Central Valley and Anadromous Creel Survey,
- collect and analyze data on adult American shad captured as part of other trapping and netting programs,
- increase tagging efforts for adult white sturgeon,
- increase trawling efforts in the lower Sacramento River and Suisun Bay for juvenile white sturgeon,
- assess monitoring methods for green sturgeon including use of fyke nets to capture young-of-the-year green sturgeon at the Red Bluff Diversion Dam on the Sacramento River and egg and larval sampling in the upper Sacramento River and Feather River, and
- increase striped bass monitoring efforts in shallow water areas to better understand juvenile habitat use.

Monitoring of status and trends species is intended to provide data on common species "representative" of groups of species rather than attempting to monitor all 165 species of fish that have been captured from the Bay-Delta system. Many of these species are already monitored adequately by existing programs. The species that were not adequately sampled because of habitat preferences or gear efficiencies were divided into three groups:

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- Monitoring of species that mainly use the Bay-Delta as large-sized juveniles or adults could be improved by expansion of existing programs utilizing gill nets and trammel nets and recording data for all species captured rather than just program target species (e.g., striped bass). Additional new elements could include an index of fish health and a creel census.
- Monitoring of species using rocks, pilings, and other structures in brackish water areas will require selection of appropriate methods such as baited traps, bait angling, or creel census.
- Monitoring of species using habitats not sampled by present programs would involve adaptation of existing programs or design of new programs to sample these areas. For example, there is no sampling for fish occupying areas of intermediate depth between shallow-water channel edges and deeper-water midchannel stations.

Assessment of food chain dynamics requires sampling on the basis of three salinity regimes or regions and the species expected in each one. The regions are the Delta, brackish waters, and polyhaline waters. Monitoring would include diet studies for poorly understood species and monitoring of contaminant body burdens to examine bioaccumulation of contaminants through the food chain.

Research recommendations fell into four broad categories.

- Studies to improve the suggested monitoring program.
- Studies to develop new monitoring indicators.
- Studies to provide baseline data and methods that will be useful in detecting and assessing the effects of new introductions.
- Continually analyze and interpret data collected by the monitoring program to clarify and update research needs.

Measures of abundance, distribution, contaminant body burdens and diets were suggested as possible indicators. The research studies also identify the need for additional measurements on topics such as physiological condition that might serve as indicators.

Fish-X2 Relationships (Appendix *VII.A.1*) –The X2 standard is currently an important regulatory tool in the Bay-Delta system (X2 is defined as the distance in kilometers up the axis of the estuary to where the tidally averaged near-bottom salinity is 2 psu). The X2 standard is based on correlative relationships, derived from existing data, between X2 and abundances of some estuarine species. There is no consensus regarding the usefulness of the X2 standard for managing the Delta. The factors leading to lack of consensus range from disagreement over the statistical validity of the correlations underlying the standard to the fact that the ecological processes underlying the correlations have not been elucidated. Presumably with some understanding of the underlying cause and effect relationships encompassed in X2, more direct management actions might be possible for some species, which could result in lower water costs relative to the present X2 standard. Given the great importance of these issues in guiding management decisions, a small work team was formed to design a research program to elucidate the causes of the Fish-X2 relationships. The activities needed to monitor X2 and the relationships of organisms to X2 are encompassed under other ERP and other Common Program activities.

The suggested research program includes a detailed conceptual model, and a research plan including 30 possible studies. The program is designed in a stepwise manner so that the outcome of earlier studies determines whether subsequent studies are conducted. Many of the specific research studies require similar approaches

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and the research program will be organized around a common framework including consistent approaches for data analysis, hydrodynamic modeling, and population monitoring. Hydrodynamic and population monitoring were also recurring themes. The list of individual research projects is too detailed to summarize but seven general issues are the basis of the conceptual model.

- Variation in the physical environment with X2.
- Variation in retention and recruitment of organisms with gravitational and lateral circulation.
- Variation in retention and recruitment of organisms with circulation patterns in the low salinity zone.
- Variation in the extent or quality of physical habitat with X2.
- Variation in food supply with X2.
- Variation in entrainment effects with X2.
- Effects of X2 distinguishable by comparative studies of delta smelt and longfin smelt ecology, two species with similar life histories that appear to relate to X2 in very different ways.

Because this is primarily a research program, no indicators were identified.

Delta Smelt (Appendix *VII.A.7*) –Similar to the Fish-X2 relationships, the status of delta smelt and the response of the population to management actions are of high interest in the Bay-Delta system. Recovery of the delta smelt population is a high priority for CALFED as well as many Federal and State agencies and stakeholder groups. Given the high level of interest, a small work team was assembled to address monitoring and research needs for delta smelt.

The conceptual model summarized current knowledge and highlighted hypotheses for testing to clarify critical aspects of delta smelt life history. Existing monitoring programs, primarily IEP, covered most monitoring needs but several types of additional monitoring are needed.

- Improved monitoring and delineation of spawning habitat.
- Additional larval monitoring in the Delta and Suisun Bay.

The proposed research program included four general areas of emphasis:

- studies of basic biology and physiology,
- studies of habitat extent and quality,
- studies of growth and condition, and
- integrated monitoring studies of larval transport and recruitment processes.

Comparative statistics derived from delta smelt abundance and distribution indices might serve as a useful indicator of the performance of CALFED management actions. Given the high interest in delta smelt, such an indicator might be useful at a variety of levels.

Bay-Delta Shallow-water Habitats and Watersheds (Appendix *VII.A.2*) – Restoration or rehabilitation of Bay-Delta shallow-water habitats, primarily tidal wetlands and marshes, is a major component of the ERP as presently envisioned. Given the importance of these management actions to the CALFED program, a strong monitoring and research element is required. This component is very similar to the River Fluvial Geomorphology and Riparian Issues group because, although the general concepts of shallow-water ecosystem function are recognized, the outcomes of specific actions are still difficult to predict. An additional layer of uncertainty is added when benefits to specific native species are expected because the importance of shallow-water habitats to many native species has not been established.

The conceptual models emphasized the processes important to the maintenance of tidal flat and tidal marsh habitats. Emphasis was placed on the interaction of physical and ecological processes. A

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separate discussion of diked marshlands was also provided. These wetland types were emphasized because it appears that the most extensive ERP rehabilitation actions concern these types of habitat. Shallow open-water areas were not considered. Additional conceptual models may have to be formulated for other types of habitat that become the focus of ERP actions.

Because of the large area encompassing Bay-Delta wetlands, the many different types of habitats, and the number and extent of rehabilitation projects proposed, a traditional baseline monitoring design appeared impractical. Instead, the proposed design focuses on the types of habitats to be rehabilitated. The monitoring scheme is based on standardized project-level monitoring and comparisons of results with data from reference (least-disturbed) sites. A six-step outline for developing project designs and monitoring programs was presented.

- Set qualitative project goals.
- Develop a conceptual design for the project.
- Select quantitative performance indicators and monitoring elements that address the goals.
- Select stressor indicators and monitoring elements.
- Identify reference conditions and reference sites.
- Design the project-specific monitoring program.

Proposed performance and stressor indicators and the monitoring elements required to evaluate each indicator included the following:

- wetland integrity,
- shoreline change,
- channel morphology,
- wetland hydrology,
- tidal elevation,
- habitat patchiness,
- sediment characteristics,
- water quality,
- target population status including special status species identified by CALFED or other agencies,
- community structure of plants, invertebrates, fish, birds, and small mammals, and
- intensity of human activity.

Monitoring methods were not specified but presumably will be a mixture of methods used, similar to recommendations of the River Fluvial Geomorphology and Riparian Issues group. A separate element for Bay-Delta Shallow-water Fishes (Appendix *VII.A.3*) was submitted as a stand-alone product.

Research needs were derived from CALFED documents, other CMARP work team products and other existing programs in the Bay-Delta region, including the Bay Area Wetlands Ecosystem Goals Project and the Research Recommendations for the Regional Monitoring Strategy. General topics for focused research include:

- avian resources,
- fish resources (see Bay-Delta Shallow-water Fishes below),
- small mammals,
- marsh physical processes, and
- various needs for implementing and understanding marsh restoration.

Bay-Delta Shallow-water Fishes (Appendix *VII.A.3*) –Restoration of shallow-water habitats in the Bay-Delta region is a major component of ERP. It is assumed that such restoration will result in increased populations of desired fish species; however, supporting evidence for this assumption in the Sacramento-San Joaquin estuary is minimal. Monitoring and research are needed to determine if populations of native species actually respond in any way to habitat restoration projects and, if so, the processes that cause positive or negative responses.

The conceptual model incorporates several important ideas. Although most resident

and migratory species of the Bay-Delta system can be found in shallow-water habitats at some time in their life cycle, such habitats are not necessarily of special importance to maintenance of the population. For other species, shallow-water habitats may be essential for completing all or part of the life cycle. The ecological function of shallow-water habitat varies among species. Important functions of shallow-water habitat could include spawning habitat, foraging habitat, refuge from predators, and near-shore migration corridors. Habitat use by fishes may vary seasonally and annually.

Two ongoing IEP programs provide sufficient coverage of the Delta, though some expansion of both surveys was suggested, and additional elements may be needed later as new monitoring and sampling methods are refined. Recommendations for project-specific monitoring emphasize pre- and post-project monitoring data and comparison of project results with results from non-project sites. Suggested variables included:

- presence/absence of species,
- relative abundance of common species,
- diets of common species,
- measurements of physiological variables ranging from condition factor to contaminant body burdens, and
- monitoring of the distribution and abundance of shallow water habitat types.

Two areas of research were prioritized.

- Develop sampling methods for shallow-water habitats.
- Resolve key questions regarding the use of shallow-water habitats by various species of fish and the importance of such use to population dynamics.

Sampling issues are presently being addressed by several IEP-sponsored studies and may be at least partially resolved in the near future. Most of the fish-use aspects are not presently being studied.

Chinook salmon (Appendix *VII.A.8-9*) – The separation of the Bay-Delta system and river system chinook salmon monitoring plans is artificial and was required by the organization of the report. In reality, these two portions of the plan will be tightly integrated into a single life-history-based plan across all habitats. Restoration of salmon runs is a major objective of CALFED. Monitoring and assessment of the effectiveness of CALFED actions is essential to evaluating success.

The suggested monitoring program stressed existing monitoring programs for juvenile abundance, distribution, and survival. Recommendations for new monitoring included:

- sample migrating juveniles as they exit San Francisco Bay,
- supplement existing studies of survival using coded-wire-tagged hatchery fish with similar studies using tagged wild fish if possible,
- monitor physical parameters including water quality and hydrodynamics in conjunction with the salmon studies, and
- monitor prey availability and fish community assemblages.

A detailed list of research topics was presented and prioritized. Six high priority areas of research were identified.

- Evaluate the importance of various types of lower river and Delta habitat to various salmon life history strategies and juvenile survival.
- Determine the causes of reduced survival in the central Delta compared to the mainstem Sacramento River.
- Assess various methodologies for determining race, basin or hatchery origin, and age structure.
- Assess new techniques for indexing the abundance and survival of emigrating juvenile salmonids. Implement the improved methods.
- Identify the influences of hydrodynamics on the survival and abundance of juvenile salmonids.

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- Determine if food is limiting the survival of juvenile salmonids in the Delta.

Ten lower-priority issues were also identified (Appendix *VII.A.8*). Specific indicators were not suggested but various measures of abundance and survival might serve as indicators.

Steelhead (Appendix *VII.A.11*) –The river phase of the steelhead life history was addressed earlier under River Systems. New monitoring and research elements suggested for the Bay-Delta relate to evaluation of Bay-Delta water operations on steelhead emigration and rearing. For chinook salmon, this separation is a consequence of report organization and the two parts of the program are actually closely integrated. Specific needs mentioned included:

- determine the timing of smolt emigration through the Delta,
- determine the magnitude of diversion of smolts into the South Delta, and entrainment at the pumping facilities, and
- assess the effect of the loss of estuary rearing habitat.

Monitoring for Nonindigenous Organisms (Appendix *VII.A.14*) –This monitoring element primarily addresses the Bay-Delta ecosystem, generally acknowledged to be one of the most intensely invaded ecosystems in the world. The work team provided a justification for a separate nonindigenous species monitoring component rather than depending on the general monitoring programs already discussed above. Three fundamental objectives were identified for the monitoring program: 1) detect new introductions, 2) monitor the spread of recent introductions, and 3) identify and assess mechanisms of introductions. Two closely linked research purposes are understanding how introduced organisms affect the ecosystem and understanding the different factors that affect the success or failure of introductions. CALFED has already established a group to examine issues associated with non-native invasive species. This component of ERP-CMARP will be modified as needed to meet the needs of that group.

Three elements are needed in the monitoring program to meet the general objectives.

- Sampling must include habitats where introduced species are commonly first detected. Existing monitoring programs must collect, identify, and report new species.
- Organisms must be recognized as new introductions. This is an important problem for small organisms such as invertebrates and algae.
- A system to ensure accurate and timely identification of suspected exotic species is needed.

Although not explicitly identified, this monitoring element links to all other monitoring elements through collection of organisms. All monitoring programs should have procedures in place to identify and report suspected new non-indigenous species.

SUMMARY OF ERP RESEARCH NEEDS

The research needs identified for each monitoring element have already been summarized in the individual element sections (see Appendices *VII.A.1-14* for details). The needs identified are extensive. Some work teams have been very specific about what studies should be conducted. Other recommendations were very general. This difference is directly related to the existing levels of knowledge. Work teams addressing topics with existing (or recently completed) monitoring and research programs presented specific and focused research proposals. Work teams addressing topics relatively unstudied in the Sacramento-San Joaquin system were more likely to present general topics for research.

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The extensive nature of the research recommendations also results from the CALFED objective to understand ecological processes to aid in adaptive management. General monitoring is inadequate to develop a complete understanding of these processes. Manipulative experiments or detailed study of natural situations are needed to meet the objective. Given the long list and potentially high cost of the research elements recommended, it is highly likely that CALFED will have to prioritize the research elements. Such a prioritization must strike a careful balance between specific needs in subject areas where much is known and general needs in subject areas where little is known. A major determinant of priority will be the importance of each topic to achieving CALFED goals and objectives.

LINKAGES AMONG ERP-CMARP COMPONENTS

Linkages among the various ERP program elements were addressed in each of the work team plans (Appendices *VII.A.1-14*). Consideration of these linkages result in a more integrated view of ERP-CMARP than the individual elements might suggest. All of the work teams recognized the efficiency provided by coordination of site selection and sampling activities.

Integration of river activities will largely center on the 40-50 long-term monitoring sites selected for the fluvial geomorphology component and sites where anadromous fishes are monitored by existing programs. In the Bay-Delta system, integration largely centers on existing monitoring programs with long-term data sets from established sampling networks. Sampling efforts can be coordinated for efficient use of available personnel and equipment. Such integration lends additional credence to comparisons among different data sets.

The division of the ERP-CMARP into River and Bay-Delta sections was the primary means of providing the work teams with manageable assignments and will not be carried into the implementation phase. Site selection, data collection, and data analysis will be integrated across the entire ecosystem, although appropriate methods may change as sampling moves from riverine to tidal habitats. For example, river resident fishes and anadromous fishes are sampled using different methods in rivers and estuaries, but if the sampling program is integrated in all other aspects, the data can be very valuable to understanding species and communities throughout the system. In some cases similar methods can be used across habitat types but the work team plans gave them different emphasis. For example, the use of aerial photography is appropriate for the identification and quantification of habitat types in both the rivers and the estuary; however, the work team addressing river fluvial geomorphology highlighted the use of aerial photography, while the Bay/Delta shallow-water habitat work team did not. This process of design integration will be one of the major challenges in refining CMARP.

The final version of the ERP-CMARP must integrate the data needs of other ERP teams as they are finalized. The need to include the species and habitat monitoring needs of the Conservation Strategy has already been mentioned. Clearly, all monitoring and research components will have to be designed to integrate general community monitoring and special-status species monitoring to the greatest extent possible. It is likely that some focused special-status species monitoring will be required. There is a CALFED group currently considering introduced species issues. The needs and recommendations of that group will have to be considered in the final design of the ERP-CMARP monitoring strategy for introduced species.

Linkages will also be necessary between ERP-CMARP and the Strategic Plan for the Ecosystem Restoration Program (Strategic

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Plan), if ERP adopts the Strategic Plan wholly or in part. The Strategic Plan identifies 12 important issues and opportunities to consider in developing an adaptive management program, all of which will require monitoring and research. The issues are: 1) introduced species, 2) natural flow regimes, 3) channel dynamics, sediment transport, and riparian vegetation, 4) flood management as an ecosystem tool, 5) flood bypasses as habitat, 6) shallow-water habitats, 7) contaminants, 8) limiting factors, 9) fish-X2 relationships, 10) decline in Bay-Delta system productivity, 11) entrainment of fish at pumps, and 12) the importance of the Delta for chinook salmon. All but the entrainment issue are directly addressed by one or more ERP-CMARP or Water Quality Program elements. Entrainment issues are mentioned in a number of CMARP Bay-Delta system work team products. Programs directly focused on entrainment issues (at least at the Federal and State facilities) will likely be needed when the preferred alternative is selected and as part of real-time monitoring programs designed to guide project operations.

LINKAGES OF ERP-CMARP WITH OTHER COMMON PROGRAMS

The ERP-CMARP has linkages to other CALFED Common Programs (Chapter 4-K). Linkages of ERP-CMARP with elements of the Water Quality Program were the most commonly identified. These linkages included contaminants and general water quality measures important to organisms such as salinity. ERP actions to increase areas of wetland and other shallow-water habitats may also affect water quality by increasing the production of forms of organic carbon that can form disinfection byproducts during water treatment, an important human health consideration, and increasing bacteria-induced mercury methylation, which could have both ecosystem and human health effects. It was also recognized that bioassessments of fishes, invertebrates, and algae can be useful for both ecosystem and water-quality monitoring.

Linkages of the riverine components of ERP-CMARP with the Watershed Monitoring Coordination Program were commonly recognized. From an ecological perspective, the boundary between ERP and the Watershed Monitoring Coordination Program is completely artificial and it is possible that the boundary will blur in some cases, when CMARP is implemented.

The Water Transfers Program has potential ecological effects depending on the tools used. In-channel conveyance and diversion have implications for stream flow and hydrodynamics that may have to be addressed by ERP-CMARP. Less obvious are potential effects of conjunctive use of groundwater on ecosystems. Because groundwater and surface water are dynamically linked, groundwater withdrawals can have direct effects on stream flow of nearby streams and water levels in wetlands. The quality of groundwater entering these systems may also be important to ecological functions. The effects of ERP actions on water must be monitored. For example, assessments of evapotranspiration rates of restored wetlands and riparian forest might be necessary to understand effects of ERP actions on water transfers and water use efficiency. Possible effects on water quality for urban use of increased organic carbon loading from restored wetlands are also potentially important. There are also linkages between ERP and the Levees Program, through the Levee Habitat Mitigation Monitoring Plan (Levees Report, Appendix *VII.G.1*). Levees provide both terrestrial and instream habitat. Construction and maintenance activities to ensure levee integrity will be assessed for site specific and cumulative effects on the biological communities associated with them.

Perhaps the most important potential linkage between the ERP-CMARP and

other Common Programs is the selection of a preferred alternative and the choice of storage and conveyance tools chosen to implement the alternative. Many of the monitoring and research programs will have to be tailored to assess the success and effects of those choices. For example, reconfiguration of Delta channels to provide protection for fish species will have to be assessed to determine if those benefits are realized. The monitoring and research elements summarized above should not be viewed as static. The elements of ERP-CMARP should continue to evolve to best meet CALFED needs as those needs are clarified.

LINKAGES OF ERP-CMARP WITH NON-CALFED PROGRAMS

The ERP-CMARP, as presently described, constitutes a massive effort in both scope and cost; however, additional prioritization of program components and coordination with existing programs will maximize efficiency and reduce cost considerably. The CMARP inventory effort has documented many programs spending considerable sums of money on monitoring and research (Table 2-2). Presumably, coordination of CMARP efforts with other programs will result in benefits to both groups. Such coordination could range from simply using compatible data formats, to supplementation of ongoing programs with CALFED funds, to implementation of new CMARP programs that will provide data useful to the non-CALFED programs. Many of the individual work teams recognized these linkages and included them in their recommendations (Appendices *VII.A.1-14*). Consideration of the Fish-X2 (Appendix *VII.A.1*) and delta smelt (Appendix *VII.A.7*) components provides a useful example of the levels of integration that may occur in the final CMARP design. These two components are very important in the context of CALFED goals and appear expensive. However, as recognized by the delta smelt work team, ongoing monitoring of the IEP is largely sufficient for CALFED delta smelt needs. The recommendations for additional monitoring could be met by supplemental funding to IEP from CALFED. Much of the proposed delta smelt research is already funded and ongoing under IEP or other funding, including CALFED Category III funds. Some aspects of the research program have not been initiated and this work could be expedited by making additional funds available. The research identified under the delta smelt component should be highly compatible with the delta smelt-longfin smelt comparative study included in the Fish-X2 research design. The research in the Fish-X2 component is not as well funded by ongoing programs but is designed in an efficient sequential manner that should keep costs to a minimum. The IEP annually funds a variety of special studies and some of the Fish-X2 research may qualify for such funding. Work done under the delta smelt component will fulfill some of the research needs. Ongoing hydrodynamics work is funded by IEP, the USGS Ecosystem Program, and California Department of Water Resources Planning. Coordination of those programs with Fish-X2 hydrodynamic data needs may be possible, perhaps with supplemental funding from CALFED. Presumably other cost savings can be found for these and other ERP-CMARP components; however, some components will likely have to be heavily funded if functioning programs do not exist and the component is deemed to be a high priority CALFED need.

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Chapter 4, part C. WATER QUALITY

CALFED PROGRAM GOALS AND OBJECTIVES

The CALFED Bay-Delta Program's goal for water quality is to improve the quality of water of the Sacramento-San Joaquin Delta Estuary for all beneficial uses; including domestic, industrial, agricultural, recreation, and aquatic habitat. Providing good water quality for agricultural and industrial uses includes lowering mineral, nutrient, and metal concentrations in water such that the water is nontoxic and can be reused. The goal for drinking water quality is to reduce pathogens, nutrients, turbidity, and toxic substances in source waters to the Delta through watershed protection measures. In addition, bromide and organic carbon levels would be low enough to meet drinking water regulations. Good water quality for recreational use involves reduction of disease-causing organisms in the water and reduction in nuisance algal blooms.

Because water quality is intrinsically linked to ecosystem health, this section of the monitoring plan also addresses the CALFED Ecosystem Restoration goal of rehabilitating the capacity of the Bay-Delta system to support, with minimal ongoing human intervention, natural aquatic and associated terrestrial biotic communities in ways that favor native members of those communities. The CALFED Watershed Management Coordination Program goal, to help coordinate and integrate existing and future local watershed programs and to provide technical assistance and funding for watershed activities, will be partially addressed by the water-quality-monitoring program.

The water-quality-monitoring program scope includes baseline, trend, effectiveness, compliance/mitigation and operations monitoring. The program addresses the programmatic water-quality actions outlined in the CALFED Phase II Report (11/98) (Table 4-2).

GOALS AND OBJECTIVES OF THE MONITORING PLAN

The goal of the water-quality-monitoring plan is to monitor water quality and associated physical and environmental variables to document the effects of CALFED Stage 1 actions on water quality and on the ecosystem (Table 4-3). A monitoring network will be established to evaluate the success of proposed CALFED Water-Quality Program Plan actions, to address or verify identified water-quality problems, and to assess trends, loads, and sources of important water-quality constituents. The major question, "Is Delta water quality improving?", will be addressed through this monitoring program.

Monitoring Principles—The water-quality-monitoring plan is based on several monitoring principles. To maximize the efficiency and effectiveness of monitoring, the monitoring plans are based on conceptual models (For example, see *Appendix VII.B.4*: Disinfection Byproduct Precursors, and San Joaquin Basin Dormant Spray Pesticides). Also to maximize efficiency and effectiveness, the monitoring plan uses existing programs as much as possible (Table 4-6). For example, the proposed contaminant monitoring program is based on the Sacramento River Watershed Monitoring Program, the USGS National Water-Quality Assessment Program and special programs, the Interagency Ecological Program and the San Francisco Estuary Institute Regional Monitoring Program. The water-quality-monitoring plan is integrated with monitoring plans for the other common programs (see "Linkages" at the end of this chapter). To the extent possible, local and interagency cooperation and involvement is encouraged and has been received in some areas. The proposed program should be integrated with monitoring efforts by local watershed groups.

Table 4-2. Water-Quality Program Actions

Drinking Water	Improve source-water quality to reduce potentially toxic and carcinogenic disinfection by-products by controlling TOC, pathogens, turbidity and bromide
Pesticides	Reduce impacts of pesticides through development and implementation of Best Management Practices, for both urban and agricultural uses, and support of pesticide studies and pilot projects for regulatory agencies while providing education and assistance in implementation of control strategies for the regulated pesticide users.
Organochlorine Pesticides	Reduce the load of organochlorine pesticides in the system, including residual DDT and Chlordane, by reducing runoff and erosion from agricultural lands through Best Management Practices. Sediment control will also protect valuable topsoil and prevent costly maintenance of drainage systems.
Trace Metals	Reduce impacts of trace metals such as copper, cadmium, and zinc in upper watershed areas, near abandoned mine sites. Reduce impacts of copper through urban stormwater programs and agricultural Best Management Practices. Study the ecological impacts of copper in the Delta. Determine the feasibility of copper reduction in the Delta.
Mercury	Reduce mercury in rivers and the estuary by source control at inactive and abandoned mine sites. Also study bioavailable mercury in the rivers and the estuary and its potential threat to human health.
Salinity	Reduce salinity through reduction of leaching of agricultural land via irrigation improvement, crop selection and changes in land use. Reduce imports of salt and study non-agricultural source contributions. Salinity reductions in the river would also incorporate real-time management of salt discharges. San Joaquin drainage problems have been evaluated in several studies over the past two decades. Complete resolution of the San Joaquin drainage problems is beyond the scope of the CALFED Bay-Delta Program.
Selenium	Reduce selenium, through irrigation control, crop selection, and possibly land fallowing or land retirement. Impacts of selenium will be further reduced by real-time management of selenium laden agricultural drain water released to the San Joaquin River to minimize concentrations in the river when selenium discharges occur.
Turbidity and Sedimentation	Reduce turbidity and sedimentation, which affect several hydraulic areas in the Bay/Delta and its tributaries, including treatment of drinking water sources. Study ecological impacts of sedimentation. Control sedimentation in several watersheds to protect spawning beds and maintain capacity of streams.
Low Dissolved Oxygen	Reduce impairment of rivers and the estuary caused by substances that exert excessive demand on dissolved oxygen. Oxygen-depleting substances are found in waste discharges, agricultural discharges, urban stormwater, sediment, and algae.
Toxicity of Unknown Origin	Through research and monitoring, identify parameters of concern in the water and sediment within the Delta, Bay, Sacramento River and San Joaquin River regions and implement actions to reduce their toxicity to aquatic organisms.

Table 4-3. Water-Quality Monitoring Objectives

1. Assess effects of CALFED activities (including Ecosystem Restoration, Storage and Conveyance, Water Transfers, Water Use Efficiency, Watershed Management Coordination, and Levee System Integrity Programs) on water quality
2. Determine sources, loads, and trends of water-quality constituents of concern
3. Assess system productivity of Bay/Delta waters
4. Monitor water and sediment quality as necessary to comply with CALFED actions
5. Provide continuing data on water-quality constituents of concern, such as bromide, that may indicate the need for further CALFED actions to improve water quality.
6. Assess ecological and human-health related to water and sediment quality, including monitoring contaminant concentrations in biota.

RECOMMENDED MONITORING

Five workgroups addressing different regional and constituent groups developed the recommended monitoring. The five groups are Sacramento Region, San Joaquin Region, Bay-Delta Region Contaminants, Bay-Delta Region Ecosystem Productivity, and Bay-Delta Region Drinking Water. Full reports from these workgroups are in Appendices *VII.B.1* through *VII.B.4.* The individual monitoring programs were integrated into the comprehensive program presented here. The water-quality-monitoring program is summarized for environmental contaminants, ecosystem productivity, and drinking water.

Environmental Contaminants

Contaminant monitoring is designed to monitor both human health and ecosystem effects of contaminants. This monitoring would address the CALFED actions to improve aquatic environments by reducing the concentration and loading of contaminants. The contaminants monitored are based on lists of contaminants developed by the CALFED Water-Quality Program, Regional Water-Quality Control Boards, the U.S. Environmental Protection Agency, and technical experts. These programs will be coordinated to provide information on the following classes of constituents:

- General water and sediment chemistry
- Nutrients
- Metals and trace elements
- Pesticides
- Turbidity and sedimentation
- Pathogens
- Water and sediment assays
- Bioaccumulation
- Ecological effects of contaminants

The list of contaminants will be amended if other contaminants, not now being regulated or considered for regulation, become important.

General Water and Sediment Chemistry

Measurements, such as temperature, specific conductance or electrical conductivity (EC), salinity, pH, total dissolved solids, dissolved oxygen (DO), are general indicators of water quality. Temperature and pH are critical in determining speciation of other water-quality constituents. This is important in determining the fate of constituents and, in some cases, bioavailability or toxicity of contaminants. EC, a measure of salinity, is often related to other constituents and can serve as a surrogate for other measurements. Salinity measurements are important because salinity criteria need to be met in the Bay-Delta estuary, according to Bay-Delta water rights agreements.

Sediment characteristics such as grain-size, total organic carbon (TOC), ammonia and sulfides are recommended to assess the condition of the benthic habitats.
Many of these general chemical measurements have ecosystem effects. Elevated temperatures and low dissolved oxygen levels may adversely affect migration and spawning of salmon and steelhead, for example.

Nutrients
Nutrient concentrations can indicate the potential for algal blooms, which can cause problems in drinking water taste and odor and for ecosystem effects such as eutrophication. Algal blooms can also contribute to disinfection by-product production, a drinking water concern. Monitoring of nutrient concentrations is useful to determine possible sources of nonpoint-source pollution such as from agriculture, dairies and livestock operations and from urban runoff.

Metals and Trace Elements
High concentrations of metals and trace elements can be toxic to humans and aquatic organisms. Some trace elements such as selenium, bioaccumulate and can pose a threat to wildlife even though dissolved selenium concentrations may be relatively low. Monitoring of metals and trace elements will focus on particular contaminants of concern in different watersheds. In the Sacramento watershed, metals such as mercury, cadmium, chromium, copper, and zinc are released from abandoned mines. Mercury buried in hydraulic mining debris throughout the estuary, delta and watershed may be available for biological uptake. In the San Joaquin watershed, trace elements of most concern are selenium, boron, and molybdenum. Monitoring and special studies in the Bay-Delta to identify sources and effects of mercury and selenium to the Bay-Delta are proposed.

Pesticides
Pesticides will be selected for monitoring based on the quantity of pesticide used in a particular location, the pesticide's potential to cause toxicity to aquatic organisms, the timing of application, the physical properties of the pesticide, and its demonstrated capacity to mobilize in the environment. Certain pesticides that are no longer used but are persistent in the environment (DDT, toxaphene, dieldrin, and chlordane) are proposed for monitoring as well.

Turbidity and Sedimentation
Turbidity and sedimentation are of concern for contaminant, drinking water and ecosystem effects. Contaminants, such as organochlorine pesticides, metals, and other inorganic constituents such as phosphorus, can be transported with sediments. Turbidity and sedimentation will be monitored to assess how they affect water quality and water treatment (see 2. Drinking Water, below). Ecosystem effects include smothering of spawning gravels and effects on ecosystem productivity, transport of contaminants, and benthic effects. Salmon emigration may be affected by precipitation-induced increases in turbidity in rivers and streams. Positive effects of turbidity and sedimentation may include sediment recruitment for habitat and decreased light infiltration that reduces algal blooms in the Delta.

Pathogens
Pathogens such as *Giardia* and *Cryptosprodium* are proposed for monitoring in both the Sacramento and San Joaquin watersheds. However, better analytical test methods are needed to assess the viability and actual human health risks associated with existing pathogen levels in the system (See 2. Drinking Water, below for more detail).

Water and Sediment Bioassays
Water and sediment bioassays will be used to monitor toxicity to biological organisms. Toxicity monitoring is essential because toxicity may result from an unknown

C-021907

C-021907

contaminant or from a combination of contaminants, that may not be detected by analysis of individual contaminant levels. Toxicity identification evaluations (TIEs) are proposed to analyze the source of detected toxicity. Samples will be taken in sufficient numbers so that there can be statistical evaluation of toxicity.

Bioaccumulation
Bioaccumulation monitoring is essential for assessing ecosystem and human health effects of contaminants that concentrate in the food chain. Bioaccumulation information will be used to determine the potential for ecological damage due to contaminant body burdens and to assess human health risks from ingestion of fish and shellfish. Examples of proposed bioaccumulation monitoring are determining concentrations of persistent contaminants such as mercury, PCBs, dioxins and organochlorine pesticides in bivalves like *Potamocorbula*, fish and bird tissues.

Ecological Effects of Contaminants
Ecological effects of contaminants should be monitored in close coordination with restoration monitoring. Many ecological response indicators can be used to monitor contaminant effects. For example, the number of benthic species per sample is a commonly used indicator of benthic response to contaminants. However, to evaluate whether numbers of benthic species are affected by contaminated sediments or other factors, a suite of "habitat" and "stressor" measurements must be monitored synoptically with the benthos. Monitoring selected indicators of phytoplankton, zooplankton, benthic invertebrates, and several fish species for potential contaminant effects is recommended. Measurements of production, growth, mortality, or reproductive capacity are also recommended.

Summary of Environmental Contaminant Monitoring
Environmental contaminants will be monitored for potential human health and ecosystem effects. This monitoring consists of the above general classes of contaminants, but will be focused spatially and temporally based upon existing information about these contaminants. Sufficient sampling should take place to assess statistical significance of toxicity or other effects found. For detailed information about specific monitoring proposed for each region and class of contaminants, see Appendices *VII.B.1* through *VII.B.4.*

Ecosystem Productivity
In addition to monitoring environmental contaminants, the water-quality-monitoring program consists of monitoring to determine the biological productivity of the water and sediment. System productivity is a measure of ecosystem health. Ecosystem productivity monitoring includes monitoring of physical processes, conventional water quality (not including contaminants or human health effects), and the status of lower trophic levels (microbes, phytoplankton, aquatic plants, and invertebrates, not including decapod shrimp or crabs). The following general classes of variables are proposed for monitoring:

- Basic physical variables
- Flow variables
- Chemical constituents
- Primary producers
- Microbial communities
- Zooplankton
- Sediment quality
- Benthic fauna

Basic physical variables
This includes climate, meteorological measures, salinity, temperature, suspended sediment/water clarity, and light attenuation. These variables affect the biological productivity of the system. Salinity, temperature and water clarity will be monitored for both ecosystem contaminants

(discussed in the previous section) and for ecosystem productivity.

Flow variables
Total daily inflow, diversion flows, tidal flows, and net (tidally-averaged) flows provide the essential underlying information defining the hydrologic environment of the Bay-Delta and thus for interpreting and analyzing data from the estuary.

Chemical constituents
Dissolved oxygen, pH, nutrients, organic nutrients and organic carbon along with physical factors such as light attenuation are important in assessing ecosystem productivity. Many of these constituents will be monitored for ecosystem productivity, environmental contaminant and drinking water purposes.

Primary producers
Primary producers are basic components of the food web, upon which the ecosystem depends. The biomass of phytoplankton is an indicator of the quantity of food energy (carbon) available at the base of the food web. Excessive phytoplankton biomass can suggest eutrophication. Primary production will be assessed by measuring the variables: phytoplankton biomass, phytoplankton primary production, phytoplankton species, benthic microalgae, and quantity and quality of submerged aquatic vegetation.

Microbial communities
Microbial communities, characterized by bacterial counts, biomass, and metabolic rate, are proposed for monitoring on a periodic, but infrequent basis, perhaps every quarter or in alternate years. Bacteria are an important part of the Bay's food web, but measurements are somewhat difficult and require specialized expertise.

Zooplankton
Zooplankton, a component in the food chain, will be assessed by monitoring mesozooplankton, macrozooplankton, microzooplankton, gelatinous zooplankton, and zooplankton secondary production. Assessing this step in the food chain is critical for ecosystem food-web analysis.

Sediment quality
Sediment quality is an important factor in assessing ecosystem health. Sediment contaminated with toxic substances may result in acute or chronic toxicity to benthic organisms and therefore affect ecosystem productivity. As described earlier (see Environmental Contaminants, Water and Sediment Chemistry), sediment characteristics will be monitored.

Benthic fauna
Benthos community composition can serve as an indicator of water quality and of changes in lower trophic level aquatic community structure and secondary productivity. Several reasons justify this monitoring:

- Benthic fauna are an important trophic step between living and detrital particulate organic matter and higher trophic levels including fish, birds, and people
- Benthic fauna contribute to the flux of dissolved and particulate material (including contaminants) between the sediment and the overlying water
- The types and abundance of benthic animals and their variation are commonly used as indicators of water quality
- The benthos of coastal aquatic systems is particularly susceptible to invasions of non-indigenous species released from ballast water. Because most benthic organisms do not move far after settlement, the benthic community provides a continuing record, through changes in species composition or abundance, of the effects of both short- and long-term changes in the environment.

Summary of System Productivity Monitoring
By monitoring water quality and the lowest levels of the ecosystem food chain, changes

in the ecosystem as a result of CALFED actions may be documented. Many components of system productivity monitoring will also provide information to the other water-quality-monitoring program elements and to the ecosystem-monitoring program.

Drinking Water

Nearly 23 million people are dependent on the Sacramento-San Joaquin Delta for their drinking water supply. There are public health issues associated with providing good quality water from the Delta (see Table 4-4). Disinfection by-products (DBPs) are produced when source water containing organic matter and bromide are disinfected in drinking-water-treatment facilities. Example DBPs include trihalomethane (THM), haloacetic acid, and bromate (see Table 4-4). Although DBPs could be decreased by reducing the amount of disinfectant used, drinking water regulations enforced by the Department of Health Services require certain disinfectant concentrations and contact times. Reducing the amount of disinfection can result in greater quantities of disease-causing pathogens surviving the disinfection process. There are technological and cost limitations to treating pathogens and DBP precursors (DBPP) in drinking water. Therefore, it is critical that the Delta source water be closely monitored so that CALFED actions can be taken to produce the best quality source water possible.

Water utilities using Delta water as a source of drinking water face significant challenges in meeting federal drinking water standards on DBPs due to much higher levels of DBPPs in Delta water compared to the national averages. These utilities are able to meet current standards after considerable investment in drinking water treatment facilities.

Future drinking water regulations could become much more stringent if results from ongoing research indicate significant health risks of DBPs to humans. For example, the placeholder limits in Stage 2 of the Disinfectanct/DBP Rule, to be promulgated in 2002, would lower the Stage 1 limits on DBPs by 50%. Currently, Stage 1 of the Disinfectant/DBP Rule, promulgated December 1998, reduces the existing total THM limits by 20% and imposes a limit on the heretofore-unregulated DBP bromate. For utilities using ozone for disinfection, the new Stage 1 limit on bromate could be difficult to meet, especially during droughts when the bromide level in Delta water could be 10 or more times higher than that of the national average. Given the relatively few ozonation treatment plants using Delta water and their short histories of operation, it is too early to tell if the Stage 1 bromate limit could be met during drought conditions.

For the longer term, the potential combination of higher disinfection requirements and more stringent limits on DBPs could make it extremely difficult for Delta agencies using existing advanced treatment processes (ozonation and chlorination with enhanced coagulation) to comply with future regulatory standards unless Delta water quality is significantly improved, especially during droughts.

TOC, bromide, and pathogenic organisms in Delta waters need to be controlled so water utilities using Delta waters can meet current and new drinking water standards and provide drinking water that will not cause adverse health effects.

Table 4-4. Drinking Water Contaminants and Potential Health Effects

Drinking Water Contaminant	Potential Health Effects
Pathogenic organisms	Infections; illness; possible deaths
Trihalomethanes, haloacetic acids, and other disinfection by-products	Cancer; spontaneous abortions; liver; kidney, and nervous system toxicity
Bromate (a DBP)	Cancer

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C-021910

However, CALFED actions may increase the concentration of constituents of concern in Delta waters. In particular, creation of wetlands as part of the CALFED Ecosystem Restoration program will likely increase concentrations of particular forms of TOC with a high propensity to form DBPs. However, due to the land conversion from agriculture to wetlands, DBPPs that would have been produced under agriculture will not be formed. Also, the increased tidal exchange resulting from the wetlands may increase the concentration of bromide and Total Dissolved Solids (TDS) in Delta waters. Due to impending regulation, elevated bromide concentrations may indicate the need for further CALFED actions to improve water quality.

Subsidence of Delta islands may increase the loads of DBPPs in island drainage. Peat island drainage has been previously shown to contain higher concentrations of dissolved organic carbon (DOC), THMFP and other DBPPs than freshwater inputs to the Delta, the Sacramento and San Joaquin Rivers (Amy et al., 1990, DWR, 1990). Drainage on Delta islands will increase as peat islands continue to subside, thereby increasing the loads of DBPPs pumped off island. Therefore, if subsidence mitigation is not a CALFED priority, DBPP loads associated with continued subsidence will continue to increase.

The key drinking-water-constituents of concern to be monitored are DBPP sources, concentrations and loads (TOC and bromide), pathogenic organisms (*Giardia*, *Cryptosporidium*, coliform bacteria, and viruses), the concentration of other chemical contaminants (pesticides, metals, and other organic compounds such as MTBE), TDS or salinity, nutrients, and turbidity (Table 4-5).

Summary of Drinking Water-Monitoring
CALFED, through the Water Quality Program Plan, proposes activities to improve water quality at an affordable cost. However, certain CALFED actions may significantly increase the concentration of drinking water contaminants in Delta waters, thereby exacerbating existing conditions, particularly in relation to formation of DBPs. CMARP will monitor changes in contaminant concentrations to ensure that water quality is not further degraded as a result of CALFED ecosystem actions. Drinking water-quality contaminants are undergoing increasingly stringent regulation. Further degradation of Delta source waters would increase the cost and decrease the effectiveness of water treatment.

Table 4-5. Drinking Water Constituents of Concern

Monitoring Constituent	Significance to Drinking Water Quality
TOC (DBP precursor)	Formation of disinfection by-products
Bromide (DBP precursor)	Formation of brominated disinfection by-products and bromate
Pathogenic organisms	Waterborne diseases
Chemical contaminants	Regulated drinking water-quality constituents
TDS or salinity	Taste and odor problems (salty taste), corrosion of infrastructure and appliances, effects on wastewater reclamation programs, groundwater conjunctive use programs and blending projects, health concerns (sodium)
Nutrients	Taste and odor problems (algae-geosmin and 2-methylisoborneol), effects on filtration (algae)
Turbidity	Effects on filtration and disinfection

RESEARCH NEEDS

Research needs for environmental contaminants, agricultural contaminants and drinking water contaminants are listed below. For detailed lists of research questions, see Appendices *VII.A.6, B.1, and B.2*).

Environmental Contaminants

- Determine causes of unknown water and sediment toxicity
- Develop toxicity testing with resident organisms
- Develop contaminant effects indicators in the estuary.
- Study bioaccumulation of contaminants
- Determine sources of mercury and other contaminants
- Determine fate and transport of mercury, selenium and other contaminants
- Estimate sediment loadings and predict changes in sediment loadings due to CALFED actions including ecosystem restoration projects and changes in storage and conveyance
- Research methods to manage urban stormwater drainage/urban runoff to minimize toxicity to resident organisms
- Research control methods of introduced aquatic weeds/species that minimize toxicity to nontarget organisms
- Develop Best Management Practices to reduce the transport of pesticides and other contaminants to water sources

System Productivity

- Reevaluate the flow-X2 relationship and update it (base the relationship on a larger dataset and make any changes in the relationship necessary)
- Develop carbon and nutrient budgets for the estuary and its sub-regions
- Develop models of phytoplankton dynamics for the estuary and its sub-regions
- Determine the relative importance of various organic carbon sources in the northern estuary
- Determine the fate of bacterial production in the northern estuary
- Continue and expand work on retention mechanisms in the Low-Salinity Zone and seaward
- Assess the role of benthic microalgae in the estuarine food web
- Model studies of the food web
- Study the role of introduced zooplankton species in the food web
- Continue studies of the influence of *Potamocorbula amurensis* on estuarine food webs
- Anticipate the role in the food web of additional introductions of non-indigenous species
- Determine the roles of benthic invertebrates and various size classes of zooplankton in the food web leading to species targeted for restoration
- Sediment studies to estimate loadings of sediment from the mainstem rivers into the Bay and Delta
- Sediment studies to determine deposition rates, residence times, and burial rates for sediment in representative habitat types in the Bay-Delta
- Determine benthic production in each major habitat
- Determine the effects of shallow water restoration projects on primary production
- Determine the importance of sediment and nutrients to production of phytoplankton and aquatic plants
- Determine factors that control higher aquatic plant growth in the estuary

Drinking Water

- Determine loads of DBPPs associated with key sources (e.g., agricultural, wetland, riparian, and island drainage).
- Assess potential loads of DBPPs produced by CALFED programs such as Ecosystem Restoration.

- Develop accurate predictive models of pathogen and DBPP behavior and transport, along with other tools to assess and predict the effects of CALFED programs on concentrations of DBPPs (including bromide) reaching major drinking-water intakes in the Delta.
- Assess the potential effects of operational changes (such as reservoir operations, flow barriers, or exports) on delivered water quality using aforementioned models.
- Identify methods for accurate determination of pathogens.
- Identify and develop source control measures for mitigation of pathogen and DBPPs.
- Perform and evaluate pilot scale implementations of source control measures.
- Improve water quality models that predict final DBP concentrations in treatment plants after disinfection.

LINKAGES

Ecosystem Restoration—Water quality is an integral part of ecosystem health. The productivity of the ecosystem depends on such factors as temperature, salinity, nutrient concentrations and dissolved oxygen. Aquatic and sediment toxicity monitoring provide information both on water-quality and ecosystem effects of pollutants. The measurement of contaminant effects on fish reveals the presence of contaminants in the water as well as the resultant effects on fish. Water-quality investigations in the upper tributaries will be linked with other ecosystem measurements such as aquatic life, riparian vegetation, etc.

The following is a partial list of monitoring common to both the Water Quality and Ecosystem Restoration programs.

- Composition and health of benthic invertebrate species can be an indicator of ecosystem health and therefore provide information on contaminants, introduction of non-indigenous species, and productivity of the ecosystem.
- X-2 or salinity monitoring is important both for the ecosystem and water-quality effects.
- The potential water-quality effects of ecosystem restoration activities, such as the creation of shallow-water habitat, setting back levees and/or the flooding of peat islands will be monitored.
- Measurements of constituents important to the productivity of the ecosystem such as microbial communities, sediment quality, light attenuation, salinity and temperature.
- Non-indigenous species affect both the ecosystem and water quality. For example, the non-indigenous species *Potamocorbula,* the Asian clam, filters Bay waters increasing water clarity, but decreasing the nutritive value of the water to aquatic organisms.

Delta Levees and Storage and Conveyance—Water and sediment quality monitoring is important for obtaining water-quality permits for levee maintenance and dredging operations. In turn, dredging and levee building operations need to be closely coordinated with water-quality monitoring. Monitoring of sediment (described in the ecosystem section of this chapter) provides information on water quality, levee erosion, channel scouring and sedimentation. Mitigation and levee- enhancement restoration work required for levee repair work will be closely linked with Water Quality and the Ecosystem Restoration programs.

Water Transfers and Water Use Efficiency—Ground and surface water-quality monitoring will be integrated with the Water Transfers and Water Use Efficiency programs. The quality of water (salinity and concentrations of contaminants such as selenium) will limit water transfers and the reuse of water. Also, measurements of water quantity (both groundwater and

C—021913

C-021913

surface water) are important for both the Water Transfers and Water Use Efficiency programs as well as calculations of loading of contaminants for the Water Quality program.

Watershed Management Coordination—Water-quality monitoring in the upper tributaries (above dams) and lower watersheds will be coordinated with the Watershed Management Coordination program. This program will involve local resources and will conduct restoration activities in the upper watersheds that may affect downstream water quality. Water-quality monitoring will provide information on watershed function and human activities, (such as source contaminants) and will be closely coordinated with monitoring of ecosystem attributes (such as vegetation, fish, and invertebrate species).

Table 4-6. Major Existing Water-Quality Monitoring Programs

Program Name	Region	Constituents Monitored								
		General	Metals	Nutrients	Organics	Sediment	Pesticides	Pathogens	Biological	Toxicity
California Department of Fish and Game	Sac.	X					X		X	
Department of Pesticide Regulation	Sac./San Joaquin	X					X			X
Compliance Monitoring, DWR	Bay-Delta	X		X						
Municipal Water-Quality Investigations Program, DWR	Bay/Delta	X	X	X	X		X	X		
State Water Project Water-Quality Monitoring Program, DWR	Bay-Delta	X		X	X			X		
Interagency Ecological program	Bay/Delta	X	X	X			X		X	
Central Valley Ambient Monitoring Studies/RWQCB	Sac./San Joaquin		X							X
San Francisco Estuary Regional Monitoring Program, SF Estuary Institute	Bay-Delta	X	X	X	X	X	X		X	X
National Water-Quality Assessment Program, United States Geological Survey	Sac./San Joaquin	X	X	X	X		X		X	
Sacramento River Watershed Program Monitoring program	Sac.	X	X	X	X	X	X	X	X	X
Toxic Substances Hydrology Project, USGS	Bay-Delta						X			

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Chapter 4, part D. DELTA LEVEE SYSTEM INTEGRITY

MONITORING OBJECTIVES

The fundamental goal of the overall Delta Levee System Integrity Program is to "reduce the risk to land use and associated economic activities, water supply, infrastructure, and the ecosystem from catastrophic breaching of Delta levees." The specific elements of the Delta Levee System Integrity Program are discussed fully in the CALFED Long-Term Levee Protection Plan and include:

1. **Base Level Protection Plan:** Target – Improve and maintain Delta levees to the Public Law 94-99 (PL 84-99) standard.
2. **Special Improvement Projects:** Target - Improve and maintain levees at key Delta locations to a level commensurate with the benefits protected.
3. **Subsidence Control Plan:** Target – Reduce or eliminate risk to levee integrity from subsidence.
4. **Emergency Management and Response Plan:** Target – Enhance existing emergency management and response capabilities to protect critical Delta resources in the event of a disaster.
5. **Seismic Risk Assessment:** Target – Identify risk to Delta levees from seismic events and develop recommendations to reduce levee vulnerability and improve their seismic stability.

The monitoring elements selected by the CMARP Levees Technical Team will support a determination of whether the above program elements are achieved.

Indicators have been identified for each of the program elements. An indicator is a set of system attributes that collectively provides a convenient way to evaluate the status of the overall system. Indicators will be used to show progress towards the CALFED Levee Program goals. For example, the indicator for the Base Level Protection Plan element, "number of islands/tracts with levees meeting the minimum PL84-99 standard," will be determined by a compilation of cross-section, inspection, and other data, and this determination will be used to measure progress towards the Base Level Protection Plan goal of improving all Delta levees to the PL84-99 standard.

Additionally, monitoring elements must be developed to insure the success of environmental mitigation required to offset the effects from implementation of any of the above elements.

Levee Monitoring Objectives Containing Physical Properties

1. Establish that a base level of flood protection for Delta levees at the PL 84-99 standard, or higher as necessary, has been achieved and maintained.
2. Establish that special levee improvements have been achieved and maintained in key Delta locations to a level commensurate with the benefits protected.
3. Establish that the risk to levee integrity from subsidence has been reduced.
4. Establish that an emergency management and response plan with the capability to protect critical Delta resources in the event of a disaster has been adopted and maintained.
5. Quantify Delta levee seismic risk and compare it to other failure modes.

Levee Monitoring Objectives Containing Biological Properties

Establish that effects from any construction/management action associated with achieving the overall objectives of the Delta Levee System Integrity Program are mitigated as appropriate. Construction/management actions include:

A. Levee improvements or maintenance.
B. Excavation of material at borrow sites and its transport to the construction sites.
C. Channel dredging for fill material.
D. Placement of dredge reuse material.
E. Subsidence control features.

CONCEPTUAL MODEL AND/OR LISTING OF HYPOTHESES AND ASSUMPTIONS OF THE SYSTEM

Common Survey Standards
Monitoring plans for Delta Levee System Integrity Program elements are directly or indirectly dependent on accurate vertical and horizontal data. A common coordinate system for quantifying and mapping features that are tied to vertical and horizontal position data in the Delta is critical in determining levee standard compliance, providing emergency response, and evaluating the effects of subsidence and seismic activity. Specifically, minimum survey-control standards are needed to develop a network of vertical and horizontal control points in the Delta.

Without this common survey standard, true elevations and horizontal positions for Delta levees cannot be known, thereby leading to a false sense of confidence in survey data and flood protection. Appendix *VII.G.f* contains specific recommended methodology for establishing the needed common survey standards for the Delta.

Models and Assumptions of the Levee System
The Delta Levees component of CMARP does not have a classic, analytical model levee condition or behavior. However, several specific factors can be measured relative to each of the five Delta Levee System Integrity Program elements.

1. <u>Base Level Protection Plan and Special Improvement Projects</u>

Levees may be built to various standards, depending on the level of flood protection desired. It is the goal of the Long-Term Levee Protection Plan to eventually implement Public Law 84-99 (PL 84-99) performance criteria for non-project levees in the Delta (See Attachment A to Appendix *VII.G.a*). It is envisioned that higher flood protection standards may be desirable at key Delta locations to a level commensurate with the benefits protected. Most Federal project levees in the Delta already meet the PL 84-99 standard. PL 84-99 criteria include specific cross-section dimensions that must be achieved and maintained. The geometry of the levee will significantly influence how the levee responds to geotechnical and hydraulic forces in the system.

Once a levee is built to a desired standard for flood protection, it is imperative that it be maintained to resist the many forces that work to undermine its integrity. The first step in levee maintenance is levee inspection, which detects various problems before they become critical threats. Levee inspections evaluate the condition of the levee crown road, the condition and inspectability of the land and water sides of the levee, the presence of levee encroachments, and evidence of animal-burrowing damage. Once a problem is detected with any part of the levee, maintenance should proceed. Appendix *VII.G.a* describes the specific monitoring plan for these elements. (In some cases, the Special Improvement Projects element may include monitoring from other elements such as the Subsidence Control element.)

2. <u>Subsidence Control Plan</u>
Subsidence has substantially contributed to the Delta islands current condition of relatively tall levees protecting interiors below sea level. Recently, however, the risk to levee integrity from subsidence has

C-021917

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diminished. Land management and levee maintenance practices have improved, and subsidence rates have decreased. In addition, it has been determined that a zone of influence (ZOI) extends from the levee crest to some distance inland, beyond which subsidence will not affect levee integrity. However, subsidence within the ZOI may potentially impact levee integrity. The ZOI for a reach of levee can be determined using site-specific data. The Subsidence Control element will include monitoring to determine if levee integrity may be compromised due to subsidence (Appendix *VII.G.b*).

3. Emergency Management and Response Plan
Delta levees have a history of failure, bringing the devastating effects of flooding to various land uses. Many of these levees failed without warning and were not tied to a single stressful event (storm, etc.). Proper emergency response activities can be a cost-effective supplement for levee protection; however, they cannot substitute for a proper maintenance and repair program.

Delta levees protect approximately 527,300 acres of farmland, 67,000 acres of urban development, and 82,800 acres of native habitat. The Delta's channels and adjacent banks provide habitat for fish and wildlife, accommodate shipping, provide local water supply, protect infrastructure and convey water to nearly 23 million Californians. Most of the protected land is below sea level and therefore emergency response actions are unusually important and require prompt response and action. A levee failure can endanger public safety and inundate thousands of acres of farmland up to 20 feet in depth; it is a costly process to reclaim the island. Also, such an event can cause significant salinity intrusion degrading Delta habitat and impeding the operations of major State and Federal water delivery systems.

An effective emergency response system is critical to the long-term protection of the Delta. The emergency response system must be monitored to insure that it adapts as conditions and needs change in the Delta (Appendix *VII.G.c*).

4. Seismic Risk Assessment
Earthquakes can cause levees to fail by slumping or liquefaction of underlying soils. To date, there have been no known Delta levee failures or island inundations as a result of seismic events. However, several active faults are located sufficiently close to the Delta to present a threat to Delta levees.

In 1992, the Department of Water Resources, Division of Engineering completed the "Phase I Report, Seismic Stability Evaluation of the Sacramento-San Joaquin Delta Levees." Subsequently, the Department took several actions to reduce some of the unknowns that influence the evaluation of levee stability during an earthquake.

Assessments by the U.S. Geological Survey concluded that there is a high probability that a large magnitude earthquake will occur in the San Francisco area within the next 30 years. This conclusion, together with the 1989 Loma Prieta Earthquake, has increased concerns for the seismic stability of levees protecting islands in the Sacramento-San Joaquin Delta.

There is concern because the islands in the Delta are generally 10 to 15 feet below sea level. The levees are usually composed of uncompacted sands and silts and are built without engineering design and/or good construction methods. Levees composed of such materials may experience liquefaction and damage during moderate-to-strong

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earthquakes. The inundation of one or more islands in the Delta during a period of low outflow could result in saline water from the San Francisco Bay being drawn into the Delta. This could significantly impact the export of water as well as numerous other public facilities and resources that afford a wide range of benefits to the people of California.

Generally, foundation soils in the Delta consist of varying amounts of organic soils. Knowledge of the dynamic behavior of organic soils in the Delta is essential for the determination of ground response to earthquake shaking (Appendix *VII.G.d*).

5. Habitat Mitigation
The Long Term Levee Protection Program includes measures to control subsidence, and reconstruct, relocate and maintain levees in the Delta. These measures will likely require significant amounts of fill material to be extracted from sources within and around the Delta, including dredging from Delta channels, and their placement on and around levees. This work may result in significant effects on terrestrial and aquatic resources. Monitoring and research will help quantify these effects and any necessary compensation (Appendix *VII.G.e*).

MONITORING AND RESEARCH ELEMENTS

Following is a list of monitoring elements that the CMARP Levees Technical Team recommends for inclusion in the overall assessment of levee integrity and durability pursuant to the Delta Levee System Integrity Program. Each of these monitoring elements, including their respective research components, is described in detail in Appendices *VII.G.a-f*. Indicators for each of the Levee Program elements are described in Appendix *VII.G*.

1. Levee Standard Monitoring Plan: Appendix *VII.G.a.*
2. Subsidence Control Monitoring Plan: Appendix *VII.G.b.*
3. Emergency Management and Response Monitoring Plan: Appendix *VII.G.c.*
4. Seismic Risk Assessment Monitoring Plan: Appendix *VII.G.d.*
5. Habitat Mitigation Monitoring Plan: Appendix *VII.G.e.*
6. Common Survey Standard: Appendix *VII.G.f.*

INDICATORS

Indicators for evaluating progress toward the goals of individual Levee Program elements are described in detail in Appendices *VII.G.a-f* and are summarized below:

1. Goal: The Base Level Protection goal is to improve and maintain Delta levees to the PL84-99 standard.
Indicator: The number of islands / tracts with levees meeting the minimum PL84-99 standard.

2. Goal: The Special Improvement Project goal is to provide additional flood protection for key islands that provide state wide and national benefit.
Indicator: The number or levee miles or islands / tracks with enhanced, above PL84-99, flood protection, (Static factor of safety greater than 1.5). It is also suggested that a panel be convened to make a qualitative assessment of progress towards the Special Improvement Project goal.

3. Goal: The Subsidence Control goal is to reduce or eliminate the risk to the levee system from subsidence.
Indicator: The number or levee miles or islands / tracks with subsidence control measures.

4. Goal: The Emergency Management goal is to enhance existing emergency and response capabilities.
   Indicator: Because of the large number of variables and the qualitative nature of assessing emergency management and response capability, a specific indicator has not been identified. It is suggested that a panel be convened to make a qualitative assessment of progress towards the Emergency Management goal.

5. Goal: The Delta Levee Seismic Risk Assessment goal is to identify the risk to levees from seismic events and develop recommendations to reduce seismic vulnerability.
   Indicator: The number of levee miles or islands / tracks that have received seismic upgrades. (Seismic stability factors of safety greater than 1.0). It is also suggested that a panel be convened to make a qualitative assessment of progress towards the Delta Levee Seismic Risk Assessment goal.

LINKAGES

Monitoring and research proposed by the CMARP Levee Workteam overlap with other existing programs, CMARP workteams or components of the CALFED Program in many areas.

Much of CALFED Program work will require horizontal and vertical control. A single base map/control is critical. Horizontal and vertical datum will be needed by the CALFED storage and conveyance and ecosystem restoration program elements in addition to the Levee Program.

Many proposed components in the "Levee Standard Monitoring Plan," Appendix *VII.G.a*, are already being monitored by the DWR Central District as part of its administration of the Delta Levee Maintenance Subventions and Special Flood Control Projects Programs. The Subventions Program Maintenance Criteria presently conforms to the 1986 Flood Hazard Mitigation Plan for the Delta. Many nonproject "local" levees in the Delta have adopted the State's Short Term Levee Rehabilitation Plan standard found in the Flood Hazard Mitigation Plan for the Delta (1986)(HMP). To continue eligibility for FEMA disaster-assistance funding, these districts have submitted profiles and cross sections documenting minimum geometry and levee profiles to FEMA, the State Office of Emergency Services and the Delta Levee Maintenance Program. Requirements for compliance with the HMP are summarized below:

1. Levee Profile. Program participants are required to make a profile of the levee crown not less than every fifth year, or more often if determined necessary by the District Board (such as after severe storms).
2. Levee Cross Section. DWR retains copies of existing cross sections documenting that levees meet minimum HMP cross section criteria. When districts have brought their levees into compliance with HMP they are required to update cross sections, at intervals no greater than 500 feet, in rehabilitation projects areas. Copies of this information have also been submitted to FEMA.
3. Annual Levee Maintenance Inspection
   DWR and DFG annually inspect nonproject levees in the Delta in accordance with Water Code Section 12989, the 1986 Flood Hazard Mitigation Plan, and AB360 habitat requirements. The reviews include the following levee maintenance:
   - vegetation removal, road surface maintenance, roadway crown grading, and gate repair on the levee crown,
   - vegetation removal, hazard tree removal, mature tree trimming, slipouts, erosion, cracking, and subsidence on the land side levee slopes,
   - vegetation removal, revetment slippage, slipouts, erosion, cracking,

and Subsidence of the water side levee slopes,
- control of encroachments that affect levee integrity, and
- control of rodents that affect levee integrity.

In addition, approximately every two years, the U.S. Army Corps of Engineers inspects those levees for continuing eligibility with PL 84-99 certification.

The Storage and Conveyance Program of CALFED will also need the bathymetric data proposed in the "Levee Standard Monitoring Plan," Appendix *VII.G.a*, to monitor for sedimentation and scour. In addition, the Ecosystem Restoration Program will require information on sedimentation and scour as they impact benthic habitat and other ecosystem elements.

Research on sediment toxicity and characterization data proposed in the "Levee Standard Monitoring Plan," Appendix *VII.G.a*, is also of concern to the Ecosystem Restoration Plan. The ERP goals include the creation of shallow water habitat, which may involve dredged material. This research is also of concern to the Water Quality Program to quantify water-quality effects from dredge activities and placement of dredged materials.

Some data collection proposed in the "Subsidence Control Monitoring Plan," Appendix *VII.G.b*, is currently completed by other agencies. The Natural Resources Conservation Service obtains soil property information for publication, and some of this information may be applicable to the Plan. The "Subsidence Control Monitoring Plan" also calls for sea-level data, which are collected by NOAA, EPA, and USGS.

Some monitoring proposed in the "Seismic Risk Assessment Monitoring Plan," Appendix *VII.G.d*, is currently being done as part of the DWR DOE seismic studies program. This includes installation and monitoring of surface and subsurface strong motion instruments at four locations in the Delta, field and laboratory testing of soils at locations where surface and subsurface seismographs were installed, sponsored research on the dynamic response characteristics of organic soils, and additional dynamic response analysis.

Many monitoring elements proposed in the "Habitat and Mitigation Monitoring Plan," Appendix *VII.G.e*, are currently completed by DWR's Central District in conjunction with DFG in administering the Subventions and Special Programs Projects. Documentation for participation in the AB360 Program includes habitat assessments in areas where levee work may occur. DWR's Central District has begun compiling these data on a GIS database. In addition, many individual permits for levee construction and maintenance will likely require monitoring for success of mitigation. Finally, permits for dredging will likely require monitoring to assess effects of dredge activity.

Chapter 4, part E. SUBSIDENCE ON DELTA ISLANDS

CALFED GOALS AND OBJECTIVES

Reducing and reversing Delta island subsidence relates to the objectives of the Water Quality and Ecosystem Restoration Programs and more indirectly affects the Levee System Integrity program. Subsidence control measures could change the concentrations and quality of organic carbon in Delta water exports, thus affecting drinking water quality. In addition, the feasibility of wetland rehabilitation of subsided land depends on restoring its elevation to sea level. In the longer term, reducing and reversing island subsidence affects emergency management in the Delta islands since the consequences of a levee breach become more severe as the islands continue to subside.

CONCEPTUAL MODEL

The problem of controlling subsidence on Delta islands can be divided into five subject areas:

1. **Effects of Subsidence on Land Use and Water Quality** – As islands subside, the rate of water seepage through the levees increases. Increased seepage increases pumping costs, and can affect levee stability and increase the loads of dissolved organic carbon (DOC) and disinfection byproduct precursors (DBPP) in drainage water pumped back into the channel. The current amount of seepage and the effects of island subsidence on seepage, levee deformation, and water quality have not been quantified.

1. **Causes and Rates of Subsidence** – Subsidence of Delta peat soils is primarily caused by microbial oxidation of soil organic matter and secondarily by peat soil consolidation. Accurate estimates of present-day subsidence rates and prediction of future subsidence rates are important for determining where subsidence control efforts should be focused. Previous estimates are out-of-date.

2. **Peat Thickness**– Since the oxidation of peat results in land subsidence, the thickness of the peat determines future potential land subsidence. The available data are based on land-surface elevations determined in 1974 and 1975 and are out-of-date and inaccurate.

3. **Priority Areas for Subsidence Control** – Priority areas identified for subsidence control efforts are out-of-date and need to be reassessed based upon current subsidence rates and measures of peat thickness.

4. **Land- and Water-Management Practices for Reducing and Reversing Subsidence** – Oxidation of soil organic matter is dependent on soil moisture, temperature and organic matter content. Possible land- and water-use options for reducing, stopping or reversing subsidence include permanent shallow flooding, reverse flooding, deep flooding to create open-water habitat, saturated pasture, accretion of the land surface with imported biomass, and mineral capping of peat soils. Studies are presently under way to evaluate some of these options.

MONITORING AND RESEARCH ELEMENTS

Following are the monitoring and research recommendations for better quantifying, understanding, and controlling subsidence on Delta Islands and its effects on water quality:

Future Effects of Subsidence on Land Use and Water Quality

- Quantification of hydrologic inputs and outputs for Delta islands, including

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seepage, drainflows, irrigation diversions and crop consumptive use.
- Effects of current and future seepage on levee stability.
- Effects of future subsidence on levee deformation.
- Economic consequences of continued subsidence on agricultural production.
- DOC and DBPP loads (concentration times volume) in drainage water from Delta islands.
- Quantification of the increased amount of sea water that could intrude onto Delta islands after levee failure as a result of continued island subsidence.

Causes and Rates of Subsidence
- Present subsidence rates for peat soils throughout the Delta need to be quantified.
- Improved quantification of soil consolidation and microbial oxidation, the processes causing subsidence.
- Organic matter content of soils in Delta.

Peat Thickness
- Peat thickness for soils in the Delta.

Priority Areas for Subsidence Control
- Identify priority areas for future data collection and subsidence control based on present-day subsidence rates and peat thickness and organic matter content.

Land- and Water-Management Practices for Reducing and Reversing Subsidence
- Effects of different vegetation and water-management practices on biomass accretion.
- Long-term biomass and land-surface accretion rates.
- Feasibility of large-scale application of biomass accretion.
- Effectiveness of other practices that can be used to control subsidence such as reverse flooding and wet pasture.
- Feasibility of using dredge materials for reversing the effects of subsidence and reducing microbial oxidation of peat soils.
- Effects of applying dredge material to peat soils.
- Effectiveness of sediment transport onto Delta islands for reversing the effects of subsidence.
- Utility of areas capped with dredge material.
- Effects of subsidence control efforts on water quality.

LINKAGES

The reduction and reversal of subsidence on Delta islands is strongly linked with the monitoring and research needs of the Levee System Integrity Program, Water Quality Program and Ecosystem Restoration Programs.

Delta Levees –The Levee System Integrity and Delta island subsidence control programs are interested in rates of subsidence, results of efforts to reverse subsidence, the extent of peat soils, and seepage rates through the levees.

Water Quality— Most of the water that seeps (or is siphoned as irrigation water) onto the islands must be pumped back into the channels. This water contains DOC and DBPPs derived from peat soils and crops. The concentrations of DOC and DBPPs in Delta island drainage water are of interest to both island subsidence and water quality programs.

Ecosystem Restoration – Islands with sunken interiors are not part of the natural landscape of the delta. Continued subsidence of islands coupled with high levees makes it difficult to find locations for wetland restoration efforts with normal water-flow dynamics from the rivers and tides. New knowledge gained from subsidence reduction and reversal efforts could benefit the Ecosystem Restoration Program. Permanent shallow flooded wetlands (ponds) on Twitchell Island have been shown to cause net-increases in biomass accretion.

Chapter 4, part F. STORAGE AND CONVEYANCE

CALFED GOALS AND OBJECTIVES

Unlike the other programs discussed here, storage and conveyance is not a common program of CALFED. Whereas the common programs are included in all CALFED solution alternatives, storage may or may not be included in alternatives. The following types of new storage are being evaluated by CALFED: upstream surface storage, in-Delta surface storage, south of Delta off-aqueduct storage, and groundwater storage. Storage of water in surface reservoirs or groundwater basins can provide opportunities to improve the timing and availability of water for all uses. The benefits and impacts of storage will vary depending on the location, size, and operational policies of the storage project.

Conveyance describes the various ways that water can be moved from storage to the point of use. There are many possible configurations for conveyance.

MONITORING ELEMENTS, RESEARCH QUESTIONS, AND LINKAGES

This section will discuss projects that address storage and conveyance issues and their resulting monitoring elements and research questions. Linkages between these projects and CALFED common programs are also identified.

Delta channels bathymetry
New topographic and bathymetric maps of the Delta are needed because land surface is subsiding, levee construction and maintenance continues to alter profiles and elevations of levees, and channels continue to adjust geomorphically to altered hydrology and sediment inputs. These maps are needed to implement the Delta Levees Program, plan through-Delta channel modifications and Delta wetland restorations, and to improve Delta water quality simulation models. A hydrodynamic model being developed for the proposed State Water Project/Central Valley Project (SWP/CVP) intake structure and fish-screening facility at Clifton Court Forebay will also need data on channel cross-sections. A U.S. Army Corps of Engineers (USACE) comprehensive study of flood protection on the mainstem Sacramento and San Joaquin Rivers and in the Delta will need land surveys and channel geometry measurements to update a Delta hydrodynamic model.

This work will provide useful input to the CALFED Ecosystem Restoration, Long-Term Delta Levee System Integrity, Water Transfers and Water Use Efficiency, and Water Quality Common Programs.

Streamflow measurement network
The network of continuous streamflow gages in the Bay-Delta watershed has declined over the past decade due to shrinking budgets. An adequate network of gaging stations is necessary to evaluate water availability, water quality, water transfers, water use efficiency, and other aspects of the CALFED program. An inventory of existing gages is being assembled for CMARP to help evaluate where gaps may exist in the network. The USACE comprehensive flood protection study will also require historic streamflow and stage data at various key locations in the south and central Delta regions, as well as flood hydrographs and flood frequency analyses. The hydrodynamic model being developed for the proposed SWP/CVP intake structure and fish screening facility at Clifton Court Forebay will need data on velocities and surface water elevations.

This streamflow-measurement network will provide useful input to all of the CALFED common programs, especially the Water Transfers and Water Use Efficiency programs.

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Climatic effects on Central Valley hydrology
The range of streamflows that result from climate-driven natural-runoff in the Sierra Nevada has a lot to do with what management plans can and cannot guarantee for ecological health and water quality in the Bay-Delta system. Extreme high and low streamflows can cause effects in the system, which cannot be managed. The frequency and severity of these events need to be determined and incorporated into CALFED planning. Recent modeling efforts have demonstrated that streamflow variations—and potentially, water-management variations—can be forecast with useful levels of skill at lead times ranging from days to seasons. These improvements in snowmelt and rainfall-runoff models are possible through improvements in weather and climate predictions.

This work will also provide useful input to all of the CALFED common programs.

Wetlands water use
One approach being considered by CALFED for improving ecosystem quality in the Delta is the conversion of some agricultural lands to wetlands. However, an initial evaluation by CALFED staff found that wetlands would increase net water use on the converted lands. This needs to be studied further. Informational needs include

1. evapotranspiration rates of specific vegetative species,
2. operational procedures for proposed wetlands, and
3. development of standardized, pond-specific vegetative compositions.

Seasonal wetlands will not use as much water as permanent wetlands. Pond maintenance practices such as dewatering and discing activities will impact infiltration and evaporation losses. The vegetative mix in the wetlands will affect the applied water requirements, vegetative consumptive use, and irrigation efficiencies.

This work will provide useful input to the Ecosystem Restoration and Water Transfers and Water Use Efficiency common programs.

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Chapter 4, part G. WATER TRANSFERS

PERTINENT CALFED GOALS AND OBJECTIVES

The goal of the Water Transfers Program is '*to provide a framework of actions, policies, and processes to facilitate, encourage and streamline a properly regulated and protective water market which will allow water to move between users, including environmental users, on a voluntary and compensated basis.*' (The CALFED Bay-Delta Program Water Transfer Program Appendix, Early Review Draft, October 1, 1998, 38 p)

A water transfer is the artificial conveyance of water diverted under a legal water right, a contract, or groundwater extraction, from one area to another, across a political or hydrologic boundary. Water transfers are considered a tool to take an identified supply of "extra" water, and convey that "extra" water to an area where there is presently a shortage of water for beneficial uses. This section addresses potential water transfers that involve the Central Valley aquifer system, including transfers that conjunctively involve surface and ground water.

The CALFED Program will not participate in water transfers as a water supplier or user but rather will act to facilitate transfers between willing parties when a proposed transfer meets the goals of the CALFED Program.

CALFED solution principles suggest water transfers should not:

- raise or lower groundwater to unacceptable levels,
- induce land subsidence to unacceptable levels,
- alter the quality of surface or ground water to unacceptable levels,
- precipitate unacceptable direct or indirect burdens on the socioeconomics of transfer areas
- increase or decrease groundwater discharge to the land surface, streams, and wetlands to unacceptable levels
- provide water for transfer that results in an unacceptable reduction in water for other beneficial users.

MONITORING, ASSESSMENT, AND RESEARCH OBJECTIVES

Monitoring, assessment, and research programs should provide data and information to determine the effect of a water transfer on the quantity and quality of surface water and groundwater, land subsidence, the biological system, and the socioeconomic setting, and should pursue the following objectives:

1. Establish background or ambient conditions.
2. Identify and evaluate trends.
3. Elucidate existing or emerging problems.
4. Provide program management guidance.
5. Increase knowledge of natural and human factors affecting the groundwater resource.
6. Ensure compliance with statutory and regulatory mandates.
7. Evaluate program effectiveness.

The goal of the proposed monitoring program is to collect the data that will be necessary to assess the effects of a water transfer.

The goal of the data-assessment program is to define the techniques and procedures necessary to quantitatively evaluate the monitoring data so that 1) effects of the water transfer can be distinguished from other water-resource management activities and natural system variability, and 2) assurance is provided that the transfer is operating within established guidelines.

The goal of the focused research program is to improve our understanding of important hydrologic, chemical, and socioeconomic processes to assure that monitoring and assessment are adequate to determine the effects of a water transfer.

CONCEPTUAL MODEL

Central Valley Aquifer System

The Central Valley of California is a north-northwest-trending topographic basin filled with tens of thousands of feet of gravel, sand, silt, and clay derived from the adjacent mountains. Surface water drains from the valley through a single outlet, the Carquinez strait, after passing through the inland delta of the Sacramento and San Joaquin Rivers. The foothill boundary of the Central Valley represents the areal extent of the valley's basin-fill aquifer system. The Central Valley aquifer system has been divided into two subregions— Sacramento Valley and San Joaquin Valley. They are separated by the Sacramento-San Joaquin delta.

Precipitation is more abundant along the east side of the valley. This precipitation produces runoff that is used for agricultural, groundwater recharge, and urban purposes. For this reason, every major east-side river has a dam and a reservoir. West-side streamflow is intermittent and flashy, but some watersheds do have dams. Flows from both sides of the valley contribute recharge to the aquifer.

Sacramento Valley Aquifer

The Sacramento Valley Aquifer system has been conceptualized as a single heterogeneous aquifer where aquifer hydraulic properties vary with the proportion of fine-grained sediment. Ground water in the Sacramento Valley is generally of good quality. Ground water on the east side of the valley is low in dissolved solids and high in silica, reflecting the quality of recharge water from the mostly granitic rocks of the Sierra Nevada and metamorphic rocks in the foothills. Reducing conditions produce high concentrations of dissolved trace elements (iron, manganese, and arsenic) near the center of the valley. Ground water on the west side of the valley is lower in silica and higher in dissolved solids concentrations than ground water on the east side. Dissolved solids concentrations generally increase from north to south along the axis of the Sacramento Valley.

San Joaquin Valley Aquifer

The Corcoran Clay Member of the Tulare Formation underlies about 5,000 square miles of the San Joaquin Valley, separating the basin fill sediments into a lower confined aquifer and upper unconfined to semiconfined aquifer. Groundwater on the west side of the valley contains a higher concentration of dissolved solids than groundwater on the east side. Groundwater on the east side of the valley is characterized predominantly by dissolved calcium, calcium-sodium, or calcium-magnesium bicarbonate. West side groundwater contains mostly dissolved sodium, magnesium, and calcium cations and sulfate and chloride anions.

Land subsidence caused by hydrocompaction of debris flow deposits, and compaction caused by extraction of ground water and hydrocarbons has occurred over wide areas of the San Joaquin Valley. Land subsidence from groundwater extraction has also occurred in the southwestern Sacramento Valley.

Groundwater flow and Aquifer Hydraulic Properties

The direction and rate of movement of ground water and solutes in alluvial aquifer systems is controlled by aquifer geometry, hydraulic properties of the sediments, and differences in hydraulic head in the saturated zone. Similarly, the relation between flow in streams and adjacent aquifers is controlled by the interconnection of high permeability sediments between the streambed and the aquifer.

Current knowledge of ground water in California rarely allows accurate prediction of where or when stream flow depletions will occur as a result of groundwater extraction. Surface flow decreases caused by ground water pumping increases could take place in a few days, a few weeks, or many months.

Baseline hydrogeologic characterization data are needed to adequately assess the movement of water and solutes in response to a water transfer. In addition, the ability to define areas of potential land subsidence and aquifer compaction is dependent on an accurate assessment of the spatial distribution of clay layers throughout the aquifer. Although there have been several studies on the geologic structure of the Central Valley, there are many gaps in the understanding of the overall structure of the aquifer, and very few detailed characterization studies have been completed.

Water balance
The availability of water resources in a particular area might be considered by a simple water balance:

Inflow – Outflow = Change In Storage

Each term in the simple balance equation has many components that must be measured or estimated. Surface water resources are quantified and managed by measuring runoff, reservoir level, releases, and water use. These components of the surface-water balance provide a means of closely managing the resource. In contrast, three equivalent components are absent in the management of groundwater resources -- recharge to the aquifer, extraction (pumpage), and water use. Without these components of the groundwater balance, it is difficult, if not impossible, to manage groundwater resources to the same degree as surface water.

Implementing a water transfer will alter the water balance (both ground water and surface water) for the area transferring the water and for the area receiving the water. Because ground water and surface water are dynamically linked, determination of the water balance must integrate components of both ground water and surface water. Groundwater levels, stream stage and discharge, and water levels in wetlands or other surface water bodies are all affected by changes in the overall water balance for the basin.

Under natural conditions, the amount of recharge (inflow) is equal to the amount of discharge (outflow), and changes in storage are minimal. However, stresses on the groundwater system, such as pumping, changes in stream discharge, and variations in net infiltration due to irrigation, alter the natural balance and result in a change of storage. Storage changes are reflected by fluctuations of water levels in the aquifer. Conjunctive use and artificial storage and recovery projects require water quality/quantity information to assess impacts and evaluate the success of any program.

Water balance calculations will help to define whether water proposed for sale is new, real, or paper water (see Appendix *VII.C* for definitions).

Socioeconomic Factors
There may be unintended effects on those not a party to a water transfer, such as adverse effects on other legal water users, local economies, and environmental resources. Indicators that could identify potential third-party impacts should be monitored.

It is generally recognized that certain types of transfers can have adverse impacts on local economic conditions. Fallowing transfers, for example, may result in lower agricultural production in the source area and may impact local employment of farm

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workers and others. Groundwater transfers or transfers of surface water with groundwater replacement may result in lower groundwater levels, lower groundwater quality and higher pumping costs for other local groundwater users. In extreme cases, impacted groundwater users may lose the use of existing wells because of water quality degradation, and/or lower groundwater levels.

MONITORING PLAN ELEMENTS

To achieve monitoring and research objectives, two scales of monitoring are required -- regional and site specific. The data collected from regional and site-specific networks complement each other, and provide a comprehensive evaluation of the effects of a project. Regional data are adequate for detecting generalized trends or gross changes in flow patterns, water quality, or land-surface elevation.

Site-specific monitoring measures the effects of a particular project on local conditions, such as local pumping depressions, water quality, sensitive environmental habitats or local economies. Site-specific monitoring should be of sufficient detail to provide a means of distinguishing between the effects of the project and of other ongoing activities in a particular area. Design of site-specific monitoring networks at groundwater extraction sites will depend on details provided during site characterization studies.

In both types of monitoring networks, establishing baseline conditions is essential to assess the effects of the project. Assessment of the effects of water transfers, especially during the initial phases of a transfer, will of necessity rely heavily on the regional baseline data.

Without improvements to existing monitoring networks, the ability to adequately assess the effects of water transfers is severely limited (Appendix *VII.C*).

Hydrogeologic characterization
Characterization of aquifer structure and boundaries includes the following components:

1. aquifer geometry
2. degree of confinement
3. regional scale mapping of hydrogeologic boundaries, including:
   - major stratigraphic boundaries reflecting changes in depositional environment
   - single depositional units that restrict vertical flow over broad areas
   - bedrock structure
   - faults
4. local-scale mapping of hydrogeologic units to define the spatial variability of aquifer hydraulic and mechanical properties
5. delineation of aquifer boundaries using water chemistry characteristics (isotopes, major ion composition)

Water balance
The following components must be determined to estimate changes in the water balance as a result of a water transfer. These data need to be monitored at a regional scale to provide context for local scale studies.

1. Groundwater levels
2. Stream stage and discharge
3. Surface water deliveries
4. Net infiltration (precipitation + applied water – return flow – ET)

Land Subsidence

1. Paired aquifer compaction and discrete-interval, groundwater-level recording installations at groundwater extraction sites.
2. Land surveys coordinated with regional Geodetic networks.

Water quality

1. Ground water quality and temperature
2. Surface water quality and temperature

Socioeconomic Factors

1. Agricultural employment
2. Rural business sales and employment
3. Population size
4. Cropping pattern and acreage
5. Number and size of farms
6. Value of agricultural output
7. County tax collection and expenditures
8. Labor force and unemployment

RESEARCH

The research questions relevant to water transfers are an extension of questions that are relevant in the design of a groundwater monitoring and assessment program. Research into the following subjects would greatly improve the ability to manage groundwater in the unsaturated and in the saturated zone.

- Vadose zone processes and rates of recharge
- Interaction of regional- and local-scale processes
- Better methods to quantify interaction between ground and surface water
- Effects of climate variability on watershed processes
- Improved methods for storage, manipulation, and coordination analysis of data
- Land subsidence processes and predictive capabilities
- Scale variant hydrogeologic characterization
- Processes controlling water quality including the effects of increased rate and volume of extracted groundwater on water quality
- Effects of water transfers on persons, businesses or agencies that are not a party involved in the transfer (3rd party effects)

LINKAGES

Water Quality Program: The Water Transfers Monitoring Program refers to the Water Quality Program for quantitative information on stream flow and stream chemistry at all monitored sites in the Central Valley.

Storage and Conveyance Program (as well as the California Department of Water Resources—Division of Operations and Maintenance, Office of State Water Project Planning, and the U.S. Bureau of Reclamation, Central Valley Operations Office). The Water Transfers Program refers to these agencies for information regarding availability, and suitability of conditions for water transfer through surface-water conveyance facilities.

Ecosystem Restoration: The ecosystem restoration program must assess the ecological suitability of water transfer through the riverine and deltaic environments.

Water Use Efficiency Program: The Water Transfer Monitoring Program relies on information compiled under the Agricultural and Urban Water Conservation components of the Water Use Efficiency Program to assess future water supply and demand in the state to determine transfer needs, and to provide detailed land and water use information for water balance determinations and socioeconomic considerations.

Watershed Management Coordination Program: The effects of water transfers on riparian corridors, wetlands, and stream basins upstream of the Central Valley need to be monitored and assessed by the Watershed Management Coordination Program. The Water Transfers Program also relies on the Watershed Management Coordination Program for information on spatial and temporal input of precipitation to the Central Valley.

Various local, state, and federal agencies (Appendix *VII.C*): Socioeconomic information adequate to assess the economic effects of water transfers will have to be provided by agencies exterior to the CALFED program.

Chapter 4, part H. WATER USE EFFICIENCY
(Conservation and Water Recycling)

I. CONSERVATION

This CALFED Program addresses four categories of Bay-Delta problems--ecosystem quality, water quality, water-supply reliability, and system integrity. Water-use efficiency is clearly related to the goal of improving water-supply reliability and can help achieve other program objectives by improving water quality or enhancing ecosystem health. CALFED has based its Water Use Efficiency Common Program (WUECP) for conservation on improved urban and agricultural water management planning, technical and financial assistance, and the resultant implementation of cost-effective urban Best Management Practices (BMP) and agricultural Efficient Water Management Practices (EWMP).

AGRICULTURAL WATER USE AND CONSERVATION

The monitoring objectives for agriculture must address questions that show WUECP is succeeding well enough to assure various stakeholders of its effectiveness. To determine the WUECP's effectiveness, the following questions need to be answered for the agricultural sector in the CALFED solution area:

1. How many endorsed agricultural water-management plans exist in the CALFED solution area, how many are completed but not endorsed, and how many acres do they represent?
2. Which EWMPs are being implemented and what is the magnitude of their implementation?
3. Have the EWMP's achieved permanent reductions in growing-season-applied water or depletions for crops, and are sufficient mechanisms in place to maintain their effectiveness?
4. What is the relationship of the water applied to crops and their actual needs, defined as evapotranspiration (ET) of applied water/potential irrigation efficiency at the farm, district and regional levels?
5. Are increased planning and assistance programs reducing applied water and depletions beyond the projections in State and local plans?
6. Has the reduction in applied water had positive, negative, or neutral effects on third parties and the environment?

In general, the measurement needs for determining agricultural water use efficiency within the CALFED Solution Area include:

1. Land-use surveys every five years of all agricultural counties with more than 50,000 irrigated acres, to be consistent with updates of the California Water Plan. These land-use surveys must include water source and irrigation method, by crop.
2. Annual land, soil, and water-use survey of the Delta including real-time ET data for the Delta lowlands.
3. Data of water applied on agricultural fields are needed for all irrigation, for a number of irrigation seasons, and for surface- and ground-water sources. Estimation of the distribution uniformity of individual irrigation, and seasonal application efficiency are needed to estimate the optimization of on-farm water use, on an annual basis.
4. Estimates of the reuse of surface and subsurface drainage water and ground water to quantify the relationship of on-farm efficiencies to higher district and regional efficiencies. Initial data gathering should be completed over a three-year period and updated every five years thereafter.
5. Annual update of acreage using various irrigation methods including estimates of their efficiency based on a standardized set of assumptions and formulas.
6. Annual review and update of crop coefficients for estimating crop water

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use to be used in annual water balances by planning sub-areas.

7. Length of all canals and laterals (lined and unlined) linked with areas being irrigated by various irrigation methods, using GIS and GPS technology to be used in the determination of evaporation and seepage.
8. Documentation of EWMPs to be implemented from agricultural water-management plans, with particular attention to those practices related to improving water delivery, measurement, and pricing.
9. Documentation of environmental and third-party effects of conservation measures from the implementation of EWMPs.
10. Annual documentation of crop rotation and fallowing sequences because of agronomic practices or government programs.

Major gaps in knowledge of irrigation efficiency and crop water use should be filled to help CALFED and CALFED agencies reach their objectives. The priorities for such research are:

1. Develop a complete and improved set of crop coefficients (Kc) for all 250 California crops,
2. Determine the feasibility of attaining distribution uniformities (DU) greater than 80 percent for re-designed and manufactured irrigation equipment,
3. Evaluate improved agronomic practices that would increase yields while reducing resource inputs and improve sustainability, and
4. Develop new crop varieties that would have the same effects as #3 above.

URBAN WATER USE AND CONSERVATION

The objectives for the monitoring program in the urban sector need to assure stakeholders of the effectiveness of the WUECP. Similar questions to those posed above for agriculture apply to the urban sector in the CALFED solution area. Additional monitoring is required to determine:

1. How many certified urban water management plans exist in the CALFED solution area and how many remain uncertified?
2. Are BMPs being effectively implemented and are they being implemented within the criteria established by the California Urban Water Conservation Council (CUWCC)?
3. Have the BMPs achieved permanent reductions in applied water or depletions and are sufficient mechanisms in place to maintain their effectiveness?
4. What is the relationship to the theoretical need (or efficiency on a per-capita water use basis)?
5. Are increased planning and assistance programs reducing applied water and depletions beyond the projections in state and local plans?
6. Has the reduction in applied water had positive, negative or neutral effects on third parties and the environment?

In general, the measurement needs for determining urban water use efficiency within the CALFED Solution Area include:

1. Annual landscape surveys of all irrigated landscape acreage within agencies having more the 3,000 connections.
2. Annual estimate of ET data for surveyed landscapes using appropriate landscape coefficients and applied water data for landscape to determine the efficiency of landscape irrigation.
3. Annual consolidation of existing data; improvement of data quality and quantity from water audits and leak detection to assess reductions in unaccounted water.
4. Annual consolidation of existing data; improvement of data quality and quantity from Commercial, Industrial and Institutional (CII) customers, including surface and groundwater users.

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5. Annual detail of interior water-use data to evaluate changes in single family and multi-family water use.
6. Annual updates of water-use data for all customer classes and gross per-capita water use; chart trends.
7. Annual estimates of seasonal and peak water use from water agency data; evaluate trends in seasonal and peak water use versus baseline water use values.
8. Assess the implementation of 14 BMPs and estimate their costs and benefits from biennial reports provided to CUWCC.
9. Assess the quality of urban water management plans and those that have exemplary planning elements and/or BMP implementation.

The major knowledge gaps in the urban sector are related to water budget irrigation scheduling of landscapes using the California Irrigation Management Information System (CIMIS) and estimates of water savings from new technologies in the residential and CII categories.

1. Investigate whether urban landscape irrigation water budgeting can be improved by expanding CIMIS into urban areas and developing landscape evapotranspiration coefficients for the various mixtures of plants in urban landscapes.
2. Conduct interior residential water end-use studies (faucets, showers, landscapes, etc.) similar to the national study and evaluate water savings from use of new technologies and conservation measures.
3. Conduct interior commercial water use efficiency studies and evaluate water savings from use of new technologies and conservation measures.

II. WATER RECYCLING

MONITORING OBJECTIVES AND RESEARCH NEEDS

The CMARP monitoring objectives for water recycling are based on the goals of CALFED's Water Use Efficiency (WUE) common program, which estimates a potential for recycling between 1.4 to 2 million acre-feet a year by 2020. (For more details and a description of laws and regulations governing water recycling in California, see the Water Use Efficiency Technical Appendix to the Programmatic EIS/EIR.) The policy framework for implementing CALFED's preferred program alternative states that Stage 1 of implementation will be a 7-year period that starts when the Programmatic EIS/EIR is certified. During this period, information about the effects of CALFED's WUE common program will be gathered and analyzed as the program is implemented. Findings from the analyses will be used to determine the performance of CALFED WUE program actions and change program management to improve performance if necessary.

The role of CALFED agencies in carrying out the Water Use Efficiency Program is to encourage and build upon local and regional implementation of efficiency measures. CALFED agencies are to: (1) offer support and incentives through expanded planning, technical, and financial assistance; and (2) provide assurance that cost-effective efficiency measures are implemented. With regard to water recycling, the Water Use Efficiency Program includes the following actions to encourage water recycling statewide:

- Help local and regional agencies comply with the water recycling provisions in the Urban Water Management Planning Act.
- Expand state and federal recycling programs in order to provide sharply increased levels of planning, technical, and financing assistance, and develop

new ways of providing assistance in the most effective manner.
- Provide regional planning assistance that can increase opportunities for use of recycled water.

These actions are expected to reduce demand for Delta exports, increase availability of water for transfer to other users or for environmental flows, and improve water quality in the Delta and its tributaries. In addition, they should help California reach the water recycling goals adopted in Water Code Section 13142.5(e): 700,000 acre-feet/year by 2000 and 1 million acre-feet/year by 2010. To assess the extent of the above actions in reducing demand and improving water quality, more accurate data are needed about the following:

- quality of the source water available for recycling,
- amounts of water available for recycling (amounts of wastewater being generated),
- amounts and quality of recycled water produced by treatment plants,
- costs of producing and delivering the recycled water,
- amounts of recycled water actually used and distribution of those uses, and
- benefits derived from uses of recycled water.

In addition, financial and cost data for existing water recycling projects would allow CALFED to forecast financial assistance that may be needed to achieve the estimated water recycling potential.

GOALS AND OBJECTIVES OF THE MONITORING AND RESEARCH PLAN FOR WATER RECYCLING

Monitoring Goals. To assess local agencies' responses to CALFED water recycling program actions, monitoring and data gathering during years 1 through 5 of Stage 1 implementation will focus on the following key indicators:

- quantities of wastewater collected and treated,
- amounts and quality of recycled water produced by treatment plants,
- quantities of recycled water delivered to various uses (agriculture, municipal and industrial, landscape irrigation, habitat restoration or enhancement, or stream flow augmentation),
- the effects of water quality on the amounts of recycled water produced and on the end uses of the recycled water,
- the capital outlay and other costs of producing and distributing the recycled water, and
- the prices charged for delivery of recycled water to water retailers.

Analyses of data about the above indicators will allow CALFED agencies to determine the cost-effectiveness of water recycling projects and the quantities and quality of water actually delivered and used. These determinations will allow CALFED to: (1) better determine the effects of water recycling on water supply reliability and water quality; (2) assess where and when its planning, technical, and financial assistance are most effective; and (3) refine and target future CALFED water recycling assistance.

Research Objectives. Several interests have argued that the ranges of future recycled water production in CALFED's PEIS/PEIR will not be attained unless certain actions are taken and additional incentives are provided to local agencies. Comments on the draft PEIS/PEIR described an array of hurdles to project development and implementation, and comment letters suggested the following actions for resolving some of the implementation issues:

- More closely coordinate actions taken by the Department of Health Services, the State Water Resources Control Board, the Regional Water Quality Control Boards, and the California

Plumbing Standards Commission. Resolve any differences that may exist between requirements set forth in the Uniform Plumbing Code and DHS policy regarding recycled water and potable water pipelines.
- Provide incentives for local water and wastewater agencies to coordinate their water recycling efforts.
- Remove the institutional hurdles to efficient sale and transfer of recycled water among water and wastewater agencies.
- Provide clear, concise guidance on and assistance with accounting for all benefits of proposed recycled water projects in cost-benefit analyses and other planning studies required by state and federal regulatory agencies.
- Conduct a statewide economic evaluation of water recycling that quantifies the pollution prevention, hydrologic, economic, and environmental effects of reductions in water diversions stemming from increased water recycling.
- Assess the potential for water recycling to help achieve water supply augmentation, reliability, and water quality and ecosystem health objectives of CALFED and evaluate these potential benefits.
- Provide ongoing public outreach and communication about the high value of recycled water, and improve public understanding of the water quality goals in Title 22 of the California Code of Regulations.

To address these suggestions and help assure effective implementation of the CALFED Water Use Efficiency Common Program, CMARP research could investigate:
- Interactions among and program policies or regulations of DHS, SWRCB, the Regional Water Quality Control Boards, and the California Plumbing Standards Commission.
- The economics of water recycling.
- Existing statewide infrastructure available for the treatment, transport, and storage of recycled water.
- Effects of source water quality on the costs of producing recycled water.
- Public perception and acceptance of recycled water for various uses.

See the technical appendix *VII.E* for further research needed to encourage the beneficial use of recycled water.

LINKAGES

A major factor in the production, distribution, and use of recycled water is water quality. The quality of water entering treatment plants directly affects the levels and amount of treatment necessary. The quality of the recycled water produced affects the types and amount of beneficial reuse. Therefore, a link between CMARP's water use efficiency and water quality elements is necessary. Water quality monitoring and research data useful for refining CALFED's water recycling program management include:
- A comprehensive assessment of salinity sources in wastewater collection systems.
- Impacts of salt accumulation on agricultural products and sensitive turf areas.
- Fate and transport of salts, organics, disinfection byproducts, viruses, protozoa, and bacteria in ground and surface waters.
- Effectiveness of using constructed wetlands to remove nitrogen.
- Toxicity and disposal of brines resulting from use of membrane technologies.
- Impacts of recycled water on valves, seals, and O-rings.
- Information about the levels and amount of treatment required to lower the risk of adverse health effects stemming from disinfection byproducts, viruses, protozoa, and bacteria in water and wastewater.

- Adequacy and refinement of microbiological risk assessment methodologies.
- Real-time pathogen monitoring techniques.
- Adequacy of treatment in the vadose zone (groundwater recharge systems).
- Evaluation of sources of recycled water other than urban wastewater (for example, process rinse water).

Chapter 4, part I. WATERSHED MANAGEMENT COORDINATION

PERTINENT CALFED GOALS AND OBJECTIVES

The goal of the CALFED Watershed Management Coordination Program is to help coordinate and integrate existing and future local watershed programs and to provide technical assistance for watershed activities relevant to achieving the goals and objectives of the CALFED Bay-Delta Program.

The watershed monitoring plan addresses these program objectives:

- Describe the basic biophysical functions and processes of a watershed, including linkages from upper watersheds – to lower watersheds – to the Bay-Delta.
- Identify watershed functions and processes relevant to the CALFED goals and objectives
- Describe how land use and other human activities affect and are affected by watershed functions and processes
- Illustrate benefits that accrue from watershed plans and projects designed to favorably affect the CALFED goals and objectives
- Provide monitoring assistance to aid watershed organizations.

The geographic scope of the Watershed Management Coordination Program includes watersheds at all scales within the CALFED solution area. The Watershed Management Coordination Program supports whole-watershed approaches. Consequently, at larger scales, there is overlap between the geographic purview of the Watershed Management Coordination Program and other CALFED programs that focus on the Bay-Delta and the alluvial Central Valley.

Given this overlapping geographic scope, the watershed monitoring plan shares objectives of the Ecosystem Restoration Program, addressing rehabilitation of the capacity of the Bay-Delta estuary and its watershed to support natural aquatic and associated terrestrial biotic communities in ways that favor native members of those communities, with minimal ongoing human intervention.

Likewise, watershed monitoring addresses objectives shared with the Water Quality Program, addressing aspects of water quality improvement for environmental, agricultural, drinking water, industrial, and recreational beneficial uses of water.

GOALS AND OBJECTIVES OF THE WATERSHED MONITORING PLAN

Monitoring Goals

The purpose of this plan is to promote monitoring and information exchange locally and regionally to facilitate trend evaluation and adaptive management related to watershed health and to assist development of community-based institutions for watershed stewardship. The principal goal of this plan, consequently, is not to prescribe particulars, but rather to develop a framework that will assist local watershed programs and managers participating in the Watershed Management Coordination Program in developing their own monitoring programs. For the most part, monitoring will be designed and implemented by local organizations, drawing on local expertise and local resources. CALFED can best assist in this by:

- identifying a set of common elements that should be addressed in a coordinated way in monitoring programs at various scales,
- coordinating access to needed baseline data and background landscape information in integrated, readily usable formats (including GIS), and
- providing a framework for summarizing monitoring data and coordinating information exchange across watersheds.

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Refining this framework will be an iterative process involving program participants.

Program participants have repeatedly emphasized the importance of watershed monitoring as a tool for building community cooperation, knowledge, and stewardship ethics. Mutual effort in formulating monitoring needs, designing and implementing a monitoring program, and interpreting results provides an important mechanism for opening communication and gaining consensus on needed actions. Monitoring designed and carried out entirely by agencies unconnected with local communities does not provide these beneficial effects, and cannot benefit from the knowledge base and observation opportunities that rest with local residents.

This plan is also intended to serve CALFED managers in evaluating program success, and, in serving needs of program participants for baseline and background information, to provide CALFED with needed information on basic biophysical processes, linkages, functions, and landuse relationships, as outlined in the program objectives.

Problem Statement

Watershed management concerns itself with the composite of human activities, landscape characteristics, and natural processes that together affect quantity and quality of water downstream, as well as ecological health and social well-being within the watershed. The central problem for a watershed monitoring program is to provide a basis for measuring outcome of particular management actions or trends and evaluating these against a background of variation over time and space.

Watershed monitoring addresses both physical conditions of the landscape and human actions that affect those conditions. Themes identified as high priority for monitoring include:

- Watershed conditions that affect flow and sediment regimes, water quality, and flood hazard.
- Habitat conditions that affect species of the Bay-Delta, especially those species that move out of the lower reaches during part of their lives.
- Habitat conditions that affect support of populations and species that are integral to ecosystem integrity and biodiversity at local scales.
- Productivity and other characteristics of vegetation in watersheds that affect sediment and nutrient inputs to the Bay-Delta and shape regional carbon budgets.

Trends in urbanization and agriculture were identified as having major effects on watershed conditions. These and other landuse practices affect rate and quantity of water reaching streams, input of sediment and contaminants, vegetation patterns, and availability of suitable habitats. Watershed improvement actions related to landuse practices are a major focus of the Watershed Management Coordination Program. Consequently, landuse elements are included within each monitoring theme.

Social and economic relationships related to water and watershed management are of high priority to participants in the Watershed Management Coordination Program. People living in watersheds are affected by availability and quality of water for various uses, economic exchanges related to water and water management, and maintenance of ecosystem and habitat functions that support resource-dependent livelihoods, valued species, and quality of life. Costs of watershed improvement are incurred by communities that may or may not receive the economic benefits of improved water quality or quantity. Likewise, downstream environmental and economic costs are not necessarily accounted for in upstream land-use decisions. Given the importance of these issues, themes related to social and economic aspects of watershed conditions

and management actions are included in this monitoring framework.

Scale Issues

The various users applying watershed monitoring information for their varied purposes perform tasks that fall into two distinct categories:

1. Detect, describe, and analyze trends and processes at various scales.
2. Evaluate effectiveness of particular practices in achieving desired results.

These two purposes require information on the same set of ecological and social themes, but focus at different scales. At these different scales, different process attributes come to the forefront. We highlight these contrasts in our discussion of monitoring elements (Appendix *VII.H*).

At all scales, hydrologic processes are strongly influenced by background characteristics of landscape, weather, and past history of natural and human-related change. In addition, extreme events at irregular intervals have large effects on system characteristics. Consequently, the problem of detecting trend and change due to management actions against this background of large and irregular spatial and temporal variation is a major issue at all scales. We identified central integration of background landscape and climatic information, current and historic, in forms readily usable for watershed-based analyses at all scales as a high priority component of CALFED support for watershed monitoring. Ready access to this information will facilitate local monitoring efforts while serving CALFED's internal needs as well.

The overall monitoring framework we propose employs data collection and analysis at three scales:

1. <u>Basins and Sub-basins</u> (CalWater Hydrologic Units and Hydrologic Sub-Areas).
   This is the scale at which information on input to the Bay-Delta system is needed to interpret ecosystem response and water-management implications of trends. Monitoring at this scale focuses on flow regime, water quality, and sediment regime characteristics, interpreted in light of
   - long-term and current weather,
   - basin geology, landforms, and vegetation, and
   - broad patterns of change in land use and vegetation related to agriculture, urbanization, road construction, and logging.

   Trend monitoring is the central focus at this scale. Direct effectiveness monitoring (interpretation of relationships between observed trends and specific management actions) is generally not feasible at this scale, although projections from observations at smaller scales (see 3. below) can be used to estimate management effects.

   Existing monitoring systems and landscape data are adequate for many parameters of interest at this scale, although substantial effort will be required to integrate data from diverse sources and convert them into forms that can be readily analyzed across ownerships and jurisdictions. Composite trends in population and habitat conditions for species of special concern are appropriately evaluated at this scale based on monitoring conducted at finer scales. Similarly, composite trends in habitat availability, species diversity, and distribution of non-indigenous species should be evaluated at this scale.

2. <u>CalWater Planning Unit.</u>
   This is the scale (6,000 to 30,000 acres) at which relationships between watershed health attributes and trends in land-use and management practices can be realistically differentiated from background variation. Local governments, citizen groups, and agencies often make management

decisions and conduct planning at this scale. Interpretation of trends observed at basin scale relies on consistent monitoring of a uniform core set of watershed attributes at this scale. A system for summarizing and providing access to data across watersheds and regions is needed to facilitate trend analysis of this kind. We recommend that the Watershed Management Coordination Program support establishment of such a system.

At this scale, local concerns and objectives, local institutions, and characteristics of local landscapes appropriately take major roles in shaping monitoring programs. Consequently, it is not appropriate for CMARP to recommend a uniform monitoring program beyond the limited set of core attributes needed for regional trend and cumulative effects analysis. Instead, we propose developing a set of prototype monitoring programs addressing different objectives in different landscapes to serve as templates and/or points of departure for locally developed monitoring programs.

3. Small Watershed or Stream Reach. Although cumulative effects of land-use trends may be detectable in larger watersheds, effective adaptive management feedback and estimates of program success rely on focused monitoring of contrasting practices in small watersheds or stream reaches. Attributes monitored at this scale should be selected to address specific questions regarding specific actions or practices, or to provide a basis for estimating parameters difficult to measure directly in larger watershed units. For example, sediment regime and habitat quality/species distribution parameters are appropriately monitored on a network of small sites.

RECOMMENDED MONITORING

In each of the major monitoring theme areas, the workteam developed a conceptual model identifying important system elements and relationships. These were then used to identify 1) baseline (e.g., streamflow records) and background landscape data (e.g., geologic mapping) needed for monitoring design and trend interpretation, and 2) central monitoring elements appropriate at the three scales identified above. Specific monitoring needs largely depend on locally defined priorities, consequently the following is not intended to be exhaustive or tightly prescriptive. Selection of a specific set of common core parameters and associated standard methods is a subsequent task to be carried out in collaboration with program participants.

Flow and Sediment Regimes – Geology, landforms, climate and weather, and regional vegetation patterns largely shape characteristics of flow and sediment regimes. Baseline and background data on all of these are high priority at all scales, along with ongoing recording of weather (especially precipitation, runoff, and evapotranspiration parameters), streamflow, groundwater, and suspended sediment and solute loads. Other aspects of sediment regime are high priority for focused monitoring (see below). Floods have major effects on many system properties and merit particular attention.

Flow and sediment regimes are affected by activities that accelerate erosion and alter runoff/infiltration relationships. Roads and agriculture are of particular concern at all scales, as are increased rate of slope failure associated with logging and wildfire. Activities that directly alter streamflow and ground water have major effects on flow and sediment regimes downstream; of major concern are dams, diversions, ground water pumping, irrigation practices, and urban runoff. Activities that affect stability and roughness of channels, banks and

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floodplains, directly or through vegetation modification, also affect sediment regimes. Again, roadbuilding and agriculture are major concerns for direct effects, and logging and grazing affect riparian vegetation in some areas. In large watersheds, broad patterns of land-use change produce detectable effects on sediment and flow regimes. More subtle differences in land-use patterns and management practices have effects that, although indistinguishable from background variation several miles downstream, have major consequences for local habitat values and significant cumulative effects at broader scales. Effects of irrigation practices and mine drainage on solute loads are of major concern in some watersheds (see Water Quality, below).

At large-watershed scale, baseline and periodically updated background data are needed on broad patterns of landuse, urbanization, road network density, water use and flow manipulation (both surface and groundwater). At intermediate scale, detailed background data are needed on agricultural land and water use practices, wildfire, logging, and roads with associated monitoring of near-stream vegetation cover, rates of channel change, and rates of slope failure. Focused monitoring is needed at small scales to address rates of sediment production and channel change associated with particular agricultural, logging, and road building practices. Existing monitoring programs provide much of the direct monitoring of flow needed at broader scales. Sediment regimes are less adequately addressed by existing monitoring at these scales. Still, the primary needs are for central integration, better access to existing data sources, and evaluation of patterns and trends in light of baseline and background data mentioned above.

Water Quality – Water quality includes elements of water temperature, suspended sediments, and undesirable chemical constituents from natural sources and human activities. We refer to the Water Quality and Ecosystem Restoration Program monitoring plans for monitoring elements related to drinking water quality, aquatic productivity, and sources and ecosystem effects of contaminants and pollutants. Water quality elements addressed in this framework focus on sediment and water temperature as habitat characteristics, vegetation attributes that affect sediment movement and channel shading, and activities that affect these vegetation attributes.

Near-stream vegetation structure, water temperature, and suspended sediment are appropriately monitored at fine scales in conjunction with species and habitat monitoring. Focused monitoring is needed to address relationships among logging, grazing, road construction, and other practices and these water-quality attributes.

Habitats – Human activities have substantial effects on the extent of habitats and maintenance of processes and conditions that support survival and reproduction of native species as well as establishment and spread of non-indigenous species.

Alteration of flooding regime and disruption of sediment supply due to dams, levees, and gravel mining have drastically altered channel geomorphic processes, severely affecting habitat values and successional process. Groundwater pumping, diversions, and other water management activities have affected flow regimes, water tables, and water quality in ways that have major effects on habitat availability.

Habitat destruction and fragmentation from agriculture and urbanization, loss of pollinators and dispersal agents through pesticide use and other effects, and spread of non-indigenous species further limit ability of landscapes to support the full complement of native species that have been present historically.

Modification of riparian vegetation and alteration of channel-floodplain relationships affects primary production and transfer of organic matter from the terrestrial to the aquatic system. These changes have ramifications for community composition and species diversity across many species groups, locally and downstream. Wetlands like those that once occupied much of the Central Valley have high rates of primary production and accumulation of organic detritus (e.g., peat formation). Loss of wetlands, coupled with agricultural practices that cause net loss of organic matter from soils, especially peat soils of former wetlands, have altered the regional carbon budget.

Background/baseline data with periodic update are needed on extent and configuration of habitats and distribution of native and non-indigenous species, especially species of special concern. Focused monitoring will be developed to address population trends and habitat quality for special status species in conjunction with the Conservation Strategy. Trends in species diversity at large-watershed scale should be monitored based on analysis of composite trends in multispecies inventories at small-watershed scale.

Background data needs include mapping of habitat distribution and comprehensive distribution data for special status species and focal species groups (e.g., birds, fish, vascular plants). Monitoring of sediment and channel dynamics, vegetation structure, productivity and detritus regimes, and management practices that directly affect habitat quality should be planned in coordination with habitat mapping and species inventories so that results can be effectively used in evaluation of trends at broader scales. Monitoring of vegetation and detritus should ideally be planned so that it also provides a basis for assessing implications of wetland restoration and landuse practices on regional carbon budgets and community trophic structure.

Economic/Demographic – Human population, demographics, and patterns of economic activity have major effects on watershed conditions. Improvement of watershed function requires modification of landuse and management practices, with associated costs, benefits, and other consequences for local and distant communities. Likewise, water transfers and other aspects of management and sale of water and hydroelectric power have direct and indirect economic impacts. Associated environmental impacts have their own economic and social ramifications, affecting quality of life, viability of resource-dependent livelihoods, and human health.

Specific monitoring needs in this area largely depend on locally defined priorities. Elements will generally include human population and demographics, patterns of employment and economic activity, economic costs and benefits related to water quality, flow regime, and selected quality-of-life indicators.

Watershed Action/Education – Education and community values influence and are influenced by watershed improvement actions and, as discussed previously, the act of watershed monitoring itself. Consequently, this is an important element in analysis of Watershed Management Coordination Program's effectiveness. Current directories of community-based watershed actions and monitoring programs should be maintained by the Watershed Management Coordination Program. Further detail and priorities in this area will be developed by program participants.

RESEARCH QUESTIONS

Applied research to evaluate and improve effectiveness of watershed restoration practices is a high priority. Research at small scales on implications of alternative agricultural, forestry, and road construction practices on flow and sediment dynamics is needed for interpretation of system trends and program effectiveness at larger scales.

Development of baseline data resources and GIS tools for analysis of physical, biotic, and cultural characteristics of landscapes is essential for analysis of trends and management effects. Development and integration of this information into useful, multipurpose, web-accessible databases constitutes a technological challenge. Although not research in a strict sense, this task requires the type of expertise, resources, and approach ordinarily employed in research.

LINKAGES

Ecosystem Restoration – Watershed monitoring provides information on flow, sediment, water quality, and nutrient dynamics relevant to analysis of ecosystem characteristics and habitat quality in the Bay-Delta, as well as feasibility of restoration of channel geomorphic processes. It also provides data on habitat availability and quality for species that use habitats outside the Bay-Delta. Watershed monitoring provides the basis for analyzing trends in land-use practices that have major effects on the Bay-Delta ecosystem.

Water Quality – The Watershed monitoring program refers to the Water Quality program for description of elements related to natural and anthropogenic dissolved constituents and contaminants and to design a program that will provide data for assessing effectiveness and cumulative effects of watershed improvement actions. Watershed monitoring provides information on land-use patterns, sediment delivery and transport data, and biotic response related to water quality.

Water Transfers – Watershed and Water Transfers monitoring programs share a need for detailed baseline information on geology, geomorphology, weathering (e.g., background rates of solute production), and climate. Both programs address effects of land-use patterns on groundwater dynamics and use. We refer to the Water Transfers monitoring program for description of elements related to groundwater measurement, agricultural practices, demographics, and patterns of economic activity. Watershed monitoring is expected to provide data needed to evaluate environmental consequences of water transfers.

Delta Levees – Watershed conditions have implications for flood risk, and sediment regimes have implications for channel maintenance. Watershed and Delta Levees programs share a need for information on extreme precipitation and flow events, although the scale of focus differs because of the need here for analysis of alternative management actions and land-use trends in small watersheds.

Storage and Conveyance – Watershed monitoring contributes information on flow and sediment regimes relevant to water availability and maintenance of storage capacity in reservoirs. It also provides information on land-use practices relevant to interpreting trends in flow and sediment regimes. Storage and conveyance monitoring provides information relevant to estimating consequences for downstream users, including economic costs and benefits, associated with watershed improvement and land-use trends.

Chapter 4, part J. CATEGORY III PROJECT MONITORING And DATA REVIEW

Early in its planning stages, CMARP recognized the need for review of monitoring activities for the projects being implemented through the Category III Program. The Category III Program was initiated to implement environmental restoration projects to provide immediate benefits as an early implementation step of the CALFED environmental restoration plan. During 1997, more than 70 projects were authorized for funding through Category III. During 1998, at least 60 more were authorized. Feedback on Category III project effectiveness will be important in laying the framework for subsequent decisions on funding other projects and on water project operations.

CMARP, in general, is tasked with defining the longer term monitoring and assessment needs associated with CALFED Stage 1 actions and, additionally, with assessing the effectiveness of Category III projects. Accordingly, CMARP developed a process to provide review of Category III project monitoring plans, and is developing an infrastructure to provide a review of data/project effectiveness as information from those projects becomes available.

The process developed and utilized for Category III projects, presented schematically in Figure 4-1, emphasizes the use of a technical workteam to provide review of the monitoring activities of the projects. Note that "monitoring" was defined broadly to include any kind of data acquisition that would, hopefully, be supportive to the increase in knowledge and understanding of the system and/or project effectiveness. While not all projects would have a restoration-monitoring plan per se (such as a research project not doing restoration), most projects are appropriate to the broader data-acquisition definition.

WORKTEAM RESPONSIBILITIES

The first task was to clarify the scope of responsibilities of the Category III monitoring workteam. Several potential activities that this workteam could be responsible for and/or involved with include:

A. Review and comment to project proponents on monitoring, reporting and assessment plans for ongoing and planned Category III projects.
B. Review and assessment of monitoring data/information. This review includes various levels
   1. satisfactorily meeting project objectives,
   2. adequacy of data,
   3. evaluation/ assessment/ interpretation of data relative to other data on local basis, and
   4. evaluation/ assessment/ interpretation of data relative to overall ecological/biological objectives.
C. Serve as a data clearinghouse.
D. Develop and/or provide guidance on monitoring protocols/ indicators/ strategies for future projects.

The initial focus of the workteam was identified to be item (A) and at least the *first* level of evaluation in item (B). The workteam will not provide review of general project management, planning, or construction aspects of the project except as it specifically relates to biological/ ecological monitoring and data collection.

The CMARP steering committee recognizes the need for all of the above activities, and is developing approaches for the long-term program. A need currently exists, however, for a near-term implementation review process, to be consistent with a long-term program, which will include these additional review elements.

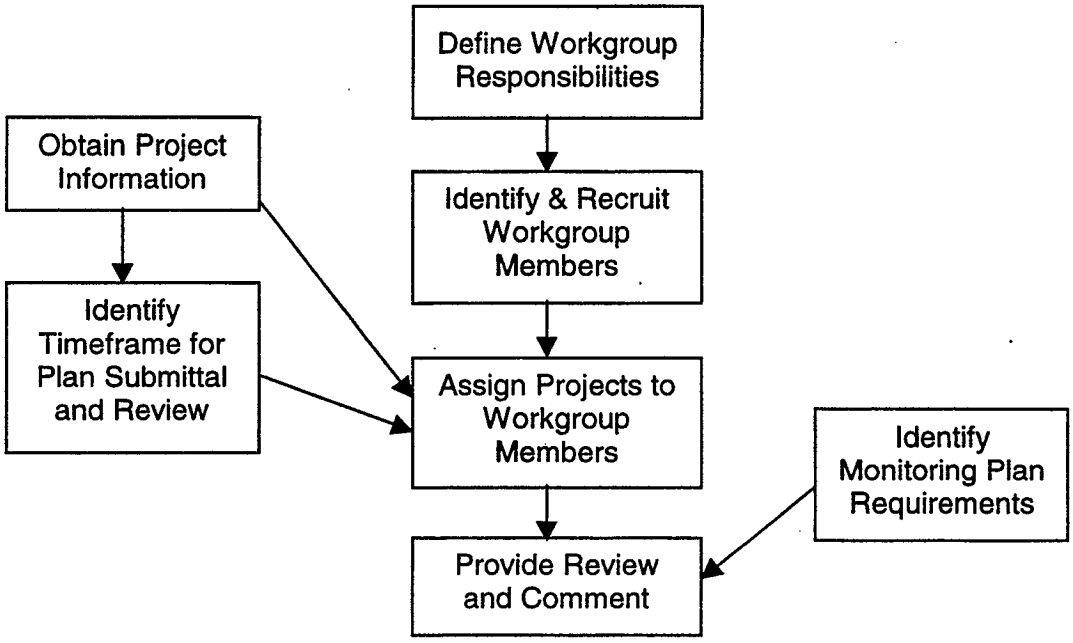

Figure 4-1. Category III Monitoring Workgroup Process

For example, feedback to the CALFED Integration Panel on the effectiveness and related issues in implementing projects is critical to making new or additional funding recommendations as part of the FY1999 and FY2000 funding decisions. Initial feedback may not yet include evaluations of project data and results but does include information on how the implementation of projects is progressing and clarification of project objectives, hypotheses, and monitoring methodologies. Also, a process/system for the centralization and sharing of project information and data from the ongoing Category III projects needs to be developed and implemented. The data collection includes project descriptions, data, analysis, mapping, monitoring methodologies, etc. The efforts to describe monitoring methods and protocols used in the ongoing Category III projects will also serve as a basis for future projects.

THE MONITORING PLAN REVIEW PROCESS

A parallel task to developing the workteam responsibilities was to recruit a qualified workteam of technical specialists (Table 4-7). Because of the variety of technical specialties within the various projects, a diverse group was needed. Approximately twenty agency and non-agency personnel were recruited, based primarily on their technical abilities and availability.

Individual project information was collected, including the executive summary from the original proposal, the most recent scope of work, and monitoring plans, if available. For projects without monitoring plans per se, the scope of work served to provide much of the above information and was used for the review. The project packages were also used to help develop an understanding of the timeframe for submittal of monitoring information appropriate to each project.

Table 4-7. An outline of information expected to be in the monitoring/data-collection methods plan

Project and Monitoring Objectives	– include objectives, hypotheses, assumptions, and conceptual framework/models
Monitoring Approach and Design Methodology, with supportive rationale	– parameters to be measured, duration, frequency, type of equipment, constituents, locations, integration with other projects, etc. – provide references or copies of protocols being followed
Data Sampling Procedures	– number and type of samples, handling, preservation, storage, analytical techniques, data synthesis and analysis
Analysis and Reporting	– report frequency, content and format; evaluation approach, use of peer review; metadata, data management and format; etc.

Projects were assigned to members of the workteam based on their technical knowledge. At least three members were assigned to each project, although most projects have more reviewers, and project packages were distributed based on the assignments. Review comments are being coordinated and consolidated through the workteam chair.

Currently, monitoring plans for projects authorized in 1997 and 1998 are being reviewed, or the work team is awaiting information from project proponents. Project data/ conclusion review is premature, but the intent is to soon begin developing the process by which data/conclusions will be reviewed, shared with interested parties, and integrated into the decision-making process for the next funding round.

RECOMMENDATIONS BASED ON THE ONGOING CATEGORY III MONITORING REVIEW PROCESS

The experiences of the Category III review process provide useful information for the developing CMARP and related CALFED processes. Some of the more important points are:

1. Early review of monitoring and research methods is needed, ideally as soon as the project is authorized to be funded in order to assist in finalizing the scope of work and budgets. A standard format would be useful, to emphasize the need to articulate and link the objectives, conceptual models, assumptions, hypotheses and methods. The shift toward increasing communication of thoughts, concepts, and rationale is challenging and thus, a cooperative spirit from everyone involved is critical to effectively develop and implement the adaptive management process.
2. The review team needs to include experienced, locally involved specialists, and "external" peer review. However, the challenge of scheduling and commitment of time from these busy individuals exists. Diverse skills and knowledge are needed, and thus the workteam needs to expand in order to have the diversity, interaction, and availability of knowledge. A subgroup focus to enhance member interaction may be the best approach to accomplishing the goals of this type of workteam, similar to IEP workteams.
3. The important process of reviewing data/conclusions needs to be developed to demonstrate (and implement) how

feedback on funding from interested parties and eventually to decision-makers will be accomplished.

4. The request/need for monitoring and research information from projects funded by different sources needs better coordination, including working through any differences in agency goals and approaches. This need for coordinated requests also applies to permitting and otherwise-involved agencies and organizations (Endangered Species Act consultation, etc).
5. The protocols/methods presented through these early Category III projects should serve as a basis (in conjunction with other available information) for developing standardized protocols for subsequent projects.
6. Continue progress toward linking monitoring of local projects to regional and systemwide monitoring and evaluation. Also, a need exists to define the policy and process for monitoring over the longer term (beyond 2 to 3 years).

Chapter 4, part K. INTEGRATING CMARP MONITORING

During development of the initial monitoring and research plans, the Work teams identified many common data needs among the CALFED Common Programs (Table 4-8). Integrating these common needs should make CMARP less extensive and costly than suggested by the compilations of individual plans. The degree to which a single monitoring program can serve multiple CALFED programs, however, will require more detailed development of the individual monitoring program components. This refinement will be done collaboratively by CMARP, CALFED and agency staff, and stakeholders.

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Table 4-8. Joint information needs of the CALFED Programs.

Information Topic	CALFED Programs That Need This Information						
	Delta Levees	Ecosystem Restoration	Storage & Conveyance	Watershed Management Coordination	Water Quality	Water Transfers	Water Use Efficiency
Streamflow Network	x	x	x	x	x	x	x
Water Quality (Surface & Groundwater)	x	x	x	x	x	x	x
Effects of Habitat Restoration	x	x	x	x	x	x	x
Species	x	x	x	x	x	x	x
Habitats – Extent, location, quality	x	x	x	x	x	x	x
Surface-Groundwater Interactions	x	x	x	x		x	x
Watershed Conditions		x	x	x	x	x	x
Land Use		x	x	x	x	x	x
Water use		x	x		x	x	x
Storage, conveyance, conjunctive use		x	x	x	x	x	
Bay-Delta Hydrodynamics	x	x	x		x	x	
Sedimentation	x	x	x	x	x		
Non-Indigenous species	x	x	x	?	x		
Extreme flow predictions	x	x	x	x			
Levee Improvements	x	x	x		x		
Land Surface Characterization	x	x	x	x			
Bathymetric Mapping	x	x	x		x		
Sediment Toxicity	x	x	x		x		
Subsidence	x	x	?			x	
Channel geometry/movement/scour	x	x	x	?			
Productivity/X2		x			x		
Bioassessment/Contaminants		x			x		

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Chapter 5. DATA MANAGEMENT, ASSESSMENT, AND REPORTING

INTRODUCTION

A vast array of data are being collected and analyzed in the San Francisco Bay-Delta area and its associated watershed by federal and state agencies, universities, private institutions, scientists and technicians. CMARP will build upon these existing efforts to provide CALFED with the information needed to make management decisions and to provide feedback to the public, government agencies and elected officials about the effects of CALFED actions. CMARP will facilitate making this information available to managers and other interested parties in a meaningful and understandable format and will work to resolve those monitoring, analysis and reporting gaps which exist between the needs of CALFED and the information that is currently available.

This chapter is organized into the following sections: Information Requirements, Coordination between CALFED and Existing Programs, Information Gathering and organization, CMARP Quality Assurance, Indicator Selection, Analysis and Integration, Reporting, Conclusions, and Examples and Tables. This chapter focuses on the various tasks that need to be accomplished and leaves the discussion of who will accomplish these tasks to the Institutional Structure chapter (Chapter 6). The Implementation chapter (Chapter 7) contains a discussion on early implementation tasks for data management, assessment and reporting.

INFORMATION REQUIREMENTS

Audience for CMARP Reports
CMARP must meet the information needs of a wide and diverse set of people including CALFED Program Managers, the CALFED Policy Group, the CALFED Ops Group, CALFED Agencies, Scientists, Stakeholders, Legislative Staff, and the public. In general, the level of detail desired by each group is expected to be different as shown in Figure 5-1. The process, therefore, must be both robust and flexible to address these diverse needs.

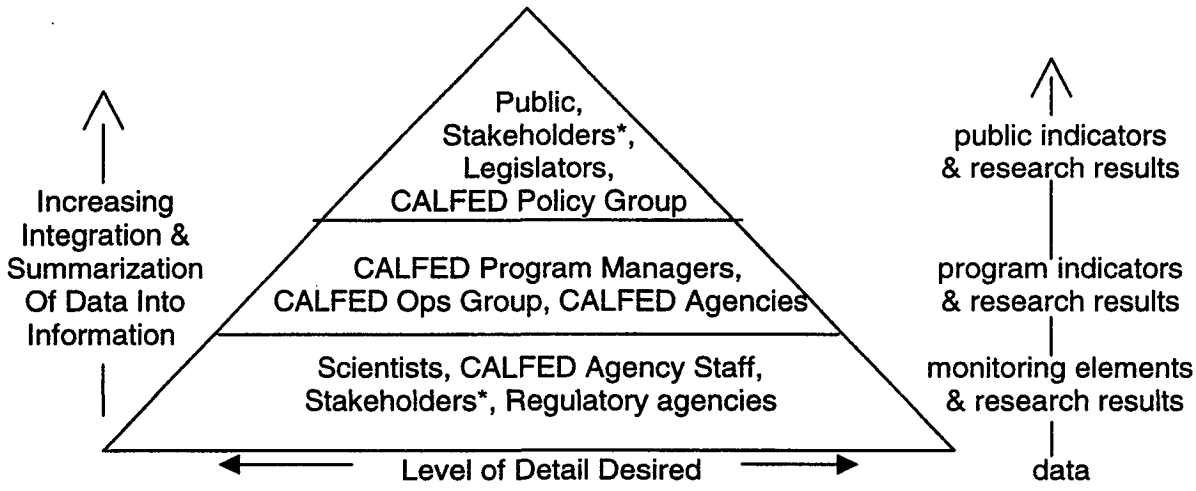

Figure 5-1. Level of Detail Desired by Different Audiences of CMARP Information and Reports. (Note: * While some stakeholders are expected to be interested mainly in basic summarized information about the system, other stakeholders are involved either in the actual collection of data or are very interested in information at all levels of the system. Consequently they are included at all levels of the diagram)

Information needs of the three groups
The anticipated needs of each level of the triangle are summarized below.

The Public, Stakeholders, Legislators and the CALFED Policy Group (top of the triangle) are expected to be interested in questions about the "big picture" and less concerned with the details of monitoring and research. Primarily this group's information needs are anticipated to be:

- actions CALFED has taken
- status of CALFED program goals and objectives
- status and trends of indicators of ecosystem health, water quality, water supply reliability, and levee system integrity
- new issues that have arisen
- new information that influences Stage II implementation decisions
- financial accountability
- the effect of CALFED actions on the individual person
- location of more detailed information
- clear method for making concerns known

Some of the needs of this group will have to be addressed through a joint effort between CALFED programs elements and CMARP – for example, in a joint annual report.

CALFED Program Managers, CALFED Ops Group and CALFED agencies (middle of the triangle) need additional information on which to make their decisions. Their additional information needs are anticipated to be:

- specific information upon which to base decisions
- status of individual CALFED project/action goals and objectives
- status of those factors (pressure/stressors) that influence valued system components
- what adaptive management actions could be used to improve knowledge of the system
- what uncertainties for managers have been removed through research
- what level of confidence is attached to information and results
- status of program meeting compliance and mitigation regulations
- computer models and geographic information system (GIS) as tools for decision-making
- a forum to communicate with scientists

Scientists, agency staff, and some stakeholders (the base of the triangle) work with very detailed information. This group's needs are anticipated to be:

- access to research and monitoring results of other scientists and agency staff, preferably through greater publication of results in peer reviewed journals rather than only in "grey" literature such as technical reports
- general access to data, metadata and reports
- increased communication and collaboration with other researchers, stakeholders, and agency staff
- a forum to communicate with managers

Historical Data Needs
CALFED Program Managers have already been using existing data and information to meet their information needs. The following list of historical data needs was gathered mostly from a survey of CALFED program managers and is subject to revision, as more information becomes available. However, this list is a good base on which to begin building the CMARP data management, assessment, and reporting process.

- Data from the Municipal Water Quality Investigations Program from the DWR Division of Planning and Local Assistance
- USGS flow and water quality data for the Delta and tributary streams
- USBR EC data in the Delta and flow and quality data for the CVP
- State Water Project water quality and flow data from DWR Division of Operations and Maintenance

- IEP data, all water quality data collected by DWR and other agencies in the Delta.
- Water quality monitoring data from the City of Stockton
- Water quality and flow data from Contra Costa Water District, Santa Clara Valley Water District, North Bay Aqueduct contractors, and Metropolitan Water District (all SWP contractors)
- Water Quality: data collected through the Sacramento Regional Comprehensive Monitoring Program (Sacramento Watershed Monitoring Program) and DWR's Water & Environmental Monitoring and Northern and Central California Water Management Programs
- Hydrology: stream flows, for as many systems within the Central Valley as possible. Progression of water development projects- dams, reservoirs, diversions, canals, etc.
- Fish & Wildlife: fisheries, wildlife, birds, phytoplankton, zooplankton, benthos data from IEP, CDFG, USFWS, DWR, SFEI, CVPIA, EBMUD, USGS, CAMP, etc.
- Habitat: Extent and location such as given by the EcoAtlas project of SFEI or the riparian vegetation mapping and fluvial geomorphic surveys conducted by DWR for SB1086
- Land use: Changes through time; urban, suburban and rural development; agricultural development; land ownership changes on a broad scale -- public vs. private.
- Demographics: Population distributions and levels over time
- Historic disturbance: recent events and how they have shaped the current appearance of the landscape; e.g. fires, floods, hydraulic mining, railroad construction, etc.
- Levee profiles and cross section drawings
- Bathymetric studies
- Levee data: land surface elevation, subsidence rates, horizontal extent of peat and organic soils, ground water levels / elevations, peat and organic soil properties, sea level rise
- Site-specific and cumulative impacts to terrestrial and aquatic habitat, as well as terrestrial and aquatic species of concern, associated with levee improvements
- Water quality impacts associated with the dredging or deposition of material in the Delta waterways
- Site-specific and cumulative benefits derived through compensatory mitigation for impacts associated with levee improvements, including mitigation banking

COORDINATION BETWEEN CALFED AND EXISTING PROGRAMS

Six principle areas of coordination need improvement between CALFED and existing programs to create a system that channels information effectively to decision-makers:

1. better organization of and access to information,
2. coordinating CALFED needs with existing programs,
3. regional focus and coordination of monitoring and research,
4. identify and filling gaps in data collection, assessment, quality assurance, management and reporting,
5. facilitating the process of converting data into condensed information usable by decision-makers, and
6. improving communication between scientists and decision-makers.

CMARP's role is not to interfere with what is already working well, but instead to provide a greater level of coordination and regional focus to the research and monitoring efforts currently occurring. Figure 5-2 illustrates how CMARP's role complements the existing projects by helping to integrate information at a regional level.

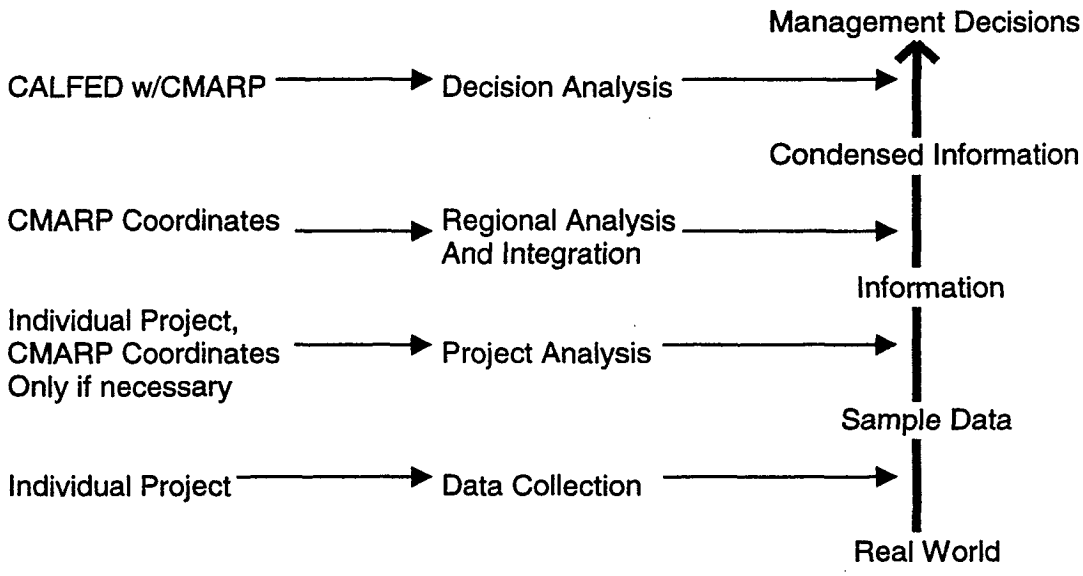

Figure 5-2. Providing Information to Managers and Decision-Makers.

Figure 5-3 provides a more detailed conceptual model illustrating 1) the steps involved in collecting the different types of information and integrating them for decision-makers, 2) the feedback loop between CALFED and CMARP, and 3) the feedback loop within CMARP as new research and monitoring needs are identified and acted upon.

Data Management, Assessment and Reporting Guiding Principles

Several guiding principles are identified to better facilitate the data management, assessment and reporting process:

1. coordinate closely with CALFED program managers and agencies in order to be responsive to their scientific information needs.
2. use existing monitoring programs to meet CALFED needs whenever possible.
3. focus on having any new analyses that are needed for CALFED be conducted by the researchers or agencies actually collecting the data, to the extent feasible. This may require additional funding by CALFED. If the original researchers are not able to do the additional analyses needed, then they may be conducted under the direction of CMARP science staff, in collaboration with the original researchers.
4. strongly encourage publication of research, monitoring, and project results in peer-reviewed literature.
5. make every effort to be an unencumbered channel of information flow between scientists and managers with strong effort made to avoid changes in purpose or content of reports and figures as they travel from scientists to managers. This will require close collaboration and feedback between CMARP and the researchers involved.
6. act as a communication bridge between scientists and managers -- working to get the information produced by scientists into the hands of managers in an understandable form, and working to help scientists better understand the needs of managers.

The areas needing improved coordination by CMARP include information gathering, quality assurance, indicator selection, analysis and integration, and reporting. These topics are subject headings in the rest of this chapter.

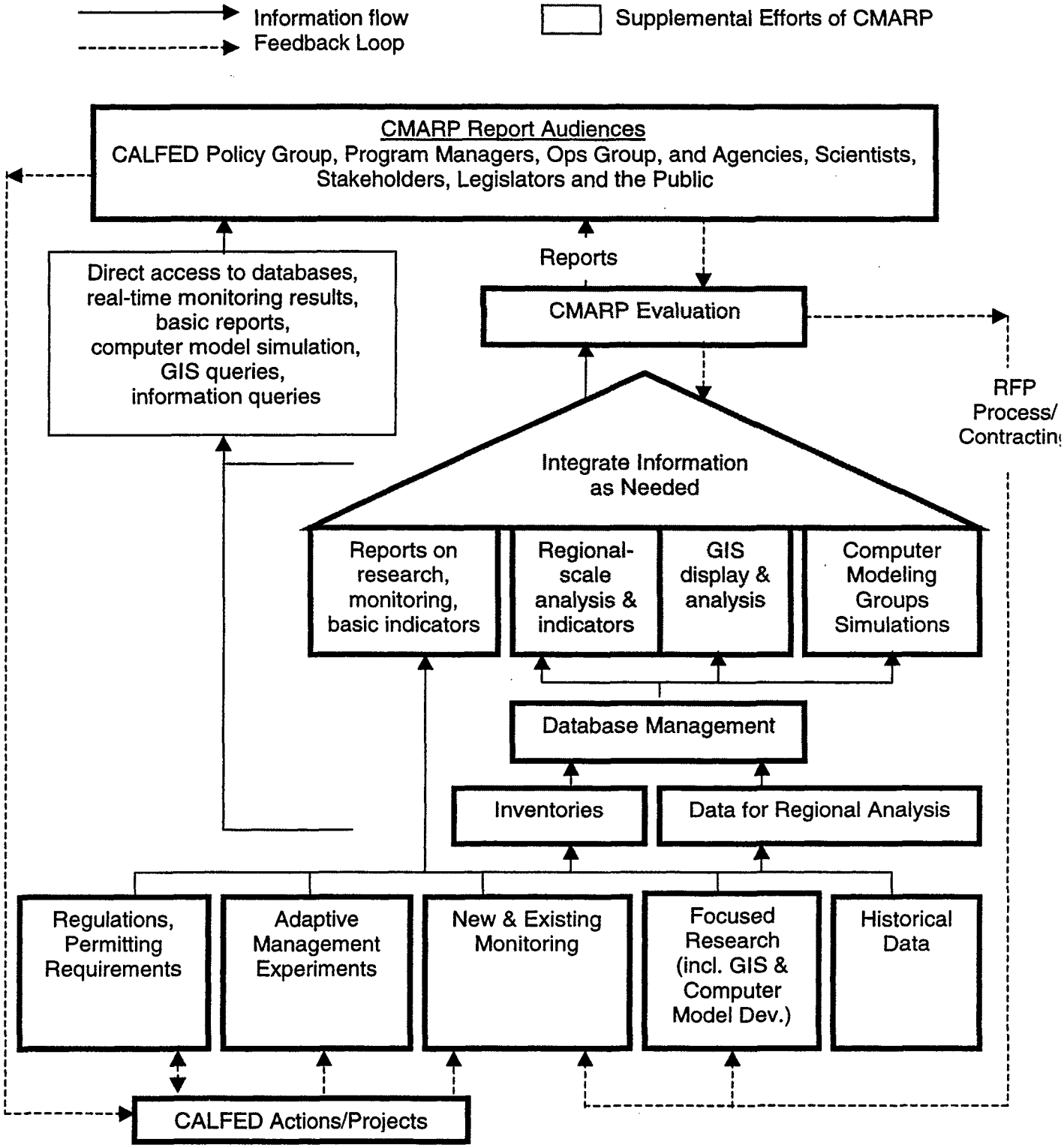

Figure 5-3. Conceptual Model of Information Flow and Feedback Loops between CMARP and CALFED.

INFORMATION GATHERING AND ORGANIZATION

One of the principal needs in the CALFED Bay-Delta system is better organization of and access to the enormous amount of information available. A large number of monitoring, research, restoration, and watershed projects are already occurring. However, lack of communication among programs has historically been a problem, and few people are aware of the full range of information already available. The scope of CALFED requires efficient organization of the information available from a regional perspective.

Three types of support tools are recommended: metadatabases, an integrated relational database management system, and a system to track reports and information.

Metadatabases and Inventories
Metadatabases are used to inventory what information is available and where it is located. They contain information about data sets, such as the owner, content, quality, accessibility, etc, but do not contain the actual data themselves.

Several important sources of metadatabase information currently exist. The biggest sources include CERES (California Environmental Resources Evaluation System, http://ceres.ca.gov/), the Information Center for the Environment (ICE, http://ice.ucdavis.edu), San Francisco Estuary Institute (SFEI, http://www.sfei.org), and the Interagency Ecological Program (IEP, http://www.iep.water.ca.gov). Some of these metadatabases and databases include

- California Rivers Assessment (CARA)
- Natural Resources Projects inventory
  - Watershed Projects Inventory,
  - California Ecological Restoration Projects Inventory,
  - Noxious Weeds Database Project
- Geospatial Waterbody System
- Coastal Water Quality Monitoring Inventory
- California Watershed Information System
- California Ocean and Environmental Access Network (Cal-Ocean)
- California Wetlands Information System
- California Botanical Database (Cal-Flora)

The number of monitoring and research efforts being conducted in the CALFED Bay-Delta system is extremely large and there is no single existing metadatabase that links them all. To avoid duplication of effort, reduce the costs involved in providing information to CALFED, and improve coordination among agencies and researchers, CMARP is building a metadatabase of monitoring programs in the CALFED Bay-Delta system and associated watersheds (see Chapter 2). Over 600 monitoring programs have been identified. This metadatabase will allow CALFED to identify monitoring programs that it can coordinate with to meet its information needs. The current version of this metadatabase is being tested at the SFEI web site http://www.sfei.org/cmarpinv/.

CMARP will organize access to the existing metadatabases of GIS coverages (CERES, ICE, Army Corps of Engineers Comprehensive Review Study, etc.) and organize filling in gaps related to CALFED needs. Other metadatabases may become necessary in the future such as 1) larger research efforts related to CALFED's objectives, and 2) computer-modeling efforts related to CALFED's objectives, but these are currently of lower priority.

Additionally the development of a comprehensive list of scientists, agency staff, stakeholders, managers, etc. associated with CALFED into a queryable database is recommended. Also the Institutional Structure peer review process (see Chapter 6) also calls for the development of a list of experts who can be contacted by CMARP for peer review of reports, projects, etc.

These metadatabases and inventories will be accessible on the CMARP web page together with links to other web sites.

CMARP Database Management
Lack of coordination in data reporting, quality assurance, and database management among monitoring efforts can make it difficult to combine data across monitoring efforts and make regional information available quickly. For example, in previous years the reporting of spring-run chinook salmon monitoring required each data provider to fax or email the information to a central location where the data were re-entered. This process was time-consuming and error-prone.

In the past, one strategy attempted to solve these problems was to create a centralized database that combined data from multiple monitoring programs. Several problems were encountered because such efforts required data providers to turn over their data to a centralized database. This process was time consuming and data providers were understandably reluctant to lose control over their data. The process of making corrections to the centralized database was slow and tedious which resulted in the existence of multiple versions of the same data set– one set on the data provider's computer system and a second version in the centralized database. This scenario was unacceptable to most data providers.

Rapid advances in technology have made it possible to create a centralized, integrated database system allowing rapid gathering and dissemination of data to meet the needs of CALFED, agency staff and stakeholders, while still meeting the needs of data providers to maintain local control over their data, utilize low-effort in sharing their data, easily update and make changes to the data sets, and have only one version of a data set in existence.

The proposed solution is a Relational Database Management System (RDBMS). This system will allow individual data providers to manage their own data locally, while contributing to a larger comprehensive database. Each data provider will have control over its own data, which will be fully protected within the data management structure. Only the data provider will have permission to change its own data. Data will be uploaded with stringent QA/QC into a comprehensive database where it will be normalized, standardized with common units and labeling, and made available to users for reports and applications. Data providers will be immediately notified of problems. The database system will also allow geo-referencing. The intent of the CMARP 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.

Relational Database Management Systems and the World Wide Web are easily accessible technologies, and training is readily available. Most users are already using Internet browsers, such as Netscape Navigator/ Communicator or Internet Explorer. Once adapted to each data provider's system, the database provides an easy-to-use, customizable graphical user interface (GUI) that is easily learned. Exporting the data to the RDBMS can be accomplished with a simple export command or through an automated process that updates the RDBMS on a daily basis.

Use of the RDBMS will be driven by those areas where management has the greatest need for more efficient and coordinated reporting of regional information to facilitate decision-making.

A prototype of this system is currently being implemented for Spring Run Chinook salmon. A Bay/Delta and Tributaries (BDT) Relational Database Management System (RDBMS) is being developed by IEP, SRWP and CVPIA/CAMP in conjunction with California Urban Water Agencies (CUWA). Data providers manage their own

data locally, equipped with customized software that will dynamically update the centralized comprehensive server. Evaluations of this system will be based on actual use and feedback from data providers and users. The CMARP Data Management Work Group will formulate user surveys to gather information on the efficacy of the system directly from users. This will include groups using the system to supply information to GIS, data analysis software and other data-driven applications. Evaluating a working system will allow CMARP to effectively and realistically assess how well this type of system will address its needs.

By using the Bay/Delta and Tributaries Relational Database Management System as a prototype, CMARP can quickly and efficiently provide a data management tool that can be utilized by CMARP data providers, data users, agency staffs, and stakeholder groups. Such an integrated data management system will be a highly efficient means of compiling information quickly and encouraging a much wider use of the data by multiple agencies and stakeholders, such as CDFG, CUWA, SFEI, DWR, and IEP. This system will be an invaluable resource to CMARP.

A more detailed description of the proposed CMARP Relational Database Management System can be found in the CMARP Data Management Work Group Appendix *VII.H.*

Reports and Information Tracking
A large number of reports are already generated by existing programs. Some examples of these reports are included in Tables 5-1 and 5-2, at the end of this chapter. CMARP will coordinate with existing monitoring program managers to get copies of their reports and facilitate getting those reports into the hands of CALFED decision-makers as quickly as possible. To keep the large amount of material involved organized, it is recommended that a systematic process for tracking, organizing, and querying the information, reports, and data sets from CALFED-related research and monitoring programs be developed.

CMARP QUALITY ASSURANCE

The quality of the information used by CMARP depends on two different levels of focus:

1. the quality of the data collection and analysis by the individual programs and
2. the integration of data from several monitoring programs for regional analysis efforts.

- Individual Programs – The quality of data collection and analysis by individual programs can be divided into three basic areas:
  a) the adequacy of the quality assurance/quality control plan of the individual monitoring program,
  b) the effectiveness and efficiency of the monitoring plan design in meeting its stated goals and objectives, and
  c) how closely CALFED's needs match the needs and objectives of the individual monitoring program. These issues will be resolved on a case-by-case basis.

- Regional Coordination– Integration of data from multiple monitoring programs for regional analysis efforts is limited by three basic problems:
  d) dissimilar units, basic error-checking, resolving outliers, etc.,
  e) differences in sampling methodology, detection limits, precision, laboratory protocols, equipment, experience of personnel, and nomenclature, and
  f) gaps in space, time and frequency among current monitoring efforts.

These six issues (a through f) are discussed further in the Data Assessment and Reporting Team Appendix *VII.I*

The level of quality assurance is highly variable among the various monitoring programs in the CALFED Bay-Delta solution area. Each program has QA/QC standards and laboratory methods suitable to its own needs and convenience. In general the level of QA/QC for water quality measures is much higher than that for ecosystem measures. However, even for water quality measures, the detection limits among laboratories can vary greatly causing some programs to report "Not detectable" for some pesticides whereas a research-grade laboratory could report the actual concentration. This lack of consistency in QA/QC standards makes it difficult to combine and compare data from multiple monitoring programs.

In addition, the level of communication between the data collectors and data analyzers can greatly affect the quality of the information. Often if this communication is poor, inaccurate assumptions are made about how the data are collected. Ease of communication with the original data collectors should be maintained. Data included in a CMARP database must have some "confidence level" assessment attached to them about the accuracy of the data.

The current level of regional coordination among programs is unclear at present. Some programs, such as the San Francisco Regional Bay Monitoring Program and the U.S. Geological Survey National Water Quality Assessment Program, provide regional assessments of water quality. The Interagency Ecological Program is an effort to provide regional coordination of ecological monitoring and research. Further efforts at regional coordination will build on these efforts already in place.

It is important to note that CALFED and CMARP can only request that existing monitoring programs share their data and/or make changes in their existing monitoring design. It is hoped that existing monitoring programs will be willing to assist CALFED in meeting its needs, in exchange for being part of a regionally coordinated monitoring effort, and having better exchange of information and communication among researchers, particularly if CALFED is able to pay any additional costs that are incurred. Obviously each program's own needs and objectives are expected to take precedence over CALFED needs.
A final issue, which will help assure quality of data collection and analysis used by CMARP, is external review, particularly external peer review of study proposals and progress, and publication of results in peer-reviewed literature. CMARP will place a strong emphasis on publication of results in peer-reviewed literature and will use this standard in all its activities. The process of external review and peer review is further discussed in Chapter 6.

INDICATOR SELECTION

Using indicators is an important method of summarizing and reporting large amounts of information in a concise and effective format. The development and analysis of indicators for trends is anticipated to be a major function of CMARP in the future. Indicators are defined as

> *"direct or indirect measures of some valued component or quality of a defined system, used to assess and communicate the status and trends of that system's 'health'."* [from a lecture given by Jim Bernard of the Green Mountain Institute for Environmental Democracy at the "CMARP Integration Workshop", October 21, 1998, Bodega Bay, California]

Some examples of indicators relevant to CMARP include: 1) spatial extent and distribution of habitat patches, 2) dissolved oxygen in river water near Stockton, 3) number of delta levee miles or islands/tracts meeting the minimum

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99 standard, 4) the amount and quality of recycled water produced by treatment plants, 5) collection of juvenile chinook salmon at certain sampling locations that indicate the start of the spring salmon migration to the ocean, and 6) the position of X2.

Although some indicators could be the same as the monitoring elements identified by the CMARP work teams, indicators generally summarize information derived from multiple sampling locations in a way that is more informative to managers. For example, the total number of salmon harvested/year would be calculated from the reports of commercial and recreational harvest in the ocean, Sacramento and San Joaquin rivers, and tributaries.

Several different efforts at identifying indicators have already been undertaken. 1) the CALFED Indicators Group has developed a set of over 150 landscape level and ecosystem level indicators for assessing the health of the ecosystem (ERP Ecological Indicators Group, 1998), 2) the Environmental Defense Fund (October 8, 1998) has developed a set of approximately 10-12 core ecosystem indicators, 3) some CMARP Work Teams, such as Delta Levees and the Water Use Efficiency, have identified programmatic indicators, and 4) some of the CALFED Programs themselves, such as the Ecosystem Restoration Program, have developed programmatic indicators to evaluate the success of CALFED actions during Stage I. The efforts of these different groups will be integrated and developed further into specific, practical indicators that are agreed upon by all groups involved.

ANALYSIS AND INTEGRATION

A great deal of analysis is occurring at the level of individual projects. However, the areas where CMARP can provide the greatest assistance are the regional analysis and integration of research and monitoring results in the CALFED Bay-Delta solution area. These higher levels of integration involve the analysis of indicators, analysis of adaptive management experiments, and better coordination among GIS efforts.

Analysis of Indicators

Much of the information needed to calculate CALFED indicators can be gleaned from existing agency reports and databases. Examples of such reports are shown in Tables 5-1 and 5-2, at the end of this chapter. Where such information is sufficient for CALFED purposes, the role of CMARP will be to facilitate the process of synthesizing and transmitting the information to decision-makers and to make the information generally available. Where the current analysis and reporting mechanisms are inadequate to meet CALFED needs, CMARP will focus on arranging for additional analysis and reporting, preferably by those researchers actually involved in collecting the information. However, CALFED should be willing to pay for these additional analyses to be conducted in a timely fashion. Unfortunately, when unpaid requests for analyses and reporting are made of busy researchers and agency staff, they receive low priority and serious time delays in reporting occur. Some specific types of analyses are anticipated.

Development of Baselines—To gain sufficient understanding of the Bay-Delta System upon which to make decisions and to evaluate the effect of CALFED actions once initiated during Stage I Implementation, it is important that baselines for indicators be developed as soon as possible using historical information and data collected before implementation actions begin.

Regional analysis across wide spatial and temporal scales—An important function of CMARP is the coordination of regional monitoring efforts among programs so that new analyses can be conducted across wide spatial and temporal scales. Regional

monitoring and analysis provides a broader, landscape-level picture than is achieved by looking at individual locally-targeted monitoring projects. Well-organized regional analysis can detect trends earlier with greater confidence since variation across space and time can be more accurately assessed. The data can also be used for evaluating correlations among different types of data (e.g., effects of nutrients, temperature and light on productivity) and for improving sampling methodology. Studies of this kind have already been used in IEP-related studies to refine the information needs of water quality, nutrient, and plankton sampling programs (i.e. what are the tradeoffs between the number of sites and the frequency of sampling in terms of being able to detect certain kinds of changes).

An example of how pulling together information on a regional scale is useful for decision-making is the process the CALFED Ops Group uses to anticipate salmon outmigration and reduce entrainment at the pumping facilities. This process is described briefly in Example A at the end of this chapter.

Develop correlations and hypotheses about cause-effect relationships—Various areas of uncertainty exist about the San Francisco Bay-Delta, such as how the ecosystem functions and reacts to change or how water transfers affect neighboring areas. Although a great deal of data are collected throughout the San Francisco Bay-Delta and its associated watershed, the agencies collecting these data sometimes do not have the time or the resources to analyze the data beyond the scope of their program's objectives. It is expected that some of these data can be combined and analyzed to identify possible cause-effect hypotheses, which can then be used as a foundation for prioritizing research needs. One function of CMARP will be to sort through the numerous uncertainties identified by the CMARP workteams, determine those addressable with existing information, and arrange for those analyses. An additional task is to continue monitoring currently established correlations for changes that can indicate shifts in the functioning of the system. Example B at the end of this chapter shows such a shift. In this example, mysid abundance is weakly correlated with the position of X2 until the late 1980's when clam density began to increase. In this case, the introduction of a new species changed the strength of existing correlations in the system.

Adaptive Management Experiments
The CALFED program is committed to a process of adaptive management, which will involve experiments. CMARP will work to facilitate communication between researchers and decision-makers to identify where adaptive management can be effectively applied and to design experiments that will yield as much information as possible without compromising other management issues or causing undue risk to species of concern. This will likely involve experiments that manipulate the system to better determine cause-effect relationships and pilot projects to test hypotheses of system functioning. CMARP will also facilitate analysis and reporting of these experiments by those researchers and agency staff most directly involved.

The Vernalis Adaptive Management Program (VAMP) and the CVPIA Delta Action 8 program provide examples of existing adaptive management experiments. The VAMP program investigates the relationship between juvenile salmon survival and flows and export rates in the San Joaquin River in April-May. The CVPIA Delta 8 program investigates the relationship between juvenile salmon survival in the Sacramento River under different export regimes in December-January.

Geographic Information Systems (GIS)
A comprehensive assessment of the GIS needs of CALFED and greater coordination

among GIS efforts is necessary in the CALFED Bay-Delta solution area. The creation of a GIS team is discussed in Chapter 7.

REPORTING

An important tool in communications between researchers and decision-makers is an effective reporting system. An effective reporting process facilitates getting focused and understandable interpretations of the overwhelming amount of information currently being generated about the CALFED Bay-Delta system into the hands of decision-makers. This will involve compiling and evaluating the results from monitoring of indicators, research programs, regional monitoring analyses, real-time monitoring data, permitting and regulation requirements, GIS efforts, and computer modeling efforts and delivering it to decision-makers in a manner that is accessible, timely and understandable.

Characteristics of reporting system
CMARP's reporting role is to (1) make its information accessible to all interested CALFED participants, (2) facilitate the process of integrating and summarizing the information to the extent desired by decision-makers and the public, (3) sift through this information to find that information specifically requested by decision-makers and facilitate getting the information to them, (4) ensure presentation in a format that is clear and understandable to decision-makers, and (5) facilitate managers' understanding of the science involved and facilitate scientists' understanding of management needs.

CMARP will be building on current reporting efforts to meet the needs of CALFED program managers. Some examples of these reports are shown in Tables 5-1 and 5-2, at the end of this chapter. Table 5-2 provides a preliminary summary of web-page real-time monitoring reports.

The reporting system should be characterized by transparency, accessibility, objectivity, reliability, high quality and rapid reporting of results.

Types and Frequency of Reports
The types and frequency of reports will be determined by the needs of the public and of CALFED program managers. Each of the CALFED Programs is different in nature and purpose and has differing reporting needs. These needs will be more completely understood as the CALFED process moves forward. Reporting needs are expected to range greatly in frequency and content including annual reports, a science conference, real-time monitoring, monthly and quarterly reports, fact sheets, responses to information queries, and web page reporting. Listed below are the reporting recommendations for the future CMARP. The amount of staff resources available and the priorities dictated by CALFED and CMARP will determine whether each recommendation is implemented and the quantity of such activities. It is of critical importance that managers receive the information they need in time to assist decision-making.

General Annual Reports— The general annual report should be a joint effort between CALFED and CMARP and include contents reflecting the activities of each. This annual report would be directed primarily towards the public, stakeholders and legislative staff. The recommended content of the annual report includes: 1) summary of CALFED actions taken during the year, 2) status of indicators for valued system components and their influencing factors, 3) status of CALFED program goals and objectives, 4) highlights of what has been learned, both positive and negative, during the year, 5) highlights from research projects completed and underway, and 6) a fiscal summary. The recommended delivery date of the Annual Report is the third week of April (approximately the same time as the IEP spring newsletter currently comes out, which includes indicators that should also

be included in the Annual Report). The first annual report delivery date is recommended to be April 20, 2001. A trial annual report focusing on Category III Project results could be made in April 2000.

Annual Science Reports—An annual science report is recommended to report the proceedings of the Annual Science Conference and to summarize the monitoring and research results of the previous year. This report would be targeted to a more scientific and technical audience than the General Annual Report.

Annual Science Conference—An annual science conference is recommended to bring CALFED Program Managers, scientists, and agency staff together. Various research and monitoring efforts would be briefly reported and new issues raised. The Annual Science Conference is described further in Chapter 7.

Real-Time Monitoring Reporting—CMARP expects to use some real-time monitoring reporting. Real-time monitoring refers to the near-immediate reporting of data usually with a delay between collection and reporting ranging from a day to a few weeks depending on the type of data. Although such data typically are "raw" and often have not been reviewed for quality control, the information is useful for compliance monitoring and for early detection of changes and problems so program managers can respond quickly or initiate more focused monitoring or research.

In particular, the CALFED Ops Group already makes effective use of real-time monitoring, using data that relate stream-flow, turbidity, and the location of species of concern in the Delta to make decisions about pumping Delta exports. CMARP will not interfere with decision support systems that are already working well, but will attempt to facilitate the process of getting information to decision-makers, where needed, and to increase access of this information to other CALFED program managers.

The Water Quality Program anticipates needing monthly status reports, which will probably include a brief 3- to 4-page summary of the status of water quality indicators, and monitoring elements. Each of the CALFED water management programs (Storage, Conveyance, Water Transfers, Water Use Efficiency) will need regular access to information such as water flow-rates, height (stage), water quality and ground-water levels.

Because real-time monitoring can be expensive, CMARP will coordinate reporting of results from existing real-time monitoring efforts. Initiating new real-time monitoring efforts will be considered only after the considerations of purpose, expense, and diminished data-quality risk have been weighed.

Periodic Technical Meetings & Bulletin—Maintaining an atmosphere of open communication between science, management and stakeholders should help increase understanding and cooperation among the three groups and encourage proactive solution of problems. Frequent technical workshops or meetings are recommended, possibly on a quarterly basis, during which CALFED program managers, CMARP, scientists, managers, and stakeholders can meet for 1) updates on progress, 2) explanation of what the data reveal, and 3) discussion of new issues. A quarterly bulletin could be issued for the purpose of this workshop.

Fact Sheets – Development of fact sheets is another important reporting function. Fact sheets are 1-4 page summaries used to quickly and effectively explain important issues and increase public awareness. Some possible examples include descriptions of important non-indigenous species, descriptions of conceptual models of ecosystem functioning, and answers to frequently-asked questions.

Information Query Response—One important function of CMARP is to organize information so that it can be easily queried by managers, scientists, and other interested parties. In addition to having information on the web, CMARP will also respond directly to queries for information from program managers, scientists, agency staff, and stakeholders. Some queries will be simple requests for information; for example the Delta Levees Program will likely need to be able to query the status of delta-levee monitoring on a regular basis. Other requests for information will require some additional analysis and work, such as a request for information relating to a new invasive species (e.g., mitten crab collection at the south-delta pumps). CMARP's role will be to channel the request for this information, with funding, to those researchers and agency staff with the best ability to answer the question and to facilitate getting a timely response to decision-makers.

This process will be developed further as the specific needs of each of the CALFED programs become clear. As CMARP evolves, the ability to answer queries efficiently and quickly depends on the amount of staff time available and the amount of time and effort needed to create an accessible and frequently updated web page.

Web Page Reporting—CMARP will make intensive use of web-page technology to make information available quickly and effectively to all interested parties. It is anticipated that the CMARP web page will include (1) current status of public indicators, program manager level indicators, and additional monitoring elements of special interest to scientists, agencies and stakeholders; (2) access to metadatabase information compiled through the CALFED process; (3) access to the CMARP monitoring and research database; (4) copies of annual reports, quarterly and monthly status reports and journal articles related to CMARP; and (5) links to related web sites.

Creating and maintaining this web page will require planning and investment in staff and training from the beginning. In the long run, this investment will greatly reduce the amount of staff time spent answering queries for basic information and greatly increase access of information to all interested parties.

CONCLUSIONS

In conclusion, by 1) providing better organization of and access to information, 2) coordinating CALFED needs with existing programs, 3) providing regional focus and coordination of monitoring and research, 4) identifying and filling gaps in data collection, assessment, quality assurance, management and reporting, 5) facilitating the process of converting data into condensed information usable by decision-makers, and 6) improving communication between scientists and decision-makers, CMARP will be providing a very needed service to CALFED itself, to CALFED agencies, and to the stakeholders.

EXAMPLES AND TABLES

Example A. An Example of the CALFED Operations Group Decision-Making Process

The CALFED Operations Group has developed a hierarchical consensus-driven process for quickly incorporating current environmental information into decisions regarding operations of the Central Valley Project (CVP) and the State Water Project (SWP). This process is depicted in Figure 5-5 and is summarized below. A more detailed description of the process is in the Data Assessment and Reporting Team Appendix *VII.I.*

To accomplish this process the CALFED Ops Group established the "No-Name Group" which keeps all involved agencies and interested parties informed about the

take of environmentally threatened or endangered listed species and other related issues that affect CVP/SWP operations. Sub-groups have been created which in turn analyze data and propose operation actions regarding specific issues such as winter-run chinook salmon, delta smelt, real-time fish monitoring, etc.

One such sub-group is called the Data Assessment Team (DAT) which consists of biologists from CALFED agencies and stakeholder group and CVP/SWP operators. This group compiles and interprets fishery-related data and disseminates the interpreted information to the CALFED Ops Group. DAT has been involved with evaluating spring-run Chinook salmon. DAT assesses data compiled from 13 sites for two indicators of the start of the spring run: either direct capture of Chinook salmon or abrupt changes in river flow or water clarity which are often associated with the beginning of the salmon run. When an indicator is found, DAT assesses the situation and makes recommendations within 24 hours for the adjustment of CVP/SWP operations. DAT then notifies the No-Name Group Chair, CVP/SWP Operators, and the co-chairs of the CALFED Ops Group.

Figure 5-4 shows a simple conceptual model relating water pumping in the south Delta, water supply reliability and health of the salmon. Figure 5-5 shows the decision process of the CALFED Ops Group. Figure 5-6 shows the relationship between salmon salvage, river flow rates, delta outflow rates and time of year.

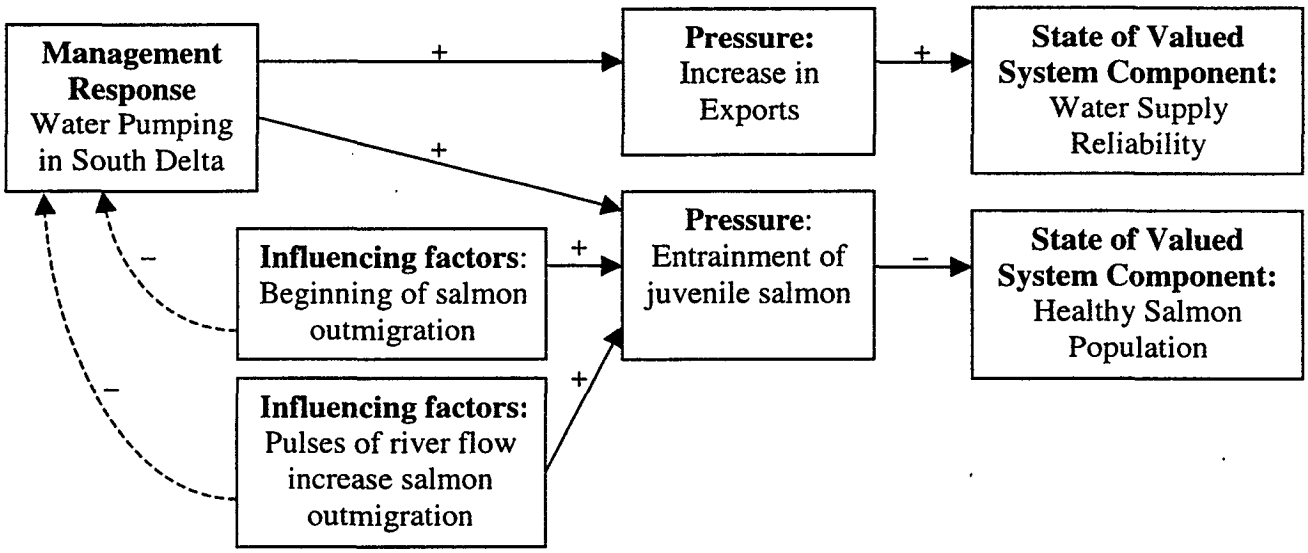

Figure 5-4. Relationship between management of water pumping in south Delta and corresponding effects on water supply reliability and the salmon population.

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C-021964

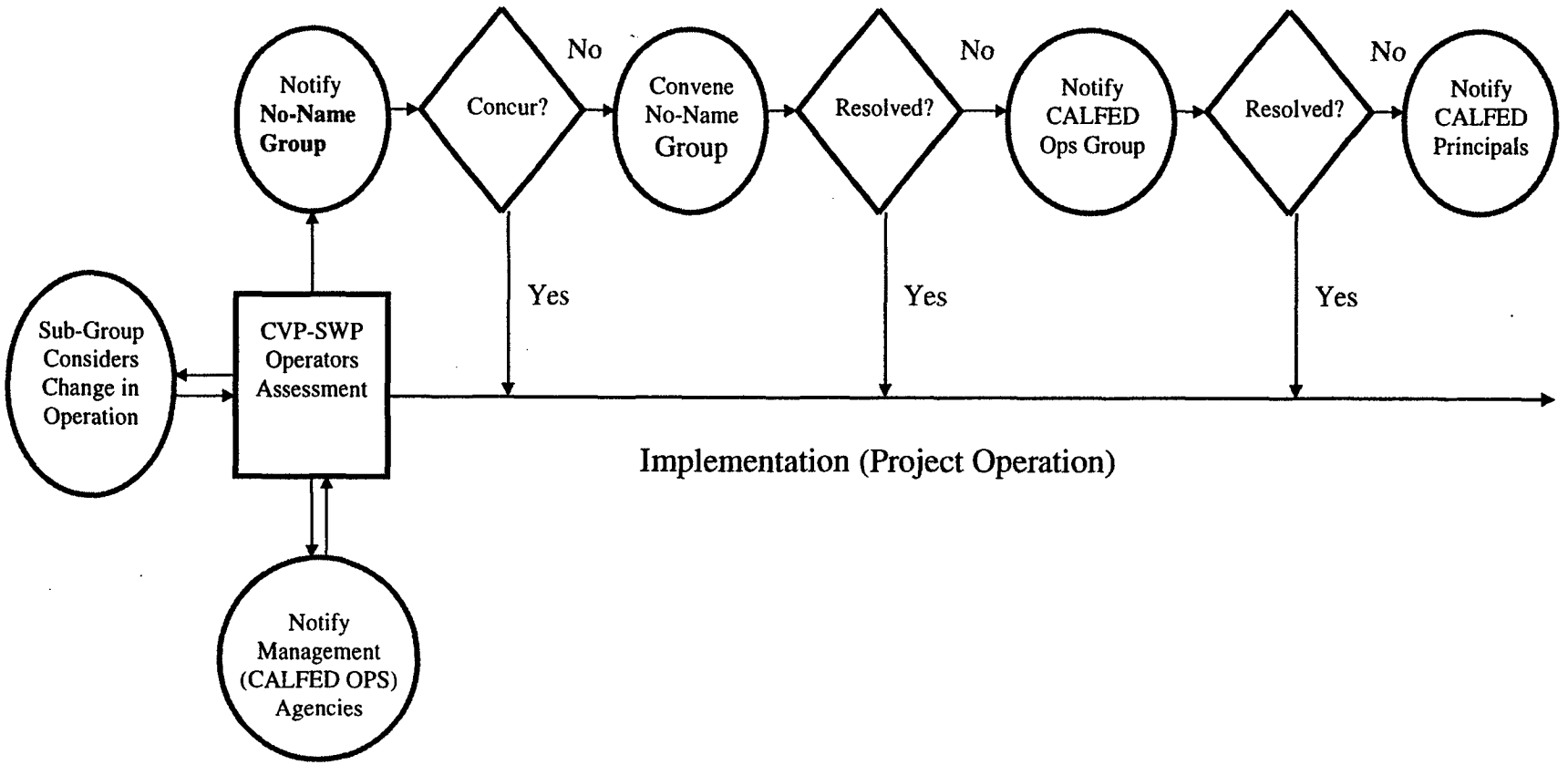

Figure 5-5. CALFED Ops Group Decision Process

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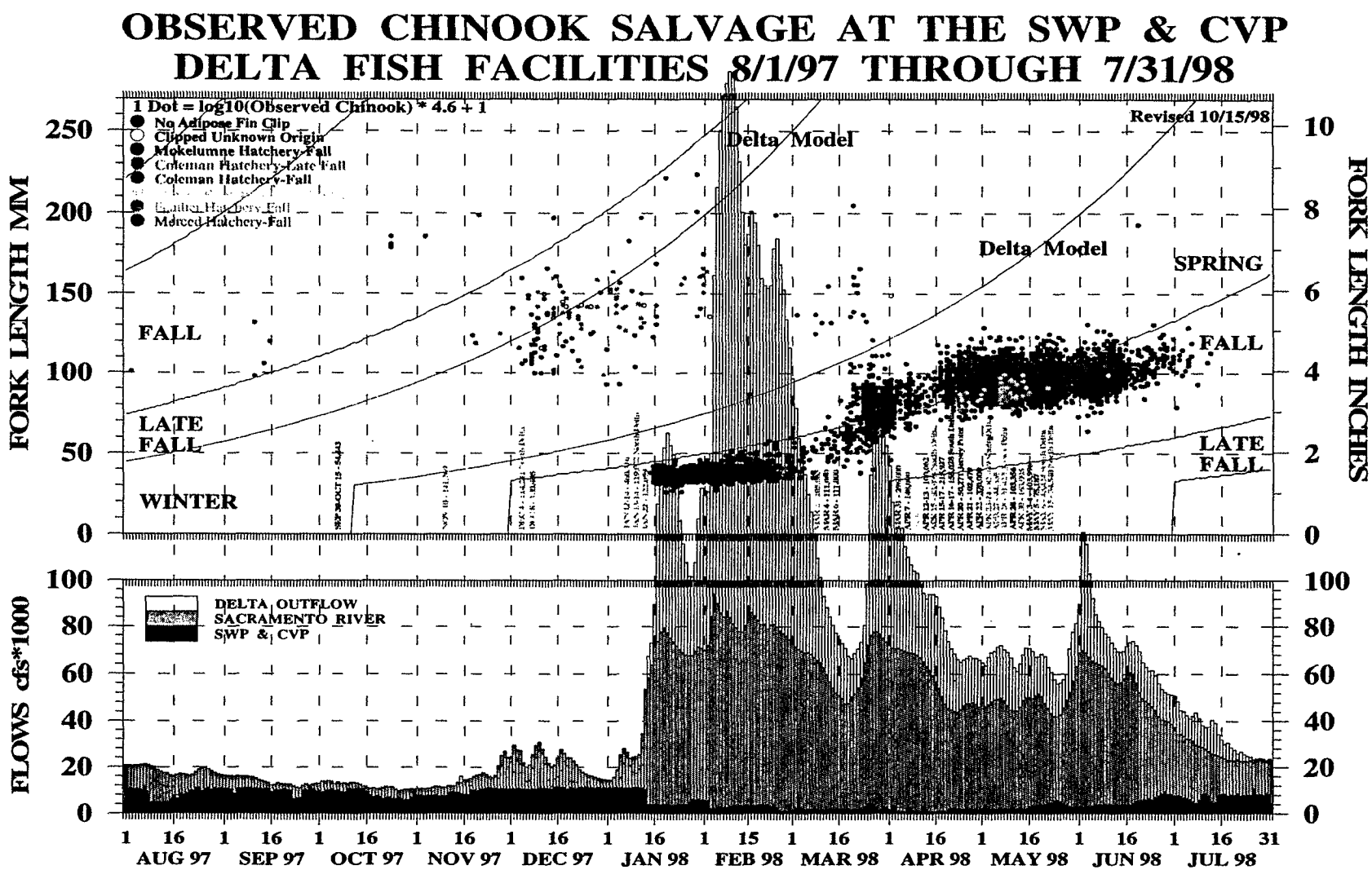
Figure 5-6. Plot of Chinook salmon incidental take at the SWP & CVP Delta Fish Facilities from 8/1/97 through 7/31/98 created by Sheila Greene, Dept. of Water Resources. In addition to showing Chinook salmon salvage, the plot relates salmon salvage to flows and exports and shows the timing between hatchery releases and recapture at the facilities. The plot also shows the length criteria the hatchery fish fall in. For example late-fall chinook are released from Coleman hatchery from November to January. The plot shows how many of the recovered late-fall hatchery fish actually fall in the late-fall length criteria.



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Example B. Correlating Mysid abundance, X2 Position, and Clam density

Developing correlations among different types of data are useful for discerning possible cause-effect relations, which can be further researched through an RFP process. In addition such correlations are important for discerning developing problems. For example, the following figure shows that mysids were weakly correlated with X2 position until the late 1980's when clam density began increasing. This emphasizes that the San Francisco Bay-Delta ecosystem is a constantly changing system. Coordination between managers and researchers is needed to rapidly identify such changing relationships and incorporate them into the decision-making process.

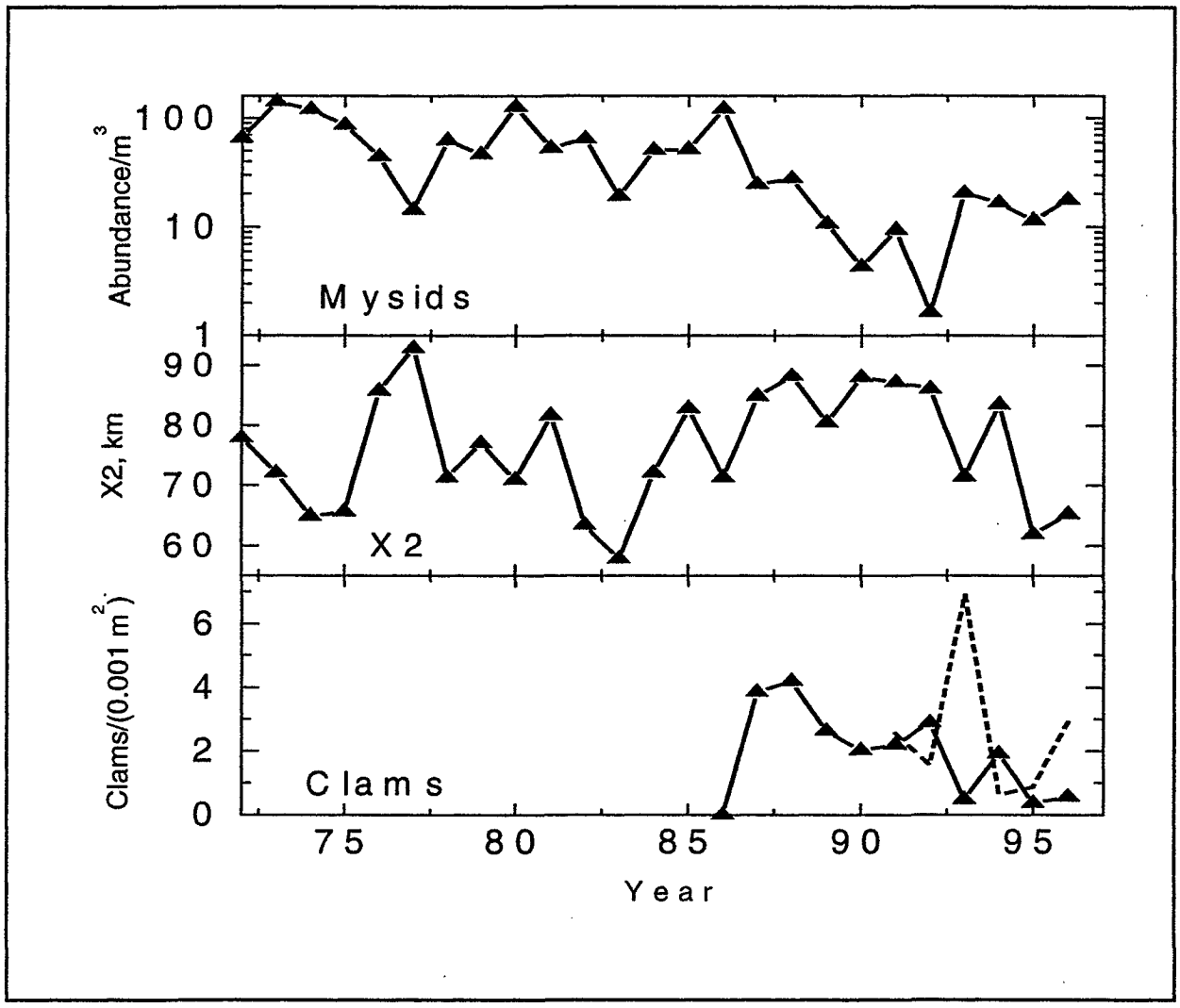

Figure 5-7.Time series for mysids (*Neomysis* and *Acanthomysis*) (top graph), X2 (middle graph), and clams (*Potamocorbula amurensis*) (bottom graph), annual means for sampling seasons for stations in Grizzly Bay (triangles) and San Pablo Bay (dashed line). Mysid abundance is weakly related to X2, but evidently affected by clams: the lowest abundances of mysids were post-clam, and even when flow increased after the drought in the 1980's-90's, mysid abundance failed to recover much beyond its previously lowest value.

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Table 5-1. Examples of periodic and non-periodic reports from agencies and programs in the CALFED Bay-Delta solution area.

Periodic Reports		
Program Acronym	**General Report Title or Reference**	**Frequency**
CAMP	Comprehensive Assessment & Monitoring Program Annual Report	Annual
DWR	Cal. Dept. of Water Resources—Bulletin 120: Water Conditions in California	Annual
	Dept. of Water Resources-- Bulletin 160: California Water Plan	Every 5 yrs
	Dept. of Water Resources-- D1485 Annual Water Quality Report	Annual
	Dept. of Water Resources-- Reclamation Board General Manager's Report	Monthly
	Dept. of Water Resources-- Water Conservation News	Quarterly
IEP	Interagency Ecological Program (IEP) Annual Reports	Annual
	Interagency Ecological Program (IEP) Newsletter	Quarterly
PRBO	Point Reyes Bird Observatory--Flight Log: Newsletter of the California Partners in Flight—*http://www.prbo.org/PRBOJournals.html*	Biannual
	Point Reyes Bird Observatory--Observer Online *http://www.prbo.org/PRBOJournals.html*	Biannual
RMP	Regional Monitoring Program (RMP) Annual reports	Annual
	Regional Monitoring Program (RMP) Quarterly Newsletter	Quarterly
RWQCB	Regional Water Quality Control Board reports	
SCMP	Sacramento Coordinated Monitoring Program Annual Report	Annual
	Sacramento Coordinated Monitoring Program Summary Report	Every 2-3 yrs
SFEI	Grasslands Bypass Monitoring Program - monthly, quarterly, annual reports	monthly, quarterly, annual
SFEP	San Francisco Estuary Project "Estuary" Newsletter	bi-monthly
SWP /CVP	"Preliminary SWP and CVP Salvage Estimates" weekly report from the Fish Facilities Monitoring Unit, Bay-Delta & Special Water Projects Division, California Department of Fish & Game	weekly
USGS	U.S. Geological Survey-- Water Resource Data Annual Reports	Annual
	Sacramento River Watershed Program Annual Report	Annual
	Sacramento River Watershed Program Monitoring Plan	Every 2-3 yrs

Non-Periodic Reports	
Program Acronym	**General Report Title or Reference**
USACE	PL84-99Delta Specific Standard and PL84-99 Overview
CVAP	Central Valley Aquifer Project Reports
DWR	1995 Inspection Report: Flood Control Project Maintenance Repair
	Dept. of Water Resources—Bulletin 118: Evaluation of Groundwater Resources
	Dept. of Water Resources—Bulletin 192-82: Delta Levees Investigation
IEP	Interagency Ecological Program Technical Report Series
FEAT	Final Report of the Governor's Flood Emergency Action Team: May 10, 1997
NAWQA	National Water Quality Assessment Program- Sacramento River Basin & San Joaquin-Tulare Basin Reports
PRBO	Point Reyes Bird Observatory--Scientific Publication & Special Reports *http://www.prbo.org/Publ.html#Focus*
RASA	Regional Aquifer-System Analysis (RASA) Program Reports
RMP	Regional Monitoring Program (RMP) Technical Report Series

Program Acronym	*Non-Periodic Reports*—continued General Report Title or Reference
SFEI	Biological Invasions Program Studies & Reports
SFEP	San Francisco Estuary Project Status & Trends Reports
SJVDP	San Joaquin Valley Drainage Program Reports
SWRCB	California Environmental Protection Agency – State Water Resources Control Board – Publications *http://www.swrcb.ca.gov/*
USGS	Historical work by Joe Poland on Land Subsidence, for example "Land Subsidence in San Joaquin Valley, California as of 1980", USGS Professional Paper 437i by Ireland, Poland and Riley, 1984.
	San Francisco Bay Estuary & Dixon Field Station studies
	"Land Subsidence Case Studies & Current Research", Association of Engineering Geologists Special Publication No. 8, 1998, 576 pages

Table 5-2. Examples of real-time monitoring web-page reporting from agencies and programs in the CALFED Bay-Delta solution area.

Real-Time Monitoring Web Page Reports		
Program Acronym	**Web page name**	**Current Reports**
Audubon	Birdsource Bird Counts *http://birdsource.cornell.edu/*	Audubon Christmas Bird Count
CDFG	California Dept. of Fish & Game—Central Valley Bay-Delta Branch—Fish Facilities Unit Monitoring & Operations Projects *http://www.delta.dfg.ca.gov/*	Fish Salvage Monitoring; Striped Bass Monitoring; Spring Run Chinook Salmon; Delta Smelt
DWR	California Dept. of Water Resources California Cooperative Snow Surveys *http://cdec.water.ca.gov/snow/*	Snowpack Status; Precipitation; Runoff; Reservoirs; Water Supply
	California Dept. of Water Resources California Data Exchange Center *http://cdec.water.ca.gov/index.html*	Current River Conditions; Snowpack Status; River Stages/Flows; Reservoir Data/Reports; Weather Forecasts; Precipitation/Snow; River/Tide Forecasts; Water Supply;
	California Dept. of Water Resources Delta Environmental Compliance Section *Http://wwwoco.water.ca.gov/cmplmon /Cmhome.html*	Delta Ops Summary; Water Quality Conditions; Hydrology Conditions; Bay-Delta Standards; Delta Smelt; Winter-Run Salmon
	California Dept. of Water Resources *Http://wwwdwr.water.ca.gov/*	Surface Water; Ground Water; River Forecast; Reservoir Info
	California Dept. of Water Resources Municipal Water Quality Investigations *Http://wwwdla.water.ca.gov/supply /sampling/mwq/main.htm*	Water Quality Conditions
	California Dept. of Water Resources State Water Project Analysis Office *Http://wwwswpao.water.ca.gov/*	General Information
	California Dept. of Water Resources State Water Project Operational Reports *http://wwwoco.water.ca.gov/subpages /opreports.menuo.html*	SWP Operations Data

Program Acronym	Web page name	Current Reports
DWR (cont.)	California Dept. of Water Resources State Water Project Water Quality Monitoring Program *http://wwwomhq.water.ca.gov/wq/astalist.htm*	Automated Water Quality Stations; Pathogen Monitoring Program; Pesticides, Herbicides & Other Organic Substances
IEP	Interagency Ecological Program Real-Time Monitoring *http://www2.delta.dfg.ca.gov/data/rtm98/*	Fish sampling
	Interagency Ecological Program *http://www.iep.ca.gov/data.html*	Time Series Database; Long-Term Monitoring Data; Historical Short-Term (Special) Studies; Estuary Data Viewer--Water Quality; IEP Comprehensive Database
SFEI	San Francisco Estuary Institute Regional Monitoring Program Data *http://www.sfei.org/rmp/data.htm*	Conventional Water Quality Parameters; Trace Elements; Trace Organics; Aquatic Bioassays; Sediment Bioassays; Sediment Quality Characteristics; Bivalve Condition & Survival
USACE	U.S. Army Corps of Engineers Water Control Data System *http://www.spk-wc.usace.army.mil/*	Midnight Reservoir Status; Monthly Reservoir Reports; Reservoir Storage, Inflow, Outflow; Hourly Time Series Reports; Release Change Notification; Average Reservoir Status; Weather & River Forecasts/Summaries
USBR	U. S. Bureau of Reclamation Central Valley Operations *http://www.mp.usbr.gov/cvo/index.html*	CVP Water Supply Report (DAMS); Sacramento River Temperature Report; Delta Accounting Reports; COA Report; Folsom Permissible Storage; Monthly Water Operations Forecast; Trinity River Flow Schedule; Delta Outflow
USFWS	USFWS Bird Monitoring *http://www.fws.gov/r9mbmo/statsurv /mntrtbl.html*	Bird Monitoring
	USFWS-SSJEFRO Chinook Salmon Monitoring Summary Report *http://www.delta.dfg.ca.gov/baydelta/monitoring /ychin.html*	Fall, late-fall, spring and winter run chinook salmon caught by gear type. Coded wire tag releases & recoveries
USGS	U.S. Geological Survey-- San Francisco Physical Oceanographic Real-Time System *http://sfports.wr.usgs.gov/sfports.html*	winds; currents; current profiles; forecasts
	U.S. Geological Survey--Water Resources of California Real-Time Data *http://wwwdcascr.wr.usgs.gov/sites/*	Streamflow Network
	U.S. Geological Survey-- Bird Monitoring in North America *http://www.im.nbs.gov/birds.html*	USGS Bird Monitoring in North America
	U.S. Geological Survey- Water Quality of San Francisco Bay-*http://sfbay.wr.usgs.gov /access/wqdata/*	Water Quality in San Francisco Bay

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Chapter 6. INSTITUTIONAL STRUCTURE TO IMPLEMENT CMARP

INTRODUCTION

The CMARP Phase 1 report states that the Steering Committee will develop recommendations for creating an institutional structure to implement the CMARP over the long-term. These recommendations would emphasize flexibility. They would be made after review of the strengths and weaknesses of large scale environmental monitoring programs both locally and around the country, after consulting with the agencies and stakeholders involved in CALFED and the organizations that would be expected to participate as partners within CMARP. While progress has been made in reviewing large-scale environmental monitoring programs and in consulting with participating agencies, partner agencies and stakeholders, these external evaluation and consultation processes have not been completed. Thus, the recommendations of this Chapter are considered preliminary.

The characteristics or attributes CMARP participants believe that the program should display and the functions they believe the structure needs to perform are listed. This Chapter describes the elements needed of a management structure to ensure that the functions are carried out and the processes that the structure will need to implement to ensure that the attributes are obtained. Largely because the long-term arrangements for the implementation of the CALFED program have not yet been determined, CMARP participants believe that the final form of the CMARP Institutional Structure cannot be resolved at this time. Issues upon which additional input would be helpful have been identified.

Because of the uncertainty about the long-term CALFED Institutional Structure, this Chapter uses several terms, which need definition. It is presumed that there will be some CALFED sanctioned body to which the CMARP will report and from which it will receive direction and funding authorization. This body might be a continuation of the current policy group, a newly comprised Board, an existing agency or a new organization. This institution is referred to as the **Decision-making Body**, and the long-term monitoring, assessment and research program is referred to as *CMARP*. Use of this term does NOT imply that it is organized and governed in the same fashion as the CMARP Steering Committee used for Phase II. The term **Monitoring, Assessment and Research Organization** *(MARO)* is used, loosely, to cover any possible arrangement, from an interagency working group to a newly formed Institute; it is the organization that will be responsible for implementing CMARP. *The CMARP Team* refers to all scientists and other personnel working on CMARP, including those formally within the MARO, and in the larger body of CMARP participants and contractors.

ATTRIBUTES OF A CMARP INSTITUTIONAL STRUCTURE

Discussions among the workgroup participants and with those interviewed led to the conclusion that certain principles or primary sets of attributes ought to underlay all deliberations on institutional structure for the program. Any recommended institutional structure for CMARP must address these principles.

Responsiveness to Management Needs-- The primary purpose of CMARP is to provide the information and scientific interpretations and advice necessary for CALFED to fully implement its preferred alternative, including the common programs, and for the public and government agencies to evaluate the success of CALFED. The ability of the program to provide the kind of information needed by managers as they move forward

through the decision process is, therefore, paramount. The types of management needs to which the CMARP must respond include:

- documenting compliance with regulatory standards,
- detecting and reporting trends in environmental condition,
- measuring CALFED program performance,
- providing timely information for decisions, and
- collaborating with management to execute active adaptive management.

Scientific Quality – The importance and cost of the decisions to be made in the CALFED process and the demands of the adaptive management require that these be based upon the best scientific information that can be made available. CALFED managers need to be assured that the scientific work they are funding, and upon which they will be relying, is of the highest quality possible. Quality will be enhanced by:

- Scientific competence and credibility achieved through publication of results in peer-reviewed scientific journals.
- Scientific breadth and depth resulting from a broad mixture of disciplines and expertise represented in the MARO and the CMARP Team.
- Independence such that CMARP scientists have the ability to determine how best to do their work and be free of attempts to influence their findings, achieved at least in part by extensive use of external scientific review.
- Commitment to long-term monitoring, assessment and research to reduce uncertainty.

Accountability -- Accountability encompasses responsiveness and quality, but also includes the concepts of cost-effectiveness, transparency of process, and participation. There appears to be strong support for a substantial increase in funding for monitoring, assessment and research. With additional funding is an increased sensitivity to accountability, which requires:

- easy access to all of the data and information upon which decisions are based.
- collaboration among scientists, stakeholders and resource managers.
- an open, consistently applied and transparent process for setting program priorities and making funding decisions.
- cost-effectiveness achieved by building upon existing programs and by employing competitive solicitation processes.

Some of these attributes stand in opposition to each other. For example, independence implies an absence of control while responsiveness requires a degree of control over program decisions. Over-emphasis on cost-effectiveness may threaten commitment to scientific excellence. Responding to urgent management needs could threaten the commitment to long-term monitoring. The greatest challenge in the implementation of CMARP will be to achieve the appropriate balance among these competing principles.

FUNCTIONS OF THE CMARP INSTITUTIONAL STRUCTURE

Perhaps the first question to address in considering an institutional structure for implementation of CMARP is what it is that CMARP must do for CALFED. The CALFED Decision-making Body will need information to answer short-term questions before proceeding with the staged decision-making process, and measurement of the long-term conditions in the Bay-Delta and associated performance measures to determine whether individual projects initiated by the common programs are successful and whether the problems of the Bay-Delta are being solved. The principle function of CMARP is, therefore, to manage the direction of the monitoring, assessment and research program to provide this essential information.

CMARP will also be the scientific arm of CALFED and will be prepared to assist in the design of the adaptive management program. This assistance must come from individuals who understand experimental design and the design of field programs. In addition to analyzing trends, CMARP must be prepared to initiate scientific research, including monitoring, modeling, and data analysis, to determine whether things are changing and what effect the CALFED actions have had. Although this will not always be possible, it should be the idea behind all of the performance assessment.

The functions that the institutional structure created for CMARP must carry out include the following:

- designing and directing the monitoring, assessment and research program,
- collecting, managing and distributing data,
- analyzing and interpreting data, and reporting the findings,
- orchestrating external scientific review of projects and programs, and
- collaborating with management on adaptive management.

It is assumed that some new core organization or organizations would need to be created, whether through formal or informal means, to serve as the recipient for CALFED funding and to serve as the focal point for accountability. These general functions require that several tasks be carried out by the MARO and some by the broader additional array of individuals and organizations that make up the CMARP Team. The Structures and Processes discussed below illustrate by whom and how these functions might be carried out.

ELEMENTS OF THE INSTITUTIONAL STRUCTURE

Given the need for the functions described above, certain elements of an institutional structure will be needed. The following elements will serve to increase the probability that the Monitoring, Assessment and Research Program will achieve the desired attributes and can fit into any number of structural approaches. These elements collectively would comprise the MARO:

1. Science Review Board, advisory to highest Decision-making Body for CALFED.
2. A highly visible position of Chief Scientist with direct access to decision-makers.
3. A highly qualified team of scientists and support staff to assist and advise the Chief Scientist, which is referred to as the Core Technical Staff.
4. A Science Coordination Team, made up of individuals from the agencies and organizations responsible for implementing major elements of the monitoring, assessment and research program.

Science Review Board -- The Science Review Board will play an important role in guiding the Decision-making Body with regard to its use of science in adaptive management and decision-making. Because science inherently produces uncertain results, often complicated by contentious debate among conflicting interpretations, the Decision-making Body may need assistance in understanding the quality and usefulness of the information upon which they are asked to make decisions. The Science Review Board will help the Decision-making Body make these judgments. The Science Review Board will also assist in using scientific information to evaluate whether the CALFED program is reaching its dual goals of improving water supply and restoring the Bay-Delta ecosystem. It would ask such questions as "Is the condition of the Bay-Delta system improving?" "Is the CALFED program using adaptive management experimentation effectively to reduce uncertainty and improve management?" This level of review addresses not the quality of the

scientific program *per se*, but the use of science in the management program.

The Science Review Board should include a combination of prominent scientists who have expertise in CALFED-type programs and issues, but do not work in the area, and prominent scientists with local experience and expertise who are independent of CALFED agencies and stakeholders.

The development of the Science Review Board needs to provide both for some stability and for turnover and fresh ideas and viewpoints. Staggered terms of 3-5 years would provide this. The Board needs both to be allowed the highest degree of independence, yet be able to work closely and hold the trust and respect of the CALFED Decision-making Body. It is suggested that professional societies such as the American Fisheries Society, the Estuarine Research Federation, the National Academy of Sciences, the National Science Foundation, or the Wetlands Society would make nominations to the Board. The Board should select new Board members itself; it should be self-renewing. The Decision-making Body should have the power to veto a proposed nominee, but not to make the selection. This leaves the question of the original selection of the Board. The solicitation of an original slate of candidates could be contracted to the National Academy of Sciences or some other well-respected and neutral group of eminent scientists.

Since the primary source of information for the Science Review Board will be CMARP, judgments on the quality, breadth, and applicability of the work done by CMARP will, to some extent, be a necessary by-product of the Science Review Board's principle role. The Decision-making Body may also look to the Science Review Board for assistance in evaluating the quality and effectiveness of CMARP. Since this exercise will, to a degree, involve evaluation of the talents and judgment of the Chief Scientist and the Science Coordination Team that reports to the Chief Scientist, an arm's length relationship between the Board and the Chief Scientist should be maintained.

Chief Scientist -- Scientific leadership is key to the success of CMARP, and is more important than any other aspect of the organizational structure set up to operate or govern the program. While it is possible that this leadership will emerge from within the agencies and organizations that will be participating in CMARP, or from a coordinating committee created to guide CMARP, it is just as likely that it will not. An endeavor of the magnitude and importance of CMARP must have strong leadership. Providing a position of Chief Scientist will help ensure high levels of credibility and accountability. Regardless of the particular arrangement chosen, numerous individuals, agencies, and organizations will be involved in CMARP. Without a central figure charged with making the program work and producing results, it will be very difficult to determine where responsibility for problems or deficiencies in the program lies.

This individual will need the breadth and depth of understanding of environmental and related sciences to be able to fashion a program that entails all of the subject matter described in other sections of this report. He or she will need to have the credibility and enthusiasm to inspire the confidence of all of the scientific personnel working on CMARP, whether or not those scientists work directly for him or her. He or she must be able to identify and draw upon the expertise of scientists from around the country as well as those locally to assist in peer review and external review processes. This individual will need extraordinary communication skills in order to understand the needs of decision-makers, relay scientific findings to them in understandable terms, and communicate with public audiences and scientists from a variety of disciplines. He or she must be able to

simultaneously speak the truth and maintain the trust and confidence of all of the stakeholders. Finally, he or she must be at least a bit of an iconoclast, and be willing to challenge the paradigms that influence our current understanding of the Bay-Delta system.

The Chief Scientist will report to the head of the agency or organization in which his or her position resides and also directly to the CALFED Decision-making Body. Duties of the Chief Scientist will include the following:

1. Be responsible for the overall direction and quality of the monitoring, assessment and research program.
2. Assemble and direct a Core *Technical Staff* that can provide the type of analysis and interpretation of monitoring information discussed in Chapter 5.
3. Chair a *Science Coordination Team* designed to keep all of the agencies and organizations that implement elements of the program working collaboratively.
4. Identify (through communication with the Decision-making Body, Science Review Board, Stakeholder Advisory Committee, etc.) the management issues that need to be addressed through CMARP.
5. Identify and help resolve technical controversies, through consensus building, where possible.
6. Produce an annual work plan of monitoring, assessment and research to be approved by the Decision-making Body.
7. Ensure that the external review functions are carried out, supported, and heeded.
8. Convene an Annual Science Conference.

The Chief Scientist has the ancillary duty of interacting with the regulatory agencies. There is a feedback loop with the regulatory agencies such that regulatory monitoring might be improved, and the information produced feeds and affects the regulatory process.

Core Technical Staff -- A team of individuals to assist the Chief Scientist as a core staff needs to be assembled. The Chief Scientist should have a fairly free hand (subject, of course to budgetary limitations) in assembling this team; he or she ought to be able to 'recruit' from within agencies (as well as from external organizations). This team would advise and assist the Chief Scientist in

- developing the annual work plan to address monitoring, assessment and research needs,
- help to develop and lead research programs in conjunction with extramural researchers,
- form working teams to operate monitoring programs which are largely agency-conducted,
- nurture partnerships with scientists in other research organizations,
- critically review and analyze CALFED- and non-CALFED-funded monitoring-program data,
- work with data generators to interpret and produce publishable findings based on current data, and
- report periodically and as needed to the Decision-making Body and the public.

This team will consist of a number of highly qualified scientists representing a broad array of expertise in the environmental sciences. It would be desirable to have a mix of individuals that includes some that have extensive experience within the Bay-Delta system and that have developed relevant expertise working in other systems, and some that are well-established in their fields and others who are at the beginning of their careers. One way to ensure that a continual stream of new thinking and approaches flows into the Core Technical Staff would be to assign a number of time-limited postdoctoral positions to the team. The scientific staff would also need various forms of support, including technical, data management, graphics, and administrative.

Science Coordination Team – The agencies and organizations (including stakeholder organizations) that currently conduct major monitoring, assessment and research programs will need to play an important role managing the comprehensive program proposed by this document. These are the programs upon which CMARP will need to be built. The comprehensive program will result from the combination of these programs and the new efforts initiated in directed response to CALFED needs. In some cases, especially where expansion or redirection of existing efforts is required to make the CMARP program work, these same agencies and organizations will need to be involved in helping to craft the changes and will need to be conducting additional work. This team will be the mechanism by which the Chief Scientist keeps all of these efforts moving in a coordinated fashion, and ensures cooperative working relationships among all of the partner organizations within the CMARP Team. The team will be responsible for helping to develop the annual work program for CMARP. Because each of the elements of the CMARP program will undergo periodic review, the membership of this team will have to be kept flexible, allowing for adding new members when a new player is identified, or dropping off an organization that no longer is playing a pivotal role.

PROCESSES

There are several processes by which the structures described above will carry out the functions of CMARP. Commitment to these processes is as important to the success of CMARP as the structures set up to operate them. Critical processes include:

1. control of money flow and budgeting of funds,
2. external scientific review of programs, proposals, and products,
3. partnerships between internal and external scientists, management,
4. science management partnership for adaptive management,
5. resolving technical conflicts
6. data collection, data management and information handling,
7. annual Science Conference, and
8. stakeholder advisory mechanisms.

Control of Money Flow and Budgeting of Funds -- The MARO will need to serve the function of distributing the funds allocated for research and monitoring and accounting for the funds and the work done. To ensure accountability and to give CMARP the opportunity to have a coherent program, it will be desirable for the flow of money to CMARP for the CALFED funded portion of the program be directly from the Decision-making Body to the organization that houses and provides administrative support to the Chief Scientist. The MARO should have the authority to make grants and contracts and should be provided with the necessary administrative support.

CMARP will have to continually undergo evaluation and adjustment to ensure that it is accomplishing its goals. This future development will have to take place within the MARO. While the program activities should be planned on a multi-year basis, there will be an annual budgetary cycle for CALFED appropriations. CMARP will have to be translated into annual work plans (that would contain the annual increment of multi-year monitoring and research elements) each year so that it can be submitted to the Decision-making Body for review, approval and funding.

Some limitations should be set on the way the total amount of funding available for monitoring, assessment and research is spent. First, it is clear from the remainder of the CMARP report that monitoring, assessment, and research will be needed. It would be counterproductive to make dramatic shifts year to year in the proportion of funding between these three major activities. Over time, as understanding of

the system increases and monitoring methods become more efficient, there may be a gradual shift to providing a larger portion of the funding to assessment and research. It will also be important to reserve some portion of the budget for "urgent management needs". From time to time, unanticipated situations will occur that may demand an immediate response by mobilizing special studies to enable rapid response to acute management issues. This should be taken into account during budget planning such that CMARP can respond quickly to such situations without causing irreparable harm to long-term trend monitoring or multi-year research programs that have already been put into place. A goal should also be set for a continuing, significant proportion of funding to be spent externally to the MARO in grants to researchers in universities, non-governmental organizations and the private sector.

External Scientific Review – The credibility, quality and timeliness of the external review of the science used by and produced by the CALFED program is key to achieving numerous desired attributes. It will be essential to assure that funds are effectively spent, that information produced is of high quality, that the program is responsive to management needs, and that the program does not become insular but remains open to new ideas. Such review is required at three points in the development and implementation of the program:

1. review of the overall direction and quality of CMARP,
2. selection of research proposals and monitoring program elements, and
3. review of CMARP products.

Program Review

External program review involves review of the overall quality and direction of CMARP. It addresses the questions "is CMARP providing the scientific information needed for CALFED management decisions?" "Is it asking the right questions?" "How well can it answer these questions?" The Chief Scientist may wish to form one or more expert external review panels to delve in depth into questions about the program as a whole, or about a specific program element. It may be desirable, for example, to call a panel of experts on fish population dynamics to advise the MARO and to review how well CMARP is monitoring fish populations. The Chief Scientist may also choose to make use of intensive workshops to address a specific issue. For example, if the CMARP funded several years of research exploring Fish-X2 relationships, the Chief Scientist might want to organize a workshop involving local researchers who had been working on these problems and a number of outside experts to address 1) whether the questions had been solved sufficiently, 2) whether additional resources should be applied to the problem, and 3) directions that future research effort ought to take.

Proposal Selection

The CMARP work program will involve work done internally by its Core Technical Staff, work done by agencies and organizations participating on the Science Coordination Team, work done externally by universities, agencies, non-governmental organizations, and the private sector, and projects involving collaboration among parties "internal" and "external" to the CMARP Team. It will involve a combination of monitoring program elements, research projects, and projects involving original approaches to assessment of existing data sets. The Chief Scientist will need to develop processes that ensure that ALL projects and program elements funded by CALFED would be subject to essentially the same proposal solicitation and review process, regardless of source. To do this will require instituting an objective process for the anonymous peer evaluation of proposals for new monitoring, assessment and research that is efficient and achieves broadest acceptance of the process within the CALFED community.

- *Research Proposal Solicitation*—A list of approved management and study questions will be developed by the Chief Scientist, Core Technical Staff, and Science Coordination Team with input from managers, field scientists, and stakeholders. The Chief Scientist would prepare one or more Proposal Solicitation Packages designed to solicit proposals for addressing the identified study questions. The Proposal Solicitation Packages would be designed to allow for and encourage multi-year, collaborative projects. The solicitation process will also provide for projects that might be termed assessment, in that they may be focused on original analyses of existing data rather than original fieldwork. The Chief Scientist will also recommend the criteria to be used in proposal evaluation.

- *Proposal Review Process*—It will be the job of the Chief Scientist to see that appropriate and qualified reviewers are identified and that the process is done professionally. The Chief Scientist will rely upon a two-tiered review system:
  1. a Peer Review Coordination Panel with members reimbursed for their time, and
  2. a large group of pre-qualified technical experts who provide the first level of anonymous review (these reviewers will be offered honoraria for their services).

  The Peer Review Coordination Panel would comprise a group of 10-15 technical experts, nominated by the MARO. The members should be active estuarine, freshwater, fisheries, wildlife, or watershed research scientists/engineers who have a high degree of stature, are well connected with other scientists in their respective fields, represent different specialties within these fields, and have some familiarity with the San Francisco Bay-Delta watershed system. The Chief Scientist would ensure that Peer Review Coordination Panel members have no conflicts of interest (e.g., current or pending support from the Program or personal or institutional stake in the outcome).

  The members of the Peer Review Coordination Panel will be tasked with soliciting and overseeing the anonymous external (mail) review of proposals. Each member will solicit reviews by at least three experts for each proposal within his/her specialty areas, then summarize and prioritize the member's findings for presentation to the other members of the Panel. Reviewers will score the proposals, based on their scientific merit and the relevance to the Proposal Solicitation Package. When all reviews have been received, the proposals will be ranked by the Peer Review Coordination Panel based on the external mail reviews and the Panel's own evaluation. The Peer Review Coordination Panel will develop an overall prioritization of the proposals and will make funding recommendations to the Chief Scientist for his or her review of the recommendations. Until the Decision-making Body is constituted, the Chief Scientist will submit the CMARP annual work program to the CALFED Integration Panel for approval.

  The Peer Review Coordination Panel will be modeled after that used by the *Exxon Valdez* Restoration Program. In the *Exxon Valdez* Program, the Peer Review Panel meets annually for several days to review the entire annual program, including progress on multi-year projects and all of the new proposals that have been submitted for funding. Reviewers serve for several years, allowing them to become familiar with the goals and management needs of the program's decision-makers and

the strengths and weaknesses of the monitoring, assessment and research programs. In addition to passing judgment on individual projects as proposed, they make suggestions to augment weak but high priority projects by combining projects, bringing in additional experts to assist in certain projects, and suggesting how to redesign certain projects for future reconsideration. In this fashion they help to ensure that the proposal solicitation, review and selection process results in a coherent program of research rather than a collection of disparate projects.

- *Monitoring Proposal Solicitation*— Because monitoring elements may continue for a number of years with little change, it may be necessary to develop a different schedule for review of the monitoring elements of the program and the research and assessment elements. Thus, major elements of the monitoring program might be resolicited on a five-year cycle. The Chief Scientist would direct preparation of proposal solicitation packages seeking applicants from public and non-profit agencies, the private sector, and academia. The package would describe data collection standards, quality assurance procedures, and data delivery requirements. The Peer Review Coordination Panel would rank applicants on the basis of their qualifications and demonstrated performance, availability of required equipment and permits, the effectiveness of data collection plans, and proposed cost. The Chief Scientist would select a proposed grantee from applicants with high rankings to include within the recommended work program that would be submitted to the CALFED Decision-making Body. Grantee performance would be evaluated annually based on quality and timely delivery of data prior to renewal of the grant.

Review of CMARP Products

Review of completed projects addresses the quality of the products produced. It asks the question, "Was the work done in a scientifically credible manner?" The ultimate process for doing this will be the peer review process that attends publication of the results in scientific journals. Another, more preliminary step will need to be provided. Getting papers published in peer reviewed literature typically takes two years or longer; CALFED managers will often want or need the information produced, including an assessment of the quality of the information, much faster than that. The solution may be a process similar to that used by the South Florida Water Management District. They have set up their own quick turn-around peer review process. A large slate of pre-qualified external reviewers are available who can provide thorough peer review on a fee-for-service basis in a very short time frame. This process serves the dual purpose of providing the managers with information that they are assured is of high quality in a reasonable time frame and increasing the success of District employees in publishing their papers. This same system could be applied to any information product produced by CMARP, even if it were not destined for publication in the peer-reviewed literature. However, as a matter of principle, we recommend that the program results be published to the extent practicable.

CMARP participants are aware that no peer review process is without flaws, and that peer review and publication will not resolve all issues of quality and credibility. Nor is it meant to be suggested that scientific work that has not been reviewed is by definition of poor quality. Rather, it is believed that a commitment to extensive impartial review will add credibility to good work already being done and will tend to raise the standards for work done and will increase

the overall perception of quality and credibility of the entire program. Extensive peer review as suggested here will require the commitment of substantial funding and staff support; without this support it is unlikely to achieve its purpose.

Partnerships between Internal and External Scientists

These partnerships comprise the CMARP Team and are based upon collaborative working relationships between and among the Chief Scientist, the Science Coordination Team and the agencies and organizations conducting CALFED funded AND non-CALFED funded environmental monitoring, assessment and research. The CMARP inventory of monitoring programs for the Bay-Delta and its tributary rivers shows the tremendous breadth and depth of the monitoring programs currently in existence. Many individual scientists in universities and other institutions are carrying out research relevant to CALFED needs, independent of these monitoring programs. While many of these efforts are not directly related to CALFED, a large number are producing data and information that is of tremendous value to CALFED, and may form a large portion of the comprehensive program that CMARP proposes. Upon this existing framework, the CALFED funded monitoring, assessment and research program will be superimposed. A large part of the challenge of implementing CMARP will be to knit together these disparate programs and determine where the most value added will result from an expenditure of CALFED funding.

A network of data sharing and research collaboration and an attitude of common purpose amongst all of these organizations would serve CALFED well. The Chief Scientist and the Science Coordination Team could help to create such a network and multiply the effectiveness of their funding through a variety of means. Applying the same review process to internally and externally funded work is one such means, and providing extra-mural funding will be another. The program should seek additional means of creating incentives for participation in and cooperation with CMARP. If this is done, a much larger virtual organization comprising much more effort and expertise than CALFED could ever pay for will materialize. If the MARO becomes known for its stature and professionalism, other organizations will want to associate themselves with it. It is further possible that if the MARO establishes very high standards of performance, and funds projects and programs of those agencies and organizations that meet those standards, it can create a situation in which all of the agencies and organizations working in the Bay-Delta strive to meet that standard. This would have a positive influence on the quality of all of the environmental monitoring, assessment and research done in this region. (This has been the experience of the *Exxon Valdez* Oil Spill Restoration Program.)

Science-Management Partnership to Carry Out Adaptive Management

Active adaptive management, if employed by CALFED, will require a partnership between decision makers, stakeholders, managers of the natural resources, and scientists. In particular, this will mean bringing those responsible for the common programs together with the Chief Scientist and the Teams that assist him or her. This partnership is necessary because policy makers and stakeholders will have to be willing to take short-term risks with the resources, the resource manager will have to negotiate necessary agreements to acquire the resources, and scientists will have to design experiments using the resources. Successful adaptive experiments reduce long-term risks to resources by taking carefully designed, short-term risks. Adaptive experiments often focus on unusual conditions, and

thereby accelerate the rate of learning beyond what would naturally occur.

CMARP recognizes that while scientific input is vital in the process of proposing and carrying out adaptive management experiments, final decisions upon whether such experiments are carried out will, in each individual case, be made by resource managers, not scientists. Passive adaptive management and other means of modeling and experimentation that do not put resources at risk will also be used in attempts to reduce uncertainty wherever appropriate.

Resolving Technical Conflicts— Numerous technical conflicts threaten to prevent or hamper progress in reaching consensus on priority actions. Examples might include the nature of the Fish-X2 relationship or the role of habitat restoration in recovery of listed species. Mechanisms for resolving such technical conflicts are needed that focus the debate clearly on policy issues. One approach that might help to reach consensus would be to gather technical experts with opposing views on a given issue in a workshop setting for the express purpose of identifying specific, additional, directed efforts to collect additional data, perform additional experiments, or conduct new modeling exercises. The use of external reviewers to evaluate all existing information pertinent to a given issue might be another avenue.

Data Collection, Data Management, and Information Handling

Data Collection, Reporting and Management—Many agencies, organizations, and individual research scientists will be collecting data and providing these data and their interpretation to the MARO. It is not envisioned that the MARO will be managing all of this information, but it will have to set quality assurance guidelines, metadata standards, and reporting requirements. It will also need to set guidelines for making data available and may need to assist some members of the CMARP Team with this task. A certain subset of the data will need to actually be managed by the MARO. Data management is discussed more fully in Chapter 5.

Likewise, it is not anticipated that all of the research needed for the program will be conducted within the MARO. It will be the intent of CMARP to make wide use of universities, non-governmental organizations and the private sector to actually propose and carry out individual research projects, or perhaps even larger-scale, multi-year research program elements. The amount of research conducted by the organization itself, as opposed to the entire CMARP Team will depend upon how large a scientific staff is created for the organization; nonetheless, this is an activity that can go on externally as well as internally.

Data Analysis and Interpretation—Turning the data into useful information products will be one of the most important functions of the MARO. While the MARO will be calling on numerous members of the CMARP Team to assist in this task, it is necessary to focus responsibility for the accomplishment of this task upon the MARO itself. Much of the initial analysis and interpretation may be conducted by CMARP Team partners responsible for the monitoring program, but MARO will have a more integrative responsibility. Monitoring is an expensive activity, so the more knowledge that can be derived from the monitoring the better. This means that individuals and small teams comprising experts in the relevant discipline who are familiar with exploratory data analysis and statistics, from either the Core Technical Staff or the broader CMARP team, should be commissioned to provide ongoing and/or periodic analyses of monitoring data. Further description of this process is provided in Chapter 5 of this report.

Communication of Findings—A necessary function of MARO will be providing the findings of monitoring, assessment and research programs to the Decision-making Body, to the stakeholders and to the public. Individual researchers of the CMARP team should be encouraged to communicate individual project findings, but this will not be sufficient. It will be necessary for the Decision-making Body to have help in identifying, assessing, and understanding the limitations of the best available information upon which decisions are based. It will need to direct reports targeted at all segments of the CALFED community to be prepared. It will also be necessary to provide periodic and understandable briefings for the Decision-making Body and the public on the implications of the work being done. Mechanisms for the reporting of real-time monitoring data and annual reporting of status and trends of indicators will also be needed. These communications will be built upon successful examples of existing reporting and communication.

Annual Science Conference—
Direct communication will be enhanced among scientists and managers, partnerships among participating organizations can be strengthened, which will also help build public credibility. All individuals and organizations that received funding through the MARO would be expected to participate and present their work. In addition, the Chief Scientist and others could discuss general direction of the science program, management implications of the findings coming out of the work and what is being learned about the condition of the system and the way it functions. This conference could be an annual opportunity to publicly present and explain how indicators are being used to assess "Bay-Delta Health" and what the indicators are telling us about trends in environmental condition. Such a conference might incorporate components of two existing successful and popular events—The IEP Annual Meeting and the SFEI State of the Estuary Conference.

Stakeholder Advisory Mechanisms
Provision will be made for stakeholder participation in the Decision-making Body that approves the CMARP budget. Many stakeholder groups include people with considerable scientific expertise, whose contact with CMARP staff and contractor scientists will enhance the value of the program. Direct contact between scientists working for stakeholder groups and CMARP scientists should be encouraged. In addition, responsiveness of the overall program will depend upon the understanding of the Chief Scientist and the Science Coordination Team of the management questions that need to be addressed. A formal means, such as a Stakeholder Advisory Committee that is given the opportunity to communicate with the Chief Scientist concerning the prioritization of management questions and content of annual work plans prior to their review by the Decision-making Body would aid in this process. An alternate approach would be to include stakeholder representatives on the Science Coordination Team. Stakeholder-funded scientists should also be encouraged to communicate with and collaborate with CMARP-funded scientists on projects.

QUESTIONS TO RESOLVE IN DEVELOPING THE ORGANIZATIONAL STRUCTURE FOR A COMPREHENSIVE MONITORING ASSESSEMENT AND RESEARCH PROGRAM

The basic elements discussed above will fit into any number of structures that might be formed for the overall governance of the CALFED program. There are a number of decisions concerning the institutional structure that the workgroup discussed, and which were proposed to those who were interviewed. Largely because of the uncertainty that exists concerning the

eventual structure for the overall CALFED program and its decision-making process, it was not possible to reach conclusions on some of these questions. The following questions represent areas where the views of reviewers would be most welcome.

What is CMARP's Relationship to CALFED? CMARP has been described as the science arm of CALFED. This implies that the relationship between CMARP and CALFED is essentially a partnership. It is a partnership intended to promote science-based decision-making and an adaptive approach to managing the Bay-Delta System. We have, therefore, tried to describe elements of an organization that would both be accountable and responsive to CALFED, yet be able to carry out monitoring, assessment and research in a fairly independent manner. This is not the only relationship that could be established. It is possible to create a monitoring and assessment program that is imbedded within the CALFED Decision-making body and that only responds to specific tasks generated by program managers. It would also be possible to create a science program that was independently funded and therefore completely independent of the CALFED management structure.

To Whom or to what does CMARP Report? Because it is not certain how the CALFED program in the future will carry out decision-making, it is difficult to suggest exactly whom the Chief Scientist and the rest of the CMARP institutional structure should report. Most workgroup members felt that the Chief Scientist should be hired by and attached to some organization such that he or she did not have to personally deal with all of the administrative functions that attend to grant-making and contract management. It is necessary to define a direct relationship between the Chief Scientist and the highest Decision-making Body of CALFED, including whether it is that body that is responsible for his or her hiring and firing. This is the only way that CMARP can act as the science arm of the CALFED program, and act in partnership with CALFED in promoting an adaptive approach to managing the Bay-Delta system.

Some stakeholders felt strongly that the program should be closely attached to and responsive to an Ecosystem Restoration Authority. If the common programs are carried out as separate independent programs with different decision-making bodies, it cannot be housed within any of them and should be independent of any common programs.

What monitoring, research, and research functions should be centralized, and to what extent? The original charge to IEP, USGS and SFEI was to design a program that addressed all of the common programs. That does not necessarily imply that one overall institutional structure should address all needs. A few of the stakeholders questioned felt strongly that CMARP should concentrate on the environmental questions, and not deal with issues such as water transfer and water efficiency. They expressed the view that these latter concerns should be monitored by different organizations from the one primarily concerned with ecosystem conditions. Many felt strongly that there should be a monitoring program created specifically to serve the needs of an Ecosystem Restoration Authority. Most of the workgroup felt that there would be benefits to having one comprehensive monitoring, assessment and research program. They argued that many of the common programs have interrelated and overlapping information needs, that activities proposed to promote the objectives of one common program might have adverse effects in others, and these need to be assessed comprehensively.

Is a new agency or organization needed to implement CMARP? A number of stakeholders queried believed strongly that

a new organization should be established. Workgroup members were divided on this point. It was felt by workgroup members that a new scientific culture needed to be established, and this would be easier to do with a new organization at the core of the effort. It could be accomplished with the inclusion of the position of Chief Scientist and a commitment to extensive external and peer review. Whether or not a new organization was formed at the core of CMARP, all felt that the collaboration among the larger CMARP Team was key to success of the overall program. If a new organization is set up, care should be taken to make this organization one that enhances, rather than competes with existing programs.

Chapter 7. IMPLEMENTATION OF CMARP

CMARP will continue to evolve with the CALFED program. Prior to CALFED's record of decision (presently in June, 2000), an expected implementation structure for CMARP must be developed as part of the organizational structure needed for implementing the CALFED program. During this period, a few high priority tasks will begin, such as tasks related to diversion effects on fish and source quality of drinking water. In addition, monitoring and research program designs will be refined and focused as the actions of Stage I of CALFED implementation become firm. Finally, CMARP program costs need to be established, and program financing needs to be solidified so that CMARP can be implemented. This chapter describes activities that will take place during 1999 and early 2000 toward these ends.

MANAGING CMARP DURING DEVELOPMENT OF A CMARP IMPLEMENTATION STRUCTURE

In the absence of a CALFED implementation structure, Chapter 6 focused on defining CMARP organizational ingredients and outlining how those ingredients might relate to resource managers, decision-makers, and stakeholders. As a CALFED implementation structure becomes defined, a permanent structure for CMARP must be created. Prior to a CALFED record of decision and a permanent organizational structure, someone must continue to manage CMARP implementation and refinement activities.

The CMARP Steering Committee will continue to provide interim management of CMARP, and during 1999 will carry out the following:

- finalize and implement 1999 actions as proposed under "Implementation Tasks" below,
- oversee refinement and prioritization of monitoring designs and research questions as described under "Refinement of CMARP elements" and "Estimating Program Costs" below,
- coordinate anonymous peer-reviews of proposals to the Restoration Coordination Program (as described in Chapter 6),
- design an organizational structure to implement CMARP in collaboration with CALFED, agencies, and stakeholders, and
- coordinate review of monitoring activities for projects funded by the Category III program.

The Steering Committee will report its progress to the CALFED Management Team and Policy Group through the CALFED Executive Director. The committee will designate an agency person and appropriate support staff to direct the program during this interim period. The committee will integrate CMARP more fully with CALFED and agency programs during 1999.

Funding of CMARP is needed during 1999 to manage the program, to implement a few high-priority tasks, and to refine monitoring and research program designs. About $400,000 will be necessary to manage and refine the program during 1999. The costs of interim implementation tasks described next have yet to be estimated.

IMPLEMENTATION TASKS FOR 1999

In the absence of a chief scientist, the interim Steering Committee will work closely with CALFED's Restoration Coordination Program during interim implementation. Several projects funded through the Restoration Program directly involve monitoring and research and others have monitoring components. For example, in 1999 this program expects to fund designated actions involving organic carbon in the Delta, monitoring a newly constructed

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flooded island, determining the sources of mercury in the Cache Creek watershed, and reducing predation in the Tuolumne and Merced Rivers by isolating gravel mining pits from the streams. These projects will provide critical information needed by CALFED in Stage 1. The Integration Panel and the CMARP Steering Committee have several common members, who will facilitate coordination. The results of these examples and other similar programs will be integrated into the CMARP database.

In addition, the Steering committee, in consultation with CALFED and agency staffs and stakeholders, will recommend selected tasks for interim implementation. The following tasks are among those being considered:

- **Diversion effects on fish**. Salvage of threatened species at the SWP and CVP facilities demonstrates that the facilities entrain fish. How important the facilities are relative to other mortality factors, however, is not clear. An assessment of fish entrainment in concert with real-time monitoring results is needed to better define flexibility of project operations and use of the Environmental Water Account. CMARP would establish teams to develop monitoring and analysis efforts as described more fully below.
- **Municipal source water quality**. An expert panel, urban water purveyors, and CALFED and CMARP staffs have recognized the need to answer several questions regarding the feasibility of reducing source water concentrations of bromide, organic carbon, and dissolved solids during Stage I of implementation. A committee of selected agency and stakeholder personnel will develop questions and priorities for directed actions or proposal solicitations during 1999 as described in greater detail below.
- **Fish screen evaluation**. The IEP Fish Facilities Technical Team will be asked to develop monitoring and research needed to evaluate the two proposed Stage 1 fish screens.
- **Marking hatchery salmon**. A constant fractional marking program of salmon smolts released from Central Valley chinook hatcheries will be designed to permit evaluation of hatchery contributions to spawning escapement and ocean and inland recreational fisheries. The goal is to have the program implemented by fall of 2000.
- **Factors affecting salmon**. The IEP's Central Valley Salmonid Project Work Team and its satellite teams will develop proposals to refine understanding of factors affecting survival of juvenile chinook salmon living in and traveling through the Delta.
- **Factors affecting delta smelt**. An interdisciplinary agency/stakeholder team will use the results of the 3rd Delta Smelt Workshop as a basis for determining if additional research on delta smelt is needed to support CALFED goals and adaptive management. The prioritized list and subsequent proposals will be peer-reviewed.
- **Fish/X2 relationships**. Consonant with external peer review panel recommendations, studies to document physical and biological mechanisms involved in the Fish/X2 relationships will be selected and started.
- **Delta topography and bathymetry**. A committee of selected agency and stakeholder personnel will direct a short-term feasibility study of using new techniques to improve the topographic and bathymetric coverage of the delta. The committee will also set up a continuing process to update locations and elevations of recently-established GPS benchmarks.
- **Documenting and assessing effects of aquatic species introductions**. CMARP will take an active role in documenting introductions and determining the ecological effects of these introductions. The efforts will be closely coordinated through CALFED's nuisance and introduced species group.

- **Review of streamflow network.** All common programs have identified needs for streamflow information, and a consolidated assessment of program requirements is needed to specify what the streamflow measurement network in the Central Valley and the delta should be. During 1999, a multi-agency committee will be appointed to undertake this review with the objective of finalizing essential gage sites and any additional funding needs.

Diversion effects on fish and **Municipal source water quality** are described in greater detail below.

Diversion effects on fish (DEFT). Although there is fair agreement on the relative magnitude of fish losses from direct entrainment by the SWP and CVP pumps, there is much less agreement over the importance of indirect effects of these diversions in controlling population abundance and the recovery of threatened and endangered fish species. Accurate information about south Delta diversion effects is essential to CALFED, however, for determining if additional facilities, such as an isolated conveyance channel, are needed to recover fish species. Such information is also important in developing greater flexibility of project operations necessary for implementing the Environmental Water Account, increasing fish protection, and thereby reducing conflicts over water. CMARP must develop the information to support these critical CALFED activities and decisions.

The CALFED DEFT Team developed programmatic actions to restore habitat, improve food availability, reduce entrainment, provide migratory fish cues, and identify and reduce contaminant effects. During 1999, the CMARP program will refine existing monitoring, assessment, and research to ensure that it assesses the feasibility and relative effectiveness of such management actions. To the extent that additional funding is made available, CMARP will expand these efforts to include the following monitoring and research tasks. From specific to general, they are to:

- make real-time monitoring more effective in helping to reduce entrainment and to increase operational flexibility;
- assess influences of diversion locations and delta hydrodynamics on food web dynamics;
- increase understanding of ecological processes in the estuary and the population dynamics of chinook salmon, delta smelt, splittail, striped bass and steelhead;
- distinguish for fish the consequences of the through-delta alternative from those of the other alternatives; and
- develop an integrated conceptual model of the bay-delta watershed that includes the most essential elements and processes, and that illustrates the most important indicators and scientific issues.

Ultimately, all of these tasks must be done to resolve CALFED questions about diversion effects on fish, and CMARP must develop and make extensive use of adaptive management tools to accomplish most of the tasks during Stage I.

Municipal source water quality. Information on sources, transport, and transformations of DOC in the Delta are critical for determining how to reduce loads of DBP precursors at drinking-water diversions in the Delta. Seawater is the primary source of bromide in the Delta so that an understanding of the influences of tidal exchange and other hydrodynamic processes in the Delta are necessary to determine the concentrations of bromide transported to drinking-water diversions in the Delta.

Of particular concern is the unknown effect of CALFED's proposed restoration of up to 100,000 acres of wetlands in the Delta. Wetlands most likely produce organic carbon (TOC/DOC) that differs in unknown

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ways in quality and quantity from that being generated by farming in the Delta. CALFED needs information on these differences before deciding to rehabilitate wetlands on a large scale.

The Integration Panel asked a committee of agency and stakeholder personnel to develop a designated action to assess effects of wetland restoration on drinking-water quality. The committee developed a list of five questions. In order of highest to lowest priority, the questions are:

1. How much and what forms of TOC do wetlands generate?
2. To what extent is TOC released from wetlands altered and consumed in Delta waters?
3. By comparison, how much and what forms of TOC are released from agricultural activities?
4. What wetland management strategies may be used to limit introduction of TOC into Delta waters?
5. How will the impacts of restored wetlands change in the future as they mature?

Answers to two additional questions are needed to assess relative loads of DBP precursors from different land uses and to model the transport of precursors to drinking water intakes:

6. Based on accurate land use and vegetation surveys, what is the relative contribution of agricultural activities, wetlands, and other land uses to DBP precursors in Delta channel waters?
7. How will the transport of DBP precursors to drinking water intakes be changed by wetland restoration in the Delta.

CMARP will collaborate with the Integration Panel to facilitate and augment whatever studies are undertaken to address these questions.

REFINEMENT OF CMARP ELEMENTS DURING 1999

All monitoring programs need refinement, but some programs require more than others. For example, monitoring to meet the needs of the Conservation Strategy has only been described in the most general terms and cannot be developed further until the Conservation Strategy has been completed. Design of mitigation monitoring awaits selection of actions that require mitigation. The Watershed Management Program needs more specificity for CMARP to design and implement monitoring, and much more stakeholder involvement will be needed to help develop details. Monitoring and research for the rest of the common programs have been developed to a significant degree, and need refining as described below. In addition to these refinements, these almost-independent program designs need to be integrated into one program.

Refinements of the ERP monitoring program. Continued development of the ERP monitoring recommendations is needed to address general issues that cut across all the CMARP work teams, and refinement of specific monitoring recommendations within each work team.

The general issues that need further development for CMARP to proceed with implementation include:

- refining indicators,
- integrating identified monitoring elements,
- integrating monitoring elements with CALFED's Conservation Strategy.

In Table 7-1, the CMARP-ERP work teams are grouped based on the need for additional refinement of their monitoring recommendations prior to implementation, group 1 needing the least refinement and group 3 the most.

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Refinements of the water quality program. The water quality monitoring and research program will be refined in the following ways:

Refinement of Specific Elements of the Water Quality Monitoring Plan. (See Appendix *VII.B.*)

- Refine sampling strategy for organochlorines in fish tissue.
- Identify sediment-sampling sites in the Delta.
- Analyze results of pilot fish tissue studies in the San Francisco Bay, Sacramento watershed, and the southern Delta.
- Conduct necessary preparatory work for the pesticide-monitoring program.
- Develop a tributary monitoring program in collaboration with local stakeholders.

Refinement of Sampling Strategies, Sampling Sites, Sampling Methods, and Archival of Biological Organisms. The strategies on which the different elements of the monitoring plan are based need to be specified. Sampling strategies need to be reviewed based on the CMARP objectives of monitoring. Locations of sampling sites need to be refined based on the sampling strategies. Methods need development for sampling constituents previously not sampled. A review of tidal influence on water quality sampling is needed. A policy for storage and archiving of biological samples needs to be developed.

Quality Assurance and QA Intercalibration. A QA/QC program with participation of all monitoring programs will be necessary to combine data from several programs. Performance standards are critical and should be based on the goals and objectives of the program. Immediate implementation of QA and intercalibration exercises among all existing programs is recommended so that when the program is implemented, comparability will be assured.

Integration of Monitoring. Monitoring will need to be well coordinated and integrated to address the multiple purposes of all of the common programs. For example, benthic monitoring will be conducted to evaluate ecosystem characteristics, ecosystem productivity and contaminant effects.

Development of Indicators. Indicators of system productivity and contaminant effects need to be refined. An important issue to be resolved is inclusion of measurements for which there are no regulatory standards. In addition, some standards have an unknown relationship to ecological or human health effects.

Refinements of the water transfers and water use efficiency programs. During 1998 many monitoring networks were inventoried that may provide data important for evaluating the effects of water transfers. However, assessment of the suitability of existing networks for CALFED purposes has just begun. 1999 will be a critical year for assessment activities.

The suitability of more than 10,000 groundwater-level observation wells in existing networks for use as part of a CALFED regional groundwater-level monitoring network will be evaluated. The suitability of more than 5,000 previously sampled wells for use as part of a CALFED regional groundwater-quality monitoring network will be evaluated. Groundwater level and quality network assessments will consider the period of record, well construction details, well location, frequency of measurement, interagency coordination of monitoring, and digital availability of monitoring data. The feasibility of using the Environmental Agency's STORET database as a surrogate network of groundwater quality information could be evaluated. The feasibility of reactivating sediment compaction recorders constructed decades ago will be determined. Coordination of new horizontal and vertical geodetic control networks in the Central Valley will continue.

Table 7-1. Summary of CMARP's ERP work team accomplishments and tasks needing further development for implementation of recommended monitoring elements.

Group	Work Teams	Accomplishments	Additional Steps
1	• Hydrodynamics • Chinook Salmon & Steelhead	• Identified what needs to be monitored & why • Linked to existing monitoring programs • Recommended new monitoring & modifications to existing programs • Specified locations, timing and methods for new monitoring • Prioritized recommendations • Estimated costs	• Obtain outside review • Evaluate monitoring in relation to CALFED priorities & actions • Determine process for initiating new monitoring
2	• Fish-X2 • System Productivity:Lower • System Productivity:Upper • Central Valley Steelhead • Delta Smelt • Non-Indigenous Organisms • Benthic Macroinvertebrates • River Resident Fish Species • Fish in Shallow Water Habitats	• Identified what needs to be monitored & why • Linked to existing monitoring programs • Recommended new monitoring & modifications to existing programs • Provided some general guidance on locations, timing & methods for new monitoring	• Complete Group 1 steps + • Develop greater detail on location, timing & methodology • Prioritize recommendations • Estimate costs
3	• Shallow Water Habitats • Fluvial Geomorphology & Riparian Issues	• Identified what needs to be monitored & why • Provided some general guidance on locations, timing & methods for new monitoring	• Complete Group 1 & 2 steps + • Link to existing monitoring programs

Refinement of the watershed management program. Monitoring at smaller scales – scales of particular interest for adaptive management feedback – depends heavily on local participation and must serve the needs of local decision-makers and the public. Refinement of objectives and specific implementation plans for monitoring of biophysical parameters at these scales will require full participation of local stakeholders. Stakeholders have already identified economic and social aspects of watershed management as central to the Watershed Program, but have not reached a consensus on how these issues should be addressed in the monitoring program. Upcoming work will focus on organizing stakeholder input into defining a conceptual framework for monitoring of economic and social elements, as well as working with stakeholders to refine monitoring plans for all plan elements at smaller scales.

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Refinement of the data assessment and reporting process. Assessment of data and reporting of scientific information will play a critical role in guiding Stage I and in informing the public about responses of the natural resources to CALFED efforts. Much work remains to fulfill this role. During 1999, CMARP will focus on the following activities:

Improve access to the data of present monitoring programs. The variety of data and analysis reporting activities that exist among the different organizations active in the Bay/Delta will be linked through the CMARP/CALFED web site. The data assessment and reporting team will coordinate with the reporting efforts of the major monitoring programs identified by the inventory of monitoring efforts in chapter 2.

Facilitate the use of geographical information system tools to provide summaries of important features of the natural resources. GIS personnel of agencies, universities, and stakeholder groups have already made extensive efforts to develop common sets of GIS coverages. In addition, many of the existing databases are already geo-referenced. A team will be organized to:

- Organize access to existing inventories of GIS data and organize filling in gaps related to CALFED needs.
- Identify important data themes that need to be developed, including themes that currently exist for only parts of the needed geographic areas in the CALFED planning area
- Develop examples of GIS-based overlays of data critical to Phase I actions

Plan a first annual CALFED Science Conference. CMARP will design a conference for autumn of 2000 with presentations and a published proceedings on active research and monitoring activities related to CALFED, including science projects funded by Category III.

Develop fact sheets describing conceptual models. CMARP will collaborate with other programs to prepare fact sheets for CALFED program managers and agencies that illustrate some of the conceptual models used for designing CMARP.

Develop management-oriented indicators. Most of the indicators developed by the workteams qualify as base level indicators as described in figure 1 of Chapter 5. Development of intermediate, or management-oriented, indicators would continue during 1999.

Developing active adaptive management partnerships. CMARP is presently designed to fulfill the needs of a traditional passive adaptive management program (Chapter 1, Figure 1-1). Although this program will reduce scientific uncertainties over a period of decades, CALFED needs to reduce key uncertainties at a more rapid rate to meet program objectives. Using a more active form of adaptive management, CALFED can accelerate the learning process.
Active adaptive management as defined by Holling (1978) and Walters (1986), and as recommended in the ERP Strategic Plan (1998), involves carefully designed and monitored management actions that are valid scientific experiments. The purpose of the management actions is to reduce uncertainties by demonstrating how and why natural resources respond to those factors that affect them.

For example, some knowledge already exists about causes and effects, but knowledge about infrequent or extreme conditions is often limited or non-existent. Such unusual conditions, however, simultaneously can be circumstances when risks of irreversible resource changes are greatest and ideal times for observing important effects. Active adaptive management can create opportunities to document and evaluate unusual conditions in a controlled context, thereby accelerating learning and reducing long-term risks.

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As implied, however, active adaptive management necessarily involves taking short-term risks with resources. In addition to the practical problems of acquiring control of enough resources to create unusual conditions, active adaptive management can conflict with regulatory and management policies, which are usually designed to avoid risks and to maximize short-term economic and social benefits. These circumstances partially explain the infrequent use of active adaptive management (Walters, 1997).

Thus active adaptive management, if employed by CALFED, will require policy-level recognition of scientific uncertainties and acceptance of resource risks. CMARP envisions active adaptive management as a partnership among policy makers, stakeholders, resource managers, and scientists. Given CALFED Policy Group agreement, CMARP will help develop partnerships to design active experiments.

ESTIMATING PROGRAM COSTS

A substantial commitment to an integrated monitoring and research program will be required because of the size and complexity of the physical, chemical, and biological systems of the Bay-Delta and Central Valley, about which there is much uncertainty. However, because such a program would have significant short- and long-term benefits, it will be necessary to develop a political consensus to fund a program of sufficient size and scope to resolve the critical uncertainties. Once a funding commitment has been made, the initial program can be created based on the size of that commitment, on the assumption that existing agency programs will continue and on a set of monitoring and research priorities established for each of the CALFED programs.

Setting monitoring and research priorities among CALFED programs is a subjective and continuing task. During 1999, the CMARP steering committee will assemble a team of stakeholders and CALFED and agency staff to develop a set of initial implementation priorities for CMARP. These priorities and a total program cost estimate will be subsequently provided to CALFED.

FINANCING CMARP

Beyond agreement on a total program cost, CMARP needs assurance that funding for existing monitoring and research programs will continue at inflation-adjusted current levels of spending. These programs include those listed in Table 2-3. Although agencies are under no obligation to CALFED to continue these programs at current levels, future changes to these programs should trigger reevaluation of CMARP's level of effort.

In addition, an inflation factor is needed to sustain the level of effort agreed on for CALFED's monitoring and research activities supplemental to these programs. More substantial adjustments to this program should be contemplated as the program is reviewed periodically.

Finally, public funds are probably a primary source for CMARP because everyone benefits from the information generated. Category III and CALFED projects requiring mitigation monitoring will be a secondary source. Which agencies will eventually receive the State and Federal appropriations that fund CMARP depends on what organizational structure becomes responsible for implementing the common programs and the preferred alternative.

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