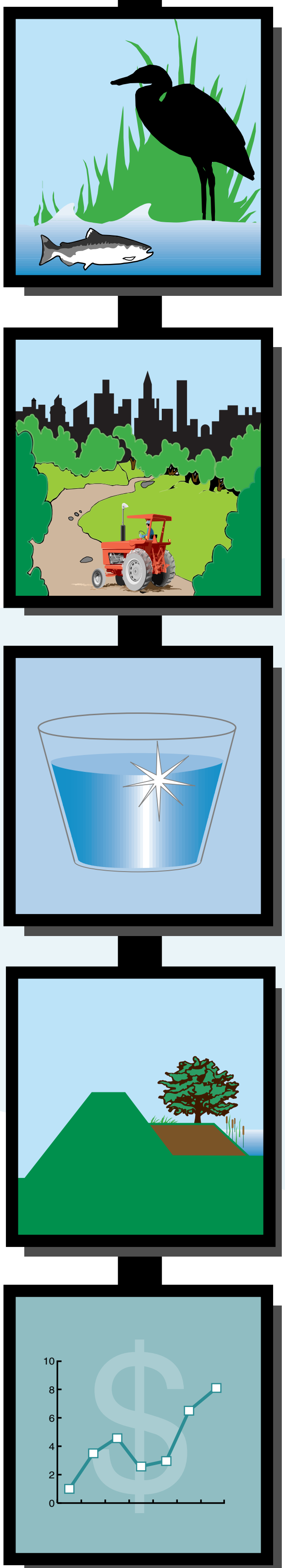


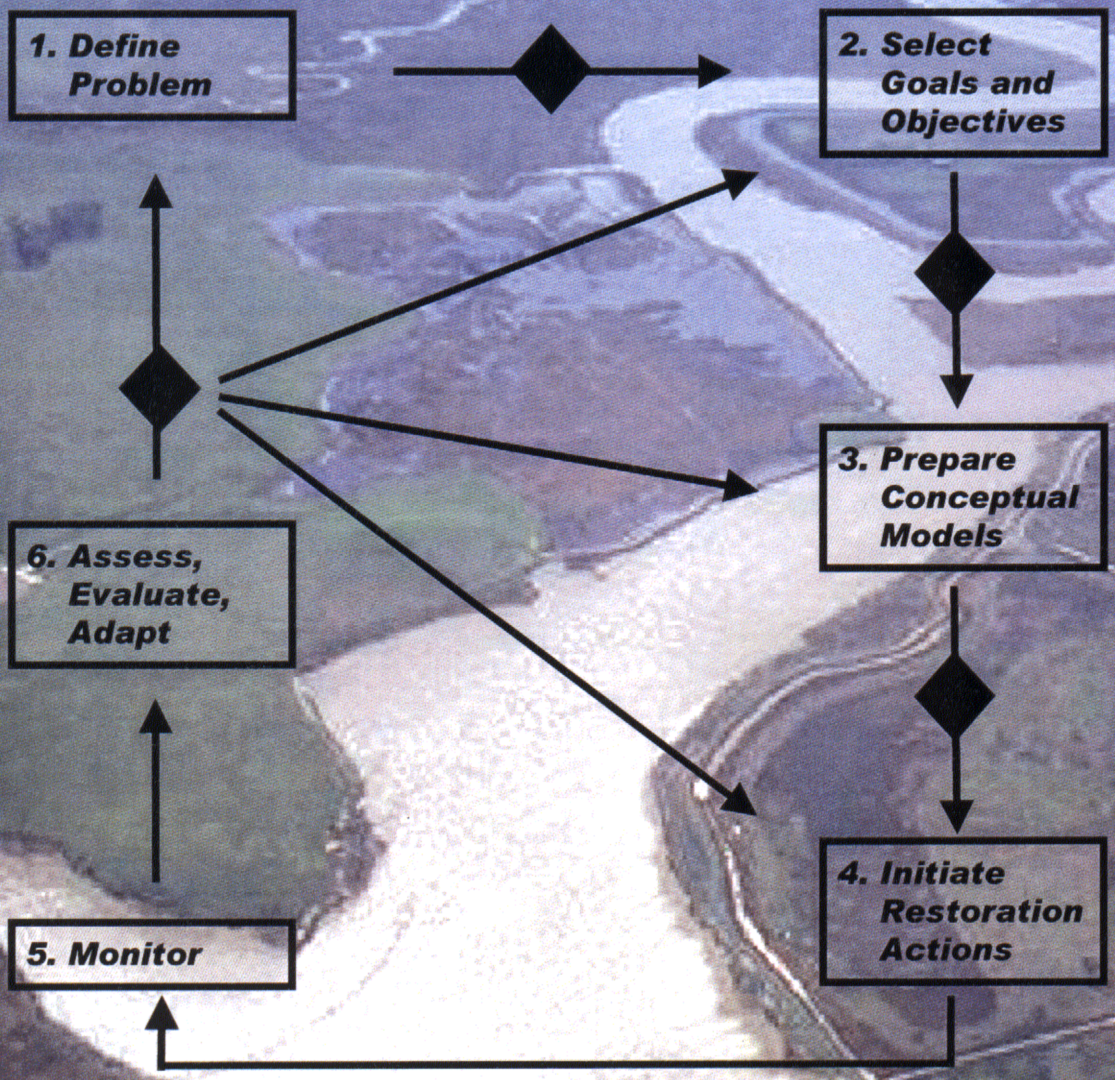
CALFED
BAY-DELTA
PROGRAM

Ecosystem Restoration Program Plan
Strategic Plan for Ecosystem Restoration

Final Programmatic EIS/EIR Technical Appendix

July 2000

ECOSYSTEM RESTORATION PROGRAM



STRATEGIC PLAN FOR ECOSYSTEM RESTORATION

CALFED BAY-DELTA PROGRAM

July 2000

CALFED BAY-DELTA PROGRAM STRATEGIC PLAN FOR ECOSYSTEM RESTORATION

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Overview of the Development of the CALFED Strategic Plan for Ecosystem Restoration

Impetus for the Strategic Plan: Scientific Review Panel

In October 1997, CALFED convened a panel of eight independent scientists for a four-day workshop to review the 1997 version of the three-volume Ecosystem Restoration Program Plan (ERPP). To ensure an independent and objective review, the panel was composed of nationally recognized scientists with experience in many of environmental restoration programs around the country but were not involved in Bay-Delta system issues. The following scientists served on the panel:

- Panel Chair, Dr. Ken Cummins, South Florida Water Management District, presently with the Cooperative Fisheries Unit, Humboldt State University, Arcata, California
- Dr. Paul Angermeier, Virginia Tech, Blacksburg, Virginia
- Dr. Michael Barbour, University of California, Davis, California
- Dr. Chris D'Elia, Maryland Sea Grant College State University New York, Albany, New York
- Dr. Tom Dunne, University of California, Santa Barbara, California
- Dr. Jack McIntyre, fisheries consultant, Henderson, Nevada
- Dr. Dennis Murphy, University of Nevada, Reno, Nevada
- Dr. Joy Zedler, San Diego State University, San Diego, California (Currently at University of Wisconsin)

In reviewing the ERPP, the panel drew upon their broad expertise in terrestrial, wetland and aquatic ecology, fisheries, plant and conservation biology, and physical processes. They also drew upon their experience in the nation's largest ecosystem management efforts including Chesapeake Bay, South Florida/Everglades, Columbia River, and other programs. Due to the brief review period and the panelists' limited experience in the Bay-Delta system, the panel did not evaluate individual actions described in the ERPP documents, but instead focused their comments on the conceptual framework of the Ecosystem Restoration Program. (The panel's Key Points and Recommendations are included in the text box on the following page.) The panel offered many constructive comments and recommendations on improving the presentation of the program's approach, utilizing scientists in the development and review of the program, employing conceptual models as educational and analytical tools, and developing an adaptive management strategy.

A key criticism by the panel was that the 1997 version of the ERPP was a plan—a menu of options—without a clear strategy for implementation. The panel provided specific recommendations on preparing a concise strategic plan document. One purpose of the strategic plan would better describe the approach of the program. It should clarify whether the program strives for true "restoration"—reverting to an historic condition—or simply rehabilitation of the ecosystem. It should also simplify and clarify ERP goals and objectives on the basis of conceptual models. The strategic plan should also provide better definition to the adaptive management strategy, including the use of conceptual and quantitative models; the use of goals and objectives to organize the adaptive management process; the development of testable hypotheses for management actions; and the design of actions as experiments. Lastly, the plan should also describe how new scientific expertise would be engaged in the development and review of the program.

Strategic Plan Core Team

Interested agricultural, urban and environmental stakeholders and CALFED staff collaborated to identify components of a strategic plan that would address the panel's key recommendations. Staff and stakeholders also recruited a team of distinguished independent scientists and environmental planners to prepare the document. A six-member team, referred to as the Core Team, spent four months during the summer and fall of 1998 developing the independent report entitled: "Strategic Plan for the Ecosystem Restoration Program." The following environmental scientists and planners served on the Core Team:

- Dr. Michael Healey, University of British Columbia, Vancouver, British Columbia
- Dr. Wim Kimmerer, San Francisco State University, Romberg Tiburon Center, Tiburon, California
- Dr. Matt Kondolf, University of California, Berkeley, California
- Dr. Peter Moyle, University of California, Davis, California
- Mr. Roderick Meade, R.J. Meade Consulting, La Jolla, California
- Dr. Robert Twiss, University of California, Berkeley, California

The focus of the Core Team's effort was to describe the ecosystem-based, adaptive management approach that will be used to refine and implement the Ecosystem Restoration Program. In particular, the plan identifies a process for prioritizing the programmatic actions described in Volume II of the ERPP. The plan added clear restoration goals and quantifiable objectives, replacing the less-specific implementation objectives in the 1997 version of the ERPP. The Core Team also identified critical ecological issues that must be addressed early in implementation as well as restoration opportunities to address those critical issues.

INTERIM SCIENCE BOARD

In January 2000, CALFED convened the Interim Science Board (ISB), which is comprised of nationally recognized independent scientists, to help CALFED staff refine the ERP and ingrain adaptive management in the implementation of the ERP. This standing science body must be of an interim duration because the final CALFED structure of governance is still being developed. CALFED anticipates that the Interim Science Board will be engaged through the Record of Decision and certification of final environmental documentation, with the possibility of extension until the final governance structure is defined and in place. Many of the ISB members have served either on the 1997 Scientific Review Panel or the 1998 Strategic Plan Core Team. The following individuals serve as members of the ISB:

- Dr. Michael Healey, University of British Columbia, Vancouver, British Columbia
- Dr. Wim Kimmerer, San Francisco State University, Romberg Tiburon Center, Tiburon, California
- Dr. Matt Kondolf, University of California, Berkeley, California
- Dr. Peter Moyle, University of California, Davis, California
- Dr. Robert Twiss, University of California, Berkeley, California
- Dr. Tom Dunne, University of California, Santa Barbara, California
- Dr. Paul Angermeier, Virginia Tech, Blacksburg, Virginia
- Dr. Dennis Murphy, University of Nevada, Reno, Nevada
- Dr. Ken Cummins, Humboldt State University, Arcata, California
- Dr Robert Spies, Applied Marine Sciences, Livermore, California
- Dr. Duncan Patten, Montana State University, Bozeman, Montana
- Dr. Denise Reed, University of New Orleans, New Orleans, Louisiana

The broad goal of the ISB is to assist the CALFED Ecosystem Restoration Program (ERP) by providing scientific advice and guidance with a management orientation. More specifically, the ISB will assist the CALFED staff to:

1. Establish a solid scientific/technical foundation for the ERP;
2. Provide scientific review, advice, and guidance;
3. Help ingrain ecosystem-based adaptive management in the implementation of the ERP; and,
4. Engage the scientific and technical questions at the root of policy issues and priorities.

The ISB meets every 4-6 weeks, with a portion of every meeting being open to the public. Meeting summaries will also be developed for every ISB meeting and made available to the public. Consult the CALFED website (http://calfed.ca.gov/) for notices of ISB meetings and to access meeting summaries.

ECOSYSTEM RESTORATION PROGRAM FOCUS GROUP

The ERP Focus Group was convened by CALFED in October 1999 to assist CALFED in the period prior to the Record of Decision to identify, address, and resolve key policy issues associated with the ERP and its implementation. The most significant issues addressed by the group included:

1. **PROGRAM INTEGRATION**: Ensure that the Ecosystem Restoration Program, the Multi-species Conservation Strategy, the Environmental Water Account, and other CALFED, and CALFED related, programs and actions are well integrated and work together.

2. **PRIORITY SETTING**: Recommend a process to set priorities, select Stage I actions, evaluate results and refine the longer-term implementation strategy.

3. **STRATEGIC OBJECTIVES**: Refine strategic objectives and recommend a process to quantify targets.

The ERP Focus Group is a joint agency/stakeholder policy forum involving the following individuals and organizations:

- Margit Aramburu, Delta Protection Commission;
- Gary Bobker, The Bay Institute;
- Mike Bonner, U.S. Army corps of Engineers;
- Byron Buck, California Urban Water Agencies;
- Steve Johnson, The Nature Conservancy;
- Dan Keppen, Northern California Water Association;
- Laura King, San Luis Delta Mendota Water Authority;
- Patrick Leonard, U.S. Fish and Wildlife Service;
- Dave Nesmith, Save the Bay;
- Tim Ramirez, Resources Agency;
- Pete Rhoads, Metropolitan Water District of Southern California;
- Steve Shaffer, CA Department of Food and Agriculture;
- Lawrence Smith, U.S. Geological Survey;
- Gary Stern, National Marine Fisheries Service;
- Frank Wernette, CA Department of Fish and Game;
- Leo Winternitz, CA Department of Water Resources;
- Steve Yaeger,; CA Department of Water Resources
- Carolyn Yale, U.S. Environmental Protection Agency.

The ERP Focus Group recommended the following to assist CALFED agencies in developing the Record of Decision:

1. Collectively adopt a policy statement, which clearly commits to the concept of a single blueprint for ecosystem restoration.

2. Endorse and support the development and refinement of ecological conceptual models as the basis for understanding the ecosystem and making informed management and regulatory decisions.

3. Commit to using sound science and the development of a comprehensive Science Program, including independent scientific review , to serve as a common resource available to all agencies and interested parties

(including agencies and programs outside the formal CALFED agencies and programs).

4. Execute a formal agreement, which defines how parties will coordinate and interact in pursuit of a single blueprint for ecosystem restoration.

5. Adopt the goals of the CALFED Ecosystem Restoration Program (herein referring to the ERPP plus the MSCS), as the shared vision of the single blueprint. In carrying out existing programs, agencies will continue to pursue the goals of those programs but will strive to be consistent with and to advance the restoration goals established in the ERP.

6. Establish the geographic scope of the blueprint as follows: "Bay-Delta estuary and its watersheds, which includes the Delta, Suisun Bay and Marsh, San Pablo Bay and their local watersheds, the Sacramento River and San Joaquin River watersheds, and San Francisco Bay and its local watersheds; and, limited to salmonid species issues, the near-shore portions of the Pacific Ocean out to the Farallon Islands and north to the Oregon border".

7. Commit to using the goals of the ERP for environmental water management, including the Environmental Water Account (EWA) and the Environmental Water Program (EWP).

NEXT STEPS

CALFED will continued to refine the 1998 Strategic Plan developed by the Core Team. While the Core Team's Strategic Plan significantly advanced the description of the adaptive management process, considerable work is needed to institutionalize and fully employ the concepts into an implementation strategy. Staff are working with members of the Core Team and the broader scientific community to prepare white papers that summarize our knowledge of the system and expected benefits of actions. These papers will be presented in a series of scientific, technical workshops in order to articulate adaptive management strategies for Stage 1 of implementation. Staff will then work with local scientists, landowners, county and city planners and others in regional and local meetings to identify restoration actions consistent with the adaptive management strategies. A more detailed description of the Regional Planning process is included in Chapter 5.

Scientific Review Panel Key Points and Recommendations

Excerpt from: "Summary Report of the Facilitated Scientific Review of the CALFED Bay-Delta Program's Draft Ecosystem Restoration Program Plan (ERPP)," prepared by CONCUR, October 31, 1997

A) **In revising the ERPP, CALFED should clearly state whether the goal of the program is restoration or rehabilitation and name the document accurately.** The term ecosystem restoration, as commonly used by ecologists, involves reverting to the extent possible to historic conditions. Another option, and perhaps a more realistic one, is to rehabilitate the ecosystem. This could involve improving habitat for native and exotic species. The ecosystem enhancement activities that encourage exotic fish species constitute rehabilitation and not restoration. The decision to restore or rehabilitate need not be made on a system-wide level -- it could be made for individual watersheds or ecological zones. One example of this choice would be to restore diked wetlands to tidal marsh downstream (restoration) as opposed to creating many impoundments upstream (such as rice fields) for upstream waterfowl habitat (rehabilitation). This distinction between "rehabilitation" and "restoration" is one among several examples of the need for refining the use of phrases and terms in the ERPP, as indicated at other points in this summary report.

B) **Simplify and focus the presentation of the program and its goals on the basis of conceptual models.** The goals should be explicit, quantifiable, and attainable. The panel agrees with CALFED's tiering approach. The use of conceptual models will be essential to determine the allocation of effort to each tier. However, a coherent defense of the tiering decision, based on ecological and other policy arguments still needs to be articulated to explain the approach to stakeholders.

C) **From the outset, the Program should embed outside scientific expertise in the adaptive management process.** This requires continuous involvement of independent science in the formulation and implementation of the ERPP. Involvement should include: 1) reviewing the rationale, methods, results, and analyses; 2) developing and reviewing recommendations and funding proposals; and 3) pointing out new opportunities. Later portions of this report provide additional guidance on how to accomplish this involvement.

D) **In order to utilize science as a basis for the adaptive management system, there is a need for the development and use of models of physical and biotic ecosystem processes with links to key biotic components.** There are several kinds of models that may be useful in the ERPP. Some are large scale, qualitative, conceptual and concerned with expressing ecosystem operation. An example of such a model is found in the U.S. Forest Service's Northwest Forest Plan. A second type is a more focused model, which may or may not be quantitative, that addresses selected aspects of ecosystem operation. It should present hypotheses that can be tested through measurements and experiments. A third type of model is a quantitative simulation that can be useful for making predictions.

E) **The ERPP report wisely promises that the program will involve an adaptive management framework incorporating decisions that are based incrementally in scientific analysis, hypothesis testing, and monitoring. Therefore the monitoring component of the adaptive management framework should be developed from testable hypotheses.** Information from monitoring should guide management of resources in the following manner: 1) The program would propose a management action to improve the ecosystem; 2) Managers would formulate alternative hypotheses that describe the outcomes of the management action; 3) The action would be conducted as an experiment, and 4) Results would be monitored by gathering data to determine which alternatives are most plausible. The panel acknowledges that not all management actions can be structured as experiments, but recommends that this method be applied wherever practicable.

F) **The recommendations the panel has made above will require continual interaction of agency managers, agency scientists, and independent scientists. Part of this interaction should entail the creation of a standing science body, a scientific and technical advisory board, composed of agency scientists, stakeholder scientists, and scientists independent of the program.** The body would facilitate the introduction of science into long-term management. The panel notes that other efforts of this kind and scale have failed due to the lack of independent scientific review. Activities to be carried out by the science body would include generating and reviewing hypotheses, formulating monitoring schemes, and reviewing and interpreting data. Another function of this body could be to resolve technical conflicts over data, analyses, interpretations, and conclusions. Designing the terms of reference and modes of operation for such a body could involve another round of review and discussions between this panel and CALFED staff.

♦ CHAPTER 1. INTRODUCTION

PURPOSE

The purpose of the Strategic Plan is to guide restoration of the Bay-Delta ecosystem. It defines an ecosystem-based approach that is comprehensive, flexible, and iterative, designed to respond to changes in the complex, variable Bay-Delta system and changes in the understanding of how this system works. The Strategic Plan:

- establishes "adaptive management" as the primary tool for achieving ERP objectives and preparing to make future decisions for large-scale ecosystem restoration;
- describes the opportunities and constraints to be considered in developing a restoration program;
- presents broad goals and specific objectives for ecosystem restoration;
- presents a stepwise procedure for selecting restoration actions in which goals are linked through objectives to actions with appropriate consideration of the degree of confidence that objectives will be achieved;
- defines a coordinated approach for integrating the Ecosystem Restoration Program and the Multi-Species Conservation Strategy;
- provides the concept of a single blueprint for ecosystem restoration and species recovery in the Bay-Delta system.

The Strategic Plan does not:

- attempt to resolve issues of land use or conflicts with activities outside the ecosystem restoration program;
- attempt to resolve conflicts between species or between habitats, except for priorities implied by the statement of objectives; or
- recommend specific projects for implementation, although general classes of projects and a method for selecting projects are presented.

> The Strategic Plan provides the conceptual framework and process that will guide the refinement, evaluation, prioritization, implementation, monitoring, and revision of ERP actions.

RELATIONSHIP OF THE ERP TO THE CALFED BAY-DELTA PROGRAM MISSION

The CALFED Bay-Delta Program was established to reduce conflicts in the Bay-Delta system by solving problems in ecosystem quality, water quality, water supply reliability, and levee system integrity. The mission of the CALFED Bay-Delta Program is to develop a long-term, comprehensive plan that will restore the ecological health and improve water management for beneficial uses of the Bay-Delta system. The Ecosystem Restoration Program (ERP) is the principal Program component designed to restore the ecological health of the Bay-Delta ecosystem. The approach of the ERP is to restore or mimic ecological processes and to increase and improve aquatic and terrestrial habitats to support stable, self-sustaining populations of diverse and valuable species.

The ERP will also help fulfill the mission of improving water management for beneficial uses of the Bay-Delta system. Current protections for endangered and threatened fish species require that exports of Bay-Delta water be reduced or curtailed when they pose a risk to the species. By helping to recover currently endangered and threatened species and by maintaining populations of non-listed species, the ERP can help ease current diversion restrictions and preclude more stringent export restrictions in the future, thereby improving the reliability of Bay-Delta water supplies.

The ERP represents one of the most ambitious and comprehensive ecosystem restoration projects ever undertaken in the United States. It encompasses a wide range of aquatic, riparian and upland habitats throughout the Bay-Delta ecosystem and near-shore ocean environment, and it addresses numerous aquatic and terrestrial species that rely upon the Bay-Delta ecosystem for part or all of their life cycle.

THE STRATEGIC PLAN FOR ECOSYSTEM RESTORATION

The ERP identifies over 600 programmatic actions that, after being refined and prioritized, will be implemented throughout the Bay-Delta ecosystem and near-shore ocean environment over the 30 or more year implementation period of the Program. The ERP is described in a two volume restoration plan, the Ecosystem Restoration Program Plan (ERPP), and the Strategic Plan for Ecosystem Restoration (Strategic Plan). Volume I of the ERPP describes the health and interrelationships of the elements of the Bay-Delta ecosystem and establishes the basis for restoration actions which are presented in Volume II of the ERPP. Volume II provides programmatic restoration prescriptions for ecological management zones and their respective units. The Strategic Plan provides the conceptual framework and process that will guide the refinement, evaluation, prioritization, implementation, monitoring, and revision of ERP actions.

The Strategic Plan signals a fundamental shift in the way the ecological resources of the Bay-Delta ecosystem will be managed, because it embodies an ecosystem-based management approach with its attendant emphasis upon adaptive management. Traditional management of ecological resources has usually focused upon the needs of individual species. Ecosystem-based management, however, is a more integrated, systems approach that attempts to recover and protect multiple species by restoring or mimicking the natural physical processes that help create and maintain diverse and healthy habitats.

THE STRATEGIC PLAN:

- describes an **ECOSYSTEM-BASED MANAGEMENT APPROACH** for restoring and managing the Bay-Delta ecosystem (Chapter 2);
- describes an **ADAPTIVE MANAGEMENT PROCESS** that is sufficiently flexible and iterative to respond to changing Bay-Delta conditions and to incorporate new information about ecosystem structure and function (Chapter 3 and Appendix C);
- describes the value and application of **CONCEPTUAL MODELS** in developing restoration actions and defining information needs, with examples of their development and use (Chapter 3 and Appendix B);
- presents **DECISION RULES** and criteria to help guide the selection and prioritization of restoration actions (Chapter 3);
- presents CALFED's broad **GOALS,** specific **OBJECTIVES AND RATIONALES** for ecosystem restoration (Chapter 4);
- presents **TWELVE CRITICAL ISSUES** that need to be addressed early in the restoration program (Chapter 5);
- describes **OPPORTUNITIES FOR RESTORATION** to address the twelve critical issues in the first seven years of implementation; (Chapter 5);
- describes Guiding Principles of the ERP and the approach for selecting actions for the **IMPLEMENTING THE ERP**, the first 7 years of Program implementation (Chapter 5); and
- describes **INSTITUTIONAL AND ADMINISTRATIVE CONSIDERATIONS** necessary to implement adaptive management, to ensure scientific credibility of the restoration program, and to engage the public in the restoration program (Chapter 6).

The Bay-Delta Ecosystem

The Bay-Delta ecosystem is large, complex, diverse and variable. It contains California's two largest rivers, the Sacramento River (which drains an area of more than 25,000 square miles) and the San Joaquin River (draining more than 14,000 square miles). These two rivers converge in the Delta (Figure 1-1), which coupled with greater San Francisco Bay, forms the largest estuary on the West Coast. Tributaries that drain the Sierra Nevada Mountains, the Cascade Range, and the Coast Ranges provide freshwater flow to the Bay-Delta estuary, thus connecting the salty water of the Pacific Ocean with mountain forests and meadows into a vast ecosystem that encompasses most of the Central Valley.

California's semi-arid climate produces pronounced variations in both seasonal and inter-annual precipitation. For instance, the Bay-Delta watershed receives the vast majority of its annual precipitation between the months of October and April, with little precipitation between May and September. The amount of precipitation that falls in the Bay-Delta watershed can vary dramatically from year to year, as demonstrated during the last decade by the drought from 1987-1992 and the floods of 1995-1998. These seasonal and inter-annual variations in precipitation produce highly variable flows of freshwater through Delta tributaries and the estuary. Historically, during wet years, much of the Central Valley would flood to form a large inland sea of shallow water habitat, and during prolonged droughts, Bay-Delta tributaries were reduced to trickles confined within narrow low-flow channels.

Regional differences in temperature and geology further cause variable flows of freshwater and sediment through Delta tributaries and the estuary. For instance, because of milder winter temperatures, most of the precipitation in the Coast Ranges falls as rain so that tributaries draining the eastern slope of the Coast Ranges produce peak flows during the rainy winter months, with reduced base flows from the late-spring through fall. In contrast, tributaries that drain the western flank of the Sierra Nevada Mountains usually carry peak flows later during the late-spring and early-summer months because they are fed by melting snow stored in the mountains by colder winter temperatures, with late-summer and fall base flows greatly reduced following the snowmelt. Tributaries that drain volcanic formations around Mount Shasta and Mount Lassen also carry peak flows during late spring, but summer and fall base flows are relatively higher and colder since they are fed by cold-glacial melt water that flows from springs.

Such variation in the amount and timing of runoff—in conjunction with regional and local differences in soils, topography and microclimates—create an extraordinarily diverse ecosystem that contains numerous distinct habitats and communities and that supports numerous plant and animal species. For example, four distinct runs of chinook salmon that rely upon the Bay-Delta ecosystem demonstrate a fine-tuning of species to a fluctuating yet productive environment. Fall-run chinook spawn in low-elevation rivers, beginning their spawning migrations in fall months as soon as water temperatures are cool so that their young can emerge and leave the rivers before unfavorable flow and temperature conditions in the early summer. Spring-run chinook salmon beat the summer low flows and high temperatures by migrating far upstream in the spring and holding in deep, cold pools through summer, waiting to spawn in the fall. Tributaries draining volcanic formations (such as the little Sacramento, McCloud and Pit rivers) provided cool water temperatures during summer months, allowing late-fall-run and winter-run chinook salmon to spawn late in the season. The ERP reflects the diversity within the Bay-Delta ecosystem by delineating 14 ecological management zones, each of which is subdivided further into smaller ecological management units.

The Need for Restoration

Numerous plant and animal species that rely upon the Bay-Delta ecosystem are listed as endangered or threatened, or experiencing declines in population abundance or geographic distribution. Some species that depended on the Delta, such as the thicktail chub, are now extinct. Such species declines indicate a much broader problem with

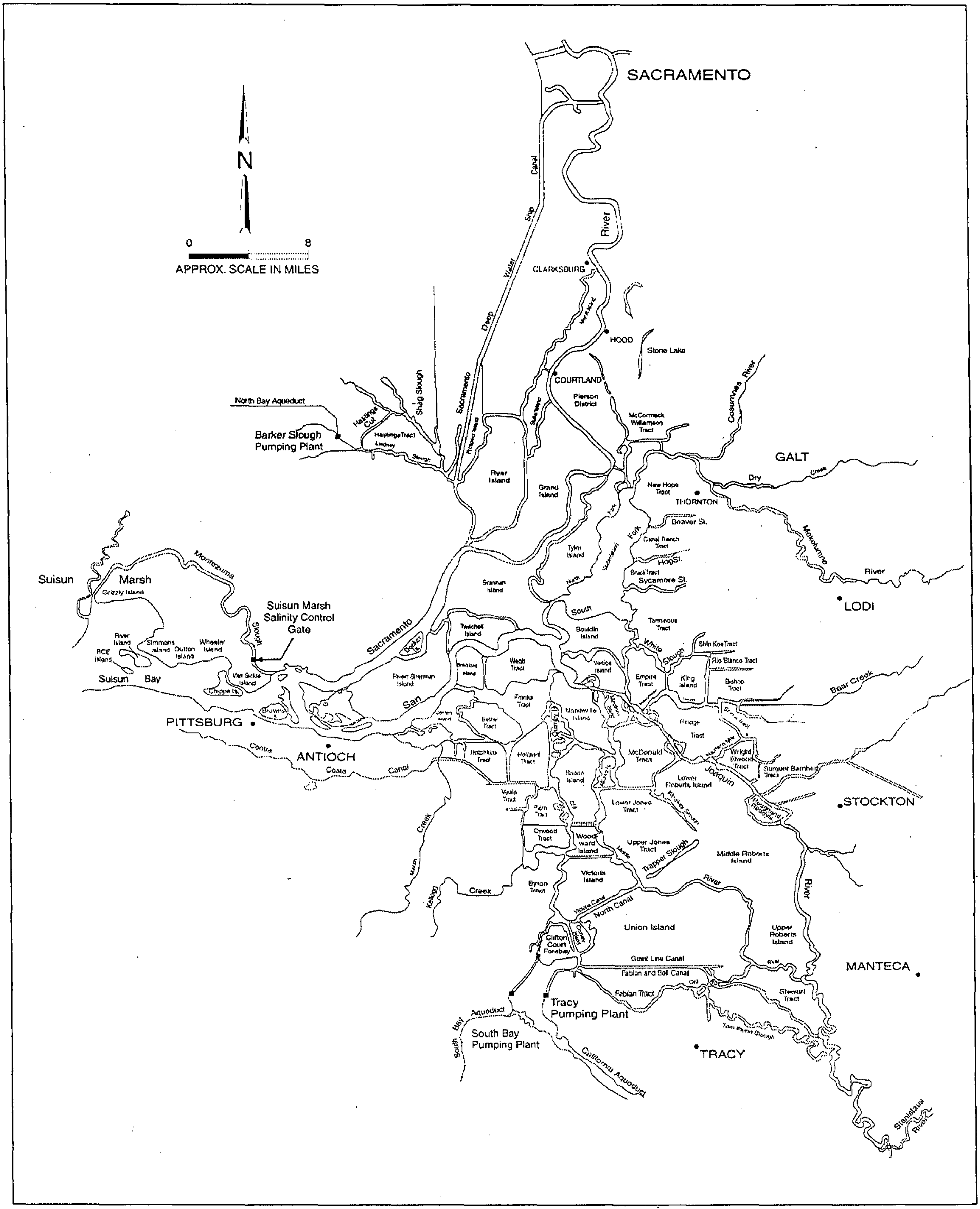


Figure 1-1: CALFED Problem Scope, Suisun Bay, Suisun Marsh, and the Sacramento-San Joaquin River Delta Regions.

deteriorating ecological health in the Bay-Delta ecosystem, as indicated by:

- a reduction in the quantity, quality, and diversity of aquatic and terrestrial habitat available to support a variety of fish, plants, birds, reptiles, amphibians, and other species;

- the alteration of the amount and pattern of water and sediment movement in Delta tributaries and through the Delta;

- the disconnection of rivers from their floodplains by levees and from their headwaters by dams;

- the alteration of the movement patterns of fish and other organisms by dams, channel modifications, changes in hydrology, and water diversions;

- the introduction of numerous non-native species, some with tremendous capacity for damage to the extant ecosystem, and the establishment of conditions that favor these species; and

- the degradation of water quality from pesticides, herbicides, industrial and municipal discharges, non-point-source discharges, and concentration of natural toxins through leaching from farms.

What is Ecosystem Restoration?

Ecosystem restoration does not entail recreating any particular historical configuration of the Bay-Delta environment; rather, it means re-establishing a balance in ecosystem structure and function to meet the needs of plant, animal, and human communities while maintaining or stimulating the region's diverse and vibrant economy. The broad goal of ecosystem restoration, therefore, is to find patterns of human use and interaction with the natural environment that provide greater overall long-term benefits to society as a whole.

Healthy ecosystems provide more than habitat for plants and wildlife; they also meet the needs of human communities. Some of the obvious human benefits include drinking water supply, recreational opportunities, and amenity values. But healthy ecosystems also provide more subtle, but no less important, benefits to human communities. For instance, vegetation helps to improve air quality and sequester carbon, rivers help transport and dilute our wastes, biotic organisms can help improve water quality and pollinate crops and vegetation, etc. In this manner, ecological processes provide valuable goods and services. Similarly, the amenity values associated with high-quality environments can help attract businesses to locate in the state, thereby stimulating local, regional, and state economies (Power 1996).

Historically, human activities have focused on the extractive value of natural resources and ecological processes without sufficient consideration of the concomitant loss of other social and economic benefits when ecological systems are altered (Healey 1998). However, growing public recognition of the social, economic, and ecological costs of environmental degradation, coupled with a growth in environmental values, has stimulated interest not only in preserving remnant ecosystems, but also in restoring already degraded ecosystems

WHAT IS ECOSYSTEM RESTORATION?

Ecosystem restoration projects throughout the world—such as projects in the Chesapeake Bay and Florida Everglades—have helped to publicize and popularize the concept of ecosystem restoration. However, a significant amount of confusion and contention still surround the concept of ecosystem restoration (Richardson and Healey 1996). Much of the confusion and contention stems from the perceived goal of ecosystem restoration; that is, the term itself seems to imply that the ecosystem will be restored to its pristine, pre-disturbance condition or some structural and functional configuration defined by a particular historic baseline. Thus, some stakeholders worry that ecosystem restoration will require the cessation of particular human activities that disturb an ecosystem, with subsequent economic dislocations. Although ecosystem restoration does require change and adjustment, there is no benefit to ecosystem restoration if it destroys the fabric of the society it is intended to serve.

Ecosystem restoration does not entail recreating any particular historical configuration of the Bay-Delta environment; rather, it means re-establishing a balance in ecosystem structure and function to meet the needs of plant, animal, and human communities while maintaining or stimulating the region's diverse and vibrant economy. The broad goal of ecosystem restoration, therefore, is to find patterns of human use and interaction with the natural environment that provide greater overall long-term benefits to society as a whole. **FOR THE ERP, WE USE THE TERM "RESTORATION" TO ENCOMPASS THE CONCEPTS OF REHABILITATION, RESTORATION, PROTECTION AND CONSERVATION.**

ACKNOWLEDGING EXISTING CONSTRAINTS TO ECOSYSTEM RESTORATION

Several human activities in the Bay-Delta watershed have irreversibly altered important ecological processes (see Appendix A). Nevertheless, these activities provide important public benefits and ecosystem restoration must occur within the parameters established by these human activities. For example, the large reservoirs and diversion facilities that comprise the Central Valley Project and State Water Project have radically altered the hydrology of the Bay-Delta ecosystem. Reservoir storage in the Sacramento River Basin captures approximately 80% of annual average runoff, while storage capacity in the San Joaquin River system detains nearly 135% of annual average runoff (San Francisco Estuary Project 1992, Bay Institute 1998). Such profound hydrologic changes underscore the numerous ecological processes that dams alter: they reduce the frequency and magnitude of flood flows that drive channel migration, scour encroaching vegetation, and cleanse spawning gravels; they trap sediment and woody debris necessary to maintain important instream habitat; they reduce the natural flow variability to which native species and communities have adapted; and they block access to historical spawning habitat for anadromous fish. Although dam removal may be possible in a limited number of cases, in most cases ecosystem restoration must occur within the parameters established by existing reservoirs. The multiple public benefits provided by most existing dams—water supply, flood storage, hydropower, recreation—simply preclude their removal.

Ecosystem restoration attempts to maintain the public benefits that existing dams provide while enhancing other public benefits associated with ecosystem restoration by better managing human activities. For instance, habitats, communities and species in the Bay-Delta ecosystem have evolved in response to the fluctuating flow conditions produced by variable precipitation patterns. Dams have reduced the natural variability of flows in Bay-Delta tributaries to the detriment of the ecosystem, but it is possible to re-operate reservoir releases so that they restore or mimic natural flow variability. In this manner, existing reservoirs can still provide—though they may diminish—water supply, flood storage, hydropower, and recreational benefits, but they can also enhance the public benefits of a healthier ecosystem by approximating a more natural flow regime.

ACKNOWLEDGING FUTURE CONSTRAINTS TO ECOSYSTEM RESTORATION

The existing constraints to ecosystem restoration in the Bay-Delta are a function of human uses of Bay-Delta resources. The California Department of Finance projects that the state's population will grow by approximately 15 million people (or nearly 48%) over the life of the Program, thereby increasing demands upon Bay-Delta resources and introducing additional constraints to restoration (see Appendix A). Ecosystem restoration must balance the need to provide resources for future consumptive use with the need to provide high-quality environments that fulfill the needs of plant, animal, and human communities.

THE SCOPE AND FOCUS OF THE ERP

The CALFED Bay-Delta Program was created to develop solutions for water and environmental management problems of the Bay-Delta system. The Program's legally defined **PROBLEM SCOPE** is the Sacramento-San Joaquin Delta and Suisun Bay and Marsh, the hub of the state's water system as well as an important estuary that many imperiled species are critically dependent on. The geographic scope for developing solutions to environmental problems is the entire watershed and near-shore ocean environment of the Bay-Delta system. While the ERP identifies programmatic actions to be implemented throughout the watershed and near-shore ocean, the ERP delineates a more focused area where the majority of actions will be implemented—the **STUDY AREA**. The Study Area includes the legally defined Delta, Suisun Bay and Marsh, North San Francisco Bay, the Sacramento and San Joaquin Rivers and their tributaries downstream of major dams (Figure 1-2). Within the Study Area, 14 Ecological Management Zones and their associated Ecological Management Units (52 units total) are delineated. Volume II of the ERPP describes the health of these management areas and presents specific management prescriptions.

This focused Study Area reflects existing constraints to ecosystem restoration. For example, large dams represent irreducible discontinuities in rivers by altering flows, trapping sediment, and impeding fish passage, such that restoration efforts in the upper watersheds are unlikely to contribute significantly to key ERP goals such as restoring ecological processes and recovering endangered and threatened species. Restoration and management actions implemented in the upper watersheds can yield other Program benefits, such as water quality and water supply improvements and reductions in reservoir sedimentation. Accordingly, other Program components, such as the Watershed Management Program and the Water Quality Program, address the upper watersheds. Similarly, there are relatively fewer management actions relevant to the CALFED mission available for central and southern San Francisco Bay.

Numerous plant and animal species rely upon the Bay-Delta ecosystem for part or all of their life cycle, and the ERP aims to maintain current population abundances of these species, at a minimum. However, a majority of programmatic actions contained in the ERP focus on improving ecological processes and habitats upon which endangered and threatened species or species proposed for listing depend since there is a more immediate need to stabilize their populations and since their recovery will help reduce conflicts in the Bay-Delta system.

RELATION OF THE STRATEGIC PLAN TO THE MULTI-SPECIES CONSERVATION STRATEGY

CALFED has developed a Multi-Species Conservation Strategy to serve as the platform for compliance with the Federal Endangered Species Act (ESA), the California Endangered Species Act (CESA), and the State's Natural Community Conservation Planning Act (NCCPA) (Multi-Species Conservation Strategy 1999). The Conservation Strategy has identified a subset of species which are federally and State listed, proposed, or candidate species, other species identified by CALFED that may be affected by and for which the CALFED Program and the ERP have responsibility related to (1) recovery of the species, (2) contribute to their recovery, or (3) maintain existing populations. The "recover species" depend on habitat conditions in Suisun Bay, the Delta, Sacramento River, San Joaquin River, and many of their tributary streams. For these reasons, the primary geographic focus of the ERP is the Sacramento-San Joaquin Delta, Suisun Bay, the Sacramento River below Shasta Dam, the San Joaquin River below the confluence with the Merced River, and their major tributary watersheds directly connected to the Bay- Delta system below major dams and reservoirs. In addition, streams such as Mill Creek, Deer Creek, Cottonwood Creek, and Cosumnes River, are emphasized due to their free-flowing status and relative high quality of habitats and ecological processes.

Secondarily, the ERP addresses, at a broader, programmatic level, Central and South San Francisco Bay and their local watersheds. These 14 ecological management zones constitute the geographic areas in which the majority of restoration actions will occur. The upper

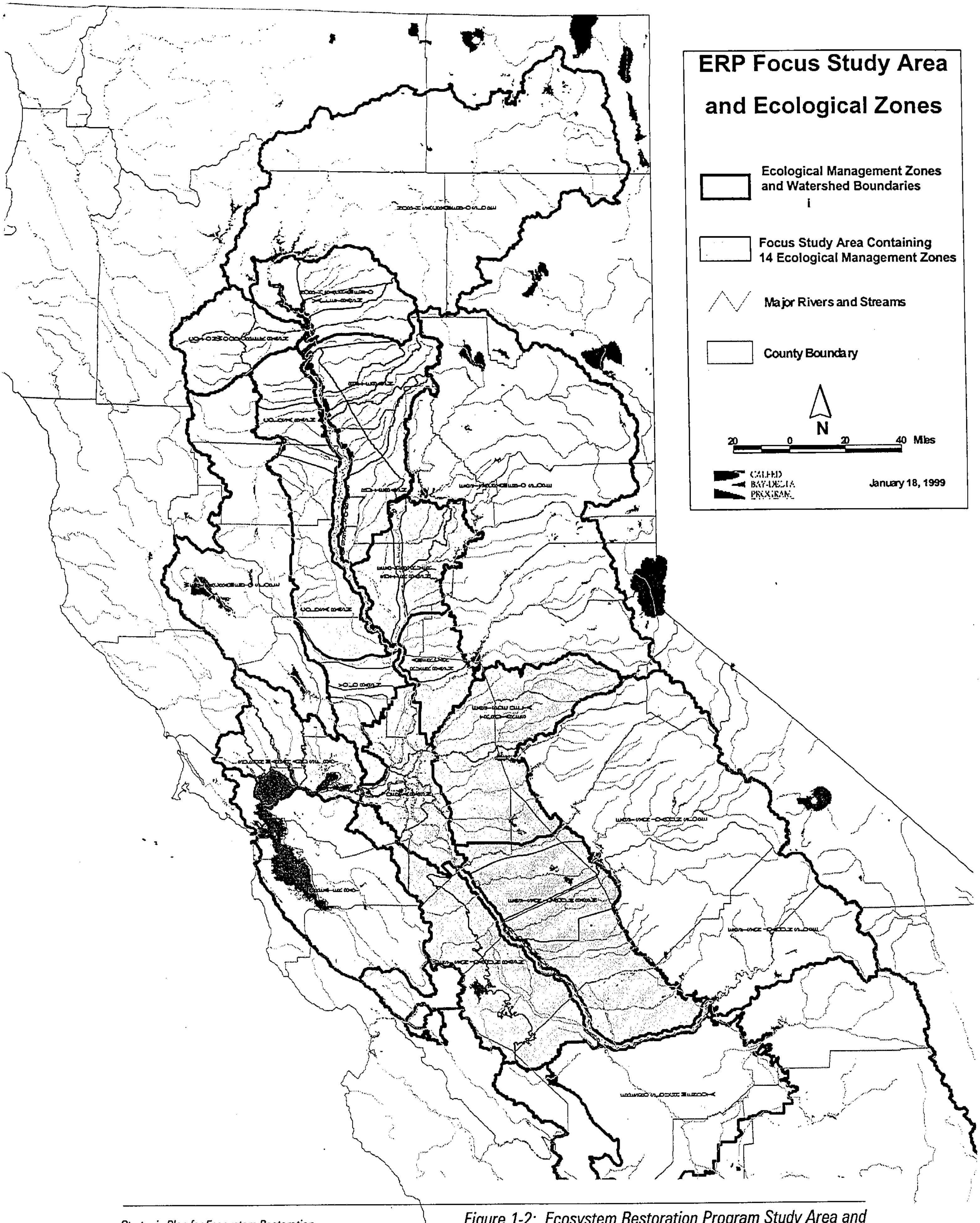


Figure 1-2: Ecosystem Restoration Program Study Area and Ecological Management Zones

watersheds surrounding the primary focus area are important and addressed through general actions that focus on watershed processes and watershed planning, management and restoration. The CALFED Watershed Program addresses the coordination of planning and restoration actions in the upper watershed .

The MSCS and the ERP are distinct parts of CALFED, but they are neither severable nor redundant. The ERP is the means by which CALFED will restore the Bay-Delta ecosystem and is the CALFED element most relevant and important for FESA, CESA, and NCCPA compliance. The MSCS conservation measures do not comprise all actions that will be credited toward, or required for, compliance with FESA, CESA, and NCCPA. The MSCS is not a separate or supplemental restoration program and does not supplant the ERP.

Rather, the MSCS:

- assesses the aggregate effects of CALFED, including implementation of the entire ERP;
- identifies species goals consistent with the ERP that reflect regulatory standards;
- refines and emphasizes certain ERP actions that are of special importance to the MSCS evaluated species; and
- identifies avoidance, minimization, and compensation measures for evaluated species.

The MSCS's species goals and conservation measures are consistent with and are incorporated in the ERP. ERP actions that are not emphasized or refined in the MSCS may nonetheless be important for FESA, CESA and NCCPA compliance. USFWS, NMFS and DFG will consider all proposed CALFED actions that would benefit or harm the MSCS's NCCP communities and evaluated species, including all ERP actions, for purposes of determining whether CALFED complies with FESA, CESA, and NCCPA.

♦ CHAPTER 2. ECOSYSTEM-BASED MANAGEMENT

THE ADVANTAGES OF ECOSYSTEM-BASED MANAGEMENT

Natural resource management is often guided by the need to recover and protect populations of endangered and threatened species. Efforts to combat population declines of endangered and threatened species often focus on specific factors in a species' environment believed to affect birth or death rates. While this species-based approach has often prevented the extinction of a species, it has also resulted in piecemeal attempts that usually fail to recover and stabilize populations of threatened and endangered species. Additionally, this species-based approach fails to address the needs of unlisted species experiencing population declines that might necessitate their future listing.

Ecosystems are more than just a collection of species; they are complex, living systems influenced by innumerable climatic, physical, chemical, and biological factors, both within and outside of the ecosystem. A new paradigm in natural resource management has emerged that acknowledges this complex interplay of forces that shape and animate ecosystems. Ecosystem-based management is an integrated-systems approach that attempts to protect and recover multiple species by restoring or mimicking the natural physical processes that create and maintain diverse and healthy habitats

By incorporating an ecosystem-based approach, the ERP and the Strategic Plan signal a fundamental shift in the way the ecological resources of the Bay-Delta system will be managed.

By adopting an ecosystem-based approach, CALFED is not relinquishing its responsibility to recover endangered and threatened species, nor is it abandoning all species-based management efforts. Ecosystem-based management encompasses species management by enhancing and sustaining the fundamental ecological structures and processes that contribute to the well-being of a species. The ERP aims to recover threatened and endangered species not only by restoring habitats, but also by restoring the ecological processes that help create and sustain those habitats.

Advantages of an Ecosystem-Based Approach over the Traditional Species-Based Approach

- Restoration of physical processes reproduces subtle elements of ecosystem structure and function in addition to the more obvious elements, thereby possibly enhancing the quality of restored habitat.
- Restoration of physical processes can benefit not only threatened and endangered species, but also unlisted species, thereby reducing the likelihood of future listings.
- Restoration of physical processes reduces the need for ongoing human intervention to sustain remnant or restored habitats.
- Restoration of physical processes may produce a more resilient ecosystem capable of withstanding future disturbances.

CONTRASTING ECOSYSTEM-BASED AND SPECIES-BASED MANAGEMENT

The difference between process-based restoration and conventional species-based management can be illustrated by the contrast between using hatcheries and ecosystem-based approaches to restore salmon. Hatcheries were initially constructed to compensate for habitat lost behind dams, but they are now used to compensate for a broad range of impacts on salmon production, including habitat degradation. This conventional, engineering-oriented, species-based approach yields an increase in fish populations, at least in the short term; however, hatcheries are vulnerable to disease and impose a variety of selection pressures that may make the fish less successful in the wild. Hatchery-produced fish compete with, and interbreed with wild fish, thereby affecting the gene pool and possibly reducing the fitness and overall vigor of local populations.

By contrast, a process-based ecosystem management approach seeks to restore the dynamic processes of flow, sediment transport, channel erosion and deposition, and ecological succession that create and maintain the natural channel and bank conditions favorable to salmon. If the processes that create the habitat for salmon can be restored, ecosystem restoration can be truly sustainable and can result in a system that benefits a range of other species as well, thereby avoiding future need for further listings of endangered species.

ELEMENTS OF ECOSYSTEM-BASED MANAGEMENT

In its monograph on the scientific basis of ecosystem management, the Ecological Society of America (1995) identified eight elements of ecosystem-based management that illustrate the character of this emerging paradigm:

1. **LONG-TERM SUSTAINABILITY IS A FUNDAMENTAL VALUE.** This element highlights the importance of intergenerational equity, suggesting that resources should be managed today to ensure that the needs of future generations will not be compromised (World Commission on Environment and Development 1987). In ecological terms, this is coming to be defined as passing on to future generations a set of natural capital resources equivalent to that which the present generation has available (Costanza and Daly 1992). The ERP addresses this element in by emphasizing the recovery of native species, by preserving biodiversity, and by emphasizing the restoration of ecological processes that allow ecosystems to be more self-sustaining.

2. **DECISIONS MUST BE BASED ON CLEARLY DEFINED GOALS AND OBJECTIVES.** This element highlights the need to be clear about what we want to achieve through management. Goals and objectives are to be stated in terms of desired future states, behaviors, or trajectories for ecosystem structure and function. Objectives are also to be stated in terms that can be measured and monitored. In this way, ecosystem management is not tied to an undefinable or unattainable pristine condition; instead, it provides considerable latitude for negotiating and defining desirable future conditions. Furthermore, because goals are to be stated in terms of measurable criteria, progress can be explicitly evaluated. The ERP and the Strategic Plan include both general goals and more specific measurable objectives.

3. **DECISIONS MUST BE BASED ON SOUND ECOLOGICAL MODELS AND UNDERSTANDING.** This element highlights the importance of rational, science-based models to decision making in ecosystem-based management. However, because humans are integral to the ecosystem to be managed, it also highlights the importance of models that integrate social, economic, and environmental components of the larger system. Conceptual models as heuristics and as a foundation for modeling expected outcomes in adaptive management are part of the Strategic Plan.

4. **COMPLEXITY AND CONNECTEDNESS ARE FUNDAMENTAL CHARACTERISTICS OF HEALTHY ECOSYSTEMS.** Evidence from management failures of the past suggests that there is considerable risk in attempting to manage individual resources independently of one another. By focusing attention on connectedness, ecosystem management reduces the risk of such failures. Restoration of Delta and estuarine ecosystems inevitably involves a concern with connectedness because of the importance of fluvial and tidal dynamics to their functioning. Recognition of the importance of interconnected habitats is also paramount when anadromous salmonids are one subject for restoration. The nested hierarchy of ecosystem management units in the ERP focus area is a further acknowledgment of the interconnectedness among elements of structure and function in the ERP focus area.

5. **Ecosystems are dynamic.** Ecosystems are complex, self-organizing systems. With complexity comes uncertainty and imprecision in prediction. Ecosystem-based management cannot eliminate surprises or uncertainty. Rather, it acknowledges that unlikely and even unimagined events may happen. The management process must be designed to cope with such events. The Strategic Plan describes an adaptive management process that helps to account for the uncertainty inherent in restoring and managing an ecosystem. The program also recognizes the importance of dynamic processes in its concern over effects of the seasonal hydrograph on particular species and in its plan to recreate meander corridors along river courses. Other dynamic elements may have to be built into the restoration program over time, however, and adaptive experimentation can help to define the necessary degree of dynamic change to maintain ecosystem function.

6. **Context and scale are important.** Each aspect of ecosystem structure and function has its own time and space scale. Spatial and temporal domains of management planning and implementation need to be congruent with those of critical ecological processes in the system to be managed. Management activities tend to be tied to social and economic schedules, not ecological schedules. Staged implementation, monitoring, and assessment schedules and adaptive experimentation all provide tools for strengthening the spatial and temporal patterning of restoration.

7. **Humans are integral components of all ecosystems.** Humans are the single greatest modifier of ecosystem structure and function. Humans will also suffer the most serious consequences of changes that make ecosystems less able to sustain human life. Therefore, management of human activities must be an integral component of plans to manage ecosystems. This element may seem rather obvious but serves to emphasize the importance of linking the ERP with activities related to water quality, water supply reliability, and levee integrity. This element also reminds us that ecosystem management is a human problem, not an ecological one.

8. **Ecosystem management must be adaptable and accountable.** Our understanding of ecosystems is incomplete and subject to change, so management planning and programs must be sufficiently flexible to respond to new information. Adaptive management provides this flexibility, and it employs the problem-solving power of the scientific method to maximize the information value of restoration actions so that we can improve our knowledge of the ecosystem as we restore it, thus improving the process of management over time.

Elements of Ecosystem-Based Management

1. Long-term sustainability is a fundamental value.
2. Decisions must be based on clearly defined goals and objectives.
3. Decisions must be based on sound ecological models and understanding.
4. Complexity and connectedness are fundamental characteristics of healthy ecosystems.
5. Ecosystems are dynamic.
6. Context and scale are important.
7. Humans are integral components of all ecosystems.
8. Ecosystem management must be adaptable and accountable.

Addressing the Uncertainty Inherent in Natural Systems through Adaptive Management

Through decades of scientific research, we have come to understand much about the Bay-Delta ecosystem and the species that depend on it; however, we do not understand all of the ecological processes and interactions that animate the ecosystem. Additional research can greatly improve our understanding, but it will never erase all of the uncertainty that is inherent in restoring and managing such a large, diverse, complex, and variable natural system. Ecosystem processes, habitats, and species are continually modified by changing environmental conditions and human activities; consequently, it is impossible to predict exactly how the Bay-Delta will respond to implementation of the ERP and other CALFED components. Restoring and managing the Bay-Delta ecosystem requires an approach that acknowledges the uncertainty in both the dynamics of complex systems and the effects of management interventions.

Holling (1998) classifies the practice of ecology according to two cultures, a dichotomy that can also describe the management of ecological systems. The first, traditional culture, is analytical and based on formally testing hypotheses to assess single causative relationships and attempting to find the single correct answer to questions and the single correct approach to solving problems. The second culture is integrative and exploratory, based on a comparative analysis of multiple hypotheses and an acknowledgment of uncertainty in management. Previous management of the Bay-Delta system has proceeded according to the first set of cultural practices. That is, historically, we have disregarded most of this complexity in resource management and treated such problems as though they were well defined in time and space and amenable to analysis (understanding) and remediation by standard methods. As failures in resource management based on this approach have become more visible and more serious, resource managers have shown increasing interest in methods that explicitly recognize the uncertainty inherent in management actions (Holling 1998). A suite of techniques collectively termed "adaptive environmental assessment and management," or simply "adaptive management," (Holling 1978, Walters 1986) has been adopted by several state and federal resource agencies as a practical approach to management under uncertainty.

According to Walters (1986), designing an adaptive management strategy involves four basic issues:

1. bounding the management problem in terms of objectives, practical constraints on action, and the breadth of factors to be considered in designing and implementing management policy and programs;

2. representing the existing understanding of the system(s) to be managed in terms of explicit models of dynamic behavior that clearly articulate both assumptions and predictions so that errors or inconsistencies can be detected and used as a basis for learning about the system;

3. representing uncertainty and how it propagates through time and space in relation to a range of potential management actions that reflect alternative hypotheses about the system and its dynamics; and

4. designing and implementing balanced management policies and programs that provide for continuing resource production while simultaneously probing for better understanding and untested opportunity.

Put another way, adaptive management involves: 1) having clear goals and objectives for management that take into account constraints and opportunities inherent in the system to be managed; 2) using models to explore the consequences of a range of management policy and program options in relation to contrasting hypotheses about system behavior and uncertainty; and 3) selecting and implementing policies and programs that sustain or improve the production of desired ecosystem services while, at the same time, generating new kinds of information about ecosystem function.

REDUCING UNCERTAINTY BY LEARNING FROM RESTORATION AND MANAGEMENT ACTIONS

Restoring and managing the Bay-Delta ecosystem requires a flexible management framework that can generate, incorporate, and respond to new information and changing Bay-Delta conditions. Adaptive management provides such flexibility and opportunities for enhancing our understanding of the ecosystem. Within an adaptive management framework, natural systems are managed in such a way as to ensure their recovery and improvement while simultaneously increasing our understanding of how they function. In this manner, future management actions can be revised or refined in light of the lessons learned from previous restoration and management actions.

The key to successful adaptive management is learning from all restoration and management actions. Learning allows resource managers and the public to evaluate and update the problems, objectives, and models used to direct restoration actions. Subsequent restoration actions can then be revised or redesigned to be more effective or instructive. In an adaptive management process, learning must be continuous so that ecological restoration continuously evolves as the ecosystem responds to management actions and to unforeseen events, and as management actions are revised in light of new information. Without effective learning, ineffective management programs are likely to be perpetuated, unanticipated successes will go unrecognized, and resources will not be efficiently allocated.

To facilitate learning, adaptive management emphasizes the use of the scientific method to maximize the information value of restoration and management actions. Resource managers explicitly state hypotheses about ecosystem structure and function based upon the best available information, and then they design restoration actions to test these hypotheses. In this respect, adaptive management treats all management interventions as experiments. This does not suggest that management interventions are conducted on a trial-and-error basis, because management actions are guided by the best understanding of the ecosystem at the time of implementation.

Adaptive management is analogous to the "clinical trial" in medicine. In a clinical trial, a new therapy is tested on many patients, the trial is carefully monitored, and the progress of the trial is evaluated at regular intervals to determine whether to continue with the trial, abandon the trial, or declare the new therapy a success. Clinical trials are not initiated unless there is a reasonable expectation of success. Similarly, CALFED will not initiate large-scale ecological restoration unless there is a reasonable expectation of success.

By treating interventions as experiments, resource managers ensure that management is as efficient and successful as possible in achieving its objectives—unsuccessful interventions will not be perpetuated or expanded and successful interventions can be modified to use resources efficiently (e.g., land, water, tax dollars). Designing management interventions as experiments can have significant benefits when it comes to evaluating success or failure, increasing understanding of system dynamics, and making better decisions in the future (Walters et al. 1988 and 1989, Walters and Holling 1990). In adaptive management, treating interventions as experiments involves:

- making management decisions based on the best available analyses and modeling of the system;
- being clear about what management intervention is expected to achieve in terms of restoring ecological structure and function and the implications for species conservation;
- designing management intervention to help distinguish among alternative hypotheses about ecosystem behavior, where practical and compatible with the long-term goals of the program; and
- monitoring the effects of management intervention and communicating the results widely so that progress relative to expectations can be evaluated, adjustments made, and learning achieved.

As in clinical trials, an adaptive management program should incorporate Bayesian statistical techniques to judge progress and update probabilities among competing hypotheses. These techniques differ from the traditional hypothesis-testing approaches that play such a dominant role in ecological practice. Bayesian techniques are used to determine the probability that a hypothesis is true given the available information; when more than one hypothesis is proposed, probabilities can be compared among hypotheses. Decision rules can therefore be built into the program that are more socially and ecologically relevant than the 0.05 significance criterion commonly used in ecology. This approach is more in keeping with the notion of the second alternative culture of ecology (Holling 1998).

MODES OF ADAPTIVE MANAGEMENT

Walters (1986) recognized three approaches to management:

- **TRIAL-AND-ERROR**, in which early management options are chosen at random and later choices are made from a subset of the early options that performed best;

- **PASSIVE ADAPTIVE**, in which a best management option is chosen on the basis of the current beliefs about system dynamics and this option is fine-tuned in relation to experience; and

- **ACTIVE ADAPTIVE**, in which two or more alternative hypotheses about system dynamics are explored through management actions.

TRIAL-AND-ERROR MANAGEMENT. The first approach is illustrated by early attempts at stream habitat rehabilitation in which alterations were made to streams, and those that proved successful (e.g., stayed in the stream, attracted fish) became favored interventions. Some element of trial-and-error is a part of virtually every management policy.

PASSIVE ADAPTIVE MANAGEMENT. Passive adaptive management is perhaps the most common form of management intervention these days. It is highly defensible in that the best management action is chosen based on the best available scientific information (although which information is best may be subject to debate). It fits well with the incremental remedial approach to policy evolution that is common to public agencies (Lindblom 1959). It is administratively simple because all "units" are treated alike, and information needs and information management are relatively simple. Learning about the system using this approach, however, is confined to a very narrow window, and there is practically no possibility of determining whether the underlying hypothesis about the system is right or wrong; therefore, although passive adaptive management takes uncertainty into account, it has only limited capacity to reduce uncertainty.

Many elements of the ERP may have to be implemented as passive adaptive projects. Passive adaptive management may be dictated because the value of knowing that option A is a better description of system dynamics than option B is less than the cost of obtaining the information, or the alternative action poses too great a threat to public safety or valuable infrastructure, or for a variety of other reasons. Despite its limitations as a tool for learning about the system, a properly designed passive adaptive experiment can provide important insights into workable, if not optimal, solutions.

Unfortunately, strict adherence to experimental protocols is impossible in such a large-scale, passive adaptive program such as the ERP. There is, after all, only one Bay-Delta system, and its various component parts are all strongly interconnected. Independent replication of control and treatment measures is impossible in either space or time, violating an important principle of experimental design. The degree to which cause and effect can be determined should be tempered by this unavoidable limitation. All manipulations within the ERP should be based on careful and creative design to enhance the opportunity for learning and an analytical program that will allow as much distinction between confounded effects as possible.

ACTIVE ADAPTIVE MANAGEMENT. Active adaptive management is the most powerful approach for learning about the system under management but also is often the most contentious. Active adaptive management programs can create the false impression that managers or scientists are going to toy with the resources on which other people's livelihoods depend. Nevertheless, there is an important role for active adaptive management in the ERP, notwithstanding the critical status of many of the species the ERP is intended to benefit. It is important to realize that the purpose of active adaptive management is not to push the system to its limits and see how it responds. Rather, the purpose is to use management as a tool to generate information about the system when the long-term value of the information clearly outweighs the short-term costs of obtaining it.

It may be useful to distinguish between two kinds of active adaptive management. For many situations, it may be clear what kind of intervention is needed (e.g., increased spring and summer flows into the Delta for salmonid conservation), but the magnitude of the intervention is uncertain. The concern is not with the form of the model relating flow to conservation, but with the parameters of the model. An active adaptive management experiment could be designed to improve the estimation of parameters by manipulating spring and summer flow in appropriate ways. For purposes of this discussion, this kind of adaptive experiment will be referred to as "adaptive probing". In some instances, adaptive probing can be designed around natural fluctuations in environmental variables. A good example is the experiment conducted to improve estimates of optimal sockeye salmon escapement to the Fraser River. The principal issue was the level of escapement that would maximize yield to the fishery. The benefit-cost ratio of the experiment to test the benefits of higher escapements was very high, but involved fishers foregoing catch to achieve higher escapements in the short term. The experiment was initiated in the 1980s with very positive results in terms of yields in the late 1980s and early 1990s. Another example of adaptive probing is the Vernalis Adaptive Management Program (VAMP) which is designed to improve the scientific basis for the protection of San Joaquin fall-run chinook salmon smolts during their migration through the Delta. The program is based on a conceptual design which is to test the hypotheses related to smolt survival from five sets of San Joaquin inflow and Delta export levels.

In other instances, the greatest uncertainty may be about the best kind of intervention. For example, which would be the management action for spring-run chinook: increased spawning escapement or reduced cross-channel transport? In this case, the concern is with the form of the model (although obviously the size of the intervention is also important). Again, an adaptive probing experiment could be designed to determine which model (escapement or Delta transport) was the more important in chinook conservation. For purposes of this discussion, experiments designed to distinguish among fundamentally different models (hypotheses) will be referred to as "adaptive exploration." The Bay-Delta ecosystem is replete with such unresolved alternatives. To the extent feasible, the ERP will capitalize on opportunities to distinguish among such alternatives through active adaptive experimentation. Tools for assigning probabilities to models and updating probabilities in the light of new information, as well as rules for efficient design of adaptive experiments, are provided in Walters (1986) and Hilborn and Mangel (1996).

Experimental Protocol for Adaptive Management

For all experiments, whether passive or active, the general protocol should be as follows:

1. **Model the system in terms of current understanding and speculation about system dynamics** and use the model to explore issues, such as the magnitude of effects that will derive from particular manipulations, how uncertainty affects outcomes, efficiency of various experimental designs, and the value of information about alternative dynamics. Models of the system may suggest that the most efficient approach is large-scale intervention, pilot or demonstration projects, targeted research, or some combination of these.

2. **Design the management intervention to maximize benefits in terms of both conservation and information.** Where the modeling of management options suggests that more research is needed before any intervention should be attempted, other management measures may be necessary in the short term to ensure that endangered species do not suffer further declines.

3. **Implement management and monitor system response.** In the case of large-scale manipulations, this must go beyond merely monitoring the response variables of interest

(e.g., fish abundance) to provide a report at the end on whether they changed in the desired direction. Monitoring, modeling, and analysis, perhaps together with targeted research, must be designed specifically to determine the extent to which the manipulation affected the variable of interest.

4. **UPDATE PROBABILITIES OF ALTERNATIVE HYPOTHESES** based on analytical results and, if necessary, adjust management policy.

5. **DESIGN NEW INTERVENTIONS BASED ON IMPROVED UNDERSTANDING.**

The experimental protocols for adaptive management are described in further detail in Chapter 3.

ADDRESSING POLITICAL, REGULATORY AND ECONOMIC UNCERTAINTY

The large scope of the ERP requires that it be implemented in stages over the course of several decades. Staged implementation facilitates an adaptive management approach by allowing resource managers to evaluate actions implemented early so that future restoration will benefit from the knowledge gained. It also allows restoration costs to be spread over several years.

Owing to the long implementation timeframe for the ERP, the ecosystem-based, adaptive management process must account for uncertainty produced by non-biological factors in addition to the ecological uncertainty inherent in restoring complex ecosystems. During the projected implementation period for the CALFED Program, there will be approximately eight presidential and gubernatorial elections. These state and national elections will inevitably affect the way existing public policies and programs are interpreted and implemented. Changes in administrations could lead to new state or federal laws, regulations, and programs relating to the regulation and management of water resources, endangered/threatened species, habitat, and ecosystem protection. Current debates concerning the need for new species listings, legal challenges to federal policies (such as Habitat Conservation Plans [HCPs], the "No Surprise" Rule and "Safe Harbor" provisions), and legal challenges to California's Natural Community Conservation Planning Act (NCCPA) process, reflect the potential for changes in law, regulation, and policy that could affect implementation of the ERP and the overall CALFED Program.

Similarly, the volatile nature of global economics has the potential to affect federal, state, and regional budgets and incomes. Fluctuations in the business cycle could ripple into the implementation of the ERP by affecting the funding available for ecosystem restoration or the demands placed upon Bay-Delta resources. The flexibility of an adaptive management approach can allow resource managers to respond to such external forces in much the same way that they respond to new information or unforeseen environmental events.

ONE BLUEPRINT FOR ECOSYSTEM RESTORATION

A single blueprint for ecosystem restoration and species recovery in the Bay-Delta System is a key ingredient for a successful and effective restoration program. Such a blueprint can be the vehicle for ensuring coordination and integration; not only within the CALFED Program, but between all resource management, conservation, and regulatory actions affecting the Bay-Delta System.

A single blueprint represents a unified and cooperative approach defined by three primary elements:

1. integrated, shared science and a set of transparent ecological conceptual models which provide a common basis of understanding about how the ecosystem works;

2. a shared vision for a restored ecosystem ; and

3. a management framework that defines how management and regulatory authorities affecting the Delta will interact and how management and regulatory decisions (including planning, prioritization, and

implementation) will be coordinated and integrated over time.

The integrated science and ecological conceptual models provide a common basis of understanding about how the ecosystem works. These elements, which include competing hypotheses and models, represent the foundation for transparent decision making based upon sound science. This is not to imply that these models are fixed, as they will be tested and modified over time in response to new information in accordance with the principles of adaptive management as part of the CALFED Science Program. Rather, the models represent a basis for guiding management and regulatory decisions at a given point in time. They also provide the rationales for these decisions.

The shared vision of ecological restoration serves to define the desired outcome. While each of the management and regulatory programs have their own distinct set of goals, establishing a unified approach requires that in meeting these goals the various programs also contribute to meeting common goals with respect to ecosystem restoration. The goals for ecological restoration and species conservation established in the ERP and MSCS provide a broad set of goals that provide the common vision for the single blueprint concept.

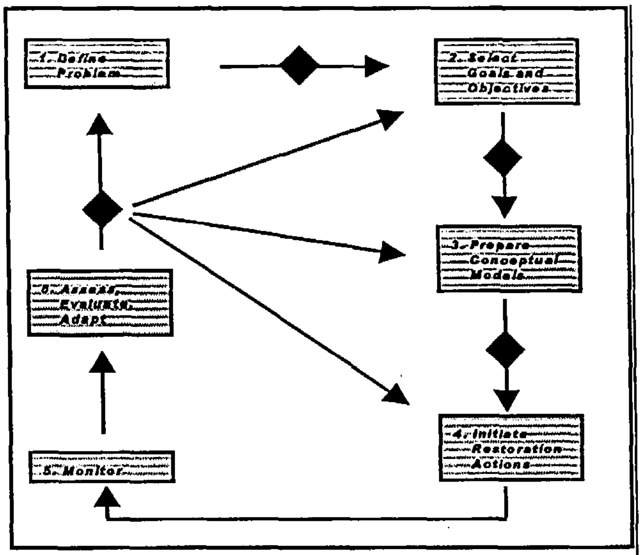
The management framework defines how parties will interact and how management and regulatory decisions will be coordinated and integrated over time. The management framework is designed to foster coordinated and consistent decision making over time. This management framework must be flexible, incorporating and responding to new information and changing Bay-Delta conditions. The framework must be designed to promote coordinated planning, prioritization, and implementation. It must also incorporate provisions for resolving management and regulatory conflicts that may arise.

Benefits of a Single Blueprint

The benefits of a single blueprint approach include the following:

- improved understanding, both of the consequences of certain actions and why specific actions are undertaken;
- increased probability of achieving the desired level of ecosystem health for the Bay-Delta system;
- cost effectiveness;
- avoiding and/or reducing the potential for conflicts that could be counterproductive;
- providing greater management and regulatory certainty; and
- increased support for the program and program funding.

♦ CHAPTER 3. THE ADAPTIVE MANAGEMENT PROCESS



This chapter describes a stepwise procedure that will help incorporate adaptive management in the restoration and management of the Bay-Delta ecosystem. The succeeding discussion describes the steps involved in an adaptive management process, and Figure 3-1 illustrates the process.

DEFINING THE PROBLEM

The first step of an adaptive management process requires clearly defining a problem or set of problems affecting ecosystem health. Defining a problem usually requires determining the geographic bounds of the problem; the ecological processes, habitats, species, or interactions affected by the problem; and the time that the problem affects the ecosystem. Volumes I and II of the ERPP define problems that affect the health of the Bay-Delta ecosystem.

DEFINING GOALS AND OBJECTIVES

Once a problem has been bounded, it is necessary to articulate clear restoration goals and tangible, measurable objectives to provide direction to restoration efforts and to measure progress. Objectives must be tangible and measurable so that progress toward achieving them can be clearly assessed. For example, the following objective statement is too vague: "Improve the quality of habitat for winter-run chinook salmon." By contrast, a more specific statement is: "Restore flows and accessibility of Battle Creek to winter-run chinook salmon spawning within 7 years." Although objectives may sometimes be stated broadly, they must ultimately be made specific through models and hypotheses that translate the objectives into restoration actions.

The Strategic Plan defines broad goals and objectives for the Bay-Delta ecosystem in Chapter 4. Volume II of the ERPP defines targets and programmatic actions for the ecological management zones and units that comprise the larger Bay-Delta ecosystem.

DEVELOPING CONCEPTUAL MODELS

Many resource managers, scientists, and stakeholders interested in the restoration and management of the Bay-Delta ecosystem have *implicit* beliefs about how the ecosystem functions, how it has been altered or degraded, and how various actions might improve conditions in the system. That is, they have simplified mental illustrations about the most critical cause-and-effect pathways. Conceptual modeling is the process of articulating these implicit models to make them explicit.

Conceptual models can provide several benefits. The knowledge and hypotheses about ecosystem structure and function summarized in conceptual models can lead directly to potential restoration actions. They can highlight key uncertainties where research or adaptive probing might be necessary. 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). Conceptual models can also help to define monitoring needs, and they

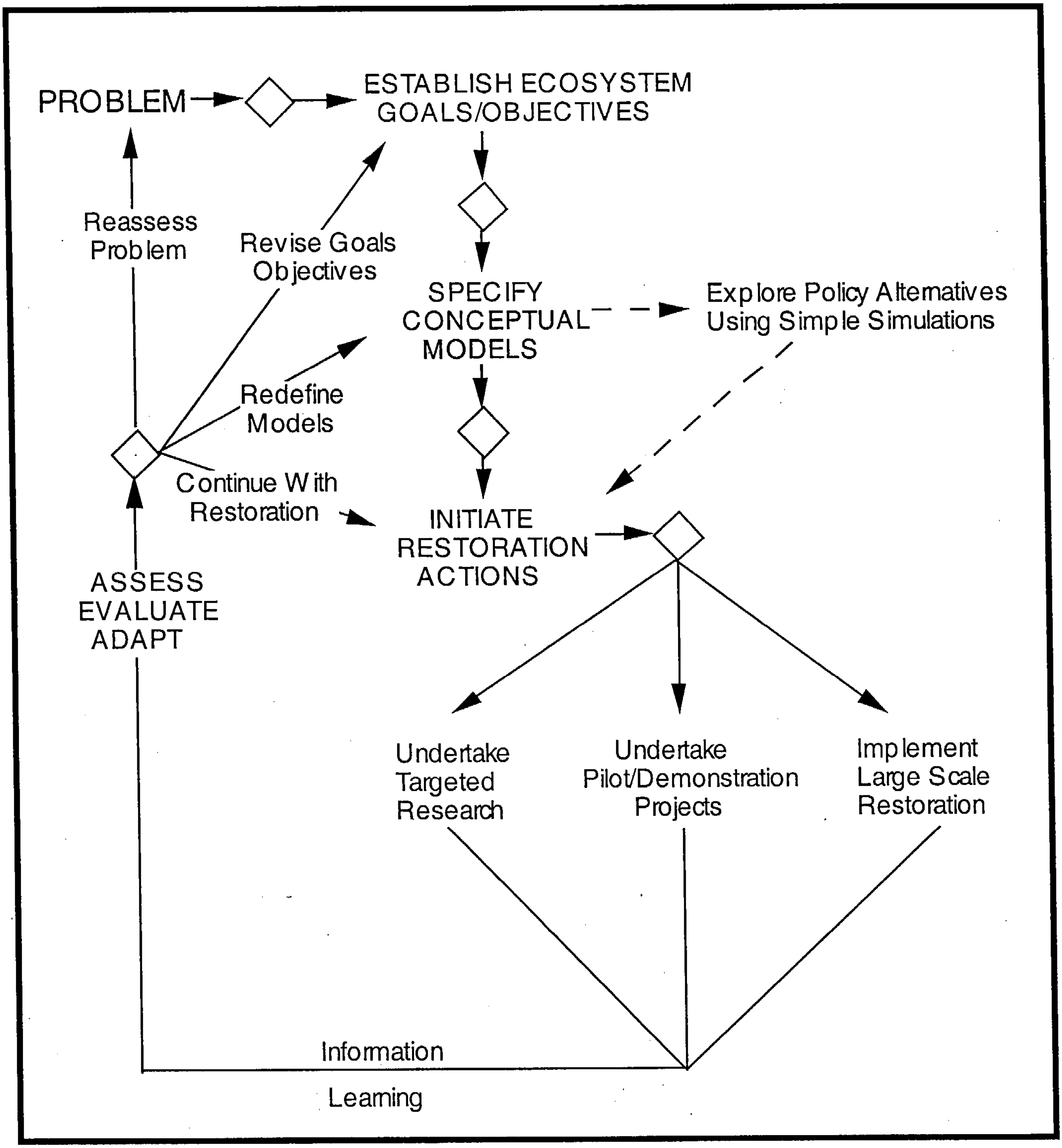


Figure 3-1: Diagram of the Adaptive Management Process.

can also provide a basis for quantitative modeling. Articulating conceptual models can also facilitate dispute resolution since differences between implicit conceptual models often underlie disagreements about appropriate restoration actions.

Conceptual models often suggest many possible restoration actions. In evaluating alternative actions, it is usually very helpful to conduct exploratory simulation modeling based on the conceptual models (Figure 3-1). These simulations are not intended to capture the complexity and richness of ecological processes, but to capture the essential elements of ecological structure and function that underlie management decision making. They are greatly simplified, clear caricatures of the system, just as the conceptual models are clear caricatures. Their purpose is to allow explicit exploration of the main pathways of causal interaction and feedback processes in the conceptual models and provide preliminary predictions of the consequences of different management actions. The simple simulations can aid the decision-making process in many ways. For example, simulation modeling can:

- identify logical inconsistencies in the conceptual models,
- clarify where the nodes of greatest uncertainty are in the conceptual models and where new information would be most useful to decision making,
- allow comparison of the benefits and costs of alternative models of the system and alternative management actions,
- provide a basis for determining how much of a particular kind of restoration action will be required to achieve measurable benefits within a specified period of time,
- provide a basis for determining the value to the ecosystem of new information that might be obtained through adaptive experimentation, and
- help communicate to a broader audience the current understanding of the problem and the explicit rationale for particular restoration measures or targeted research.

> **Developing Conceptual Models**
>
> **Conceptual modeling:** the process of articulating implicit models (simplified mental illustrations about the most critical cause-and-effect pathways) to make them explicit
> - summarize knowledge and hypotheses about ecosystem structure and function
> - highlight key uncertainties where research or adaptive probing might be necessary
>
> **Exploratory Simulation Modeling:** to allow explicit exploration of the main pathways of causal interaction and feedback processes in the conceptual models
> - greatly simplified, clear caricatures of the system
> - provide preliminary predictions of the consequences of different management actions
>
> **Quantitative Modeling:** to refine conceptual models or simulation models themselves when a more detailed evaluation of potential alternatives is required

Quantitative modeling may also be a helpful tool to refine conceptual models or simulation models themselves when a more detailed evaluation of potential alternatives is required (Figure 3-1).

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 those changes, thereby paving the way toward changes in management. This will not happen by itself but must be accomplished through a systematic, periodic (e.g., every 3 years) reevaluation of the conceptual models.

An Example of Conceptual Models

There is no recipe for developing conceptual models; nor is there a template for what they should look like. There is no unique set of conceptual models that provides a basis for ecosystem restoration and that can be determined deductively. Conceptual models should be designed for a particular purpose and should contain only those elements relevant to solving a particular problem, including alternative explanations that might yield alternative solutions. The models presented below and in Appendix B are, therefore, simply illustrations of such models and their uses

This section provides an explicit example of a conceptual model (the effects of freshwater flow on fish and invertebrates in the upper estuary) to illustrate the ways such models can be used. Several additional examples of conceptual models are described in Appendix B. The models presented here and in the appendix cover the hierarchy of spatial scales important to ecological restoration, from the landscape scale to the scale of specific ecological processes.

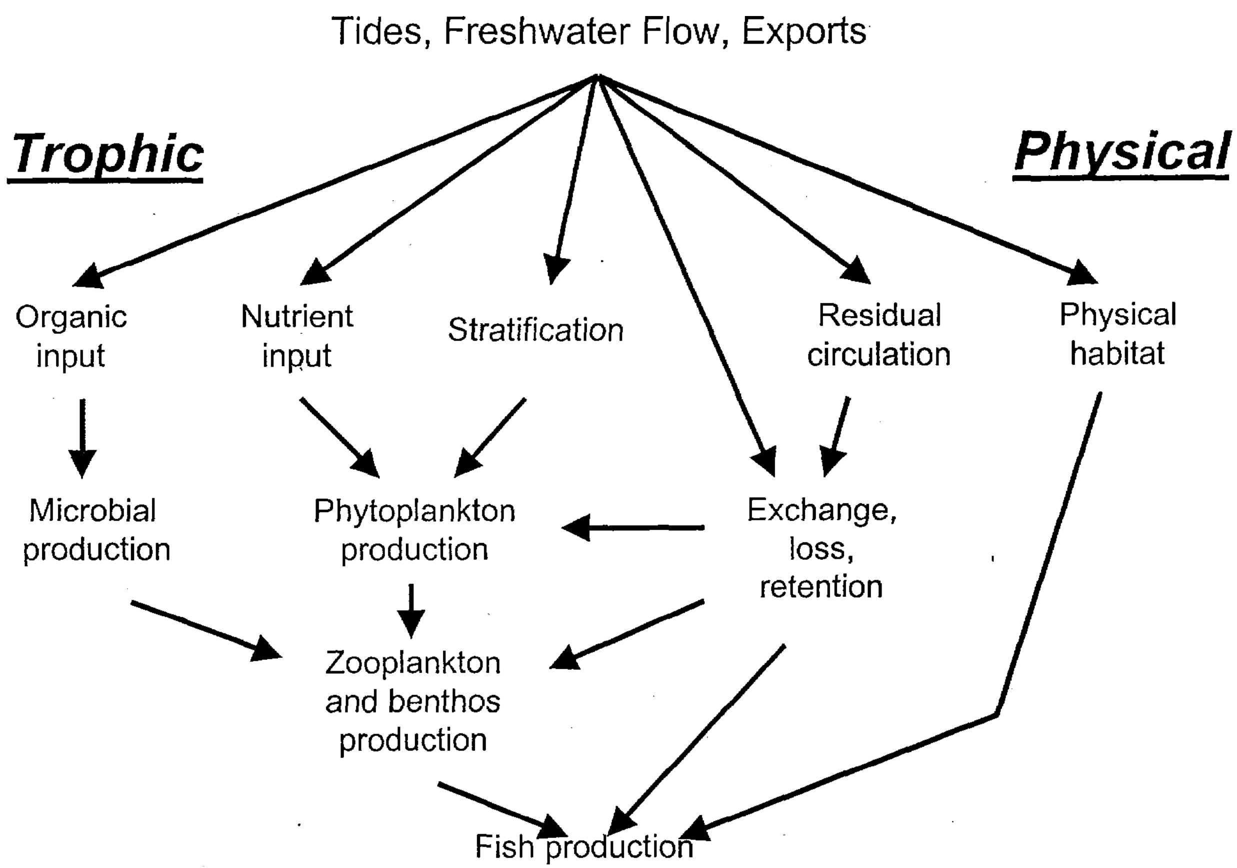
In the "Fish-X2" relationships (Jassby et al. 1995), abundance or survival of several estuarine and anadromous species is related to X2, the distance up the axis of the estuary at which daily average near-bottom salinity is 2 practical salinity units (psu). Because X2 is controlled by freshwater outflow from the Delta, it varies with both inflow and export flows. However, the relationship is entirely empirical and provides no indication of the mechanism controlling abundance or survival. The principal issue addressed here is how different concepts of the mechanism underlying the Fish-X2 relationship define different management tools for maintaining or enhancing populations of estuarine species.

Figure 3-2 illustrates the diverse mechanisms that could account for the X2 relationship for different species. The principal causative variables are freshwater flow and exports, both controllable at least to some extent, and tides, which are not under human control. Briefly, the relationships could arise (as similar ones do in estuaries in other parts of the world) as a result of stimulation of growth at the bottom of the food chain, which then propagates upward, eventually to fish. On the other hand, evidence from this estuary suggests that two kinds of direct physical effects on fish are the more likely mechanisms (Kimmerer 1998). First, flow conditions in the estuary set up by tides and freshwater input, and in some cases by export flows, may alter the retention of some species in the estuary, thereby affecting population size. Second, the amount of physical habitat may change with freshwater flow through such effects as inundation of floodplains or expansion of low-salinity shallow water habitat.

Now consider how potential management interventions are affected by these three scenarios. If the mechanism is stimulation at the base of the food chain, appropriate management actions include addition of nutrients or organic matter to the estuary. If retention is the issue, flows could be manipulated to lengthen or shorten the period of retention in the estuary. If habitat is the issue, physical restoration of habitat or judicious use of flow to increase the amount of habitat at critical times might be in order.

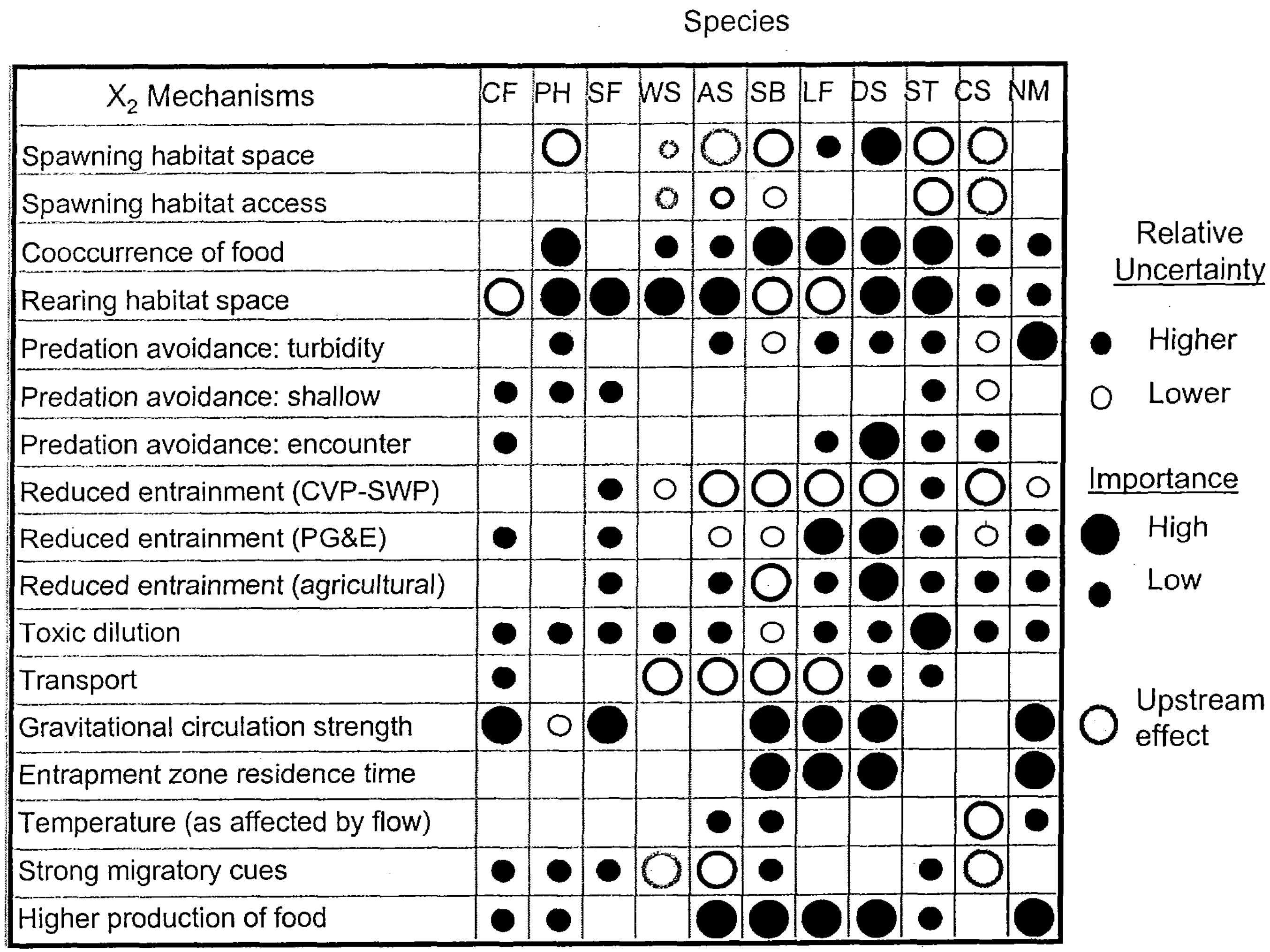
Thus, a very simple model illustrates how critically the management options depend on the assumed cause-and-effect mechanism as well as how various kinds of management interventions can be suggested by a conceptual model. To provide further detail, we use part of the Estuarine Ecology Team's report on the Fish-X2 relationships (Estuarine Ecology Team 1997). That report included a matrix (Figure 3-3) that summarized knowledge about each of the potential mechanisms underlying the Fish-X2 relationships. For each mechanism and each species, the importance of the mechanism is denoted by the size of the symbol. In addition, open symbols denote mechanism for which there is some scientific information, and closed symbols denote mechanisms about which virtually nothing is known.

Each of the mechanisms has a precise definition (Estuarine Ecology Team 1997), but we consider only a few of them here. First, examine the row labeled "Reduced Entrainment (CVP-SWP)." In addition to a number of smaller symbols, large open symbols are given for all the anadromous species except for splittail. Thus, the Estuarine Ecology Team believed that for these species, entrainment could explain at least part of the observed Fish-X2 relationships. Now examine the row labeled "Gravitational Circulation Strength." There are six large filled circles, including those for species that recruit from the ocean as well as several for those that move down-estuary during development and then reside primarily in Suisun or San Pablo Bay and the Delta. In this case, the



Note: The labels "trophic" and "physical" indicate that causative pathways on the left side of the diagram are more biological, based on feeding relationships, whereas those on the right side describe mechanisms that arise through interactions with physical conditions and abundances of species of interest. Tides, freshwater flow, and exports influence organic and nutrient inputs, stratification and gravitational circulation, and the extent of physical habitat with various characteristics. Organic and nutrient input can stimulate growth at the bottom of the food web, which may progress to higher trophic levels, such as fish. Export flow, together with residual and tidal circulation in the estuary, may interact with behavior to affect losses from the estuary or, alternatively, retention. Thus, fish may benefit from increased flow through increased food supply, improved retention in their habitat, or an increase in the quantity or availability of physical habitat.

Figure 3-2: Schematic Diagram Showing Potential Causative Pathways Underlying the "Fish-X2" Relationships



Note: Symbols indicate a potential mechanism according to the key at right. Several minor mechanisms have been eliminated to simplify the diagram. "Upstream" effects refer to flow effects that occur entirely upstream of the Delta. The species abbreviations are defined as follows:

CF = bay shrimp, *Crangon franciscorum*
PH = Pacific herring
SF = starry flounder
WS = white sturgeon
AS = American shad
SB = striped bass
LF = longfin smelt
DS = delta smelt
ST = splittail
CS = Chinook salmon (note: few major effects are in the Delta)
NM = *Neomysis* and other mysids

Figure 3-3: Estuarine Ecology Team's Summary of Potential Causes Underlying "Fish-X2" Relationships team believed gravitational circulation to be an important mechanism although there was virtually no specific information on its effects. Similarly, "Rearing Habitat Space" was considered an important probable mechanism for the largest number of species although knowledge of this topic is limited. In these latter two examples, the Estuarine Ecology Team was exercising professional judgment in the absence of hard scientific information. Similar kinds of judgments will have to be made in decisions about ecological restoration. However, by employing adaptive management, we will be able to design restoration and management actions that allow us to learn about the mechanisms governing ecological function and species abundance while restoration is proceeding.

DEFINING RESTORATION ACTIONS

Conceptual models help to shape the character of restoration actions by identifying key uncertainties or by revealing the level of confidence that a particular action will achieve a given objective. Three types of management actions can be selected for implementation (Figure 3-1). **TARGETED RESEARCH** may be necessary to resolve critical issues about ecosystem structure and function that preclude us from even defining problems adequately. **PILOT OR DEMONSTRATION PROJECTS** can help to determine the practicality or effectiveness of restoration actions, allowing resource managers to evaluate alternative actions or build confidence in the ability of a particular action to achieve an objective. For those restoration actions about which we are reasonably confident will achieve an objective, we can begin **FULL-SCALE IMPLEMENTATION.**

These three types of actions are not mutually exclusive, and all might be used to address a particular problem. Furthermore, they are a set of options and not necessarily progressive.

MONITORING RESTORATION ACTIONS

It is critical to monitor the implementation of restoration actions to gauge how the ecosystem responds to management interventions. Monitoring provides the data necessary for tracking ecosystem health, for evaluating progress toward restoration goals and objectives, and for evaluating and updating problems, goals and objectives, conceptual models, and restoration actions. Monitoring requires measuring the abundance distribution, change or status of ecological indicators.

Ecological indicators are measures of ecological attributes, populations, or processes that can be measured. Indicators include:

- response variables, such as abundance of important species, used to assess trends and measure progress;
- input variables that can be manipulated directly, such as salinity and temperature;
- summaries of habitat characteristics, such as dimensions of river meanders or area of tidal marsh habitat, that indicate progress toward a goal;
- other variables, such as birth, survival, or migration rates, that can be used to interpret the other data and assess the effects of particular manipulations; and
- intermediate variables that may help to understand the trajectory of response variables and some of which might eventually serve to indicate ecosystem condition (e.g., primary or secondary production, inputs or turnover rate of organic carbon or nutrients, or aspects of foodweb structure).

Ecological indicators should based on goals and objectives, and on important elements of conceptual models. Indicators will need to be reevaluated as the system develops and as models change.

EVALUATING AND REVISING PROBLEMS, CONCEPTUAL MODELS, AND RESTORATION GOALS, OBJECTIVES, TARGETS AND ACTIONS

As we learn more about the ecosystem, it is important that this new information feed back into the planning and management process. Problems, conceptual models, goals, objectives, quantified targets, and the restoration actions that flow from them must be re-evaluated and, if needed, revised to reflect the most current information. Such re-evaluation and revision is essential to ensure that the restoration program is achieving its objectives efficiently and to prevent wasting resources upon restoration actions that do not contribute toward achieving objectives.

To better define restoration objectives, the ERP should specify quantitative restoration targets, as best as possible. The ERP has yet to complete this important task. A process for setting, evaluating, and revising restoration targets needs to be developed. This process should be science-based, using the best available scientific information and judgement through the CALFED Science Program and the independent scientific review process.

PROPOSED ERP TARGET SETTING, EVALUATION, AND REVISION PROCESS

The process proposed here would be used to evaluate and refine existing targets, set targets for program objectives and elements without quantitative targets, and future target evaluation and refinement through the adaptive management process.

STEP 1: Initial evaluation of existing ERP targets for strategic objectives and ecosystem elements.

- Step 1A: Proposed ERP Science Board, or an equivalent independent scientific review panel, evaluates existing quantified targets in the ERPP and classifies them into three categories: (1) stated target has sufficient scientific basis and stated justification or rationale is sufficient; (2) stated target has sufficient scientific basis but stated justification insufficient; (3) stated targets needing revision (i.e., insufficient scientific basis). Steps 1A and 1B conducted concurrently.
- Step 1B: Staff (CALFED or combined CALFED/agency/stakeholder staff) identify strategic objectives and ecosystem elements without quantified targets. Steps 1A and 1B conducted concurrently.
- Step 1C: Science Board develops priority list of strategic objectives and ecosystem elements for target setting (i.e., those without targets), target revision, and additional target justification (based on information from Steps 1A and 1B). Identifying objectives and elements for which there is currently insufficient scientific information to establish targets, and the required information needs (and perhaps actions to provide needed information), would be included in this step.

STEP 2: Provide additional scientific justification for targets with sufficient scientific basis.

For targets determined by the Science Board to be scientifically sound (i.e., sufficient scientific basis) but lacking sufficient justification, staff (CALFED or combined CALFED/agency/stakeholder staff) and/or consultants would write scientific justification. Step 2 would be performed concurrent with Step 3.

STEP 3: Establish and revise targets by topic area.

For objectives and elements without existing quantitative targets or with existing targets needing revision, small technical teams would establish or revise targets and provide justifications for sets of objectives and elements by topic area (e.g., fish species, fluvial geomorphic processes, Delta wetland and aquatic habitats). Technical team composition: A team for each topic area or category composed of three to five environmental scientists and managers with expertise in the that topic. The Science Board, in consultation with ERP, agency, and stakeholder staff, would establish topic areas and select team members. The Science Board would provide scientific guidance and oversight for the teams. Staff would provide team administrative support and day-to-day management. For each objective/ element topic area, the product of this step would be proposed targets based on best current scientific information (i.e., report presenting proposed targets and scientific justification). For targets that can not be determined because sufficient scientific information is currently lacking, identify scientific information needs and related actions (research, modeling, monitoring). Step 3 would be performed concurrent with Step 2.

STEP 4: Scientific review of proposed targets.

Step 3 products (proposed targets and scientific justifications) would be reviewed by the Science Board and made available for review and comment by agency and stakeholder environmental scientists and managers. These reviews could be sequential with revisions after the Science Board and before broader review, or concurrent with revisions after all comments.

STEP 5: Policy level review and establishment of targets.

- Step 5A: Ecosystem Roundtable review, comment, and recommendations on proposed scientifically based targets. Recommendations should include policy justification.

- Step 5B: CALFED Management Team and Policy Group (or future CALFED/ERP governing entity) consideration of proposed scientifically based targets and Ecosystem Roundtable recommendations. Final policy review, revision, and establishment of targets.

DECISION NODES

Adaptive management includes several crucial decision nodes (Figure 3-1) that have the potential to be bottlenecks. Decisions about which projects to implement and which to postpone, when to gather more information and when to proceed with large-scale restoration, when to terminate projects and when to change direction, and when to declare the success or failure of a particular intervention are difficult and contentious. Although rigorous data analysis and modeling can help with these decisions, they cannot determine the decisions. Efficient progress in adaptive ecological restoration will depend on having institutional arrangements that facilitate effective communication and decision making. A significant element of subjectivity in decisions about whether to proceed will always exist. Open discussion may help to resolve many contentious issues and decisions; nevertheless, in such a large, complex public program there will always be a need for a formal dispute resolution process.

The bottleneck in decision nodes is also important for regulatory compliance. Many of the decision points in the adaptive management system will require state and federal agency approvals for actions recommended by the adaptive management process. Early identification of the decision points requiring public agency approvals can reduce the potential for delays resulting from a disconnect between the adaptive management process and applicable regulatory requirements. Adaptive management decisions made within a regulatory context also will be less vulnerable to challenges.

♦ CHAPTER 4. GOALS AND OBJECTIVES

DEVELOPMENT OF CALFED PROGRAM MISSION AND OBJECTIVES

In the scoping phase of the CALFED Program in 1996, stakeholders and agency staff developed a mission statement, objectives for four problem areas (ecosystem quality, water quality, water supply reliability and levee system integrity) and solution principles to guide the development and implementation of the Program (Figure 4-1). A series of sub-objectives were developed for CALFED's ecosystem quality objective. These sub-objectives guided the development of implementation objectives that were incorporated into the 1997 version of the ERPP. As the ERP became more specific in its approach and proposed actions, it became apparent that the CALFED objective for ecosystem quality and the implementation objectives did not provide enough specificity or direction.

In 1998, CALFED Program and agency staff, the BDAC Ecosystem Restoration Work Group and the Core Team developed the six goals which were presented in the June 1999 version of the Strategic Plan for Ecosystem Restoration. The six goals were reviewed by the Ecosystem Restoration Program Focus Group and minor revisions made in June 2000. The goals are considered final and are not intended to change. For each goal, the Core Team also developed a draft set of objectives. In revising the goals, the ERP Focus Group also revised the objectives to be consistent with the Multi-Species Conservation Strategy. The ERP Focus Group also added rationales that clarified the objectives. Some of the rationales had been prepared originally by the Core Team, but some were created by the Focus Group.

CALFED ECOSYSTEM RESTORATION GOALS

This document is a guide for achieving a reasonable level of *ecosystem quality* for the Bay-Delta system in a way that reduces conflicts among beneficial uses of California's water. The key term "ecosystem quality" is not well defined but it presumed to equate to "ecosystem health" and "ecosystem integrity" (e.g., Woodley et al. 1993). All of these terms imply the desirability of ecosystems that not only will maintain themselves through natural processes with the minimal human interference possible but also will be aesthetically attractive and produce goods and services in abundance for humans.

The ERP goal statements below provide the basis for a vision of a desired future condition of the Bay-Delta system. Basically, they lead to a definition of what is meant by "ecosystem quality" as applied to the Bay-Delta system. CALFED's goals for ecosystem restoration (referred to in the ERPP as "Strategic Goals"), developed by a diverse group of representatives from CALFED agencies, academia and the stakeholder community, are as follows:

1 Achieve recovery of at-risk native species dependent on the Delta and Suisun Bay as the first step toward establishing large, self-sustaining populations of these species; support similar recovery of at-risk native species in the Bay-Delta estuary and the watershed above the estuary; and minimize the need for future endangered species listings by reversing downward population trends of native species that are not listed.

2 Rehabilitate natural processes in the Bay-Delta estuary and its watershed to fully support, with minimal ongoing

RELATIONSHIP OF CALFED MISSION, OBJECTIVES AND SOLUTION PRINCIPLES TO ERP GOALS AND OBJECTIVES

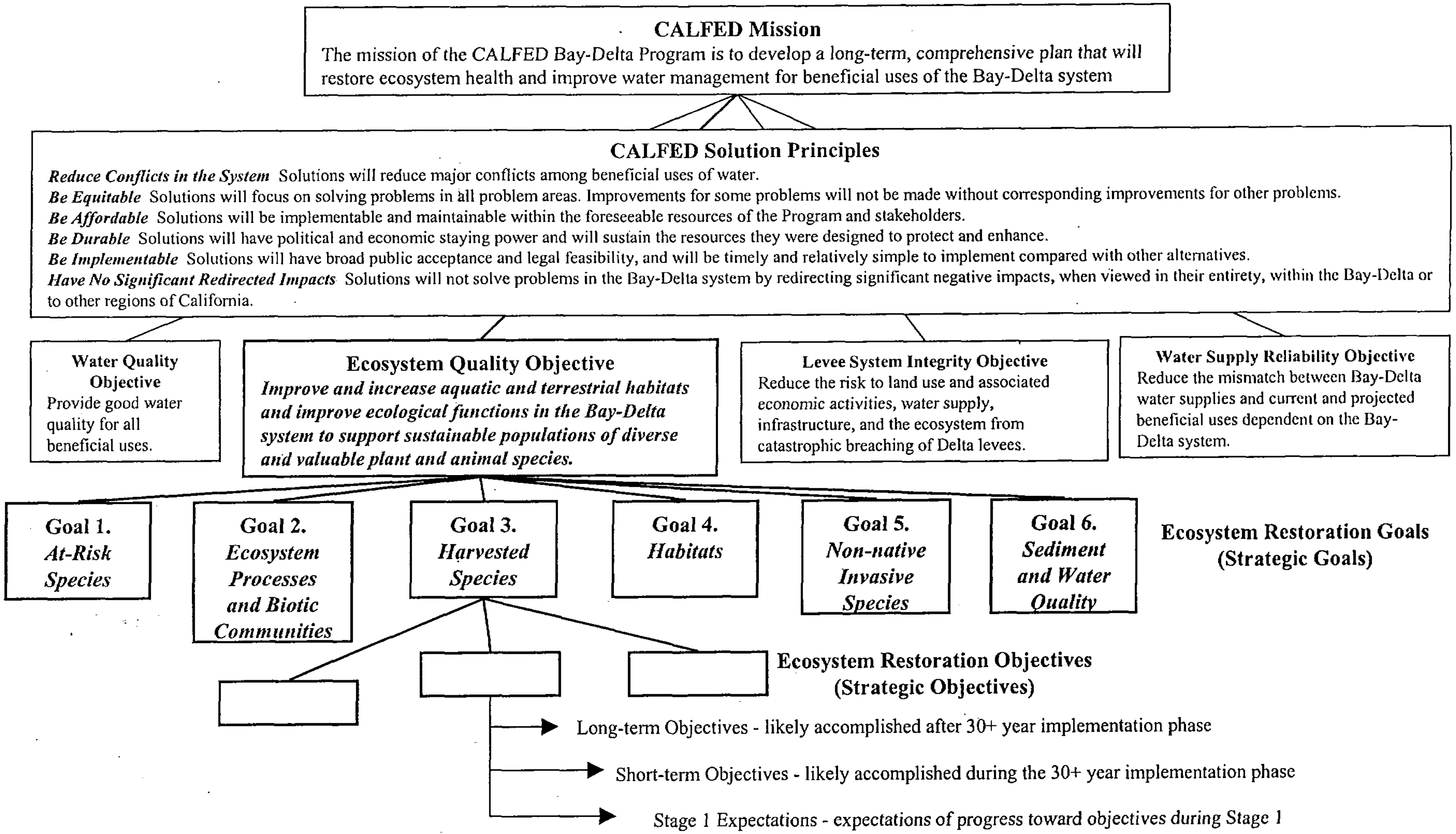


Figure 4-1: Relationship of CALFED Mission, Objectives and Solution Principles to ERP Goals and Objectives

human intervention, natural aquatic and associated terrestrial biotic communities and habitats, in ways that favor native members of those communities.

3 Maintain and/or enhance populations of selected species for sustainable commercial and recreational harvest, consistent with the other ERP strategic goals.

4 Protect and/or restore functional habitat types in the Bay-Delta estuary and its watershed for ecological and public values such as supporting species and biotic communities, ecological processes, recreation, scientific research, and aesthetics.

5 Prevent the establishment of additional non-native invasive species and reduce the negative ecological and economic impacts of established non-native species in the Bay-Delta estuary and its watershed.

6 Improve and/or maintain water and sediment quality conditions that fully support healthy and diverse aquatic ecosystems in the Bay-Delta estuary and watershed; and eliminate, to the extent possible, toxic impacts to aquatic organisms, wildlife, and people.

What Are the Goals Designed to Achieve?

First, the goals reflect a desire for ecosystems that are not continually being disrupted by unpredictable events, such as the invasion of non-native species capable of altering ecosystem processes, massive levee failures, or the collapse of populations of native species. The ecosystems should be dynamic but function within known limits, be resilient in the face of severe natural conditions, and be capable of changing in a more or less predictable fashion in response to global climate change.

Second, the goals reflect the desire for ecosystems that incorporate humans as integral parts of them, as managers, participants, and beneficiaries. According to this description, the ecosystems under the purview of CALFED are not "natural" ecosystems in which humans are primarily observers. Instead, they are systems that continue to be altered by human activity, but in a less harmful way; they include people who live and make a living in them; and they produce products that benefit the larger society, such as water, power, and food.

Third, the goals reflect a desire for ecosystems that maintain substantial self-sustaining populations of the remaining native species and some high-value non-native species (e.g., striped bass, crayfish), with large numbers of species with high cultural, symbolic, or economic value (e.g., salmon, raptors, tules).

Fourth, the goals reflect a desire for a landscape that is aesthetically pleasing and that contains large-scale reminders of the original "primeval" ecosystem, such as salt marshes, tidal sloughs, and expanses of clean, open water.

Fifth, the goals recognize that the ecosystems that will result from CALFED actions will be unlike any ecosystems that have previously existed. They will be made up of mixtures of native and non-native species that will interact in an environment in which many of the basic processes have been permanently altered by human activity and will continue to be regulated by humans. At the same time, the templates for the new ecosystems are the tattered remnants of the original systems and the natural processes that made these systems work.

Goal 1: At-Risk Species

Achieve recovery of at-risk native species dependent on the Delta and Suisun Bay as the first step toward establishing large, self-sustaining populations of these species; support similar recovery of at-risk native species in the Bay-Delta estuary and its watershed; and minimize the need for future endangered species listings by reversing downward population trends of native species that are not listed.

The conflict between protecting endangered species and providing reliable supplies of water for urban and agricultural uses was a major factor leading to the formation of CALFED. "At-risk species" are those native species that are either formally listed as threatened or endangered under state and federal laws or have been proposed for listing. The goal places highest priority on restoring populations of at-risk species that most strongly affect the operation of the State Water Project and Central Valley Project diversions in the south Delta, such as Delta smelt, all runs of chinook salmon, steelhead trout, and Sacramento splittail. The goal gives highest priority to the legal recovery of species formally listed under the federal and California Endangered Species Acts (ESAs) because of the high degree of legal protection given the species, especially under federal law.

The ERP also supports actions that will lead to the restoration of large, self-sustaining populations of these endangered species and encourages and supports restoration of populations of species whose listing has less direct impacts on water diversions from the estuary, such as salt marsh harvest mouse (marshes in San Francisco Bay) and yellow-billed cuckoo (riparian areas along the Sacramento River). Because many other native species, especially aquatic species, are also in long-term decline, the ERP overall seeks to create conditions in the estuary and watershed that increase the distribution and abundance of native species or at least stabilize populations so that trends toward endangerment and extinction are halted.

Although the overall goal of the ERP is ecosystem rehabilitation, it is highly appropriate that native species be a major focus of the rehabilitation efforts for the following reasons:

- The federal and State ESAs mandate recovery of species, but because there are often multiple at-risk species in a region, ecosystem recovery is usually necessary for achieving recovery of all the species.
- The habitats that make up the ecosystem contain mixtures of native and non-native species, and often the non-native species are part of the reason for declines of the native species (see goal 5).
- Although ecosystem recovery can be difficult to assess, the abundance and distribution of multiple sensitive native species are easier to determine and can indicate whether or not ecosystem processes have recovered.

GOAL 2: ECOSYSTEM PROCESSES AND BIOTIC COMMUNITIES

Rehabilitate natural processes in the Bay-Delta estuary and its watershed to fully support, with minimal ongoing human intervention, natural aquatic and associated terrestrial biotic communities and habitats, in ways that favor native members of those communities.

This goal recognizes that an ecosystem restoration plan must include restoration and maintenance of ecosystem processes, such as seasonal fluctuations in flow of streams and salinity of the estuary, cycling of nutrients and predator-prey dynamics, to support natural aquatic and associated terrestrial biotic communities. Biotic communities are dynamic assemblages of interacting species that occupy a common environment and share similar physiological tolerances. Ecosystem processes in natural biotic communities vary within predictable bounds. Excessive variation beyond these bounds is a symptom of poor ecosystem "health," often caused by disruptions such as introduction of exotic species or shifts in flow patterns. Particular assemblages of organisms within defined sets of conditions (the biotic communities) therefore become indicators that the ecosystem is functioning in ways regarded as desirable. For example, if the system is managed to sustain high-flow events in March and April, conditions may favor a suite of native fishes (e.g., splittail, hitch, chinook salmon) that respond positively to the increase in shallow-water habitat by flooding. Two key aspects of this goal are (1) to have self-sustaining biotic communities that will persist without continual high levels of human manipulation of ecosystem processes and species abundances and (2) to have communities in which the dominant species, as much as possible, are native species.

This goal emphasizes rehabilitation rather than restoration because so many of the physical and chemical processes in the watershed have been fundamentally altered by human activity. Dams, diversions, levees, and changing patterns of land use have altered the way water, sediments, nutrients, and energy cycle through the system. These changes, largely irreversible within human time scales, set constraints on the nature of the biotic communities that can be maintained. They will allow rehabilitation of ecosystem functioning in ways we find desirable but not restoration of the communities to some pristine state.

GOAL 3: HARVESTED SPECIES

Maintain and/or enhance populations of selected species for sustainable commercial and recreational harvest, consistent with the other ERP strategic goals.

This goal recognizes that maintaining some species in numbers large enough to sustain harvest by humans is important, even if the species are non-native. For native species such as chinook salmon, steelhead, and splittail this means maintaining populations at levels considerably higher than those required to keep them from going extinct. For non-native species such as striped bass, signal crayfish, and channel catfish, this means managing populations at harvestable levels but only as long as such management does not interfere with the restoration of large populations of endangered native fishes or disrupt the structure and function of established, desirable biotic communities.

This goal neither precludes nor encourages hatchery programs to enhance populations of sport and commercial fishes. However, hatchery programs that enhance populations of top predators in the Bay-Delta system are likely to have negative effects on other species. The goal refers to "selected" species because some species that may be harvested (e.g., *Corbicula* clams) are also nuisance species whose populations should be reduced. The species selected for harvest management must be chosen in ways that recognize that the species regarded as harvestable vary considerably among ethnic groups and can change with time. For example, most native cyprinids (e.g., splittail, blackfish, hitch) are held in high regard by many people of Chinese heritage even though they are disdained by many anglers of European heritage.

GOAL 4: HABITATS

Protect and/or restore functional habitat types in the Bay-Delta estuary and its watershed for ecological and public values such as supporting species and biotic communities, ecological processes, recreation, scientific research, and aesthetics.

Habitats are usually defined through some combination of physical features and conspicuous or dominant organisms, usually plants (e.g., salt marsh and riparian forest). Plants are often highly visible natural features and have important roles in the function of the ecosystems of which they are part (e.g., salt marshes can fix large amounts of carbon, which may cycle through the entire system). The ERPP (Volume I) identifies major habitat types in the estuary and watershed, and Moyle and Ellison (1991) identify, at a finer scale, freshwater habitat types. By definition, different habitats support different species or combinations of species and play different roles (usually poorly understood) in the dynamics of the Bay-Delta system. It therefore becomes important to protect and restore large expanses of the major habitat types identified in the ERPP and at least representative "samples" of other habitat types as identified by Moyle and Ellison (1991) and others.

Many direct benefits arise from protecting a wide array of habitats, including the recovery of endangered species and the production of economically important wild species (e.g., fish and ducks). Equally important are the aesthetic values of natural landscapes containing mosaics of habitats. Less appreciated, but also important, are the ecosystem services provided by natural habitats, such as purification of water and air and delivery of nutrients to systems producing fish and other economically important aquatic organisms (Daily 1997).

GOAL 5: NON-NATIVE INVASIVE SPECIES

Prevent the establishment of additional non-native invasive species and reduce the negative ecological and economic impacts of established non-native species in the Bay-Delta estuary and its watershed.

This goal is arguably part of the first four goals because protecting and enhancing species, communities, and habitats in an estuary and its watershed implicitly includes reducing the impact of non-native invasive species. However, the introduction of new species into the system is still occurring so frequently, and the potential for ecological damage by further invasions is so high, that the necessity for halting (not just reducing) further introductions needs to be emphasized. Hobbs and Mooney (1998) document how invasions by non-native species are a major ecological force for change in California. Cohen and Carlton (1998) have labeled the San Francisco estuary as the most invaded estuarine ecosystem in the world and document the accelerating rate at which new species continue to become established, mostly as the result of their deliberate release through the dumping of ballast water of ships. Other sources include illicit introductions by anglers (e.g., northern pike) and aquarists (e.g., *Hydrilla*). This problem needs to be dealt with quickly and directly because new invading species can negate the effects of millions of dollars spent on habitat or ecosystem restoration. Likewise, already established non-native species, such as water hyacinth and the Asian clam (*Potamocorbula*), continue to have major negative impacts on more desirable species in the system, and methods of control have to be devised. However, control methods must be less harmful to native species than the ecological disruption caused by invading species.

CALFED Nonnative Invasive Species Program

The CALFED Nonnative Invasive Species Program is a new program managed by the US Fish and Wildlife Service with the support of numerous agencies, universities and stakeholder groups. The NIS Program is developing a Strategic Plan for managing nonnative invasive species in the Bay-Delta. The NIS Program has adopted CALFED ERP's Goal 5 as its mission statement and has also identified three goals:

Goal I: Prevent new introductions of NIS into the ecosystems of the San Francisco Bay-Delta, the Sacramento/San Joaquin rivers and their watersheds.

Goal II: Limit the spread or, when possible and appropriate, eliminating populations of NIS through management.

Goal III: Reduce the harmful ecological, economic, social and public health impacts resulting from infestation of NIS through appropriate management.

Please refer to Appendices E and F of this volume for additional information on the NIS Program.

GOAL 6: SEDIMENT AND WATER QUALITY

Improve and/or maintain water and sediment quality conditions that fully support healthy and diverse aquatic ecosystems in the Bay-Delta estuary and watershed; and eliminate, to the extent possible, toxic impacts to aquatic organisms, wildlife, and people.

Similar to the difficulty in solving the problem of introduced species, solving the problems associated with aquatic toxicity could be considered part of the first four goals. However, because toxic effects are pervasive and incompletely understood, developing the needed understanding has been identified as a distinct CALFED goal. This goal is being addressed through the CALFED Water Quality Program in close coordination with the ERP.

Problems associated with toxic substances in the aquatic environment include the following:

- Persistent toxicants such as methyl mercury and PCBs can accumulate and concentrate in the aquatic food web creating health problems for carnivorous fish and for other predator organisms such as raptors and humans. (Most of the organo-chlorine compounds responsible for these effects, such as DDT and PCBs, are now banned, but residues remain in sediments and tissues of organisms.)

- As older organo-chlorine pesticides and PCBs were banned because of their persistence, ability to concentrate in the food web, and harmful biological effects, they were replaced by non-persistent chemicals, some of which are acutely toxic. Residues of these materials from agricultural applications and residential use can enter watercourses and cause temporary toxicity to resident organisms, including those upon which other organisms must depend for food. Though temporary toxicity might have important effect on the aquatic ecosystem, the effects may be too subtle to be easily observed.

- Naturally occurring toxic substances, such as extracellular algal metabolites, can also cause toxic effects that may complicate the ability to distinguish toxicity due to activities of humans.

- Considerable potential exists for ecological disasters caused by large, sudden influxes of toxic materials, such as might be caused by flood-released toxic mine wastes (e.g., Iron Mountain Mine) or by spills of a pesticide carrier (e.g., the Cantara spill on the upper Sacramento River).

- Some toxic materials can accumulate in sediments where they can negatively affect benthic organisms directly and indirectly, the food webs they support. This is an important mechanism for the continuing entry of DDT and related water-insoluble compounds into aquatic food webs, despite many having been outlawed since the 1970s. Some toxicants, such as some metals, cause relatively little environmental damage when left undisturbed in sediment beds but, when disturbed, can undergo chemical transformation into forms that cause toxicity in the aquatic ecosystem.

- Substances once thought to be harmless or not previously identified in the aquatic environment can have harmful effects in subtle ways, such as the potential for chronic, low-level stress resulting in increased susceptibility to disease or predation and reduced growth rates or fecundity (e.g., carcinogens or hormone disrupters). The impact of toxic substances is also an area in which there is high public awareness. Considerable concern exists regarding the risks of consuming harvested organisms or of drinking water from the system.

CALFED ECOSYSTEM RESTORATION OBJECTIVES

Associated with each of the six goals for the ERP is a series of objectives (referred to in the ERPP as "Strategic Objectives") (See Figure 4-2). The strategic objectives are intended to assess progress toward achieving the associated goal. The objectives are stated primarily in terms of management actions designed to have a favorable impact on the Bay-Delta system. However, some are also stated in terms of studies that will teach us how the ecosystem behaves so that principles of adaptive management can be better employed. For either purpose, the objectives must be tangible and measurable (e.g., a net increase in the abundance of a species or a successfully completed experimental study).

Individual objectives in the Strategic Plan and ERPP are (or will be) linked to conceptual models that indicate how they fit into the bigger picture of ecosystem restoration. Implicit in all the long-term objectives (and many of the short-term objectives) is the idea they will be achieved and may be changed through adaptive management. For example, several long-term objectives are designed to achieve numbers or densities of spawning salmon equivalent to those of some time in the past. However, we will not know if such numerical objectives are realistic until one or more regulated rivers have been manipulated on a fairly large scale. One way that the success of achieving objectives may be determined is through the use of indicators that are fairly easy to measure. According to the CALFED Ecological Indicators Work Group, "Ecological indicators translate program goals and objectives into a series of specific measurements that can be used to determine whether the goal and objectives have been met." Some potential indicators are implied or given in the objectives and Stage 1 expectations, but most will have to be developed.

Relationship of ERP Goals, Objectives, Targets and Actions with Simplified Example for Upper Sacramento River Floodplain and Meander Restoration

Strategic Goals (6 presented in the Strategic Plan)

Goals provide the basis for a vision of a desired future condition of the Bay-Delta system

Strategic Objectives (32 presented in ERPP Volume I)

Objectives are specific measures of progress toward meeting the goals. The objectives are based on the best available science, and are not intended to change over time except with new information. Objectives help develop and organize targets and programmatic actions. Objectives are presented for three time frames:

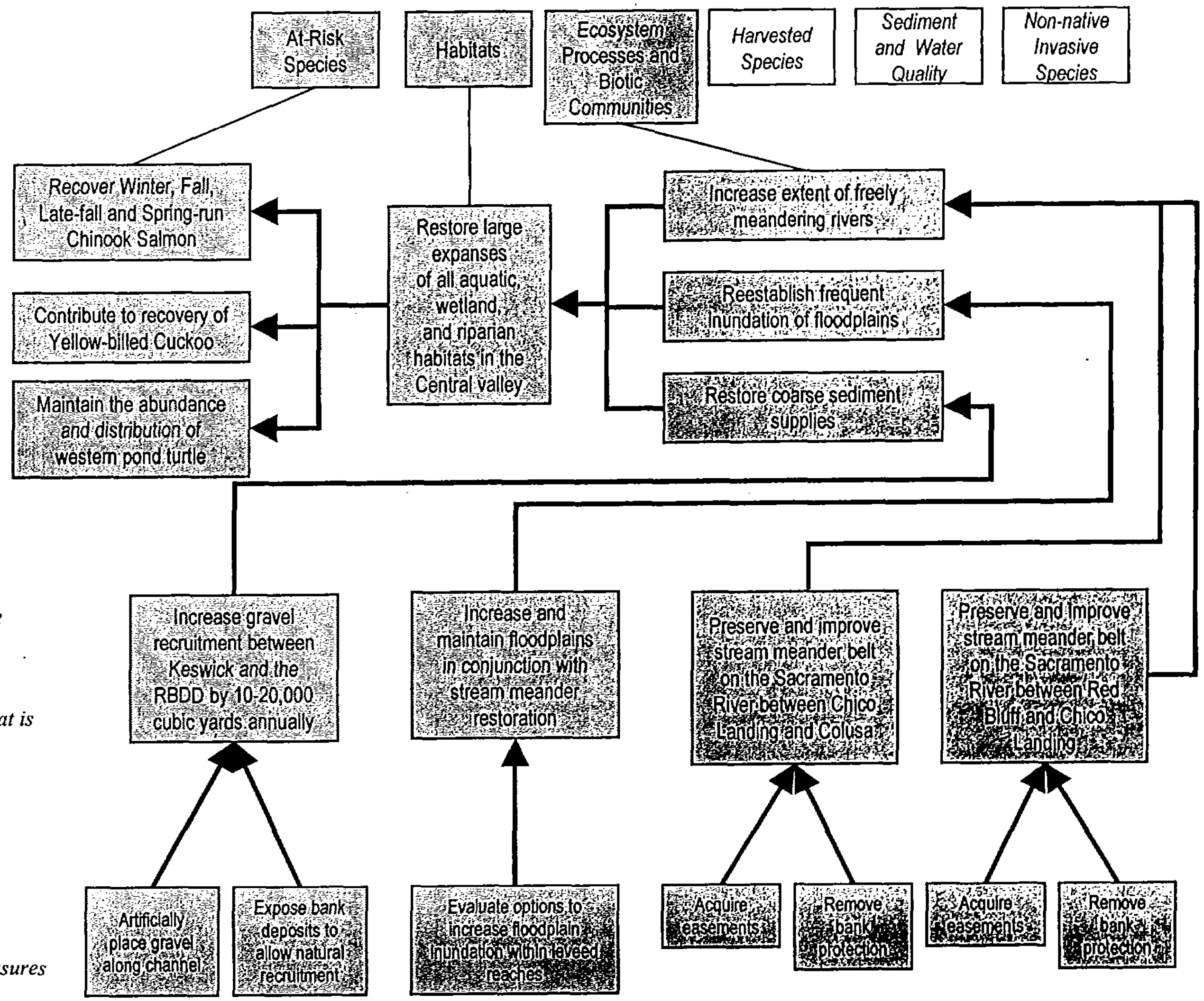
- *Long-term objectives: likely accomplished after 30+ year implementation phase*
- *Short-term objectives: likely accomplished during the 30+ year implementation phase*
- *Stage 1 Expectations: expectations of progress toward objectives during Stage 1*

Targets (over 300 presented in ERPP Volume II)

Targets are quantitative (e.g., a range of numbers) or qualitative (e.g., a narrative description) statements of what is needed in terms of the quality or quantity of desirable ecosystem attributes to meet the objectives. Targets are something to strive for but may change over the life of the program.

Programmatic Actions (over 600 presented in ERPP Volume II)

Programmatic actions are the specific implementation measures required to meet the targets.



This example is described in detail in ERPP Volume II, *Sacramento River Ecological Management Zone Vision.*

Figure 4-2: Relationship of ERP Goals, Objectives, Targets and Actions With Simplified Example for Upper Sacramento River Floodplain and Meander Restoration

The objectives under the six goals often overlap each other broadly or are closely linked. Some may even seem contradictory. Such problems (if they are indeed problems) are inherent in any program designed to make major changes at the ecosystem level. They provide yet another argument for the use of adaptive management as a basic principle to use in implementing restoration programs.

RELATIONSHIP OF GOALS, OBJECTIVES, TARGETS AND ACTIONS

Ecosystem Restoration Goals and Objectives help develop and organize the numerous components of the ERP. Goals provide the basis for a vision of a desired future condition of the Bay-Delta system. Objectives are specific measures of progress toward meeting the goals. Neither the goals nor objectives are intended to change over time except with significant a change in policy direction or new scientific information. In ERPP Volume II, one or more Targets are identified for each objective. Targets are quantitative (e.g., a range of numbers) or qualitative (e.g., a narrative description) statements of what is needed in terms of the quality or quantity of desirable ecosystem attributes to meet the objectives. Targets are something to strive for but may change over the life of the program. Programmatic actions are the specific implementation measures required to meet the targets. Figure 4-2 graphically depicts the relationship of these components.

ERP STRATEGIC GOALS, OBJECTIVES, AND RATIONALES

GOAL 1: ENDANGERED AND OTHER AT-RISK SPECIES, AND NATIVE BIOTIC COMMUNITIES

Achieve recovery of at-risk native species dependent on the Delta and Suisun Bay as the first step toward establishing large, self-sustaining populations of these species; support similar recover of at-risk native 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 native species that are not listed.

OBJECTIVE 1: Achieve, first, recovery and then large self-sustaining populations of the following at-risk native species dependent on the Delta, Suisun Bay, and Suisun Marsh: Central Valley winter-, spring- and fall/late fall-run chinook salmon ESUs, Central Valley steelhead ESU, delta smelt, longfin smelt, Sacramento splittail, green sturgeon, valley elderberry longhorn beetle, Suisun ornate shrew, Suisun song sparrow, soft bird's-beak, Suisun thistle, Mason's lilaeopsis, San Pablo song sparrow, Lange's metalmark butterfly, Antioch Dunes evening primrose, Contra Costa wallflower, and Suisun marsh aster.

RATIONALE: This objective addresses species whose populations are likely to further decline if present trends continue and corresponds to the list of species designated "R" (recovery) in the Multi-Species Conservation Strategy. Most of the species designated "R" are either formally listed as threatened or endangered under State and federal laws or have been proposed for listing and their recovery is dependent on improved habitat conditions and restoration of the Delta and Suisun Marsh and Suisun Bay. These are also species for which CALFED could reasonably be expected to undertake all or most of the actions necessary to recover the species. For species with a recovery plan CALFED will implement all necessary recovery actions within the ERP ecological management zones.

This objective places highest priority on restoring at-risk native fish species that are greatly affected by, and in turn strongly affect, the operation of the State Water Project and Central Valley Project. Anadromous and estuarine fish species populations are especially vulnerable to SWP and CVP export diversions in the south Delta. This objective also accentuates the need to recover at-risk native plants and other wildlife species that would likely be affected by CALFED Program actions.

In the early stages of CALFED implementation it is critical to make significant progress towards improving the population health of the at-risk native species addressed in this strategic objective. Without improved species health it is possible that some CALFED Program actions would not be able to move forward because of the uncertain effects to listed-species populations and the associated regulatory constraints.

This objective also addresses the need for progressive restoration by first working toward recovery of at-risk species dependent on the Delta, Suisun Bay, and Suisun Marsh so that they would no longer need to be listed in order to avoid their extinction. The next step is restoring populations to levels that can be sustained without significant human intervention or the risk of listing in the future. Large self-sustaining populations of species such as chinook salmon would also ensure the concurrent support of healthy commercial and sport fisheries.

OBJECTIVE 2: Contribute to the recovery of the following at-risk native species in the Bay-Delta estuary and its watershed: Sacramento perch, delta green ground beetle, giant garter snake, salt marsh harvest mouse, riparian brush rabbit, San Pablo California vole, San Joaquin Valley woodrat, least Bell's vireo, California clapper rail, California black rail, little willow flycatcher, bank swallow, western yellow-billed cuckoo, greater sandhill crane, Swainson's hawk, California yellow warbler, salt marsh common yellowthroat, Crampton's tuctoria, Northern California black walnut, delta tule pea, delta mudwort, bristly sedge, delta coyote thistle, alkali milkvetch, and Point Reyes bird's-beak.

RATIONALE: This objective corresponds to the list of species designated "r" (contribute to recovery) in the Multi-species Conservation Strategy. For species designated "r", CALFED will make specific contributions toward the recovery of the species for which CALFED actions affect only a limited portion of the species' range and/or CALFED actions have limited effects on the species.

The objective of contributing to a species' recovery implies that CALFED will undertake some of the actions under its control and within its scope that are necessary to recover the species. When a species has a recovery plan, CALFED may implement plan measures that are within the CALFED Problem area, and measures that are outside the Problem Area. For species without a recovery plan, CALFED will need to implement specific conservation measures that will benefit the species.

OBJECTIVE 3: Enhance and/or conserve native biotic communities in the Bay-Delta estuary and its watershed, including the abundance and distribution of the following biotic assemblages and communities: native resident estuarine and freshwater fish assemblages, anadromous lampreys, neotropical migratory birds, wading birds, shore birds, waterfowl, native anuran amphibians, estuarine plankton assemblages, estuarine and freshwater marsh plant communities, riparian plant communities, seasonal wetland plant communities, vernal pool communities, aquatic plant communities, and terrestrial biotic assemblages associated with aquatic and wetland habitats.

RATIONALE: This objective accentuates the importance of conserving all native species assemblages and biotic communities in the Bay-Delta estuary and its watershed. CALFED will undertake actions to conserve and enhance the diversity, abundance and distribution of these biotic assemblages and communities in a manner that contributes to their long-term sustainability, without precluding opportunities to improve conditions for at-risk native species.

OBJECTIVE 4: Maintain the abundance and distribution of the following species: hardhead, western least bittern, California tiger salamander, western spadefoot toad, California red-legged frog, western pond turtle, California freshwater shrimp, recurved larkspur, mad-dog skullcap, rose-mallow, eel-grass pondweed, Colusa grass, Boggs Lake hedge-hyssop, Contra Costa goldfields, Greene's legenere, heartscale, and other species designated "maintain" in the Multi-Species Conservation Strategy.

RATIONALE: This objective includes all of the species designated "m" (maintain) in the Multi-Species Conservation Strategy. These are species that are expected to be minimally affected by CALFED actions. CALFED will ensure that any adverse effects on "m" species are offset commensurate with the level of effect on the species thereby maintaining the condition of the species. At a minimum, CALFED actions will not contribute to the need to list a species or degrade the status of a listed species.

GOAL 2: ECOLOGICAL PROCESSES

Rehabilitate natural processes in the Bay-Delta estuary and its watershed to fully support, with minimal ongoing human intervention, natural aquatic and associated terrestrial biotic communities and habitats, in ways that favor native members of those communities.

OBJECTIVE 1: Establish and maintain hydrologic and hydrodynamic regimes for the Bay and Delta that support the recovery and restoration of native species and biotic communities, support the restoration and maintenance of functional natural habitats, and maintain harvested species.

RATIONALE: The restoration of most, if not all, of the native species and habitats in the Bay-Delta estuary depends on having dynamic hydrologic and hydrodynamic regimes (freshwater inflow, salinity, and Delta water circulation patterns) that approximate the historic regimes in order to create conditions favorable for all phases of the life cycles of the "key" fish species (listed in goals 1 and 3). The principal measure in place today of the suitability of the hydrologic and hydrodynamic regime for key fish species is X2, which indicates the position of the salinity gradient in the estuary.

One area in which the hydrologic regime could be altered to favor native species is the Delta. Before the development of water projects, the Delta was less saline in the spring and more saline in the summer during severe droughts than it is now. Highly variable flow and salinity conditions, including infrequent high-salinity events in the Delta, would therefore presumably favor native over introduced species.

As more is learned about the hydrodynamics of the estuary, especially the importance of the low-salinity zone and restoring flow patterns in Delta channels that support estuarine processes related to the food web and fish spawning, rearing, and migration, direct and indirect modifications of estuarine hydrodynamic and hydrologic regimes (in an adaptive management context) should continue.

OBJECTIVE 2: Increase estuarine productivity and rehabilitate estuarine food web processes to support the recovery and restoration of native estuarine species and biotic communities.

RATIONALE: The abundance of many species in the estuary may be limited by low productivity at the base of the food web in the estuarine ecosystem. The causes of this are complex and not well understood, but may include a shortage of productive shallow-water regions such as marshes, high turbidity in open-water regions of the estuary, and consumption and sequestering of available organic carbon by the Asiatic clam. Solving the problem directly is difficult but presumably other actions taken as part of the ERP, such as increasing the acreage of tidal marshlands, will contribute to the solution. A major obstacle to solving problems of estuarine productivity is our poor understanding, so solutions will have to come from research and monitoring of effects of various ecosystem restoration projects.

OBJECTIVE 3: Rehabilitate natural processes to create and maintain complex channel morphology, in-channel islands, and shallow water habitat in the Delta and Suisun Marsh.

RATIONALE: There is widespread agreement that more shallow water habitat needs to be created in the Delta and that existing shallow water habitat needs to be maintained. However, opinions differ on whether creating more habitat will actually increase abundance of desirable species. Ecosystem-based restoration is predicated on this assumption, but adaptive management demands that it be rigorously tested. Staged implementation will allow an increase in confidence in whether or not habitat restoration in the estuary will result in higher abundance of desirable species. Initially this shallow water habitat will be along Delta and Suisun Marsh channels or on small islands in the channels. Ultimately, much of this shallow water habitat would be associated with the restoration of large expanses of tidal emergent wetland, tidal channels, and tidal perennial wetlands in the Delta and Suisun Marsh (recreating large contiguous blocks of the original channel-marsh system). The desirable physical and biotic characteristics of these habitats may be created artificially at first, but the expectation is that they will be maintained by natural processes (e.g., tidal flux, sediment inputs from upstream).

OBJECTIVE 4: Create and/or maintain flow and temperature regimes in rivers that support the recovery and restoration of native aquatic species.

RATIONALE: Virtually all streams in the region are regulated or otherwise modified to some degree, and the altered flow regimes frequently favor non-native fishes. The native fish assemblages (including those with anadromous fishes) are increasingly uncommon. Recent studies in Putah Creek, the Stanislaus River, and the Tuolumne River demonstrate that native fish assemblages can be restored to sections of streams if flow (and temperature) regimes are manipulated in ways that favor their spawning and survival, usually by having flow regimes that mimic natural patterns in winter and spring but that increase flows during summer and fall months (to make up for loss of upstream summer habitats). Native invertebrates and riparian plants may also respond positively to these flow regimes. Similarly, flow regimes in unregulated (naturally flowing) streams that support the restoration and sustenance of native species must be maintained.

OBJECTIVE 5: Establish hydrologic regimes in streams, including sufficient flow timing, magnitude, duration, and high flow frequency, to maintain channel and sediment conditions supporting the recovery and restoration of native aquatic and riparian species and biotic communities.

RATIONALE: Native aquatic and riparian organisms in the Central Valley evolved under a flow regime with pronounced seasonal and year-to-year variability in magnitude, duration, and timing. Frequent (annual or longer term) high flows mobilized gravel beds, drove channel migration, inundated floodplains, maintained sediment quality for native fishes and invertebrates, and maintained complex channel and floodplain habitats. This objective addresses the rehabilitation of at least some of these ecological processes. A strategy of high-flow releases, in conjunction with natural high-flow events, lends itself well to adaptive management because the flows can easily be adjusted to the level needed to achieve specific objectives. However, it should be recognized that channel adjustments may lag behind hydrologic changes by years or decades, requiring long-term monitoring. Also, on most rivers, reservoirs are not large enough to eliminate extremely large, infrequent events so these will continue to affect channel form at irregular, often long, intervals; artificial high-flow events may be needed to maintain desirable channel configurations created during the natural events. This objective is similar to the previous one but differs in its focus on flows that are likely to be higher than those needed to maintain most native fish species but that are important for maintaining in-channel and riparian habitats for fish as well as other species (e.g., invertebrates, birds, mammals). Experimental flow releases also will have to be carefully monitored for negative effects, such as encouraging the invasion of unwanted non-native species. Natural flow regimes, including high flow frequency, in unregulated streams that support the restoration and sustenance of in-channel and riparian habitats should be maintained.

OBJECTIVE 6: Reestablish floodplain inundation and channel-floodplain connectivity of sufficient frequency, timing, duration, and magnitude to support the restoration and maintenance of functional natural floodplain, riparian, and riverine habitats.

RATIONALE: Frequent (often annual) floodplain inundation was an important attribute of the original aquatic systems in the Central Valley and was important for maintaining diverse riverine and riparian habitats. Important interactions between channel and floodplain include overflow onto the floodplain, which (1) reduces the cutting down of the channel, (2) acts as a "pressure relief valve", permitting a larger range of sediment grain sizes to remain on the channel bed, (3) increases the complexity and diversity of instream and riparian habitats, and (4) stores flood water (thereby decreasing flooding downstream). The floodplain also provides shading, food organisms, and large woody debris to the channel. Floodplain forests serve as filters to improve the quality of water reaching the stream channel by both surface flow and groundwater. This objective addresses the reestablishment of active floodplain inundation needed to support these ecological functions.

OBJECTIVE 7: Restore coarse sediment supplies to sediment-starved rivers downstream of reservoirs to support the restoration and maintenance of functional natural riverine habitats.

RATIONALE: One of the major negative effects of dams is the capture of coarse sediments that naturally would pass on to downstream areas. As a result, the downstream reaches can become sediment starved, producing "armoring" of streambeds in many (but not all) rivers to the point where they provide greatly reduced habitat for fish and aquatic organisms and are largely unsuitable for spawning salmon and other anadromous fish.

OBJECTIVE 8: Increase the extent of freely meandering reaches and other pre-1850 river channel forms to support the restoration and maintenance of functional natural riverine, riparian, and floodplain habitats.

RATIONALE: Freely meandering rivers have the highest riparian and aquatic habitat diversity of all riverine systems. Through the process of meandering, eroding concave banks and building convex banks, the channel creates and maintains a diversity of surfaces that support a diversity of habitats, from pioneer riparian plants on newly deposited point bars to gallery riparian forest on high banks built of overbank silt deposits. Similarly, wandering or braided rivers support distinct habitat types and thus are beneficial to aquatic biota. Floodplain restoration can also increase flood protection for urban areas and increase the reliability of stored water supplies in reservoirs (because reservoirs can be maintained at higher levels because of reduced need to catch flood waters).

GOAL 3: HARVESTED SPECIES

Maintain and/or enhance populations of selected species for sustainable commercial and recreational harvest, consistent with the other ERP strategic goals.

OBJECTIVE 1: Enhance fisheries for salmonids, white sturgeon, pacific herring, and native cyprinid fishes.

RATIONALE: Historically the chinook salmon fishery was one of the most economically valuable and the most culturally significant in California. Central Valley salmon and steelhead stocks have been greatly reduced due to dams and other barriers blocking access to spawning habitat, direct mortality from water diversions, altered stream hydrology and Delta hydrodynamics, direct habitat destruction and degradation, harvest pressure, and other stressors. Enhancing salmon and steelhead fisheries will require a coordinated approach of restoring key habitats and ecological processes and reducing or eliminating stressors. Enhancing the fisheries, especially the inland sport fishery, for winter and spring-run chinook salmon and steelhead will be challenging because available habitat is so limited.

White sturgeon represent an unusual situation: a success story in the management of the fishery for a native species. Numbers of sturgeon today are probably nearly as high as they were in the nineteenth century before they were devastated by commercial fisheries. The longevity and high fecundity of the sturgeon, combined with good management practices of the California Department of Fish and Game (CDFG), have allowed it to sustain a substantial fishery since the 1950s, without a major decline in numbers. Numbers of white sturgeon could presumably be increased if the San Joaquin River once again contained suitable habitat for spawning and rearing.

Pacific herring support the most valuable commercial fishery in San Francisco Bay. An important connection to the ERP is that highest survival of herring embryos (which are attached to eel grass and other substrates) occurs during years of high outflow during the spawning period; the developing fish seem to require a relatively low-salinity environment. There is also some indication that populations have been lower since the invasion of the Asiatic clam into the estuary, with the subsequent reduction in planktonic food organisms. Given the frequent collapse of commercial fisheries (including those for herring) in the modern world, it is best to manage this fishery very cautiously to make sure it can continue indefinitely.

Sacramento blackfish, hitch, and splittail support small commercial or sport fisheries. The commercial fisheries are largely unstudied and lightly regulated. Likewise, there is little information on the recreational fishery for splittail in the Delta. Because the ERP seeks to increase populations of native fishes, finding ways to make sure the native cyprinids can support fisheries for specialty markets seems very compatible with the other objectives.

OBJECTIVE 2: Maintain, to the extent consistent with ERP goals, fisheries for striped bass, American shad, signal crayfish, grass shrimp, and nonnative warmwater gamefishes.

RATIONALE: This objective addresses maintaining the popular fisheries provided by these species in a manner that does not conflict with other ERP objectives such as recovery of at-risk native species. The Delta, for instance, has been noted in the past for its productive striped bass and American shad fisheries. Currently these fisheries are depressed while the largemouth bass fishery is in excellent condition. In the absence of a comprehensive restoration effort, increasing the abundance of nonnative fishery species has the potential to limit the recovery of native species, such as chinook salmon and steelhead. Therefore, the management of these species must balance the objective of providing opportunities for harvest while not jeopardizing recovery of native species.

OBJECTIVE 3: Enhance, to the extent consistent with ERP goals, populations of waterfowl and upland game for harvest by hunting and for non-consumptive recreation.

RATIONALE: The Central Valley, Delta, Suisun Marsh, and the rest of the estuary provide important habitat for migratory and resident waterfowl. Public and private seasonal and permanent wetlands and agricultural lands managed to benefit these species following harvest support the impressive flocks of ducks and geese from the Pacific Flyway. While a significant motivation for managing these wetlands has been to support waterfowl hunting, the large associated waterfowl concentrations have become major attractions for large numbers of wildlife viewers, helping to make wetland restoration a much more publicly-supported activity. Much of the primary natural habitats for waterfowl, seasonal wetlands, permanent wetlands, riparian, and grasslands, has been lost or degraded. This has resulted in declines in suitable waterfowl nesting habitat and reductions in the amount of wintering waterfowl habitat. Areas restored to managed seasonal and permanent wetlands and agricultural croplands support increased populations of wintering waterfowl. Management of these habitats with a multi-species perspective will support goals to recover some endangered species.

The upland game guild includes resident and migratory game birds and small mammal game species defined by CDFG hunting regulations. These species are of high interest to recreational hunters in the Bay-Delta watershed. Much of the primary natural habitats for upland game, riparian, oak woodlands, and grasslands, has been lost or degraded. This has resulted in declines in native game species abundances. Agricultural croplands also support upland game. This objective addresses the need to maintain these species by restoring and maintaining the habitats on which they depend.

OBJECTIVE 4: Ensure that chinook salmon, steelhead, trout, and striped bass hatchery, rearing, and planting programs do not have detrimental effects on wild populations of native fish species and ERP actions.

RATIONALE: The salmon, steelhead, trout, and striped bass hatchery, rearing and planting programs in the Bay-Delta watershed were developed to maintain fisheries for these species that would otherwise have ceased or been severely reduced because of habitat loss and degradation, such as dams and diversions blocking access to spawning habitat. To a certain extent, these programs have succeeded by maintaining the commercial and sport fishery for some of these species. Hatcheries and planting programs have not been able to reverse the decline and degradation of wild populations of salmon, steelhead, trout, and other aquatic species. Salmon, steelhead, and trout originating from hatcheries may have aggravated this problem by interacting negatively with wild fish, introducing disease and genetic impacts, and by encouraging high harvest levels in ocean fisheries. Striped bass prey on native fish species, including salmon. There is thus a need to closely evaluate and manage all hatchery and stocking programs that take place in the CALFED area to make sure they are compatible with ERP goals and actions.

A major emphasis of the ERP is to restore wild runs of salmon and steelhead by improving habitat conditions for them and by augmenting flows in spawning streams. The role that state, federal, or private hatcheries can play in this recovery is uncertain. For severely depleted stocks (e.g., winter run chinook) hatchery rearing can provide temporary insurance against extinction due to major natural and unnatural events. For more abundant stocks, however, hatcheries producing large numbers of salmon have the potential to confuse and contravene efforts to restore salmon and steelhead using natural means. Clearly the role of hatcheries on every run of salmon and steelhead needs to be carefully evaluated to determine if and how hatchery practices should be changed or if artificial propagation of some stocks should be halted completely.

GOAL 4: HABITATS

Protect and/or restore functional habitat types in the Bay-Delta estuary and its watershed for ecological and public values such as supporting species and biotic communities, ecological processes, recreation, scientific research, and aesthetics.

OBJECTIVE 1: Restore large expanses of all major habitat types, and sufficient connectivity among habitats, in the Delta, Suisun Bay, Suisun Marsh, and San Francisco Bay to support recovery and restoration of native species and biotic communities and rehabilitation of ecological processes. These habitat types include tidal marsh (fresh, brackish, and saline), tidal perennial aquatic (including shallow water and tide flats), nontidal perennial aquatic, tidal sloughs, midchannel island and shoal, seasonal wetlands, riparian and shaded riverine aquatic, inland dune scrub, upland scrub, and perennial grasslands.

RATIONALE: All major natural habitat types in the Delta, Suisun Bay, Suisun Marsh, and San Francisco Bay have been reduced to a small fraction of the area they once occupied, resulting in a large number of at-risk plant and animal species and an increased susceptibility of the remaining areas to irreversible degradation (e.g., invasion by non-native species). The reduction trend is continuing and will have to be reversed if self-sustaining examples of these habitats, and the diverse organisms they support, are to persist into the future. The major habitat types to be restored are stated above in the objective. Within these broad habitat types are more narrowly defined habitats that also need special attention. For example, among the tidal shallow water habitats are intertidal mudflats which are major foraging and resting habitat for migratory and resident shorebirds and waterfowl. Ideally, the mudflats should be dynamic, changing in area and composition in response to freshwater flow and tides. Many are being invaded by non-native cordgrasses which turns mudflat into marsh with relatively low biodiversity. The tendency of this habitat to disappear needs to be reversed through active programs such as cordgrass control. In order to make restoration actions systematic and cost-effective, specific implementation objectives need to be established for each of the habitat types, as well as subhabitats that have distinctive ecological characteristics, and then priorities set within each objective for protection and restoration activities.

OBJECTIVE 2: Restore large expanses of all major aquatic, wetland, and riparian habitats, and sufficient connectivity among habitats, in the Central Valley and its rivers to support recovery and restoration of native species and biotic communities and rehabilitation of ecological processes. These habitat types include riparian and shaded riverine aquatic, instream, fresh emergent wetlands, seasonal wetlands, other floodplain habitats, lacustrine, and other freshwater fish habitats.

RATIONALE: The diversity and spatial extent of aquatic, wetland, and riparian habitats are declining in Central Valley watersheds, especially in lowland areas. Each habitat supports a different assemblage of organisms, and quite likely many of the invertebrates and plants are still unrecognized as endemic forms. Thus, systematic restoration of large expanses of the entire array of major aquatic, wetland, and riparian habitats in the region, with sufficient connectivity among habitats, provides some assurances that essential ecological processes will be rehabilitated and maintained and native biota will be protected, preventing future species listings.

OBJECTIVE 3: Protect tracts of existing high quality major aquatic, wetland, and riparian habitat types, and sufficient connectivity among habitats, in the Bay-Delta estuary and its watershed to support recovery and restoration of native species and biotic communities, rehabilitation of ecological processes, and public value functions.

RATIONALE: A widely accepted principle of ecosystem management is that protecting and maintaining tracts of existing viable, high quality habitat is usually more ecologically efficient, effective, and economical, than restoring degraded or lost habitat. Parcels of high quality aquatic, wetland, and riparian habitats that support native biodiversity and natural processes exist in the Bay-Delta estuary and its watershed. Protecting and maintaining tracts of existing high quality habitat to anchor larger scale habitat restoration actions is a crucial step to improving the ecological health of the Bay-Delta estuary and a top ERP priority along with restoring and/or maintaining sufficient connectivity among habitats.

OBJECTIVE 4: Minimize the conversion of agricultural land to urban and suburban uses and maintain open space buffers in areas adjacent to existing and future restored aquatic, riparian, and wetland habitats, and manage agricultural lands in ways that are favorable to birds and other wildlife.

RATIONALE: The CALFED region is one of the most productive agricultural areas in the world, so agricultural lands and practices will continue to have a significant influence on natural habitats in the area. Agricultural land is important as winter feeding grounds for sandhill cranes, various species of geese, and many ducks. It is also frequently important for foraging raptors, such as Swainson's hawk, and other birds. These benefits are lost if the land becomes urbanized and intense land use disturbs or alters adjacent wetlands or aquatic systems. The negative aspects of modern agriculture from an ecological perspective include its heavy use of pesticides and fertilizers, its efficiency of crop harvest (leaving little for wildlife), its capacity to change land use quickly (e.g., from row crops to vineyards) and its ability to efficiently use each acre of land leaving very little permanent habitat at field margins. This objective addresses the need for "open space" buffers or buffer zones of agricultural land that are farmed in environmentally friendly ways between natural habitats and more industrial agriculture lands or urban areas.

OBJECTIVE 5: Manage the Yolo and Sutter Bypasses as major areas of seasonal shallow water habitat to enhance native fish and wildlife, consistent with CALFED Program objectives and solution principles.

RATIONALE: The Yolo and Sutter bypasses are artificial floodplains constructed in the 1920s to reduce or eliminate flooding of Sacramento and other towns. When not flooded, these immense areas are devoted largely to agriculture. When flooded (mostly during wet winters), the Yolo Bypass alone doubles the wetted surface area of the Delta. Recent studies indicate that the bypasses are potentially important spawning areas for splittail and rearing areas for juvenile chinook salmon, as well as for other species. Their potential as seasonal floodplain habitat is just beginning to be appreciated. A major wildlife area has just been established in the Yolo Bypass. Managing the bypasses at least in part for fish and wildlife therefore has considerable potential and is worth investigating closely. Major problems to overcome are making improvements for fish and wildlife compatible with flood control and with agriculture. Because additional bypasses are being planned, the lessons learned in managing the Yolo and Sutter Bypasses may have broad implications.

GOAL 5: NONNATIVE INVASIVE SPECIES

Prevent the establishment of additional non-native invasive species and reduce the negative ecological and economic impacts of established non-native species in the Bay-Delta estuary and its watershed.

OBJECTIVE 1: Eliminate further introductions of new species from the ballast water of ships into the Bay-Delta estuary.

RATIONALE: The introduction of nonnative species in the ballast water of ships has made the estuary the most invaded estuary in the world; a new species is being added about every 14 weeks. New nonnative invasive species can greatly increase the expense and difficulty of restoring the estuary, and potential reduce the value of a restoration project. Aquatic invasions in various locations in the United States and the world also have harmed public health, decimated fisheries, and impeded or blocked water deliveries. Substantial reductions in the number of organisms released via ballast water are readily achievable. Around the world, restrictions and regulations governing management of ballast water and other ballast materials are being promulgated to reduce the introduction of non-native species by this means. Strict controls on ballast water exchange can be an effective strategy for addressing this objective.

OBJECTIVE 2: Eliminate further introductions of new species from imported marine and freshwater baits into the Bay-Delta estuary and its watershed.

RATIONALE: Many kinds of marine and freshwater nonnative organisms are used for bait in the Bay-Delta estuary and its watershed. Presently, polychaete worms are shipped live from New England and southeast Asia to the San Francisco Bay Area for use as bait in marine sport fisheries. The New England worms are packed in seaweed which contains many non-native organisms, some of which have been established in San Francisco Bay as a result. This is thus an example of small activity that has the potential for large-scale economic damage (see ballast water rationale). Freshwater bait fishes like the red shiner have been spreading rapidly and now dominate many streams, with unknown impacts on native fishes and on fisheries. They continue to be spread by anglers releasing unused bait. Like marine baits, other new organisms may be brought in as "hitch-hikers" in shipments of bait fishes.

OBJECTIVE 3: Halt the unauthorized introduction and spread of potentially harmful non-native introduced species of fish or other aquatic organisms in the Bay-Delta and Central Valley.

RATIONALE: CDFG has long had a policy of not bringing new aquatic species into California to improve fishing. However, illegal introductions continue, such as that of northern pike into Lake Davis. If the highly predatory pike become established in the Sacramento River and Delta, it is quite likely it would have had devastating impact on salmon and native fish populations. There is a need to develop stronger prevention strategies for illegal introductions. The conflict that developed around the necessary elimination of pike from Lake Davis demonstrates the need for developing better public understanding of the need to halt invasions. Education is also needed to make the point that any movement of fish and aquatic organisms by humans to new habitats is potentially harmful, even if the species is already established nearby. Brook trout introduced into a fishless mountain lake, for example, can eliminate the population of mountain yellow-legged frog that lives there, pushing the species further towards endangered species listing.

OBJECTIVE 4: Halt the release of non-native introduced fish and other aquatic organisms from private aquaculture operations and the aquarium and pet trades into the Bay-Delta estuary, its watershed, and other California waters.

RATIONALE: Stocks of fishes and invertebrates are imported from other regions for rearing in aquaculture facilities in the Bay-Delta system, and permits are occasionally approved to bring in new species for aquaculture. Numerous examples exist of organisms escaping from aquaculture facilities and becoming established outside of their range. These include, or potentially could include, fish, crayfish and other shellfish that could compete with or prey on native California fish and aquatic organisms, including sport and commercial species. Of greater concern is the potential for the introduction of parasites and diseases to native fish and shellfish, again including fishery species.

Many kinds of aquatic organisms are sold in aquarium and pet stores. It is likely that some species of nuisance aquatic plants (e.g., *Hydrilla*) became established through aquarists dumping them in local waterways. Nonnative turtles originating in pet stores are frequently present in ponds and have the potential to displace and spread diseases to native pond turtles. Although many organisms sold in aquarium stores are tropical and unlikely to survive in Central California (with some surprising exceptions), the industry is constantly searching for and bringing in new species from a variety of habitats. As indicated in the ballast water rationale, new species can have unexpected and sometimes large-scale negative impacts on aquatic ecosystems and can make restoration much more expensive and difficult.

OBJECTIVE 5: Halt the introduction of non-native invasive aquatic and terrestrial plants into the Bay-Delta estuary, its watershed, and other central California waters.

RATIONALE: Many areas of the Central California landscape are dominated by non-native plant species (e.g., annual grasslands, eucalyptus forests) that have displaced native species and have unexpected negative impacts. Parrot's feather, for example, is an ornamental aquatic plant that is now widespread, clogging ponds and ditches in the CALFED area, thereby creating breeding habitat for mosquitoes. Many harmful species (e.g., water hyacinth) can easily be purchased in plant nurseries and so continue to be spread into natural systems. New species and varieties of plants from all over the world are constantly being brought into California with little evaluation of their invasive qualities. Some species (e.g., Atlantic and English cordgrass) have even been imported for marsh restoration projects.

OBJECTIVE 6: Reduce the impact of non-native mammals on native birds, mammals, and other organisms.

RATIONALE: Probably few issues are as potentially contentious to the public as programs to control the numbers of house cats (both tame and feral), red fox (introduced in the Central Valley and spread to marshes throughout the Bay-Delta system), and domestic dogs in natural areas. The fact remains that such predators can have a major impact on the ability of natural areas to support wildlife, including threatened native species such as clapper rails, salt marsh harvest mice, and salt marsh song sparrows. Likewise, non-native rats and mice can impact populations of native rodents and songbirds. Thus there is a major need to educate the public about the tradeoffs in protecting abundant and conspicuous predators that prey on native species, as well as programs to rid areas of other non-native mammals.

OBJECTIVE 7: Limit the spread or, when possible and appropriate, eradicate populations of non-native invasive species through focused management efforts.

RATIONALE: Nonnative invasive species (NIS) are now part of most aquatic, riparian, and terrestrial ecosystems in California. It is usually difficult to control or reduce the spread of NIS. Preventing new introductions is the most practical, economical, and environmentally safe strategy for dealing with NIS. However, in some instances, control and/or eradication of invasive species is needed (and feasible) to protect the remaining native elements or to support human uses. Four factors should be considered in focusing control efforts. First, an introduced species is often not recognized as a problem by society until it has become widespread and abundant. At that point, control efforts are likely to be difficult, expensive, and relatively ineffective, while producing substantial environmental side effects or risks, including public health risks. Second, some organisms, by nature or circumstance, are more susceptible to control than others. Rooted plants are in general more controllable than mobile animals, and organisms restricted to smaller, isolated water bodies are in general more controllable than organisms free to roam throughout large, hydrologically connected systems. Third, although biological control is conceptually very appealing, it is rarely successful and always carries some risk of unexpected side effects, such as an introduced control agent "controlling" desirable native species. And fourth, physical or chemical control methods used in maintenance control rather than eradication require an indefinite commitment to ongoing environmental disturbance, expense, and possibly public health risks. Overall, the most efficient, cost-effective, and environmentally beneficial control programs may be those that target the most susceptible species, and species that are not yet widespread and abundant. This suggests a need to (1) assess the array of introduced species and focus on those that are most amenable to containment and eradication, rather than focusing just on those that are currently making headlines, and (2) responding rapidly to eradicate new introductions rather than waiting until they spread and become difficult or impossible to eradicate.

An example of an introduced species with currently limited distribution needing eradication that is only beginning to be dealt with is Atlantic smooth cordgrass (*Spartina alterniflora*) in San Francisco Bay. Replacing open mudflats and native cordgrass communities with monospecific stands, smooth cordgrass is a substantial threat to aquatic organisms, wildlife, and fisheries in Pacific estuaries. For example, it densely covers about 30% of the intertidal area of Willapa Bay, Washington. Its introduction into San Francisco Bay has resulted in rapid colonization of the south end of the bay. It has the potential to spread throughout the estuary. However, because of its present relatively limited distribution and abundance, smooth cordgrass can readily be eradicated using appropriate methods.

An example of an abundant species needing immediate attention is the water weed *Egeria densa*. This plant has been spreading rapidly through the Delta, where it clogs sloughs and channels with its dense growth, creating problems for navigation. From a biological perspective, it is undesirable because *E. densa* beds appear to exclude native fishes and favor introduced species.

OBJECTIVE 8: Prevent the invasion of the zebra mussel into California.

RATIONALE: The zebra mussel has done enormous damage to water supply infrastructure and to natural ecosystems in the eastern United States, through which they are spreading rapidly. It is likely that at some point a live population of zebra mussels will appear in California waters through any one of several means. Studies have already demonstrated that it will likely thrive in many parts of the California water system. Therefore, it is highly desirable to have in place a strategy to deal with a localized invasion, along with a commitment of resources from agencies so that rapid action is possible.

GOAL 6: WATER AND SEDIMENT QUALITY

Improve and/or maintain water and sediment quality conditions that fully support healthy and diverse aquatic ecosystems in the Bay-Delta estuary and watershed; and eliminate, to the extent possible, toxic impacts to aquatic organisms, wildlife, and people.

OBJECTIVE 1: Reduce the loadings and concentrations of toxic contaminants in all aquatic environments in the Bay-Delta estuary and watershed to levels that do not adversely affect aquatic organisms, wildlife, and human health.

RATIONALE: Many fish, invertebrates, and wildlife, including at-risk species in Goal 1 and harvested species in Goal 3, contain high levels of heavy metals, pesticides, and other contaminants. There is good reason to think that these toxic compounds may be having negative effects on these organisms, both acute and chronic, including affecting their ability to reproduce, feed, navigate, avoid predation, and/or fight off disease. These same compounds can affect human health through the consumption of harvested species. Systematic reduction in contaminant loads from point and nonpoint sources into the aquatic ecosystems should have positive ecological and human health benefits. In some cases, such as mercury, reduction of concentrations to safe levels may be difficult because of deposits in sediments, but strategies to reduce loads and concentrations are still necessary. This objective addresses CALFED environmental water quality parameters of concern identified by the CALFED Water Quality Technical Group including mercury, pesticides, selenium, trace metals, and toxicity of unknown origin.

OBJECTIVE 2: Reduce loadings of oxygen-depleting substances from human activities into aquatic ecosystems in the Bay-Delta estuary and watershed to levels that do not cause adverse ecological effects.

RATIONALE: As a result of the Clean Water Act, local, regional, state and federal agencies have greatly decreased the amount of contamination of California's waters by sewage, animal wastes, and other substances that deplete oxygen in the water. These organic materials and ambient river conditions cause rapid eutrophication, resulting in dominance by undesirable organisms. Such contamination, although diminished, is still common and needs to be reduced further, from both point and non-point sources. For example, low dissolved oxygen levels in the lower San Joaquin River are often a barrier to the upstream movement of adult salmon and other fish. It is worth noting, however, that release of organic nutrients into aquatic systems is not necessarily always harmful, especially if the nutrients derived from human sources essentially replace those no longer entering the system from natural sources.

OBJECTIVE 3: Reduce fine sediment loadings from human activities into rivers and streams to levels that do not cause adverse ecological effects.

RATIONALE: Fine sediment loads from human activities can and has degraded stream and river habitat in the Sacramento River watershed, the San Joaquin River watershed, and tributaries to San Pablo Bay. Sedimentation and turbidity adversely affect the quality and quantity of fish spawning habitat and other benthic stream habitat and organisms. Erosional soil discharges from agricultural lands, road construction and repair, mining sites, and urban/suburban lands in stormwater runoff and in-channel mining and dredging activities are the major anthropogenic sources of fine sediment loads into streams.

TABLE 4-1. STRATEGIC GOALS AND OBJECTIVES.

GOAL 1: ENDANGERED AND OTHER AT-RISK SPECIES AND NATIVE BIOTIC COMMUNITIES

Achieve recovery of at-risk native species dependent on the Delta and Suisun Bay as the first step toward establishing large, self-sustaining populations of these species; support similar recover of at-risk native 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 native species that are not listed.

OBJECTIVE 1: Achieve, first, recovery and then large self-sustaining populations of the following at-risk na beetle, Suisun ornate shrew, Suisun song sparrow, soft bird's-beak, Suisun thistle, Mason's lilaeopsis, San Pablo song sparrow, Lange's metalmark butterfly, Antioch Dunes evening primrose, Contra Costa wallflower, and Suisun marsh aster.

OBJECTIVE 2: Contribute to the recovery of the following at-risk native species in the Bay-Delta estuary and its watershed: Sacramento perch, delta green ground beetle, giant garter snake, salt marsh harvest mouse, riparian brush rabbit, San Pablo California vole, San Joaquin Valley woodrat, least Bell's vireo, California clapper rail, California black rail, little willow flycatcher, bank swallow, western yellow-billed cuckoo, greater sandhill crane, Swainson's hawk, California yellow warbler, salt marsh common yellowthroat, Crampton's tuctoria, Northern California black walnut, delta tule pea, delta mudwort, bristly sedge, delta coyote thistle, alkali milkvetch, and Point Reyes bird's-beak.

OBJECTIVE 3: Enhance and/or conserve native biotic communities in the Bay-Delta estuary and its watershed, including the abundance and distribution of the following biotic assemblages and communities: native resident estuarine and freshwater fish assemblages, anadromous lampreys, neotropical migratory birds, wading birds, shore birds, waterfowl, native anuran amphibians, estuarine plankton assemblages, estuarine and freshwater marsh plant communities, riparian plant communities, seasonal wetland plant communities, vernal pool communities, aquatic plant communities, and terrestrial biotic assemblages associated with aquatic and wetland habitats.

OBJECTIVE 4: Maintain the abundance and distribution of the following species: hardhead, western least bittern, California tiger salamander, western spadefoot toad, California red-legged frog, western pond turtle, California freshwater shrimp, recurved larkspur, mad-dog skullcap, rose-mallow, eel-grass pondweed, Colusa grass, Boggs Lake hedge-hyssop, Contra Costa goldfields, Greene's legenere, heartscale, and other species designated "maintain" in the Multi-Species Conservation Strategy.

GOAL 2: ECOLOGICAL PROCESSES

Rehabilitate natural processes in the Bay-Delta estuary and its watershed to fully support, with minimal ongoing human intervention, natural aquatic and associated terrestrial biotic communities and habitats, in ways that favor native members of those communities.

OBJECTIVE 1: Establish and maintain hydrologic and hydrodynamic regimes for the Bay and Delta that support the recovery and restoration of native species and biotic communities, support the restoration and maintenance of functional natural habitats, and maintain harvested species.

OBJECTIVE 2: Increase estuarine productivity and rehabilitate estuarine food web processes to support the recovery and restoration of native estuarine species and biotic communities.

OBJECTIVE 3: Rehabilitate natural processes to create and maintain complex channel morphology, in-channel islands, and shallow water habitat in the Delta and Suisun Marsh.

OBJECTIVE 4: Create and/or maintain flow and temperature regimes in rivers that support the recovery and restoration of native aquatic species.

OBJECTIVE 5: Establish hydrologic regimes in streams, including sufficient flow timing, magnitude, duration, and high flow frequency, to maintain channel and sediment conditions supporting the recovery and restoration of native aquatic and riparian species and biotic communities.

OBJECTIVE 6: Reestablish floodplain inundation and channel-floodplain connectivity of sufficient frequency, timing, duration, and magnitude to support the restoration and maintenance of functional natural floodplain, riparian, and riverine habitats.

	OBJECTIVE 7: Restore coarse sediment supplies to sediment-starved rivers downstream of reservoirs to support the restoration and maintenance of functional natural riverine habitats.
	OBJECTIVE 8: Increase the extent of freely meandering reaches and other pre-1850 river channel forms to support the restoration and maintenance of functional natural riverine, riparian, and floodplain habitats.
GOAL 3: HARVESTED SPECIES *Maintain and/or enhance populations of selected species for sustainable commercial and recreational harvest, consistent with the other ERP strategic goals.*	
	OBJECTIVE 1: Enhance fisheries for salmonids, white sturgeon, pacific herring, and native cyprinid fishes.
	OBJECTIVE 2: Maintain, to the extent consistent with ERP goals, fisheries for striped bass, American shad, signal crayfish, grass shrimp, and nonnative warmwater gamefishes.
	OBJECTIVE 3: Enhance, to the extent consistent with ERP goals, populations of waterfowl and upland game for harvest by hunting and for non-consumptive recreation.
	OBJECTIVE 4: Ensure that chinook salmon, steelhead, trout, and striped bass hatchery, rearing, and planting programs do not have detrimental effects on wild populations of native fish species and ERP actions.
GOAL 4: HABITATS *Protect and/or restore functional habitat types in the Bay-Delta estuary and its watershed for ecological and public values such as supporting species and biotic communities, ecological processes, recreation, scientific research, and aesthetics.*	
	OBJECTIVE 1: Restore large expanses of all major habitat types, and sufficient connectivity among habitats, in the Delta, Suisun Bay, Suisun Marsh, and San Francisco Bay to support recovery and restoration of native species and biotic communities and rehabilitation of ecological processes. These habitat types include tidal marsh (fresh, brackish, and saline), tidal perennial aquatic (including shallow water and tide flats), nontidal perennial aquatic, tidal sloughs, midchannel island and shoal, seasonal wetlands, riparian and shaded riverine aquatic, inland dune scrub, upland scrub, and perennial grasslands.
	OBJECTIVE 2: Restore large expanses of all major aquatic, wetland, and riparian habitats, and sufficient connectivity among habitats, in the Central Valley and its rivers to support recovery and restoration of native species and biotic communities and rehabilitation of ecological processes. These habitat types include riparian and shaded riverine aquatic, instream, fresh emergent wetlands, seasonal wetlands, other floodplain habitats, lacustrine, and other freshwater fish habitats.
	OBJECTIVE 3: Protect tracts of existing high quality major aquatic, wetland, and riparian habitat types, and sufficient connectivity among habitats, in the Bay-Delta estuary and its watershed to support recovery and restoration of native species and biotic communities, rehabilitation of ecological processes, and public value functions.
	OBJECTIVE 4: Minimize the conversion of agricultural land to urban and suburban uses and maintain open space buffers in areas adjacent to existing and future restored aquatic, riparian, and wetland habitats, and manage agricultural lands in ways that are favorable to birds and other wildlife.
	OBJECTIVE 5: Manage the Yolo and Sutter Bypasses as major areas of seasonal shallow water habitat to enhance native fish and wildlife, consistent with CALFED Program objectives and solution principles.
GOAL 5: NONNATIVE INVASIVE SPECIES *Prevent the establishment of additional non-native invasive species and reduce the negative ecological and economic impacts of established non-native species in the Bay-Delta estuary and its watershed.*	
	OBJECTIVE 1: Eliminate further introductions of new species from the ballast water of ships into the Bay-Delta estuary.
	OBJECTIVE 2: Eliminate further introductions of new species from imported marine and freshwater baits into the Bay-Delta estuary and its watershed.
	OBJECTIVE 3: Halt the unauthorized introduction and spread of potentially harmful non-native introduced species of fish or other aquatic organisms in the Bay-Delta and Central Valley.

	OBJECTIVE 4: Halt the release of non-native introduced fish and other aquatic organisms from private aquaculture operations and the aquarium and pet trades into the Bay-Delta estuary, its watershed, and other California waters.
	OBJECTIVE 5: Halt the introduction of non-native invasive aquatic and terrestrial plants into the Bay-Delta estuary, its watershed, and other central California waters.
	OBJECTIVE 6: Reduce the impact of non-native mammals on native birds, mammals, and other organisms.
	OBJECTIVE 7: Limit the spread or, when possible and appropriate, eradicate populations of non-native invasive species through focused management efforts.
	OBJECTIVE 8: Prevent the invasion of the zebra mussel into California.
GOAL 6: WATER AND SEDIMENT QUALITY *Improve and/or maintain water and sediment quality conditions that fully support healthy and diverse aquatic ecosystems in the Bay-Delta estuary and watershed; and eliminate, to the extent possible, toxic impacts to aquatic organisms, wildlife, and people.*	
	OBJECTIVE 1: Reduce the loadings and concentrations of toxic contaminants in all aquatic environments in the Bay-Delta estuary and watershed to levels that do not adversely affect aquatic organisms, wildlife, and human health.
	OBJECTIVE 2: Reduce loadings of oxygen-depleting substances from human activities into aquatic ecosystems in the Bay-Delta estuary and watershed to levels that do not cause adverse ecological effects.
	OBJECTIVE 3: Reduce fine sediment loadings from human activities into rivers and streams to levels that do not cause adverse ecological effects.

♦ CHAPTER 5. IMPLEMENTING THE ERP

INTRODUCTION

The ERP contains hundreds of programmatic actions that, after being refined and evaluated, will be implemented and monitored throughout the ERP focus area over the 30 or more year implementation phase of the CALFED program. Because of the large scope of the ERP, both in the number of restoration actions and the area within which they will be implemented, restoration of the Bay-Delta ecosystem will occur in stages. Staged implementation will also facilitate an adaptive management approach to ecosystem restoration, since it is difficult to know how the Bay-Delta ecosystem will respond to implementation of proposed ERP actions, as well as the implementation of other CALFED Program components. Later stages of ERP implementation will thus be more responsive to future Bay-Delta conditions, and they will benefit from the knowledge gained from restoration actions implemented in earlier stages. Staged implementation will also allow the costs of restoration to be spread over multiple years.

The CALFED Bay-Delta Program has defined the initial stage of implementation, Stage 1, as the first 7 years following a Record of Decision (ROD) and certification of the Final Programmatic EIS/EIR. The focus of Stage 1 is to implement the six common programs while feasibility studies, planning and design, impact evaluation, and permit acquisition on potential new storage and conveyance facilities are completed. In this manner, storage and conveyance facilities may be ready for construction at the beginning of Stage 2 if they are required, while implementation of the common programs during Stage 1 may obviate the need for, or reduce the scope of, new facilities required.

The Stage 1 action plan for the ERP will include restoration actions that are technically, economically, and politically feasible to implement in the first 7 years of the restoration program, and actions for which environmental documentation can be prepared and required permits can be acquired during the early years of Stage 1. Within these parameters, the focus of the ERP in Stage 1 is to implement those restoration actions that, based upon current assumptions and hypotheses about ecosystem structure and dynamics, will provide the greatest ecological benefits within existing constraints (such as large water supply and flood control dams), thereby improving the environmental baseline for future stages of restoration. In Stage 1, the ERP also aims to resolve critical uncertainties about ecosystem structure and function that currently hamper our ability to adequately define problems or design restoration actions. Twelve critical issues and potential restoration opportunities to address the issues are described later in this chapter. ERP implementation in Stage 1 also focuses on reducing conflicts among beneficial uses of Bay-Delta resources and building public support for long-term ecosystem restoration and management. Appendix D contains a draft list of ERP actions to be implemented in Stage 1.

Appendix D contains a draft list of ERP actions for Stage 1 implementation. The draft Stage 1 actions are a subset of programmatic actions described in Volume II of the ERPP that are feasible to implement in the first 7 years and that address key stressors for high-priority watersheds and areas of the Bay and Delta. The proposed actions in Appendix D are provisional. Continuing work efforts will help to refine the draft Stage 1 actions by articulating assumptions about ecosystem structure and function, and by applying a set of project selection/prioritization criteria.

Guiding Principles for Priority Setting

The following is a list of five consensus principles developed by the ERP Focus Group to guide prioritization of ecosystem restoration activities. These guiding principles are intended to establish fundamental ground rules for ongoing and future priority setting and funding decisions related to ERP implementation. The principles specifically address the following:

- The process for developing near- and long-term ERP actions;
- The role of science-based adaptive management; and
- Parameters for determining the balance of funding priorities and allocation.

These guiding principles will be used in combination with project selection criteria (as described later in the Strategic Plan) to determine priorities. The principles will apply in moving from programmatic actions to regional implementation plans (or Ecological Management Zone Or Ecological Management Unit Plans), as well as in moving from regional implementation plans to project-specific actions. The principles, in and of themselves, do not establish implementation strategies or priorities, but rather are intended to be used in concert with more detailed selection criteria and statutory responsibilities to facilitate an integrated and transparent decision making process for program implementation.

Decisions related to selecting/prioritizing ERP actions and ensuring compliance with state and federal endangered species laws will be integrated to the maximum extent possible to promote one consistent and efficient approach to ecosystem restoration, in accordance with a single blueprint.

Consensus Principles

1. **Basis for ERP Implementation Priorities:** The development of annual, near-term and long-term ERP implementation priorities and strategies will be based on the goals and objectives of the ERP Strategic Plan, MSCS, ESA recovery plans, and implementation plans developed for specific ecological management zones, and informed by a science based adaptive management process.

2. **Role of Science:** A science based adaptive management process will be used to review and advise on ERP strategies and priorities. This process will include adequate monitoring, research, and performance assessment activities, and an independent Ecosystem Science Board. CALFED is committed to using the best available science for ERP implementation in accordance with a single blueprint.

3. **Setting Priorities:** Final decisions regarding ERP implementation strategies, priorities, and funding allocations will be made by the CALFED Policy Group or its successor entity, based on recommendations developed through a collaborative effort involving the CALFED Science Program (including an Ecosystem Science Board), CALFED agencies, stakeholders, and the public.

4. **Funding Priorities:** ERP implementation will include strategies to address the immediate needs of species and other ecosystem components at highest risk; and comprehensive measures to protect and restore habitats, rehabilitate ecological processes, and reduce stressor impacts. The initial funding allocation between these strategies is intended by CALFED to be balanced so that the total allocation provides for a comprehensive restoration approach. Adequate funding will be provided to fully support the science-based adaptive management process and the administration and management of the ERP.

5. **Use of ERP Funds:** ERP funds will be used to implement management measures identified in the ERPP, non-mitigation measures identified in the MSCS, and/or measures developed under the ERP adaptive management process.

Refining the List of ERP Actions for Stage 1 Implementation

A series of continuing work efforts will help refine the Draft ERP Actions for Stage 1 Implementation. CALFED is developing a series of scientific white papers that will succinctly describe assumptions about ecosystem structure and function and identify information gaps to be addressed by further analysis, research and monitoring. The white papers are designed to

- Develop conceptual models that describe the key inter-relationships among ecosystem components, system dynamics, and limiting factors relevant to the white paper topic. The white papers will also indicate the degree of confidence and consensus about our understanding of the interrelationships, dynamics, and limiting factors. These conceptual models will be composed of both written description and diagrams.

- Identify uncertainties or scientific disagreements about key interrelationships among ecosystem components, system dynamics, and limiting factors that prevent us from defining or selecting management actions with sufficient confidence or consensus of being effective. The white papers will suggest adaptive management interventions, targeted research, and expanded regional monitoring for addressing these uncertainties.

- Identify general opportunities for, and constraints to, applying restoration/ management strategies and adaptive management experiments.

The current list of white paper topics include:

- Fluvial Geomorphology
- Riparian Habitat and Avifauna
- Tidal Wetlands
- Aquatic Contaminants
- Salmonids
- Delta Smelt
- Splittail
- Open Water Processes
- Diversion Effects on Fish/Environmental Water Account

The ERP has begun developing tributary assessments to help clarify the relative staging of ERP actions, and help identify packages of ERP actions to fulfill restoration objectives for specific Bay-Delta tributaries. The general objectives of the tributary assessments include:

- Identifying additional actions for potential inclusion in the ERPP;

- Refining ERP actions and targets;

- Discussing local factors limiting salmonid production, fluvial processes, and riparian regeneration processes;

- Identifying local restoration opportunities and constraints;

- Identifying potential threats to proposed ERP actions from permitted or planned human activities;

- Refining the general restoration objectives for the tributary;

- Packaging ERP actions in terms of the general restoration objectives; and

- Identifying potential adaptive management experiments.

Decision Analysis Model

The ERP has commissioned the development of a decision analysis model to help define and evaluate alternative management options for a restoration issue that is central to the ERP. A decision analysis model defines and evaluates alternative management options by characterizing: the ecological and biological benefits associated with each option; the ecological, social, and economic tradeoffs associated with each option; and the information value to be gained for each management option. The general objectives of the modeling project are to test the applicability of decision analysis modeling to CALFED restoration issues and to refine CALFED's adaptive management approach by defining experimental management options for a central restoration issue.

Taken together, the white papers and the reconnaissance-level technical analysis will help identify a subset of ERP actions that will be prioritized and evaluated using the action selection criteria described in the next section.

PROJECT SELECTION CRITERIA

The following is a draft list of criteria that will be used to prioritize and select ERP actions for implementation in Stage 1. The application of these criteria to candidate ERP actions will make the selection of Stage 1 actions more transparent.

ECOLOGICAL BENEFIT

- **PROVIDE BENEFIT FOR SPECIAL-STATUS FISH SPECIES.** While the goal of the long-term Ecosystem Restoration Program is to recover and maintain stable, self-sustaining populations of all plant and animal species that rely upon the Delta for part or all of their life history needs, Stage 1 actions will focus primarily upon restoring processes and habitats that benefit endangered and threatened fish species and fish species that are candidates for listing under the state or federal ESA. For instance, numerous Stage 1 actions focus on restoring spawning and rearing habitat and reducing stressors that affect various races of chinook salmon, steelhead trout, delta smelt, and splittail. These special-status fish species are at the center of the most strident conflicts among beneficial uses of Bay-Delta resources. Protecting the survival of special-status fish species will not only preserve integral components of the Bay-Delta ecosystem, but also helps to reduce conflict among beneficial uses of Bay-Delta resources.

- **RESTORES ECOLOGICAL PROCESSES /IS SELF-SUSTAINING.** Actions that restore the dynamic flows of water, sediment, nutrients, woody debris and biota—the building blocks of habitat—are generally preferable to restoration actions that physically reconstruct habitat. Restoring habitats by restoring ecological processes can recreate subtle elements of ecosystem structure and function that likely improve the quality of restored habitat. Restoring ecological processes can also reduce the amount of human intervention required to maintain the value of restored habitat. For example, an area of physically reconstructed salmonid spawning habitat may wash out during high flows, necessitating the continual reconstruction of habitat following high flow events. In contrast, restoring flows of water and sediment can create and maintain spawning habitat with less human intervention, such that the high flow events transport and distribute restored sediments, allowing the system to organize its own spawning habitat.

- **PROVIDE BENEFIT FOR MULTIPLE SPECIES.** The design and location of a restoration action can determine the plant and animal species that it benefits. In terms of project design, restoration actions that restore ecological processes generally benefit multiple species by recreating or mimicking the habitat conditions under which native species evolved. The location of a restoration action also helps

Selection Criteria

Ecological benefit:
- Provide benefit for special-status fish species
- Restores ecological processes/is self-sustaining
- Provide benefit for multiple species
- Provide greatest benefit-cost ratio for native species
- Are complementary

Information value:
- Improve understanding of ecosystem structure and function
- Offer information richness
- Provide results in a short time-frame and inform decisions about potential storage and conveyance facilities

Public Support/Implementability:
- Contribute to multiple Program objectives and minimize conflicts among Program components
- Have high public support and visibility
- Ability to attain Regulatory Compliance

determine the number and types of plant and animal species that will benefit. For example, the inundation of a floodplain in one part of the ecosystem may provide important rearing habitat for a particular species of fish, while the inundation of a floodplain in another location may provide not only rearing habitat for that same species of fish, but also spawning habitat for other fish species, and foraging habitat for multiple bird species. Project locations that will benefit multiple species will generally receive more favorable consideration.

- **PROVIDE THE BENEFIT-COST RATIO FOR NATIVE SPECIES.** Restoration actions will require water, land/easements, material, and financial resources for implementation. The expenditure of resources for the implementation of any action reduces the resources available for other actions. Consequently, it is important to implement actions that will optimize the ecological benefit and/or the information value gained for the resources expended. Actions with the greatest potential to improve ecological conditions or our understanding of the ecosystem for the amount of resources required to implement the action will be good candidates for Stage 1 implementation.

- **ARE COMPLEMENTARY.** Many of the restoration actions described in Volume II of the ERPP must be implemented in concert or in sequence. For example, the addition of spawning-sized gravel to a tributary deprived of its historical coarse sediment load by a dam will need to be accompanied by flow releases sufficient to mobilize and distribute the introduced sediments. Similarly, efforts to restore salmonid spawning habitat may need to be accompanied by restoration of rearing habitat to accommodate an increase in the production of juvenile fish. Actions that can be bundled together to achieve complementary effects will be better candidates for Stage 1 implementation, since they can help ensure more comprehensive restoration and speed progress toward achieving restoration objectives.

INFORMATION VALUE

- **IMPROVE UNDERSTANDING OF ECOSYSTEM STRUCTURE AND FUNCTION.** While much is known about the Bay-Delta ecosystem, there are still gaps in our knowledge about how the ecosystem is structured and how it functions. This uncertainty hampers our ability to adequately define problems are to design effective restoration actions with sufficient confidence. Improving our understanding of the ecosystem can provide a more solid foundation for the long-term ERP, by allowing resource managers to design future restoration actions to be more effective in achieving restoration objectives. Thus, projects with greater potential to improve our understanding of important ecosystem elements and dynamics will generally be good candidates for Stage 1 implementation.

- **OFFER INFORMATION RICHNESS.** The location of restoration actions can determine the value of the information that the action yields. For example, projects underlain by historical and baseline data, such as stream gauge records and baseline biological monitoring, can generally provide more valuable information by placing the results of the restoration action within a larger ecological context. Similarly, certain projects may provide unique opportunities to limit the number of confounding variables, such that the monitored response of the ecosystem to a management action can be attributed more directly to the action rather than factors beyond control.

- **PROVIDE RESULTS IN A SHORT TIME-FRAME AND INFORM DECISIONS ABOUT POTENTIAL STORAGE AND CONVEYANCE FACILITIES.** Restoration actions that yield ecological benefits and information in a short time-frame are good candidates for Stage 1 implementation since they can both build public support for the restoration program and inform the selection and design of future restoration actions. At the end of Stage 1, the Program will determine the new storage and conveyance facilities that may be needed to meet Program objectives, so restoration actions will be selected and designed for implementation in Stage 1 to help inform such decisions at the end of Stage 1.

PUBLIC SUPPORT/ IMPLEMENTABILITY

- **CONTRIBUTE TO MULTIPLE PROGRAM OBJECTIVES AND MINIMIZE CONFLICTS AMONG PROGRAM COMPONENTS.** The ERP is inextricably linked to other CALFED Program components, such as water quality, levee system integrity, and water supply reliability. Ecosystem restoration actions that also contribute to other Program components are good candidates for Stage 1 implementation since they can help ensure that progress toward multiple Program objectives is balanced--an assurance mechanism. Care in the design and location of ecosystem restoration actions will also help to minimize conflicts with other Program components.

- **HIGH PUBLIC SUPPORT AND VISIBILITY.** The public will play in important role in the types and location of restoration actions to be implemented, as well as the overall scope of restoration to be achieved. Actions that enjoy broad public support are better candidates for Stage 1 implementation since they are less likely to be mired in controversy that can delay or undermine their implementation. Pilot projects can also help build public confidence in restoration actions, thereby laying a foundation for the long-term public support that will be necessary to implement the long-term restoration program.

- **ABILITY TO ATTAIN REGULATORY COMPLIANCE.** ERP actions that can be covered adequately by the Programmatic EIS/EIR and do not require additional, site-specific documentation will be good candidates for Stage 1 implementation. However, most proposed ERP actions will require additional environmental documentation and the acquisition of regulatory permits to ensure compliance with laws and regulations. Since the preparation of environmental documents can be a lengthy process, it will be important to ensure that the proposed Stage 1 actions will be ripe for implementation in the first 7 years by identifying the permitting and environmental documentation requirements for each action and estimating the time required to complete them.

IMPLEMENTABILITY CRITERIA

The ERP Strategic Plan describes a conceptual framework and process for refining, evaluating, prioritizing, implementing, monitoring, and revising ERP actions. This conceptual framework includes the identification and application of selection criteria for screening, refining, and prioritizing ERP actions for implementation. The ERP Strategic Plan identifies three primary categories of selection criteria for refining and prioritizing ERP actions:

1. Ecological Benefit;
2. Information Value; and
3. Implementability/Public Support.

Using this conceptual framework and selection criteria as a starting point, the ERP Focus Group has examined the concept of the third suggested criteria (implementability/public support) in more detail, including how such criteria should be defined and when and how they should be applied within an overall priority setting process, including how they should be balanced with other important considerations/criteria (such as ecological benefit and information value criteria). With regard to specific criterion, the ERP Focus Group focused only on implementability criteria. The group did not review or discuss specific ecological benefit or information value criteria. A list of proposed implementability criteria developed by the ERP Focus Group for use in setting priorities and selecting projects for ERP implementation is presented below.

The purpose of implementability criteria is to ensure that issues related to the overall implementability of a proposed action are considered and evaluated in the prioritization and project selection process. The criteria themselves are meant to be screens; they are not intended to function as "on-off" switches. Rather these criteria are intended to represent important factors for evaluating the relative merits of various options. For example, one suggested implementability criterion at the project selection level is "ease of implementation." It is applied not to eliminate projects that are more challenging to undertake, but rather to rank one project characteristic against numerous other criteria that assess implementability. Furthermore, "ease of implementation" in and of itself is not necessarily an overall preferred criterion, given the adaptive management approach embedded in the ERP.

Implementability criteria for selection of ERP actions be applied both at a regional level, where a number of activities must be planned and coordinated, and at the local, project-specific level with outreach and involvement of local officials in affected areas including, but not limited to, watershed groups, local conservancies, local planning groups, property owners, and native American tribes. At the regional level of planning in particular, multiple opportunities exist for achieving multiple CALFED objectives and minimizing conflicts across Program actions, one of the key factors identified in the ERP Strategic Plan.

Regional Implementability Criteria

At the regional level, implementability criteria should be used as screens that on a broad-brush scale can help determine whether or not a project or action is implementable. These criteria should be applied early in the regional planning process in order to ensure that projects and actions are physically implementable and that coordination to enhance achievement of overall CALFED Program objectives is considered. Local interests including, but not limited to, watershed groups, local conservancies, environmental justice groups, local planning groups, property owners, and Native American tribes are to be involved in application of these criteria, to ensure that decisions are fully informed by local consideration prior to decision-making.

The following broad regional implementability criteria will be used:

- **Infrastructure Criteria:** Areas proposed for restoration should be assessed for presence of heavy development or significant existing infrastructure (e.g., large subdivisions, industrial complexes, major interstate and state highways). Areas proposed for restoration should be investigated to determine the potential for imminent or likely land use conflicts.

- **Landscape Resistance Criteria:** Projects and actions should be investigated to determine, from an ecosystem restoration perspective, their relative feasibility based on key landscape conditions such as elevation or topography.

- **Sustainability Criteria:** Proposed actions or projects should be screened for their sustainability given existing ecological processes such as floods, tides, sea level rise, wind or wave erosion, etc.

- **MSCS Consistency Criteria:** Actions or projects should be screened for their consistency with the MSCS.

- **Program Integration/Multiple Program Objectives:** These criteria assess the extent to which proposed actions foster the CALFED Program as a whole and are well integrated with other program elements, both within CALFED and with other related programs.

- **Public Outreach and Local Involvement:** This criterion ensures public outreach and opportunities for local involvement, input, and advice at the regional planning level has occurred.

Potential Conflicts at the Regional Level

In the process of setting ERP priorities at the regional level, one or more CALFED agencies, or local stakeholders, may disagree regarding the advisability of proceeding on a certain type of project proposed in a regional plan. In its proposed single blueprint for ERP implementation, the ERP Focus Group recommends a conflict resolution process to resolve differences of scientific opinion regarding ERP priorities or the implementability of a particular project or type of projects. In the event that conflict resolution efforts are unsuccessful at resolving the disagreement at the regional level, the conflict may be elevated to the CALFED Policy Group, or the proposed ERP governing entity, for resolution.

PROJECT LEVEL IMPLEMENTABILITY

At the project selection level, implementability criteria are applied to help reviewers select among competing proposals or among alternatives in the same proposal category. The Focus Group endorses the implementability criteria that have been developed for the 2001 Proposal Solicitation Package (PSP). Some of the project evaluation criteria identified in the 2001 PSP include: scientific merit of a proposal; clearly stated objectives and hypotheses; sound approach for conceptual model, project design, study methods, and analyses techniques; adaptive management approach; adequacy of proposed monitoring, information assessment, and reporting; technical feasibility of proposal; and proponent qualifications. The Focus Group encourages the Restoration Program to adopt the two additional implementability criteria, as follows:

- **CONTRIBUTION TO MULTIPLE OBJECTIVES:** These criteria should be applied at both the regional and the action-specific level. ERP actions should, when possible, interact with other CALFED actions and other related program actions to maximize achievement of synergistic benefits. Examples include ERP actions that benefit Levee Program objectives, or are consistent with the objectives of the AFRP or the Comprehensive Flood Management Study.

- **CONSISTENCY WITH REGIONAL IMPLEMENTATION PLANS:** A proposed ERP project should be consistent with the appropriate ERP regional plans, with regard to habitat types and quantities proposed for restoration. They should also be consistent with the proposed geographic area in the regional plan.

Additionally, planning and action implementation described in the ERP includes three distinct levels of planning: (1) programmatic, (2) regional, and (3) site specific. The programmatic level of planning is presented in Volume II of the ERP. The regional planning process is discussed later in this section. Site specific planning occurs immediately prior to implementation and has been in progress during the CALFED's early implementation of ecosystem restoration projects.

REGIONAL PLAN DEVELOPMENT

The purposes of Regional Ecosystem Implementation Plans are to clearly articulate an integrated planning, implementation, and scientific framework by which to successfully implement and evaluate restoration of the EMAs and EMUs which collectively constitute the Bay-Delta ecosystem. The Regional Plans will provide comprehensive plans of action that will guide proposed restoration actions during development, revision, implementation, and post-implementation periods. The urgency to rehabilitate the ecosystem can be met by addressing scientific uncertainty and proceeding with scientifically defensible Regional Plans and Implementation Strategies.

One of the primary criticisms of the draft ERP is that the plan did not present a clear restoration strategy integrated across the proposed implementation objectives and programmatic actions. The overall Strategic Plan and Regional Plans are designed to rectify this inadequacy by providing clear restoration and implementation strategies that are strongly supported at the local level.

The five important elements of Regional Plans are the what, why, when, who, and how. CALFED and agency staff can assist in the identification of restoration actions and provide a scientific basis for the actions. Other stakeholders may participate and will given the opportunity to assist in the development of actions and the scientific justification for watershed and site specific projects.

CALFED will have a greater role in determining when funding under its purview will be provided for specific projects and will have to judge the merits of numerous individual projects over the entire ERPP study area.

Local watershed groups and conservancies will have a major role in determining who will implement the actions and the manner in which the actions will be implemented. All implementation will have to comply with State and Federal law and which ever contract law (State or Federal) applies to the specific project. CALFED or its participating agencies may be able to enter in direct cooperative agreements or contracts with watershed groups or conservancies that have legal "non-profit" status as a means by which to receive funding and implement restoration actions.

A broad spectrum of participants is required in the development, evaluation, and implementation of the Regional Plans. Local watershed groups, conservancies, individuals, local governments, and State and Federal agencies will be the primary group developing these implementation plans. Other stakeholders will be invited to participate in reviewing intermediate work products. There will also be issue- specific technical workshops closely linked to the overall Strategic Plan which will have a strong link with the development of the local implementation plans.

Development of Regional Plans will require resolution of many issues related to the selection and implementation of restoration actions presented in the ERP. The major issues and areas of concern follow:

- Local participation and empowerment
- Coordination with other restoration programs
- Conceptual ecosystem models
- Implementation management
- Setting priorities
- Establishing measurable success standards
- Accountability

LOCAL PARTICIPATION AND EMPOWERMENT

Successful implementation of restoration programs and projects is composed of many building blocks. The blocks will be placed on a strong foundation of local support and involvement and science. To ensure that the foundation of the restoration program is sound, it is imperative that local groups have not only the desire to participate but also the wherewithal to assist CALFED in designing and implementing restoration actions within clearly defined areas such as an ecological management unit or watershed. In addition, the development, evaluation, and selection of restoration projects must be based on the best available science. Implementation must also be closely linked to monitoring and the collection of scientific data by which to fairly judge the outcomes of restoration efforts.

To accomplish these tasks, CALFED is looking for a consistent approach between ecological management units in developing standards and procedures. Because much of the potential success of the program depends on local support, CALFED must identify ways in which to foster local participation, and ways in which to empower local groups in the decision-making processes and implementation phase.

COORDINATION WITH OTHER RESTORATION PROGRAMS

One of the important values of an effective Local Implementation Strategy is the opportunity in incorporate coordination as one of the key planning elements. The CALFED Program offers new sources of funding and a new approach to restoration that augments and supports many of the existing restoration programs. Major programs that need to be included in the coordination aspect of the Regional Plans include close coordination with the Department of Fish and Game, National Marine Fisheries Service, and the U.S. Fish and Wildlife Service. Each of these agencies has regulatory authorities for implementing programs to protect, enhance, or restore a wide variety of fish, wildlife, and plant species. The Department of Fish and Game is required under provisions of the Salmon, Steelhead Trout and Anadromous Fisheries Program Act (SB 2261) to implement programs and actions to contribute to the doubling of anadromous fish populations over the level that was present when the act became law. The U.S. Fish and Wildlife Service (and the Bureau of Reclamation), under authority of the Secretary of the Interior, are required to implement provisions of the Central Valley Project Improvement Act, many of which address anadromous fish and riparian habitats. All agencies have major responsibilities under the State and Federal Endangered Species Acts to develop and implement recovery programs for listed species.

To improve coordination and project development the Department of Fish and Game and the U.S. Fish and Wildlife Service have independently and cooperatively established field level restoration coordinator positions to assist the agencies, local watershed groups, and conservancies in identifying, developing, funding, and implementing restoration actions. These restoration positions are critical resources than need to be fully integrated into the Regional Plans.

Conceptual Ecosystem Models

The ERP Indicators Work Group has developed draft conceptual models and ecological attributes pursuant to the recommendations of the Scientific Review Panel. Ecological attributes for the Bay-Delta-River System are organized by broad ecological zone designations which include: upland river-riparian systems, lowland river-floodplain systems, Delta, and Greater San Francisco Bay. General categories of attributes were identified (hydrologic, geomorphic, habitat, biological community, and community energetics) which reflect essential aspects of ecosystem structure and function. Understanding the ecological attributes of the Bay-Delta-River system provides a basis for developing conceptual models.

The conceptual models are designed to provide as much consistency across both ecological hierarchy and geography as possible so that information can be aggregated in a variety of ways. Input by technical experts will be more easily integrated using a common format. The next step is to apply these models to individual ecological management areas and units. This will require a critical review of the ecological interrelationships within individual watersheds.

Ultimately, these models, when fine-tuned for individual ecological management units, will provide a further basis by which to evaluate restoration needs, proposed actions, and in refining a process by which to establish restoration priorities.

Ecosystem-scale Conceptual Models

Regional Plans need to incorporate conceptual models in the planning process. Ecosystem-scale models include the Upland River-Riparian Systems, Lowland River-Floodplain Systems, and Bay-Delta Conceptual models. The attributes for the Greater San Francisco Bay and Delta have been incorporated by CALFED staff into one model called the Bay-Delta Conceptual Model. As the iterative review process unfolds it may be necessary to develop separate conceptual models for the Greater San Francisco Bay and Delta.

The ecosystem-scale models are based on distinctive geomorphic and hydrologic features which warrant the development of separate conceptual models. For example, upland river-riparian systems are characterized by steep confining topography with bedrock-controlled stream channels in a narrow floodplain. These systems generally occur in upper elevation watersheds above major dams in both the Sacramento and San Joaquin Valley. Hydrologically these areas are characterized by seasonal shifts in stream levels with periodic flooding. The lowland river- floodplain systems are characterized by flat, non- confining topography with a wide floodplain area which allows for active channel migration and floodplain development. These systems have seasonal shifts in stream levels with periodic flooding but also have greater hydrodynamic complexity and large groundwater basins, particularly in the Sacramento Valley.

For undammed tributaries the 300 foot contour was chosen as the dividing line between upland-river riparian and lowland- river floodplain systems. This is the approximate boundary where alluvial soils begin. Often, the location of dams and reservoirs coincides with this boundary. The difference in hydrologic attributes above and below dams warrant using this as a boundary. The uppermost extent of tidal influence was chosen as the boundary between lowland-river floodplain systems and the Delta. Finally, Chipps Island, to coordinate with the legal definition of the Delta, was selected as the boundary between the Delta and the Greater San Francisco Bay.

HABITAT-SCALE CONCEPTUAL MODELS

Conceptual models of habitats need to be developed to depict our current understanding of habitat structure and function. Habitat models could be used to assess technical feasibility and desirability of proposed restoration projects and to evaluate the results of restoration and management actions. A detailed riparian forest habitat model might include such attributes as hydrologic and sedimentation regime; plant composition, diversity and cover; faunal diversity; and reproduction of neotropical migrant birds. Such a model could be used to construct alternative hypotheses regarding, for example, the ecological effects of a levee setback.

SPECIALIZED CONCEPTUAL MODELS

Specialized conceptual models include models of individual tributaries, stream reaches, sections of rivers, biological communities, species populations and ecological processes. The Lower American River Conceptual Model is an example of a tributary model that could be used to track local system health and demonstrate the contribution of a particular waterway to landscape-level ecological integrity. The lower American River is essential to the migration, spawning, rearing and outmigration of chinook salmon. Conceptual models and indicators for the lower American River will be developed with the assistance of technical specialists having expertise on this system. For example, the Department of Fish and Game's Stream Evaluation Program, the Water Forum, and Sacramento Area Flood Control Agency technical specialists will likely be contributors to this process. While the general ecological attributes of tributaries in a particular geographic area may be the same, the individual tributary indicators and stressors will likely vary to reflect the different areas of concern for each tributary.

The Interagency Ecological Program's Salmon Project Work Team (PWT) is developing a life history model for Central Valley fall-run chinook salmon and a Steelhead PWT is being formed to assist in the development of a steelhead life history model. Quantitative models of hydrology, sediment transport, and carbon budget are examples of specialized conceptual models of ecological processes. Many other conceptual models have been developed (e.g., oak regeneration, vernal pools, perennial grasslands) that are useful in understanding the dynamic character of watersheds and can contribute to the scientific basis for site-specific project development.

IMPLEMENTATION MANAGEMENT

One of the most difficult challenges in the administration of the ERP is the potential design of the necessary institutional arrangements to ensure implementation of a large program in a large geographic area over a long time period (30 years). Although the nature of the implementation entity for the ERP is not a focal point in developing this Strategic Plan, it remains an important activity occurring outside of the ERP. Some of the important issues to be addressed include fostering a regional perspective, utilizing a "Problemshed" orientation, clearly defining the function of the implementation entity which will then define its structure, integrating strong mechanisms for full accountability of the program, and avoiding a fixed approach to implementation by promoting flexibility and creativity.

Some of the issues that need to be resolved include the overall assurances for implementing the CALFED program. Assurances are the mechanisms necessary to assure that the long-term Bay-Delta solution will be implemented and operated as agreed.

Setting Priorities

Phased implementation is an approach to implement actions identified in the ERPP. Phased implementation is comprised of a multistage priority strategy which assists in identifying and sequencing the implementation of the ERPP restoration actions over time and among the 52 EMUs.

Phased implementation within annual implementation programs will be modified on a recurrent basis as a result of adaptive management and the collection and evaluation of new or improved information. The shorter-term implementation programs developed within the framework of adaptive management may vary significantly from the programmatic snapshot of implementation. This is consistent with the theme of adaptive management and reflects the feedback and evaluation loops needed to refine and adjust the implementation program in the short-term.

Funding

The total for implementing the ERPP has been very roughly estimated at $2.5 billion. About half of that is available through Proposition 204 bond and expected federal appropriations. These funds will be used to provide the initial infusion of capital to move the implementation program forward. In later years, the magnitude of the annual implementation program may be constrained by the annual availability of funding. Phasing, and the overall adaptive management program, is ultimately influenced by the availability of restoration funds throughout the duration of the program, individual and cumulative costs to implement the ERPP, and priority strategies that select for specific actions to reach specific targets.

Establishing Measurable Success Standards

The success of the Ecosystem Restoration Program will be measured at various ecological scales. Generally, the scales will include the landscape (entire ERP study area), ecological zone (four distinct ecological areas), ecological management units (watersheds), abundance trend data for certain species, status of ecological processes, recolonization of restored habitat areas, and the ecological effects of site-specific projects.

The Indicators Work Group will play a major role in defining the measures of success by which to evaluate the progress of the ERP. The measures of success have not been developed at this time, and their development hinges on the refinement and critical review of the conceptual models for important aspects of the ecological processes, habitats, and species within the ERP study area.

Accountability

Because of the large size of the proposed restoration program and the estimated overall financial commitment, a strong program to track expenditures and successes is imperative. The shape of the accountability programs has not been developed but will likely include elements that address financial and environmental aspects of the restoration program.

Demonstration Watersheds

ERP Stage 1 actions will focus on restoring the critical ecological process and reducing or eliminating the primary stressors that degrade ecological health and limit threatened fish populations in several key watersheds of the ERP focus area. Improving the health of the constituent watersheds by restoring ecological processes and reducing or eliminating principal stressors will help to improve the health of the overall Bay-Delta ecosystem.

Stage 1 of the ERP will also include comprehensive, full-scale implementation of restoration actions in selected demonstration watersheds tributary to the Sacramento and San Joaquin rivers. The objective for each of the demonstration watersheds is to create healthy, resilient havens of riparian and aquatic habitat to provide refugia during prolonged droughts or other periods of extreme environmental stress. The approach in the demonstration watersheds is to fully restore the stream corridor within existing constraints (such as large dams) by using a more holistic approach that considers the entire watershed, not just the riparian corridor. Because of the comprehensive nature of restoration actions in demonstration watersheds, the Program will work with local conservancies and stakeholders to help select demonstration watersheds that provide significant potential for large-scale restoration that enjoys local support. Restoring these tributaries into healthy riparian corridors during Stage 1 will also help to recover and maintain large populations of fish species to endure severe ecological conditions such as droughts.

The demonstration watersheds will also serve as laboratories in which resource managers and scientists can test assumptions and hypotheses about ecosystem structure and dynamics and the complex interplay of stressors and how they affect ecological health. The knowledge gained from restoration in the demonstration streams will help to strategically focus restoration actions on primary stressors in other tributaries, as well as clarify how multiple stressors interact to intensify their impacts upon the ecosystem.

ADDRESSING CRITICAL UNCERTAINTIES AND IMPEDIMENTS TO RESTORATION

Decades of scientific study about the Bay-Delta ecosystem have yielded considerable knowledge about ecological relationships and functions. However, significant uncertainties about Bay-Delta ecosystem dynamics still remain, and they hamper our ability to adequately define some ecological problems or to design effective restoration actions for known problems. The following list of issues indicates substantial uncertainties about Bay-Delta ecosystem dynamics that can be addressed by designing Stage 1 actions to test current assumptions and competing hypotheses about ecosystem structure and function. Many of the following issues deal with uncertainty resulting from incomplete information and unverified conceptual models, sampling variability, and highly variable system dynamics. Developing a better understanding of how these factors affect the ecosystem early in the program will help resource managers to design later restoration actions with greater confidence in their ability to produce desired effects.

The twelve issues described below are listed in approximately increasing order of specificity but not ordered by importance. These issues are not the only ones to consider but must be taken into account to help ensure a successful program.

1. NON-NATIVE INVASIVE SPECIES

Non-native invasive species (NIS) have produced immense ecological changes throughout the Bay-Delta ecosystem, and they represent one of the biggest impediments to restoring populations of native species. We generally do not understand the mechanisms and pathways by which non-native invasive species affect Bay-Delta ecology, or the underlying mechanisms that give non-native or native species a competitive advantage. Consequently, it is difficult to select, bundle, and design habitat restoration projects so that they favor native species. Nor do we know the basic life history requirements for several non-native invasive species, which complicates the development of control and/or eradication strategies. In order to minimize the risk of potentially massive ecological and biological disruptions associated with non-native species that threaten to negate the benefits of restoration efforts, it is important to initiate an early program that meets the following goals:

- Prevent new introductions and establishment of NIS into the ecosystems of the Bay-Delta, the Sacramento/San Joaquin rivers and their watersheds.
- Limit the spread or, when possible and appropriate, eliminate populations of NIS through management.
- Reduce the harmful ecological, economic, social, and public health impacts resulting from infestations of NIS through appropriate mitigation.
- Increase our understanding of the invasion

process and the role of established NIS in ecosystems in the CALFED region through research and monitoring.

CALFED established the Non-Native Invasive Species program in 1998, which developed both a Strategic Plan (See Appendix E) and an Implementation Plan (See Appendix F) for addressing non-native invasive species in the Bay-Delta ecosystem.

2. Natural Flow Regimes

Human activities have fundamentally, and irreversibly, altered hydrologic processes in the Bay-Delta ecosystem. For example, changes in land use have affected how and when water drains from the land into stream channels; water diversions have changed the amount of water flowing through tributaries and the Delta; and dam development has profoundly altered the timing, frequency, and magnitude of flows. Extensive water development has generally affected the flow regime by reducing the seasonal and inter-annual variability of flows, as reservoirs capture and store stormwater and snowmelt runoff for later release as water supply. Such changes to the flow regime stress native habitats and species that evolved in the context of a variable flow regime. Restoring variability to the flow regime will be an important component of restoring ecological function and supporting native habitats and species in the Bay-Delta ecosystem.

Restoring variability to flow does not imply restoring a pre-disturbance, natural flow regime, which would be impossible considering the human reliance upon the water supply infrastructure that most affects the character of flow in the Bay-Delta ecosystem. Rather, restoring flow variability will generally mean mimicking the natural hydrograph—imitating the relative timing, magnitude, and duration of pre-disturbance flows.

There will likely be limited opportunities for mimicking naturally low base flows since human water supply and quality needs are so reliant upon the water releases that generally increase base flows. Also, in many reaches, re-creating low base flows may not be desirable from an ecological standpoint. For example, dams have prevented sensitive anadromous species from accessing historical holding and spawning habitats in upper watersheds, but cold water releases from the dams have permitted these fish to survive in reaches downstream of dams. Limited opportunities for re-creating low base flows should not preclude experimental management actions that examine how low-flow conditions affect native and non-native species.

Restoring flow variability will likely focus on mimicking historical peak flows to restore some measure of ecological function and to better create and maintain habitats. However, defining a flow schedule to best achieve ecological restoration objectives on streams regulated by dams is a complex task that must account for the fundamental changes that dams create, including trapping sediments and organic material from upper watersheds, as well as downstream channel adjustments to the post-dam flow regime. Historical reference conditions are instructive, but alone are insufficient to define the flow patterns that will best achieve ecological objectives. Defining ecologically functional flow schedules will also require analyzing current downstream channel and habitat conditions, and developing and testing hypotheses regarding flow requirements for various geomorphic and ecological functions. Research, monitoring, and implementation projects designed to develop a better understanding of geomorphic flow thresholds and hydrologic-biologic relationships will facilitate estimating environmental flow needs, so that environmental dedications of water are effective and efficient in achieving restoration objectives, thereby minimizing potential impacts upon water supply and hydropower generation.

To better define the extent to which rivers regulated by dams can be restored to provide some measure of ecological function, early restoration efforts will need to be accompanied by appropriate research, monitoring, modeling, planning, and feasibility studies. Examples of such projects include:

- Monitoring projects to better estimate geomorphic thresholds, such as the placement and monitoring of tracer gravels and monitoring of water surface elevations to better estimate bed mobility thresholds and gravel routing.

- Historical analysis and modeling to define or refine the non-linear relationships between flow and bank erosion;
- Monitoring to refine stage-discharge relationships and the availability, quality, and use of resultant microhabitats;
- Monitoring and modeling to determine fish passage flows past flow-related barriers;
- Monitoring and modeling to develop or refine flow-temperature relationships;
- Support studies such as an examination of sources of sediment for restoration purposes;
- Research projects that examine the mechanisms underlying native and exotic species responses to flow;
- Simulation and operational modeling to evaluate options for obtaining water to meet environmental needs;
- Monitoring and modeling to develop or refine relationships between flow and contaminant concentrations, bioavailability, and resultant dose and exposure to biota.

Several of the topics noted above can be incorporated into implementation projects. For example, the placement and monitoring of tracer gravels should be a part of any gravel augmentation project implemented to compensate for historical gravel depletion. Similarly, any riparian re-vegetation project should be structured and monitored to enhance our understanding of how native and/or non-native species of riparian vegetation respond to flow components.

3. Channel Dynamics, Sediment Transport, and Riparian Vegetation

Rivers are naturally dynamic. They migrate across valley floors as flows erode banks and deposit sediment on point bars; they occupy different channel alignments through channel avulsion; they periodically inundate floodplains; they recruit and transport sediment; and they drive the establishment and succession of diverse riparian plant communities. These physical processes provide the energy and material necessary to create and maintain healthy and diverse riverine habitats that support native populations of plants, fish, and wildlife. There is a growing recognition that the preservation of existing habitat, and the physical creation of new habitat, must be accompanied by the restoration of physical processes, not only because they help create and maintain these habitats, but also because they are fundamental determinants of habitat conditions in themselves. Restoring ecological processes as a means of restoring habitat conditions is a signature feature of an ecosystem-based management approach.

Human activities have generally reduced the dynamic processes of Central Valley tributaries, with a resultant loss of riverine habitat. Dams have reduced the peak flows essential for shaping and re-shaping channel forms and for connecting river channels with their floodplains. Dams also trap sediment and woody debris from upstream reaches, depriving downstream reaches of the fundamental building blocks for habitat. Levees and bank protection have also prevented channel migration and reduced connectivity between channels and floodplains.

It is generally infeasible to restore fully dynamic rivers because of irreversible historical changes and continued human uses. However, river channels and floodplains may be dynamic on a smaller scale so as to restore some measure of ecological function. For example, rivers can be scaled down by providing space for its meanders to migrate, though not the full floodplain width that it historically meandered across. Similarly, we can introduce coarse sediment and large woody debris into a channel to compensate for the material trapped by dams, but without attempting to match the historical scale of such material inputs. Channel-floodplain connectivity can be increased without restoring the full extent of historical floodplain inundation. While we may be able to restore ecosystem function by restoring riverine processes at a reduced scale, we cannot scale down a river indefinitely, as there are basic thresholds below which a river will cease to function. For example, there are minimum threshold flows required to initiate important geomorphic functions such as bed mobility, bank erosion, and overbank flooding.

We generally do not know the scale and balance of inputs--flow, sediment, organic material--and channel modifications that will restore riverine ecosystem function. Nor do we know how channels and habitats downstream of dams have adjusted to the post-dam flow regime and how, therefore, the re-invigoration of dynamic riverine processes will affect overall habitat. Restoring geomorphic processes so as to optimize ecosystem benefits will be a matter of both analysis and experimentation. It is also important to identify locations in the Bay-Delta ecosystem that still have, or can have, adequate flows to inundate floodplains and sufficient energy to drive channel migration.

4. FLOOD MANAGEMENT AS ECOSYSTEM TOOL

River-floodplain interaction is a vital component of riverine health. When inundated, floodplains provide valuable habitat for a multitude of species. They can also supply sediment, nutrients, and large woody debris to river channels, and provide a place for fine sediment deposition, which is an important function in light of flushing flows designed to cleanse spawning gravels. Inundation of floodplains also contributes to diverse structure of riparian vegetation. Human activities have aggressively and deliberately isolated floodplains from river channels, most clearly through levees designed to confine flows in channels. Dams have also contributed to floodplain isolation by reducing peak flows necessary to inundate floodplains.

Floodplains also provide storage of floodwaters, and there is growing interest in reconnecting rivers with their floodplains as part of a comprehensive flood management strategy. Large floods in the Mississippi River Valley and Central Valley in the last decade have exposed weaknesses in a purely structural approach to flood management and nurtured a growing recognition that we can never eliminate floods. For example, levees pulse floodwaters downstream more quickly, which provides local flood protection by transporting flood burden and risk downstream. In contrast, floodplains can actually store floodwaters and generally reduce overall flood risk by gradually metering flow back into the channel over time. For example, an analysis of hydrologic data for some Central Valley tributaries during the '97 floods indicates rising flows beginning to plateau as upstream levees were breached. The plateau effect demonstrates the ability of the floodplain to absorb part of the discharge, thereby attenuating the peak flow and reducing flood pressure on downstream reaches.

The Army Corps of Engineers, the Department of Water Resources, and the Reclamation Board are engaged in a Comprehensive Study of the Sacramento and San Joaquin River systems to examine opportunities for improving flood management through both structural and non-structural options. The Comprehensive Study and CALFED represent an important opportunity to integrate flood management and ecosystem benefits by reconnecting rivers with their floodplains.

Flood management can also provide ecosystem benefits through the evacuation of reservoir space for flood reservations. Many dams in the Central Valley reserve a certain portion of reservoir capacity to capture floodwaters, so as the rainy season approaches, dams must often release flows to evacuate water that occupies flood reservation space. Such flood management releases have the potential to provide significant ecosystem benefits if they are released to mimic the peak flows that are essential for restoring geomorphic processes.

Integrating and balancing flood management and ecosystem benefits will require several activities and adaptive management experiments. Some of the activities and actions include:

- Identifying and acquiring floodplain land or easements to provide opportunities for restoring channel-floodplain connectivity and testing flood management and ecosystem benefits;

- Quantifying the flood management benefits of floodplain storage;
- Examining opportunities for restoring river-floodplain connectivity without compromising development, such as protective ring levees, setback levees, or floodproofing;
- Re-grading existing floodplains on regulated streams so that they inundate more frequently in the context of post-dam flow regime, to facilitate testing flood management and ecosystem benefits;
- Clarifying how ecosystem restoration efforts, such as riparian re-vegetation, gravel augmentation, and channel reconstruction projects, affect flood conveyance capacity;
- Identifying hydraulic constrictions/choke points that prevent managed flow releases to inundate floodplains, and exploring options for addressing them; and
- Exploring opportunities to re-construct levees to provide some measure of habitat without reducing levee strength or reducing conveyance capacity.

5. BYPASSES AS HABITAT

The Yolo and Sutter Bypasses along the Sacramento River provide important flood management benefits in the Sacramento Valley and downstream urban areas. The realization of their relatively low-cost benefits to flood control is leading to the consideration of additional bypasses, especially in the San Joaquin Valley. The bypasses accommodate multiple uses; during the dry season, they are important areas for farming, and when flooded they provide important habitat for waterfowl, fish spawning and rearing, and possibly as sources of food and nutrients for estuarine foodwebs. For example, when the Yolo Bypass is flooded, it effectively doubles the wetted surface area of the Delta, mostly in shallow-water habitat. More frequent inundation of existing flood bypasses and the creation of new bypasses could expand the ecosystem benefits that they provide, but managing the bypasses for the benefit of fish and wildlife must be balanced with their use for flood control and farming. Achieving this balance of flood management, land use, and ecosystem benefits will require activities such as:

- Evaluating structural alternatives for directing water into bypasses so that they inundate more frequently;
- Experimenting with different inundation scenarios to study fish and wildlife preferences and benefits;
- Identifying opportunities for new flood bypasses and how they can be designed to benefit fish and wildlife;
- Examining how ecosystem habitats affect flood conveyance of bypasses;
- Evaluating the relative importance of flood bypass contributions to estuarine foodweb productivity;
- Studying what multiples uses are compatible in flood bypasses (e.g., what types of agricultural practices used in the bypasses and what types of fish and wildlife use are and are not compatible)

Recent studies of flooded bypasses demonstrate their importance for several sensitive fish species. There is some question, however, if the bypasses can be used as models for floodplain restoration actions along Bay-Delta tributaries, or if the bypasses constitute unique habitats.

6. SHALLOW-WATER TIDAL AND FRESHWATER MARSH HABITAT

Both tidal and freshwater wetlands (marsh habitats) represent critical areas for many key species, including species that are threatened or endangered or that have commercial and/or sport value. A significant portion of historical wetlands have been lost to human uses, so the ERP will restore wetland habitats throughout the Bay-Delta ecosystem as part of an ecosystem-based management approach. The underlying rationale of wetlands restoration is that rehabilitating the appropriate physical-chemical habitat in priority locations will contribute to the recovery of sustainable populations of the species of concern. The loss of these wetland habitat types is assumed to be causally linked to declines in these key species. These causal links have not been well established and habitat manipulations, designed as careful experiments on differing spatial and temporal scales, hold promise for determining the relationships that can help guide restoration efforts. However, a major concern remains that the restored habitat will be successfully colonized by non-native rather than native species.

Additional information is needed about life history and species needs relative to inundation (water depth) and salinity regimes in tidal wetlands, required by key native or non-native wetland species. The growth and reproduction of selected species of concern and their linkage to inundation-salinity (in tidal marshes) regimes in given wetland plant communities needs to be better understood to facilitate successful wetland restoration projects. Identification of limiting factors which determine the distribution and abundance of selected wetland species of concern for various inundation-salinity regimes will also facilitate increased success of restoration efforts. Evaluation of spatial characteristics (size, shape, and connectivity) for their effect on the population dynamics of selected freshwater or tidal wetland species, especially their colonization or extinction rates, should be conducted or included as part of physical interventions. This uncertainty might be addressed by making multi-year observations of arrays of habitats that differ in size, shape, and/or connectivity (nearest neighbor characteristics) or by creating such an array of habitats by planting and/or removing selected habitat patches.

Because of the complexity of wetland habitats it will be important to identify and justify animal species that can be used as indicators of acceptable wetland conditions. For example, the sustainable presence of species with long life cycles that are sessile and/or have poor dispersal habit could be good indicators of acceptable stable conditions.

7. Contaminants in the Central Valley

The Bay-Delta ecosystem receives a large variety of potential toxicants (Gunther et al., 1987; Davis et al., 1992). These include significant quantities of selenium from agricultural practices, mercury from historical gold mining and refining activities, pesticides from a variety of agricultural and home uses, polynuclear aromatic hydrocarbons from automobiles, and other metals from a variety of geochemical cycles accelerated by human activities. Moreover, there is a legacy of persistent chlorinated hydrocarbons whose effects appear to be as potentially as serious as those from any current practices. High exposures of aquatic organisms to many of these compounds occurs in the late winter and spring, when water runoff from land is greatest and many aquatic species reproduce (Adams et al., 1996) and whose eggs, larvae and juveniles are the most susceptible stages to contaminants.

Many uncertainties remain about contamination in the Delta. It is known that contaminants enter the Delta: selenium from the Western San Joaquin Valley, pesticides from both the Sacramento and San Joaquin watersheds, mercury from mines and other sources, copper used as an algaecide, PAHs, MTBE and perhaps TBT from heavy boat traffic, and metals from mining. Temperature effects on habitat suitability is also in need of study. Yet not one of these has been studied systematically or in detail in any Delta environment. Although the last several years have seen great advances in our understanding of the distribution and abundance of contaminants in the estuary (e.g., SFEI, 1995), there has not been as much emphasis on defining contaminant exposures in the Sacramento and San Joaquin Rivers and the Delta. Moreover, we have no comprehensive understanding of the risk that contaminants might pose to the health of individuals and populations in the estuary or upstream of the tidal portion of the ecosystem. To improve our understanding, we must determine the degree of contaminant exposure to aquatic organisms, if there is link between exposure and sublethal and chronic toxicity, and then use the exposure-effect relationships to determine the risks to aquatic populations in the catchment of the Bay-Delta.

It is also unclear how restored habitats, such as wetlands, will affect the transport, conversion, and bioavailability of contaminants (e.g., mercury). Examining the relationships between contaminant exposure and effects on organisms is critical to our understanding the links between the two. Actions in one area may have profound effects in another. There is also need to go beyond traditional toxicity tests and examine the overall survival and reproductive potential of organisms. Each contaminant is associated with specific target organisms and possibly target impacts on the organism. Synergistic effects upon biota of the multiple contaminants entering the system need to be evaluated. Such studies will provide insight on effectively restoring an organisms' health.

8. Beyond the Riparian Corridor

Efforts made to acquire or manage lands beyond the riparian zone can have multiple benefits. Not only can they be used to expand functional floodplain to allow natural flooding and stream meander, but they can also be managed or enhanced to provide habitat for a number of native species at risk or in decline. Habitat types found beyond the riparian corridor that support species of concern include a variety of wetland types, including: seasonal wetlands (such as vernal pools and flooded fields), perennial grasslands, and inland dune communities. A number of native species in these "upland" areas—such as waterfowl and game birds, Swainson's hawk, greater sandhill crane, California tiger salamander and western pond turtle--appear to thrive in certain agricultural lands managed to benefit wildlife species. Other species exhibit greater habitat specificity and many have suffered population declines or extirpations from past disturbances and conversion of valley bottom areas adjacent to stream channels and riparian zones. Included are such species as salt marsh harvest mouse, valley elderberry longhorn beetle, giant garter snake, and Lange's metalmark butterfly.

It is often difficult to determine the extent to which the status and trends of particular species populations are controlled by natural variability, and to what extent they are the product of human disturbances. Consequently, it is difficult to know if observed changes in the ecosystem are attributable to restoration and management actions or if they are driven by conditions beyond human control. Developing a better understanding of species-habitat interactions, species-species interactions, and species responses to variable ecosystem conditions is essential to make efforts to recover sensitive species more effective.

It is also important that progress is made toward improving and quantifying the understanding of how areas adjacent to riparian zones, in particular agricultural lands, influence ecological health. It is currently unknown how most species respond individually to disturbances common in landscape areas adjacent to riverine systems, including crop and dryland agriculture, land development, and invasion of non-native species. In California, ecosystem restoration actions are most often the neighbor to agricultural areas. Important questions remain about how agricultural practices can be enhanced or modified to improve ecological conditions and species health. Alternative pest management and fertilizer practices, cropping patterns, the use of no-till agriculture or winter flooding, and the establishment of buffer zones around cropped areas are all areas where pilot scale projects could yield information about how to best implement these types of practices on a large scale and the quantify the benefits associated with them.

There are also agricultural lands and other open space which are considered to be important in their current condition adjoining habitat areas or which have potential for future ecosystem restoration that are at risk of urban development. These areas would benefit from conservation or agricultural easements to preserve the current land use. Another significant concern remains over the potential third party impacts to areas adjoining restoration lands. Rural and agricultural communities have the greatest potential to be influenced by large-scale restoration actions, and there are concerns regarding the potential for adverse economic and regulatory effects from converting agricultural lands to ecosystem restoration areas.

9. X2 Relationships

Current management of the Bay-Delta system is based in part on a salinity standard known as the "X2" standard. This standard is based on empirical relationships between various species of fish and invertebrates and X2 (or freshwater flow in the estuary). Positive relationships with flow (negative with X2) have been observed for several estuarine-dependent species as well as some anadromous species during their migration through the Delta. As with all empirical relationships, these are not very useful to predict how the system will respond after it has been altered by various actions in the Delta, including altered conveyance facilities. This uncertainty illustrates a broader issue: a lack of predictive capability for determining how the ecosystem might respond to changes in its flow regime. This predictive capability will need to be developed to the point where it can support critical decisions about future restoration actions. This implies a need to determine the underlying mechanisms of the X2 relationships so that the effectiveness of various actions in the Delta can be put in context with this ecosystem-level restorative measure.

10. Decline in Productivity

Productivity at the base of the foodweb has declined throughout the Delta and northern San Francisco Bay. Although some of this decline can be attributed to the introduced clam *Potamocorbula amurensis*, or Asiatic clam, not all of the decline is explained. The decline at the base of the foodweb has been accompanied by declines in several species and trophic groups, including mysids and longfin smelt. The long-term implications of this suggest a potential reduction in the capacity of the system to support higher trophic levels, which could limit the extent to which Bay-Delta fish populations can be restored unless creative solutions can be found to increase foodweb productivity.

It is also unclear how actions in the watershed influence estuarine foodweb productivity. For example, more frequent inundation of floodplains and bypasses may stimulate estuarine, as well as riverine, productivity by supplying larger loads of carbon and nutrients to the estuary.

Because we know little about the different sources of decline in productivity at the base of the foodweb, and how non-native species have changed, and are changing, foodweb dynamics, early efforts to address this uncertainty will likely emphasize monitoring, research, and modeling projects that address the issue of decline in foodweb productivity. Examples of projects include:

- Research to examine how introduced species have changed foodweb dynamics, and how efforts to control or eradicate introduced species may affect foodwebs;
- Monitoring and research to identify and examine other potential sources affecting productivity at the base of the foodweb, such as contaminants;
- Monitoring, research, and modeling to examine the role of carbon and nutrients introduced from bypasses and rivers in stimulating estuarine productivity;
- Monitoring and research to understand how the restoration of geomorphic processes (such as bed mobility) and riparian vegetation stimulates aquatic invertebrate production, and how this in turn affect fish survival and growth.

Several types of implementation projects can also be structured and monitored to address uncertainties about foodweb productivity. For example, gravel augmentation projects can include monitoring of aquatic invertebrates. Riparian re-vegetation projects can include complementary monitoring to assess the relative role of insect drop and aquatic invertebrates in fish growth. Projects that create shallow-water habitat can monitor the exchange of carbon between open water environments and the restored wetlands.

11. Diversion Effects of Pumps

Both the State Water Project (SWP) and the Central Valley Project (CVP) have large-capacity pumping facilities located in the southern Delta, where they divert water into the California Aqueduct and the Delta-Mendota Canal for delivery to the San Joaquin Valley and Southern California. Pump operations can affect the circulation of water, and therefore biota, in interior Delta channels and sloughs. The pumps are a source of mortality for several species, including protected fish species. However, it is unclear to what extent pump operations affect the population size of any one species of fish or other biota, or by what mechanisms the pumps most affect fish and biota. For example, the pumps can be a source of direct morality through diversion, impingement upon fish screens, or handling mortality associated with fish salvage operations. The pumps can also have indirect affects upon fish and other biota. For example, the pumps can expose fish to higher rates of predation by drawing them into Clifton Court Forebay, which provides habitat for non-native warm-water fish species that prey upon native fish species. Similarly, the pumps can affect the survival of fish and other biota by drawing them toward the southern Delta, where there is generally less habitat available to support them. By altering the normal circulation patterns of water in the Delta, the pumps can also affect fish survival by altering migrational cues. Because the mechanisms underlying entrainment are not clear, it is unclear which restoration strategy, or mix of strategies, will most reduce the effects of pump operations on sensitive fish species.

It is also unclear to what extent other sources of Delta mortality affect the population of any given species, which has a bearing upon the relative importance of entrainment in the SWP and CVP pumps as a source of mortality. For example, there are thousands of agricultural diversions located in the Delta, and it is unclear how important they are, both individually and cumulatively, as a source of mortality for any given species of fish. Similarly, it is unclear to what extent water quality in the Delta affects the survival of biota or the population dynamics of any given species.

More information on the ecological and biological effects of entrainment and altered hydrodynamics will be pivotal for CALFED in choosing a water conveyance method, because it will help determine to what extent an isolated conveyance facility can be expected to alleviate conflicts between sensitive fish species and Delta exports. Reducing this uncertainty is also essential to ensure that the expenditure of restoration funds is well targeted.

Implementation projects conducted as adaptive management experiments will be necessary to better understand the relative importance of entrainment in the SWP and CVP pumps as a source of mortality for individual species, as well as the underlying mechanisms. Such implementation projects will require advance planning to manage risks to important resources, such as protected fish species and water supplies, and since the expense of such implementation projects will likely be significant. Such advance planning will include the development of conceptual models, simulation modeling, and decision modeling to guide the selection and design of adaptive management experiments, expanded monitoring, and targeted research. The use of an Environmental Water Account (EWA) will provide an early opportunity for adaptive management experiments designed to study the mechanisms underlying the diversion effects upon Delta ecology and biology.

12. THE IMPORTANCE OF THE DELTA FOR SALMON

Scientific opinion varies on the suitability and use of the Delta for rearing by juvenile salmon and steelhead. Although chinook salmon use other estuaries for rearing, most research on salmon in the Delta, and resulting protective measures, focus on smolt passage. However, if substantial numbers of salmon fry rear in the Delta and these fish contribute substantial recruitment to the adult population, then current actions to protect migrating smolts (e.g., pulse flows) might be modified or supplemented by actions designed to protect resident fry (e.g., extended high flows to flood shallow areas).

Early efforts to address this uncertainty will likely emphasize monitoring, targeted research, modeling, and pilot projects. Examples of such projects include:

- Expanded monitoring and research to better determine what fraction of salmon fry rear in the delta for different salmonid species, and which tributaries contribute larger fractions of salmon fry;

- Research to evaluate the survival of salmon fry that rear in the Delta versus the survival of fry that rear in tributaries;

- Research and monitoring to determine if Delta fry rearing is a life history strategy, a function of lack of rearing habitat in tributaries, and/or a function of tributary flow patterns;

- Population modeling to evaluate actions that emphasize Delta rearing and actions that emphasize smolt passage through the Delta; and

- Pilot projects that provide Delta rearing habitats for salmon fry and monitor their use.

SEIZING UPON RESTORATION OPPORTUNITIES

There are many opportunities to build upon existing restoration efforts in the Bay-Delta ecosystem, including ongoing and recent restoration projects funded by Category III, CVPIA, and CALFED's Restoration Coordination programs. Several local and regional watershed groups have also completed or are conducting restoration planning efforts that will facilitate the selection and implementation of restoration actions. For example, the Upper Sacramento River Fisheries and Riparian Habitat Plan (SB 1086) can help guide restoration of the Upper Sacramento River. There are also opportunities to implement large-scale restoration projects in the Bay-Delta ecosystem that will enable resource managers to test different hypotheses and to refine restoration methods, thereby contributing not only to the long-term Ecosystem Restoration Program, but also to restoration science in general.

This section identifies some promising opportunities for initiating large-scale ecological restoration in Stage 1 of the ERP. These are only a sample of the opportunities for ecological restoration that would potentially benefit endangered species, as well as other native species. The restoration activities described below have not been subjected to the adaptive management process described earlier in this chapter. A more rigorous assessment of the costs and benefits of the following activities might indicate that some of these projects are less promising than imagined. This list of opportunities is illustrative; it is meant to demonstrate the types of restoration activities available in the ERP.

The choice of specific examples was guided by the principles that were established in the strategic plan: that restoration of endangered species is best approached through restoration of the ecological structures and processes on which the species depend and that habitat restoration and maintenance is a dynamic, not a static, process. In light of these principles, opportunities have been identified that focus on ecological processes and that could be implemented in ways that would be largely self-sustaining. For example, opportunities identified for Bay-Delta tributaries emphasize the restoration of physical and ecological processes, rather than artificial measures to maintain populations, such as hatcheries or creation of habitats that will not be sustained by ongoing processes. Examples have also been selected that would generate results within the short timeframe of Stage 1.

OPPORTUNITIES IN THE BAY-DELTA

1. **REDUCE THE INTRODUCTION OF BALLAST-WATER ORGANISMS FROM SHIPS TO 5% OF 1998 LEVELS.** The shipping industry can greatly reduce and eventually eliminate the introduction of organisms through ballast water using existing technology. Significant progress could also be made in reducing the introduction of non-native species from other sources as well. This is a preventative rather than a restorative activity. Given the impacts that introduced invasive species have already had on the ecology of the Bay-Delta ecosystem, however, the eventual elimination of all additional species introductions is crucial to the ultimate success of the ERP.

2. **EXPAND OR ENHANCE SEASONAL SHALLOW-WATER HABITAT IN THE BYPASSES (E.G., YOLO BYPASS) AND NEAR-**

DELTA FLOODPLAINS. The bypasses and other "artificial" floodplains that flood during wet years are demonstrably productive places for juvenile salmon and splittail, as well as waterfowl. By re-engineering the weirs that release water into the bypasses, the bypasses presumably can be flooded (at least partially) on a more regular basis and could therefore be productive in most years. Habitat creation in flood bypasses presents one of the best opportunities for ecosystem restoration because large areas of habitat can probably be created at small cost while retaining the flood management functions of the bypasses.

3. **INITIATE SEVERAL LARGE-SCALE PILOT PROJECTS USING DIFFERENT APPROACHES TO RESTORING TIDAL MARSHES IN THE NORTH DELTA (AROUND PROSPECT ISLAND), SUISUN MARSH, AND THE NORTH BAY.** These projects could be designed as experiments to assess the benefits for marsh-dependent species and the most effective techniques of restoration, as well as providing an opportunity to evaluate options for minimizing or controlling invasive plant species. Note also that this kind of project represents an implementation of the three levels of adaptive management action: targeted research, pilot testing of techniques, and large-scale restoration.

4. **DEVELOP MEANS TO CONTROL INVASIVE AQUATIC PLANTS IN THE DELTA.** Invasive plants, such as water hyacinth and *Egeria densa* (Brazilian water weed), are clogging many sloughs and waterways of the Delta, not only impeding boat traffic, but also creating environments that are unfavorable for native fishes. The California Department of Boating and Waterways has an Egeria control program, but has not yet received CEQA approval for use of chemical controls. There is an immediate need to develop ways by which to control these plants that are not, in themselves, environmentally harmful. An opportunity exists for the ERP to join forces implementing ambitious eradication and control measures with agencies, organizations, and water districts concerned with the deleterious effects of these water weeds on navigation in the Delta, clogging of water intakes and fish screens, and diminished recreational uses.

5. **INITIATE TARGETED RESEARCH ON MAJOR RESTORATION ISSUES, SUCH AS: (1) HOW TO CONTROL PROBLEM INVASIVE SPECIES SUCH AS THE ASIAN CLAM (*POTAMOCORBULA AMURENSIS*) WHICH HAS A NEGATIVE EFFECT ON FOODWEB DYNAMICS IN THE ESTUARY; (2) FACTORS LIMITING THE ABUNDANCE OF HIGH-PRIORITY ENDANGERED SPECIES; AND (3) DESIGN OF HABITATS FOR SHALLOW-WATER TIDAL MARSH AND BYPASSES.** Use such research to begin addressing issues raised in the twelve issues above. Ultimately, the limited funds available for restoration will be much more effectively spent if there is a clear understanding of the relative seriousness of the diverse problems facing the estuarine and riverine ecosystems and of the ability to solve those problems. Where the research can be linked to pilot or large-scale restoration projects, the benefits will be multiplied.

6. **COORDINATE WITH THE VARIOUS LEVEE AND FLOOD CONTROL STATE, LOCAL, AND FEDERAL PROGRAMS TO ESTABLISH DESIGN CRITERIA AND STANDARDS THAT ENSURE THAT LEVEE REHABILITATION PROJECTS INCORPORATE FEATURES BENEFICIAL TO THE AQUATIC AND RIPARIAN ENVIRONMENTS OF THE DELTA.** The majority of the approximately 50 Delta islands are hydrologically disconnected by levees from the primary channel, open-water estuarine environment. Most of these levees are likely to remain in future years and to be reinforced with rock riprap, raised and widened, or rehabilitated in other ways to prevent levee failure. Potentially beneficial projects that could be incorporated into these programs include levee setbacks and creation of broad submerged benches, as well as the construction of broader levees to support riparian vegetation. Developing contingency plans for responses to major and multiple levee failures in different parts of the Delta can also provide ecosystem benefits and minimize disturbances associated with levee repair.

7. **ESTABLISH LARGE-SCALE PILOT PROJECTS ON BOTH LEVEED DELTA ISLANDS AND ON SUBMERGED ISLANDS (E.G. FRANK'S TRACT) TO TEST AND MONITOR TECHNIQUES FOR RETURNING SUBSIDED DELTA ISLANDS TO SHALLOW-WATER AND MARSH HABITATS.** On leveed islands, areas could be diked off, partially flooded, and planted with tules to examine the potential for natural deposition of organic matter to raise island levels. On submerged islands, dredge spoils and other materials could be used to create shallow-water habitats. One potential benefit of a project to convert parts of Frank's Tract to shallow-water habitat would be reduction of wave erosion affecting Delta island levees surrounding the tract.

8. **DEVELOP LARGE-SCALE PILOT PROJECTS THAT EXAMINE THE RELATIONSHIP BETWEEN VARIABLE SALINITY AND THE MAINTENANCE OF NATIVE SPECIES IN THE DELTA, ESPECIALLY IN SHALLOW-WATER HABITATS.** Historically, the Delta and other parts of the estuary had salinity regimes that fluctuated from year to year as well as from month to month and, often, daily with tides. The native organisms presumably evolved in such variable conditions and should be favored by them. Many of the non-native species (e.g., freshwater aquatic plants, freshwater and marine clams), in contrast, may be favored by the more stable conditions now present as the result of regulation of freshwater inflows into the Delta. Opportunities exist to restore large tracts of former tidal shallow-water habitat in the north Delta, lower Yolo Basin, and along river channels and sloughs in the vicinity of Sherman Island. Once these shallow-water habitats are in place, it may be possible to vary the position of the salinity gradient in these areas, thereby testing the effects of variable salinity on native and introduced organisms in the shallow-water habitats. This action would provide valuable information on such things as: (1) the extent to which physical habitat may be limiting native and introduced species, (2) how salinity gradients and variability affect conditions and species within the shallow-water habitats, and (3) calibration of models to evaluate the changes in the hydraulics of the Delta that would result from having more extensive tidelands and more breached Delta islands.

OPPORTUNITIES FOR RIVERS

1. **MIMIC NATURAL FLOW REGIMES THROUGH INNOVATIVE METHODS TO MANAGE RESERVOIR RELEASES.** There is underutilized potential to modify reservoir operations rules to create more dynamic, natural high-flow regimes in regulated rivers without seriously impinging on the water storage purposes for which the reservoir was constructed. Water release operating rules could be changed to ensure greater variability of flow, provide adequate spring flows for riparian vegetation establishment, simulate effects of natural floods in scouring riverbeds and creating point bars, and increase the frequency and duration of overflow onto adjacent floodplains. In some cases, downstream infrastructure of river floodways may require upgrading to safely accommodate a more desirable natural variability and peak discharge magnitude associated with moderate floodflows (e.g., strengthen or set levees back).

2. **MIMIC NATURAL FLOWS OF SEDIMENT AND LARGE WOODY DEBRIS.** Dams disrupt the continuity of sediment and organic-debris transport through rivers, with consequent loss of habitat, and commonly, river incision, downstream. In some cases, such as Englebright Dam on the Yuba River, dam removal can be considered as a potential solution to reestablishing continuity of sediment and debris transport, as well as opening access to important spawning and rearing areas. Most dams, however, cannot be removed, so methods must be sought to reestablish continuity of sediment and wood transport with the dam in place. Coarse sediment can be artificially added below dams to at least partially mitigate for sediment trapping by the dam and ameliorate the impacts of sediment-starved flows. This approach has been successfully used in Europe, using sediment from natural (landslide) and artificial sources (injected from barges). On

the River Rhine, enough gravel and sand are added below the lowest dam to satisfy the present sediment transport capacity of the Rhine to prevent further incision of the bed (an average of over 200,000 cubic yards annually). On the Sacramento River, gravels have been added at a rate much below the river's transport capacity so they are vulnerable to washout at high flows. A more sustainable approach would be to add gravel (and sand) on a regular basis and at a much larger scale to better mimic natural sediment loads and therefore provide the sediment from which the river would naturally create and maintain spawning riffles. This latter approach requires a large commitment of resources and should be undertaken only in rivers where other factors (e.g., temperature regime) are favorable (or can be made favorable) for recovery of species (such as the upper Sacramento). Such opportunities will be more economical where sources of dredger tailings or reservoir Delta deposits are available nearby.

While recognizing the navigation and flood safety issues associated with large woody debris in rivers, the importance of this debris to the foodweb and structural habitat for fish should not be overlooked. There is an opportunity to investigate ways by which to pass debris safely through dams and bridges. This may require replacing some existing bridges with those less prone to trapping woody debris.

3. **IDENTIFY AND CONSERVE REMAINING UNREGULATED RIVERS AND STREAMS AND TAKE ACTIONS TO RESTORE NATURAL PROCESSES OF SEDIMENT AND LARGE WOODY DEBRIS FLUX, OVERBANK FLOODING, AND UNIMPAIRED CHANNEL MIGRATION.** Most rivers in the Central Valley are regulated by large reservoirs and therefore require considerable investment to recreate the natural processes needed to sustain true ecosystem restoration; however, a few large unregulated rivers still exist, such as the Cosumnes River and Cottonwood Creek. Lowland alluvial rivers and streams with relatively intact natural hydrology should be identified and made a high priority for acquisition of conservation and flooding easements, setting back of levees, and other restoration actions because such actions on these rivers are likely to yield high returns in restoration of natural processes and habitats and, ultimately, fish populations.

4. **UNDERTAKE FLUVIOGEOMORPHIC-ECOLOGICAL STUDIES OF EACH RIVER BEFORE MAKING LARGE INVESTMENTS IN RESTORATION PROJECTS.** River ecosystem health depends not only on the flow of water, but on the flow of sediment, nutrients, and coarse woody debris and on interactions between channels and riparian vegetation, variability in flow regime, and dynamic channel changes. It is only through interdisciplinary, watershed, and historical scale studies that the constraints and opportunities particular to each river can be understood. For example, it was only after a fluviogeomorphic study of Deer Creek that the impact of flood control actions on aquatic and riparian habitat was recognized, a recognition that has lead to a proposal for an alternative flood management approach designed to permit natural river processes to restore habitats along Lower Deer Creek.

5. **UNDERTAKE FLOODPLAIN RESTORATION ON A BROAD SCALE, WHERE LAND OR EASEMENTS CAN BE ACQUIRED AND WHERE THE RIVER HYDROLOGY INCLUDES (OR CAN BE MADE TO INCLUDE) SUFFICIENTLY HIGH FLOWS TO INUNDATE FLOODPLAIN SURFACES.** Restoration of floodplain function can produce many benefits, such as reducing stress on remaining levees, reducing excessive channel scour, and encouraging establishment of riparian vegetation over a larger area within the adjacent floodplain. A range of possible measures will need to be employed to fit local conditions, such as widening flood bypasses or creating new ones; setting levees back, creating backup levee systems, or deauthorizing specific levee reaches; constructing armored notch weirs in levees and purchasing flood easements to restore floodbasin storage functions; or implementing measures described in item two above to increase the frequency and duration of overbank flow onto existing floodplains. Reactivating the historical floodplain can

provide effective, reliable and cost effective flood storage while restoring important ecological processes.

6. **Reduce or eradicate invasive non-native shrubs and trees from riparian corridors.** Of particular importance is the control of the spread of tamarisk and giant reed, two introduced species that displace native flora, offer marginal value to fish and wildlife, and cause channel instability and reduced floodway capacity. Some rivers, such as Stony Creek and Cache Creek and the lower San Joaquin River, have undergone large expansions of these non-native species, even in the past 10-15 years. A combination of large-scale eradication pilot projects and targeted research on several streams will help to temporarily reduce the rate of expansion of their range, identify the most vulnerable stream environments, and determine whether valley-wide eradication or suppression measures are warranted or feasible.

7. **Remove barriers to anadromous fish migration where feasible.** Significant progress has been made in recent years to improve salmon passage on several spawning streams (e.g., Butte Creek, Battle Creek) by removing barriers, consolidating diversion weirs, or constructing state-of-the-art fish passage structures. Existing and potential spawning areas in the ERP focus area that are not obstructed by major reservoir dams, but are currently obstructed by other barriers, should be identified and action taken to restore anadromous fish spawning upstream.

8. **Develop a partnership with the Army Corps of Engineers, Reclamation Board and DWR to fully integrate river and floodplain ecological restoration with flood management measures being considered in the 4-year Comprehensive Study underway for the Sacramento and San Joaquin River basins.** Many of the ecological approaches to river restoration listed above are feasible only if and when the overall capacity of the Valley flood control system is expanded and the risk of flooding farms and cities has been significantly reduced. In other words, more room within the managed floodways must be made available for the "roughness" of habitats and the ecologically desirable tendency of alluvial river channels to migrate by eroding of banks or spread high flows onto natural floodplains. Pilot projects and studies should be initiated that test innovative solutions to improve floodplain management with significant ecosystem benefits, such as the proposed floodplain restoration projects under evaluation along the lower San Joaquin and Cosumnes Rivers.

9. **Promote and support river-based conservancies and broad coalitions to resolve conflicts and achieve local consensus over the restoration and management of river corridors.** Local coalitions with technical and financial support from CALFED, CVPIA, and other state and federal programs have been successful at reaching broad agreement on solutions and implementing projects to restore river habitats and recover threatened fish populations. Expanding financial and technical assistance throughout the ERP focus area can yield similar benefits in other ecological management units.

Regulatory Compliance

The proposed Stage 1 actions will also need to be reviewed to determine which can be covered adequately by the Programmatic EIS/EIR and which will require additional, site-specific (second tier) environmental documentation and the acquisition of regulatory permits. Most proposed ERP actions will require additional documentation, so it will be important to ensure that the proposed Stage 1 actions will be ripe for implementation by identifying the permitting and environmental documentation requirements for each action and estimating the time required to complete them. Since the acquisition of regulatory permits and preparation of environmental documents can delay the implementation of the program, it is important to streamline the regulatory compliance process. Two mechanisms to facilitate compliance include bundling actions and building off of permits and documentation from other actions. It is possible to bundle multiple ERP and related non-ERP CALFED actions so that they are covered by a single document or permit, thereby saving time and the cumulative impacts of the actions are more adequately described. It may also be possible to build off of permits or reference environmental documents prepared for restoration actions already underway through CVPIA, Category III, and CALFED Restoration Coordination programs. (See the CALFED Handbook of Regulatory Compliance [1996] or the Regulatory Compliance Technical Appendix in the Revised Draft EIS/EIR for a more detailed description.)

♦ CHAPTER 6. INSTITUTIONAL STRUCTURE AND ADMINISTRATIVE CONSIDERATIONS

INSTITUTIONAL STRUCTURE

CALFED has not yet determined the institutional structure or entity that will be used to implement the overall CALFED Program or the constituent Ecosystem Restoration Program (ERP). The Bay Delta Advisory Council (BDAC) Assurances and Governance Work Groups have evaluated several different institutional arrangements for implementing the ERP, including:

- a continuation of informal coordination among existing CALFED agencies,
- more formal coordination of state and federal agencies through a Joint Authority, and
- a new non-regulatory agency or organization independent of existing state and federal agencies.

Regardless of the institutional structure, the ERP will not be implemented through the use of regulatory authorities. Rather, the ERP will rely on consensus-based cooperation with local watershed groups and landowners and through transactions with willing sellers only. The ERP will not preempt the existing regulatory authorities of agencies.

Many stakeholders have expressed support for a new entity to implement the ERP rather than existing CALFED agencies, reasoning that a new entity could:

- be more accountable for the success of the ERP;
- help prevent a perceived conflict of interest by separating the restoration of Bay-Delta resources from those agencies responsible for regulating Bay-Delta resources;
- be more efficient with funding and personnel resources because of more centralized funding, implementation, and decision making;
- provide greater opportunity for stakeholder participation in decision making by allowing stakeholder input, and possibly representation, on the ERP decision-making body; and
- help ensure a more scientific basis for decision making by providing independent scientific counsel and oversight more directly to a centralized decision-making body.

These are attractive characteristics of an ERP implementation entity, but it is not yet clear that a new agency or organization will be required to embody these characteristics. Reconfiguring CALFED agency administrative structures and improving interagency coordination may be able to provide greater accountability, efficiency, stakeholder participation and independent scientific oversight. There is also no guarantee that a new agency or organization will perform as planned. Determining the best institutional structure for implementing the ERP will require additional analysis and discussion among CALFED agencies and stakeholders.

Through the Bay Delta Advisory Council (BDAC) Assurances and Ecosystem Restoration Work Groups, CALFED agency personnel and stakeholders have identified some of the critical responsibilities, functions, and powers that will be required to implement the ERP successfully, regardless of the specific institutional structure or entity selected.

To conduct daily operations, the ERP implementation entity will need to perform normal administrative duties, such as the power to:

- hire and dismiss staff

- receive direct funding from both public and private sources
- enter into contracts, and
- disburse grants.

As an agent of environmental restoration and management, the ERP implementation entity will also require more specialized functions, such as the ability to:

- acquire permits,
- serve as lead agency for preparation of environmental documents, and
- acquire, hold, and sell water and property rights.

The institutional structure designed to implement the ERP will include components to help minimize conflict among stakeholders and beneficial uses of Bay-Delta resources. The features include:

- incorporating **PUBLIC INVOLVEMENT** in the planning and decision-making processes during the implementation phase;
- Informing and engaging a broad public in the ERP through a **PUBLIC OUTREACH PROGRAM;**
- Ensuring the scientific credibility of the ERP through **SCIENTIFIC REVIEW**;
- Documenting and disseminating policy and management decisions, and the scientific findings and raw data upon which they are based, through an **INFORMATION MANAGEMENT SYSTEM**; and
- Defining a **DISPUTE RESOLUTION** process to help manage conflict over intractable issues.

PUBLIC INVOLVEMENT

The CALFED process has demonstrated the value of engaging stakeholders in the planning and decision-making processes. After decades of conflict, stakeholders are now working together and with CALFED agencies to develop the long-term, comprehensive plan to restore ecological health and improve water management for beneficial uses of the Bay-Delta system. Though there are still significant points of disagreement among stakeholders and CALFED agencies, this does not detract from the remarkable success achieved thus far in defining points of agreement. The ERP institutional structure will build upon the success of public involvement in the planning phase by providing avenues for public involvement during the implementation phase. For instance, a critical strategy for implementing the ERP is to work with local watershed groups composed of local stakeholders to refine, evaluate, prioritize, implement and monitor restoration actions.

The ERP institutional structure will also explore methods for involving the public in regional planning and decision making, including the use of electronic technology. E-mail services (such as address lists and e-mail reflectors) and Internet services (such as virtual work space in which participants engage in simultaneous writing and review) can be provided for work groups and stakeholders to facilitate collaboration.

PUBLIC OUTREACH

Long-term restoration and management of the Bay-Delta ecosystem requires public support and education. Public funds will finance much of the restoration effort, so it is important that a broad public understands the benefits of ecosystem restoration. And since many human activities affect the health of the Bay-Delta ecosystem, public education will be necessary to help reduce or eliminate ecological stressors.

The public outreach program incorporated into the ERP institutional structure will use both traditional and innovative means for communicating the progress and direction of the ERP to the public. Traditional means will include the production of newsletters, brochures, press releases, and educational kits, as well as media contact.

The public outreach program will also capitalize on electronic technology to reach a broader public and to increase the type of information accessible to the public. Electronic mailing lists and a website can alert members of the public to meetings and important events. Because reproduction and mailing costs can limit or prohibit the wide distribution of important documents, electronic versions of documents posted to a website will increase the types of information that can be made available.

The public outreach program will also explore more active outreach methods, such as facilitating school visits by ERP decision-makers and scientists and arranging restoration site visits for school and community groups.

SCIENTIFIC REVIEW

An adaptive management approach to ecosystem restoration and management requires up-to-date science. Ensuring the scientific credibility of the Ecosystem Restoration Program will be an important responsibility of the entity selected to implement it, because it will help maximize the effectiveness of the restoration program and build public confidence and support. A few of the potential mechanisms for ensuring scientific credibility of the restoration program include:

STANDING COMMITTEE OF INDEPENDENT SCIENTISTS

A standing committee of independent scientists could provide scientific review and advice to the ERP implementation entity. A committee composed of recognized experts from the many scientific disciplines associated with the Bay-Delta ecosystem could help to review scientific findings, develop restoration guidelines, establish restoration priorities, design restoration actions to maximize their information value, and identify monitoring and research needs. The participation of the independent scientific committee could include informal advice or formal recommendations.

PEER REVIEW REQUIREMENTS

The ERP implementation entity can require that the science used to justify CALFED management decisions be published in national, peer-reviewed journals. This approach, used in management of the Everglades and Chesapeake Bay, provides a means of obtaining review from technical experts, free of charge, in a reasonably timely manner. It also helps to assure the quality of the science underlying the restoration program, and it provides important contact with the broader scientific community, which can be useful in establishing review teams. Because publication can take 1-2 years following the initial submission of a manuscript, management decisions will likely need to proceed following internal review by agency scientists or a standing scientific committee.

EXTERNAL SCIENTIFIC REVIEW

Annual or periodic review of the overall Ecosystem Restoration Program by a panel of scientific experts could help evaluate progress toward restoration goals and infuse the restoration program with new ideas. The panel could also assess the status of the scientific basis for CALFED actions. Experts familiar with other large-scale restoration programs could also provide valuable comparative analysis.

ANNUAL WORKSHOPS

The ERP implementation entity will conduct annual (or biennial) public meetings in which resource managers and scientists:

- describe restoration actions implemented during the previous year,
- describe restoration actions to be implemented in the following year,
- present and assess monitoring data and research findings, and
- re-evaluate restoration problems, goals, objectives and actions.

Not every restoration action will be ripe for annual review in a given year. Individual restoration actions will need to be reviewed periodically on a schedule established by the ecological time-scale appropriate to the restoration action. The interval between reviews for an individual action will be based on the time expected for the ecological process or species to respond to the restoration or management intervention.

The annual public workshops could also help to publicize the restoration program and educate and engage the public.

DISPUTE RESOLUTION

There is a long history of conflict over Bay-Delta resources. CALFED was formed to help reduce the level of conflict in the Bay-Delta system by bringing together state and federal agencies with stakeholder groups in a collaborative planning process. Working together, traditionally combative groups have helped build consensus on the broad program elements that will be necessary to simultaneously resolve the major problems affecting the Bay-Delta system. Many features of the current CALFED planning process will be incorporated into the ERP institutional structure to help prevent or reduce conflict during the implementation phase. For instance, involving the public in ERP decision-making and implementation will allow agency personnel and stakeholders to identify differences of opinion early before they fully develop and become entrenched. Similarly, working with local watershed groups to refine, evaluate, prioritize, and implement restoration actions will help build local consensus. Independent scientific review will help to resolve technical disputes, as will the adaptive management process, which can accommodate alternative hypotheses about ecosystem structure and function.

Despite a fundamental structure designed to reduce conflicts, the ERP institutional structure will need to include a dispute management strategy to address remaining conflicts or new conflicts that emerge. An effective dispute management process can help pre-empt the use of litigation to settle disputes. Litigation commonly forces each side in a dispute to take an extreme position, which can intensify conflict among stakeholders. Dispute resolution provides all parties with lower risk ways of exploring more central positions, and it can provide momentum for building consensus by enumerating points of agreement rather than focusing exclusively on points of contention.

Using a neutral facilitator to conduct the dispute resolution process will help to reduce conflict. Structuring a dispute resolution process less as a formal hearing and more as a professional workshop—with briefings, discussion, and interpretation of the information at issue—will further reduce the combative nature of the dispute.

Although specific approaches to dispute resolution will be dictated by the dispute at hand, the following general guidelines will help structure the dispute resolution process:

- A formal announcement will be made that an issue is being subjected to the dispute resolution process.
- The stakeholders to be included in the process will be identified.
- A formal description and analysis of each stakeholder's position will be provided.
- All of the main decision makers, including agencies with regulatory authority relevant to the dispute, will be identified and included in the process.
- The scope of the issue will be determined clearly.
- The means by which the final recommendation or decision is to be rendered (administrative decision, arbitration, consensus, majority vote, etc.) will be identified.
- Any limits, such as legislative mandates or limits on the delegation of authority, will be identified.

At the conclusion of the dispute resolution process, participants will compile a report identifying points of agreement, remaining points of contention, and an agenda for resolving the remaining issues.

INFORMATION MANAGEMENT SYSTEM

Underlying the public involvement, public outreach, scientific review, and dispute resolution components of the ERP institutional structure is the need for a powerful information management system. An adaptive management approach requires information. Nearly every environmental intervention offers an opportunity (and obligation) to document the ecosystem's prior condition and response to intervention and offers an opportunity to validate or revise hypotheses. Adaptive management also involves continual inventory, analysis, and interpretation of scientific data. An information management system will help collect, store, track and disseminate the decisions and raw data that drive the restoration program.

An information management system will help facilitate public involvement and scientific review by providing access to the information being used to evaluate or justify a proposed action, including not only results and conclusions, but also baseline information, monitoring data, models and their parameters, and assumptions. Participating stakeholders and CALFED agency personnel will be better informed, and individuals and organizations will be able to conduct their own independent analysis of data underlying proposed actions. An information management system could also be used in conjunction with a website to provide access to reports in common use within the CALFED community, including digital copies of printed reports.

An information management system will also be an important component of dispute management by providing common access to the data underlying decisions.

To provide rapid production and dissemination of information, the information management system will rely principally on electronic communication. However, the information management system will also accommodate the information needs of stakeholders who rely upon more traditional means of print communication.

Given the breadth and depth of CALFED issues, GIS is absolutely essential for a number of critical functions, including simple project tracking, database management, monitoring, analysis of connections between actions, and geographic visualization of complex scientific and planning information. The system should link and integrate the map libraries of all CALFED agencies and collaborators, instead of creating a new central repository. Traditional stand-alone GIS operations should be linked through web-based GIS capabilities.

♦ APPENDIX A. DEFINING THE OPPORTUNITIES AND CONSTRAINTS: A HISTORICAL PERSPECTIVE

THE IMPORTANCE OF A HISTORICAL PERSPECTIVE

The CALFED Ecosystem Restoration Program will succeed only to the extent that it is based on a solid understanding of natural physical and ecosystem processes and habitats, and how these have been changed, so that restoration actions can be effective, adequate, and realistic. To be most effective, restoration actions should restore processes that maintain conditions favorable to native species so that ecological benefits are sustainable and will not disappear in the next flood or from other impacts on artificially-created habitats. We must know the former extent of habitats and the former range of hydrologic and ecological processes to understand the habitat needs of important species, and to therefore judge the scale of restoration needed to bring about recovery and to establish healthy populations.

Many restoration actions have been very small-scale affairs when viewed in context with the losses in habitat and changes in processes since 1850. Although these projects may be very worthwhile, they should not be considered as having restored the ecosystem just because 10 acres of tidal marsh have been restored at a given site. Similarly, the irreversible changes that have occurred to hydrology and ecology of the Bay-Delta system must be recognized so that restoration goals are realistic. For example, the hydrology of the Bay-Delta system has been fundamentally transformed by massive reservoirs and diversions. Reservoir storage capacity in the Sacramento-San Joaquin River system now totals about 30 million acre-feet (MAF), with storage equivalent to over 80% of runoff in the Sacramento River Basin and nearly 140% of San Joaquin River Basin runoff (San Francisco Estuary Project 1992, Bay Institute 1998). As a result, frequent floods (important for maintaining channel form, cleaning spawning gravels, and providing periodic disturbances needed to maintain native species) have been eliminated or drastically reduced on many rivers. Most of these reservoirs are permanent, at least for the lifetimes of the structures, so restoration efforts must be designed to account for the changes wrought by the dams or must involve changes in the operation of the reservoirs. Although dam removal may be possible (with considerable ecological benefits) in a limited number of cases, as is now being considered for Englebright Dam on the Yuba River, in most cases restoration actions must be designed with the reservoirs in mind.

CONDITIONS BEFORE EUROPEAN COLONIZATION

The landscape of the Central Valley has changed on such a vast scale in the past 150 years that it is difficult to even imagine what it was originally like (see Kahrl et al. 1978, Kelley 1989, Bay Institute 1998). Arguably, the most important ecological features were the aquatic and riparian ecosystems, which covered huge areas, supported high concentrations of fish and wildlife, gave rise to many endemic species, and were the cultural focus of the Native American peoples. Before European colonization, the Sacramento and San Joaquin rivers and their tributaries carried water, sediment, nutrients, other dissolved and suspended constituents, wood, organisms, and other debris from basins (of more than 25,000 and 14,000 square miles, respectively) to their confluence in an inland delta, thence through Suisun, San Pablo, and San Francisco Bays to the Pacific Ocean. The channels of these rivers served as habitats and migration routes for fish and other organisms, notably several distinct runs of chinook salmon (*Oncorhynchus tshawytscha*), steelhead trout (*O. mykiss*), and Pacific lamprey (*Lampetra tridentata*). These species evolved to take advantage of the hydrologic and geomorphic characteristics of these river systems, some of which are discussed below. There are no firm data on pre-1850 salmon runs, but anecdotal accounts (and the large canning industry that later developed in coastal and inland cities) imply that runs were substantial, probably between 2 and 3 million per year.

The Mediterranean climate ensured that the aquatic and riparian systems were highly dynamic, driven by strong annual patterns of wet and dry seasons and longer periods of extreme drought and extreme wet. The high peaks of the Sierra Nevada intercepted much of the moisture coming off the ocean and stored it as snow and ice, which melted gradually, generating cold rivers that flowed throughout the dry summers. During periods of high snowfall and rainfall, the Central Valley would become a huge shallow lake, taking months to drain through the narrows of the Bay-Delta system. In periods of drought, the main rivers would be reduced to shallow, meandering channels, and salty water would push its way to the upstream limits of the Delta. The dry tule marshes would burn, perhaps with fires deliberately set by the native peoples, and the dry air would be filled with smoke for months at a time.

The marshes were a major feature of the lowlands of the Central Valley, especially the San Joaquin Valley, where they surrounded the huge, shallow lakes at the southern end of the valley, Lakes Buena Vista and Tulare. The Delta itself was a vast marshland, the present-day islands vaguely defined by natural levees of slightly higher ground. The river channels meandered through this marsh, making trips by boat long and arduous. Suisun, San Pablo, and San Francisco Bays were also lined with large marshes that penetrated far inland in the estuaries of in-flowing streams and in the shallows now called Suisun Marsh. The flood basins of the Sacramento River also supported extensive marshes. Upstream, the river channels were defined by thick riparian forests, with dense stands of willow, cottonwood, and sycamore close to the water, yielding to valley oak on the higher terraces. Above these woodlands were first oak savannas and then bunch grass prairies, supporting herds of pronghorn, elk, and blacktail deer.

HYDROLOGY AND LANDFORMS AND HOW THEY INTERACT TO FORM HABITAT

RUNOFF PROCESSES AND RIVERINE FORMS.

The largest rivers of the Sacramento-San Joaquin River system begin in the high elevations of the Sierra Nevada (or Cascades) and receive runoff from snowmelt, which is at a maximum in late spring/early summer, as well as rainfall in their lower elevations, with maximum flows (typically with higher peaks) in winter during storms. The highest peak flows are produced when warm rains fall on a large snowpack, such as occurred in December-January 1997. There is considerable variation in precipitation (and therefore riverflows) from year to year, but snowmelt reliably produced moderately high flows in most years. The seasonal low flows typically occurred in late summer and fall, after snowmelt had been exhausted and before the onset of winter rains. Seasonal flow variability was greatest in rainfall-dominated rivers draining the Coast Ranges, somewhat less in rivers with snowmelt contributions, and substantially less in rivers draining volcanic formations, such as the regions of Mt. Shasta and Mt. Lassen (where runoff is dominated by springflow). In the Delta, inflows from the Sacramento and San Joaquin rivers mixed, with probable intrusions of salt water during dry periods, in a complex, often stratified pattern.

The upper reaches of the rivers are typically bedrock or boulder controlled, with cascade and step pool habitats, and with little opportunity for sediment storage. In their lower reaches, the rivers flow through the alluvial Central Valley in braided, wandering, or meandering channels, historically with broad, largely forested, floodplains. Braided channels were common where streams passed from bedrock-controlled channels onto the flatter Sacramento Valley floor, depositing gravel and sand. Flatter floodplain reaches were characterized by large, meandering channels, which frequently overflowed onto the adjacent floodplains, depositing sandy natural levees along the channel, with silty (and fertile) overbank sediments behind.

In the Delta, a complex of low-gradient, multiple channels was flanked by natural levees and low-elevation, frequently inundated islands (composed largely of organic-rich sediments). The tidal estuaries of Suisun, San Pablo, and San Francisco Bays were flanked by extensive tidal marshes and mudflats.

Each of these geomorphic features, interacting with a variable flow regime, created a distinct suite of aquatic or riparian habitats, as illustrated by an actively migrating meander bend (Figure A-1). As flow passes through a meander bend, the highest velocities and greatest depths are concentrated near the outside bank, which erodes, producing a steep cut bank, commonly with overhanging vegetation. These pools are important holding habitats for adult salmon and trout. In between the meander bend pools, where flow crosses over from one side of the channel to the other, a riffle typically occurs, with shallow flow over gravel or cobble substrate, providing habitat for invertebrates (which are food for fish). Gravel riffles provide spawning habitat for salmon and trout. Shallow margins of these channels, protected areas behind exposed roots and large woody debris, and the interstices between large cobbles, provide habitat for juvenile salmon.

NATIVE SPECIES AND HOW THEY USED THE LANDSCAPE

The productive marshlands and intervening waterways were extremely attractive to waterfowl. The abundant and diverse resident populations of ducks, geese, shorebirds, herons, and other birds were augmented by millions of ducks, geese, shorebirds, and cranes migrating down in fall and winter from summer breeding grounds in the north. The migratory birds would take advantage of the expanded wetlands that were the result of the winter rains and floods. Arguably, the Pacific Flyway, one of the major migratory routes for birds recognized for North America, owes its existence to the Central Valley and its wetlands. No matter how severe the drought, there would be wetlands somewhere in the valley.

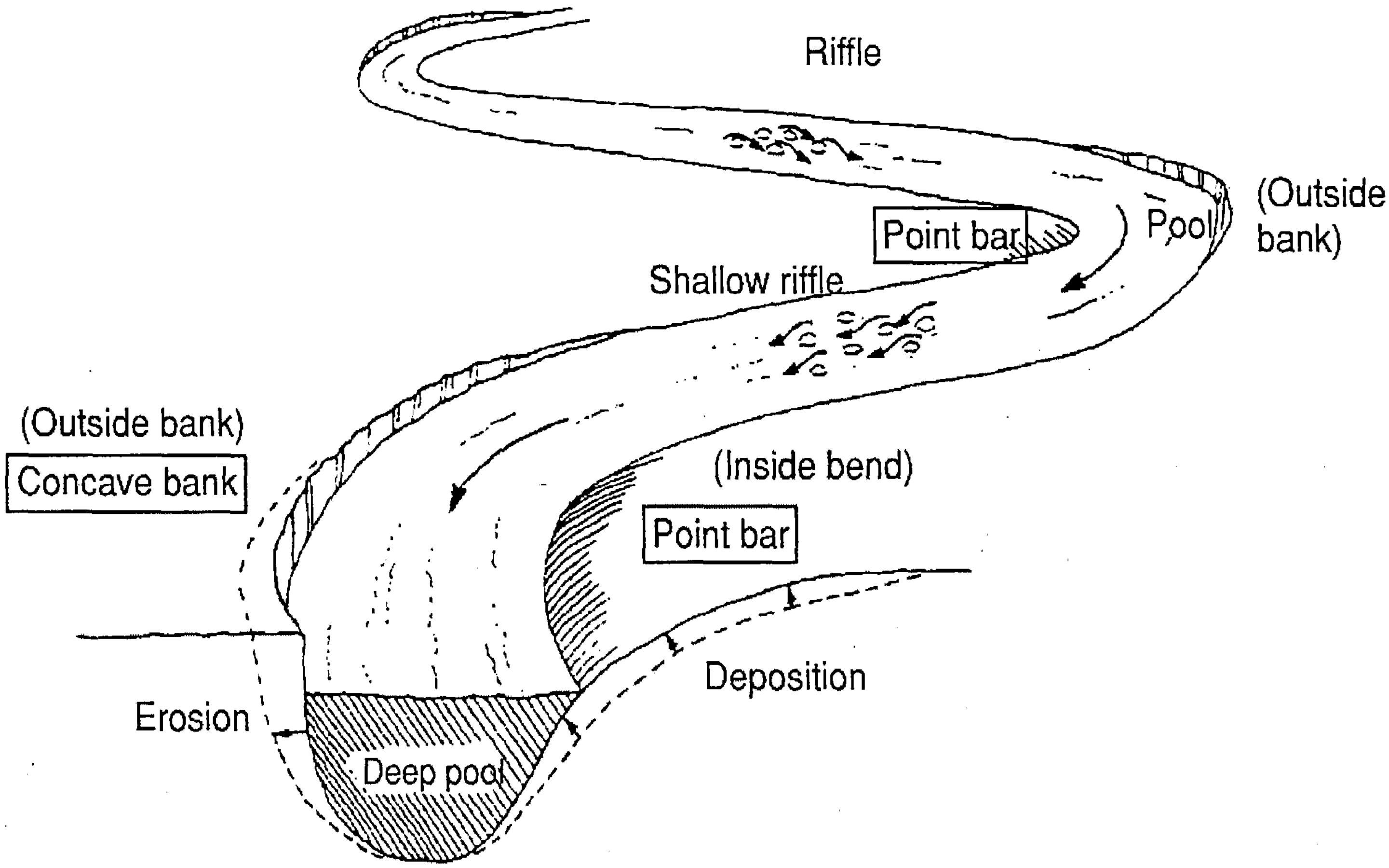
Migratory fishes also found the region to be very favorable habitat. Two to three million anadromous chinook salmon spawned in the system each year, along with large numbers of steelhead, sturgeon, and lamprey. The four distinct runs of salmon reflect a fine-tuning of this species to a fluctuating yet productive environment. Fall-run chinook were the lowland run. They came up in fall months as soon as water temperatures were cool and spawned in low-elevation rivers in time to allow their young to emerge from the gravel and leave the rivers before conditions became unfavorable in early summer. Spring-run chinook, perhaps the largest of the runs, beat the summer low flows and high temperatures by migrating far upstream in the spring and holding in deep cold pools through summer, to spawn in fall. Late-fall-run and winter-run chinook took advantage of the unusual conditions in the little Sacramento, McCloud, and Pit Rivers, where cold glacial-melt water flowed from huge springs, keeping temperatures cool even in the hottest summers, so the fish could spawn late in the season.

Steelhead migrated up in winter, when flows were high, even higher in the watersheds than spring-run chinook, and sought out smaller streams not used by salmon.

The annual influx of millions of salmon weighing 8-20 kilograms each represented a tremendous shot of oceanic nutrients injected into the stream systems, enhancing the productivity of the aquatic and riparian ecosystems and increasing their ability to support juvenile salmon and steelhead. The juveniles of all these salmon would move downstream gradually in winter and spring, taking advantage of the abundant invertebrates in flooded marshlands and the shallow waters of the Delta. In this environment, they could grow rapidly on diets of insects and shrimp, reaching sizes large enough to enhance ocean survival.

In the estuary, the abundant longfin and delta smelts could also move up and down with seasons, seeking favorable conditions for spawning and rearing of young. The short (1 to 2-year) life cycles of these fish testifies that no matter how dry or wet the year, the appropriate conditions were present somewhere in the system. The resident fishes, in contrast, were largely stream or floodplain spawners and apparently did not necessarily find appropriate conditions for spawning and rearing of young to be available every year. As a consequence, they adopted the basic life history strategy of living long enough (5 or more years) to be around when favorable conditions were present and to flood the environment with large numbers of young. Middens near Native American village sites indicate that these fishes (e.g., thicktail chub, Sacramento perch, splittail, hitch, and Sacramento blackfish) were extremely abundant and easy to harvest.

The abundance of fish in the middens also indicates that the native peoples were major predators on the



Source: California State Lands Commission 1993.

Figure A-1: Diagram of Meander Bend, Showing Variety of Forms (and thus Habitats) Associated with Actively Migrating Meander Bend.

fish, including salmon. The abundance of fish was presumably one of the reasons why these people were able to exist in relatively high densities (compared to other areas of North America). Although they may have depleted some of the resources they used (Broughton 1994), some abundant fishes were lightly used if at all. For example, the principal salmon run harvested was the fall run, both because of its accessibility and because the fish were less oily than fish of other runs, making them easier to dry for long-term storage. Other salmon runs were harvested less intensively and steelhead hardly at all.

The native species in this productive ecosystem were adapted to hydrologic extremes, with specific salmon runs adapted to take advantage of different parts of the annual hydrograph. A range of species and life stages used different habitats in different parts of the system.

CRITICAL ASPECTS OF LANDSCAPE AND ECOLOGICAL FUNCTIONS

From our knowledge of the functioning of the natural system, we can identify critical aspects that would need to be addressed in a successful restoration program.

Habitat Area and Diversity. Minimum habitat areas are needed to maintain viable populations of native species. This habitat also has to contain the complex features needed to maintain multiple species and multiple life stages of each species. For example, high-quality brackish and freshwater tideland (including shallow-water habitats, such as mudflats, tule marsh, small sinuous sloughs and distributaries, upper tidal marsh types [e.g. pickleweed], and riparian scrub) historically occurred along the Sacramento and San Joaquin River channels, in the west Delta and Yolo Basin (north Delta), and in the North Bay tidelands of Napa and Sonoma Valleys. Also historically, the salinity gradient of the estuary varied greatly seasonally and between water years, but because these habitats were well distributed along the estuarine system, there were always large expanses of shallow-water habitat associated with the saline/freshwater mixing zone (hydrologically connected). Today, these habitats occur primarily in Suisun Bay, Suisun Marsh, and lower Sherman Island. In all, the area of tidal marsh and active floodplain habitat has been reduced to probably less than 5% of its pre-1850 extent. Such massive reductions in habitat imply a substantial change in the ability of the species dependent on those habitats to sustain their population levels.

PHYSICAL AND ECOLOGICAL PROCESSES. The habitats of the pristine Bay-Delta system can be viewed as forms that developed and were maintained by processes such as flooding, sediment transport, establishment and scour of vegetation, channel migration, large woody debris transport, groundwater seepage, tidal circulation, and sedimentation. For these habitats to be sustainable in the long term, restoration of processes will be more effective than physical creation of forms no longer maintained by processes. Floodplain inundation and forest succession are two such processes along alluvial rivers.

Floodplain forests depended on periodic inundation of the floodplain to maintain appropriate moisture and disturbance regimes, which also discouraged invasion by upland species. Along many rivers, the floodplain is now leveed, and upstream dams have reduced the frequency of high flows. Thus, restoration of floodplain forests will require more than grading floodplain surfaces and planting suitable trees. Levees may need to be removed, breached, or set back, and the river will need periodic high flows capable of inundating the floodplains.

As alluvial river channels migrated across the valley bottoms (through erosion and deposition), they created new (sandy) surfaces on which pioneer riparian species (willow and cottonwood) could establish. Over time, silty overbank sediments deposited and built up the site, and later successional stage trees, such as sycamore, ash, and eventually valley oak, would establish and mature. Thus, the channel migration and its attendant erosion, deposition, and ecological succession were important processes in maintaining habitat diversity along alluvial rivers.

DELTA HYDRAULICS AND ECOLOGICAL FUNCTIONS. Bay-Delta channels were characterized by channel hydraulics that on a temporal, tidal, and seasonal basis for a given hydrologic condition supported important ecological functions such as sustaining a productive food web, providing spawning, rearing, and feeding habitat for estuarine and anadromous fish, and supporting migration of adult and juvenile fish. Reduced Delta inflow, exports from the Delta, and conversion of tidal wetlands have had a large influence on the natural hydraulic regime of the Bay-Delta. Actions such as modified water project management and flood plain and tidal wetlands restoration can contribute to restoring or a more natural hydraulic regime that sustains ecological functions and meets the life requirements of the fish and wildlife in or dependent on the Bay-Delta.

TEMPORAL VARIABILITY. The rivers of the Sacramento-San Joaquin system were dynamic environments, with temporal variations from seasonal and interannual variations in flow and sediment load, often resulting in changes to the channels themselves during floods. Such temporal variability is recognized to be important ecologically, with the periodic disturbances of floods playing an important role in maintaining riverine ecological communities (Resh et al. 1988, Wootten et al. 1996) and their habitats. Periodic droughts may also have been important, with upstream migration of salt water into Delta channels likely. This implies that seasonal and interannual variability, especially high flows, is important for restoration of the ecosystem.

In the Bay and Delta, the intrinsic value of brackish and freshwater tidelands is well documented, including high primary and secondary productivity, fish rearing and foraging habitat, and habitat for a high diversity of native animals and plants, including many at-risk species (general avian and semi-aquatic mammal [e.g., otter] habitats). Less understood are the functional relationships and interdependencies of open water (pelagic) habitats and species of the Delta to these formerly more common peripheral, shallow water habitats. Moreover, these habitats were subjected to a temporally variable salinity gradient (seasonally and year to year), with saline water intruding far upstream into the Delta during periods of low flow (especially droughts) and fresh water extending far downstream into San Francisco Bay during floods. This dynamic, temporal variability presumably favored native species, and the current reduction of such variability may have facilitated establishment of non-native species.

SPATIAL VARIABILITY. The river channels were also characterized by spatial variability (or complexity), arising from irregularities in channel form, both transverse to and longitudinal with the flow direction. For example, in meander bends the channel is typically deeper on the outside of the bend, increasingly shallow toward the inside bank onto a point bar. This variation in water depth is accompanied by variations in grain size of bed sediment and in water velocity. Longitudinally, irregularities include large-scale alternations between bedrock to alluvial reaches, steep (riffle) and low-gradient (pool) reaches, transitions between reaches of differing widths, passage over and around channel bars, and effects of boulders and large woody debris in the channel. The riverbanks were typically irregular in outline and often were made more irregular by protruding trees (living and dead). Such spatial irregularities were ecologically important because they created a diversity of habitats, which in turn supported a diversity of species and life stages of those species. The importance of complexity in physical habitat implies that in many artificially straightened or deepened channels, it may be advantageous to physically restructure the channel or to add elements likely to induce scour or deposition or both.

CONTINUITY. The longitudinal continuity of water flow, sediment transport, nutrient transport, and transport and migration of biota through the river system, as well as the longitudinal continuity of riparian and aquatic habitat along the length of a river, were important attributes of the ecosystem. The transport of gravel from mountainous source areas provided spawning habitat in alluvial channels downstream, and the continuity of channels allowed for upstream migration of spawning salmon, waterborne dispersal of seeds, and invertebrate colonization. Similarly, the longitudinal continuity of riparian vegetation flanking the stream was an important attribute of the riparian habitat for wildlife, as well as for shading the channel and providing carbon to the aquatic system. The importance of continuity implies that conservation and restoration projects should be prioritized, in part, to maximize continuity of habitat, so that sites whose restoration would connect different habitats would have priority over other, similar sites.

FLOODPLAIN INUNDATION. Alluvial channels and their floodplains behaved as functional units, with floodplains accommodating flows in excess of channel capacity. This had important ecological implications. First, as water overflowed from the channel onto the floodplain, it slowed down, because overbank flow was shallow and the floodplain was hydraulically rough, offering greater resistance to flow. Floodwaters charged with suspended sediment deposited some of the coarser part of their sediment load as they flowed overbank, typically leaving deposits of sand immediately adjacent to the channel (where the water velocity first slows) and finer grained sediment further away from the channel. Floodplain sedimentation is known to be important in alluvial rivers, responsible for measurable decreases in suspended sediment loads (Walling et al. 1998). From the point of view of water quality, the removal of suspended sediment from the water column is a potentially important effect.

Floodwater on the floodplains reduced the volume of floodwater in the channels and moved more slowly than water in the main channel. The net effect was to reduce the height of the flood wave as it moved downstream. Overflow onto the floodplain also served to limit the height of water in the channel, thus limiting the shear stress exerted on the bed. In essence, the floodplains acted as "pressure relief valves," which prevented a continuous increase in shear stress in the channel with increasing discharge. This permitted a larger range of sediment grain sizes to remain on the channel bed than would have been the case without overbank flooding because without overbank flooding, gravel may be mobilized and lost at the confined channel's higher shear stress. Similarly, overbank flows make more refuge habitat available to fish because there are zones of lower shear stress in the channel and because fish can seek refuge in the inundated floodplain.

Other important ecological interactions between the floodplain and channel include shading, food, and large woody debris provided by floodplain vegetation (Gregory et al. 1991, Murphy and Meehan 1991). During prolonged inundation of the Cosumnes River floodplain in 1997, salmon and other fish were observed feeding on the inundated floodplain, one illustration of the important migrations and interchanges of organisms, nutrients, and carbon that would have occurred frequently in the Bay-Delta system before 1850. Even along rivers where floodplain inundation was typically brief, interactions could be nonetheless important for recharging the alluvial water table, dispersing seeds of riparian plants, and increasing soil moisture on surfaces elevated above the dry season water table. Inundation of floodplains and maintenance of high alluvial water tables contributed to maintenance of floodplain aquatic habitats, such as side channels, oxbow lakes, and phreatic channels (Ward and Stanford 1995).

Floodplain soils and vegetation can also improve water quality in rivers by filtering sediments from runoff and by contributing to chemical reactions in the floodplain alluvium that can remove nitrogen and other constituents from agricultural or urban runoff.

ECOLOGICAL TRANSFORMATIONS FOLLOWING COLONIZATION

THRESHOLD EVENTS LEADING TO PRESENT CONDITIONS

GRAZING. Cattle were introduced in 1770 and rapidly expanded under Spanish rule. Along with the introduction of non-native annual grasses (which replaced most native bunch grasses), the reduction in upland plant cover, soil compaction, and reduction in riparian vegetation resulted in higher peak runoff for a given rainfall and higher erosion rates. This hydrologic transformation probably initiated a cycle of channel incision, with consequences on alluvial groundwater tables and wetlands.

GOLD MINING. Beginning about 1850, the extraction of gold transformed the channels and floodplains of many rivers, especially in the Sierra Nevada. Hydraulic mining, in which high-pressure jets of water were directed at gold-bearing gravel deposits (mostly on ridgetops), produced more than 1.67 billion cubic yards of debris, most of which was flushed from steep bedrock canyons onto the Sacramento Valley floor (Gilbert 1917). This massive influx of coarse sediment filled the river channels and spread out over floodplains, converting formerly silty farmland into gravel and sand deposits. Along the Yuba River upstream of Marysville, hydraulic mining debris created the Yuba River Debris Plain, encompassing more than 40 square miles. The bed of the Yuba River near Marysville aggraded about 90 feet, inducing the town to build levees. These could not contain the continually aggrading channel and were overtopped numerous times starting in 1875, resulting in extensive damage to the town. The increased sediment in the Sacramento River interfered with shipping and required dredging. Finer grained parts of the debris settled out in the San Francisco Estuary, adding to mudflats along the bay margins. Because of its downstream impacts, hydraulic mining was prohibited by court order in 1884, but the wave of hydraulic mining debris already in the system continued to progress downstream; the bed elevation of the Yuba River at Marysville peaked in 1905 and returned to estimated pre-mining levels by about 1950 (James 1991).

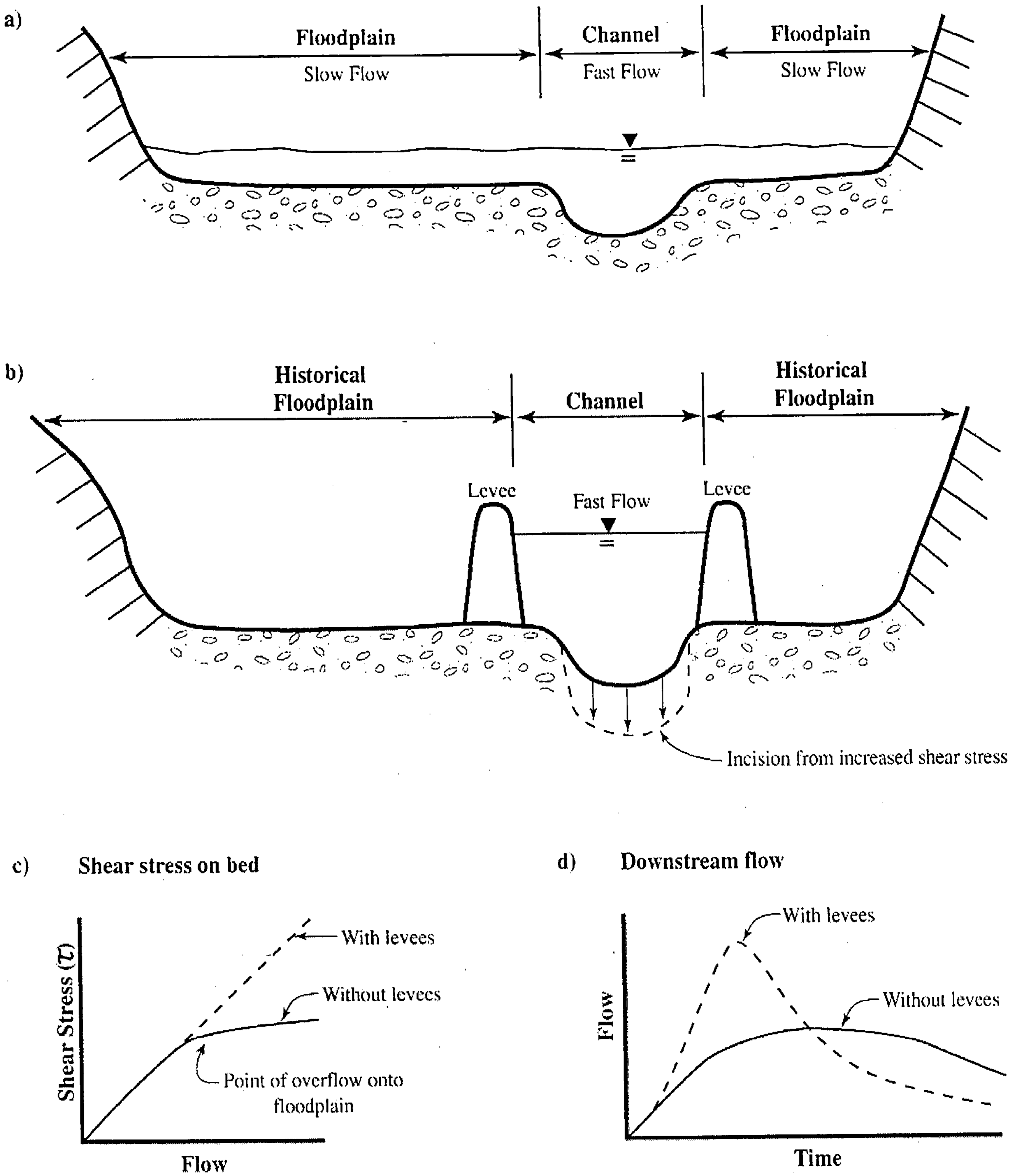
Gold-bearing floodplain and terrace gravels, including deposits of hydraulic mining debris, were extensively reworked by dredgers, which left linear mounds of tailings along many river channels in the Sacramento-San Joaquin River system. These dredger tailings have only coarse cobbles on the top, preventing establishment of vegetation except in low swales in between the tailing piles.

CHANNELIZATION FOR NAVIGATION. The Sacramento, Feather, and San Joaquin Rivers were important navigation routes, with ocean-going vessels reaching Marysville and Stockton in the 1850s. The influx of hydraulic mining sediment caused the rivers to become shallower, interfering with navigation. In response, riverbeds were dredged and levees were constructed along riverbanks (to concentrate flow and induce bed scour) to deepen channels. To facilitate navigation, large woody debris was cleared from many channels. To provide fuel for steamers, valley oaks and other trees were cleared from accessible areas near rivers.

ARTIFICIAL BANK PROTECTION. With increased agriculture and human settlement on the floodplain, it became more likely that natural channel migrations would threaten to undermine structures or productive agricultural land. To protect these resources, banks have been protected by riprap (and other artificial protection) along many reaches, including most of the Sacramento River downstream of Chico Landing. Riprapped banks effectively lock the channel in place, eliminate the contribution of gravels and woody debris from actively eroding riverbanks, and prevent the creation of new riverine habitats through meander migration. Moreover, the protected banks lack the overhanging vegetation and undercut banks (often termed "shaded riparian aquatic habitat") so important as fish habitat in natural channels (California State Lands Commission 1993). Riprap also damages the habitats of threatened and endangered bird species such as bank swallows.

LEVEE CONSTRUCTION. To protect floodplains against flooding, more than 5,000 miles of levees have been built in California, most of which are in the Bay-Delta system, and 1,100 of which are in the Delta itself (Mount 1995). Most of these are "close levees": levees built adjacent to the river channel itself (often on top of natural levees), in some cases to concentrate flow for navigation. By preventing overbank flows, levees reduce or eliminate interaction between channel and floodplain and thus reduce important ecological interactions. In addition, by eliminating overbank flows and natural floodplain storage, levees concentrate flow in the main channel, which results in greater depths, faster flow, and higher flood peaks downstream (Figure A-2) (IFMRC 1994).

FLOODPLAIN CONVERSION. Most floodplains, with their fertility enhanced by overbank silt deposits, were converted from alluvial forest or riparian marsh to agricultural land, with subsequent conversion of many areas to urban use. Valley oak woodlands were cleared extensively because they tended to occur on good soils. First cleared along the Sacramento River were the well-drained, broad, linear ridges (natural levees) developed along the current and former channels from overbank deposits. Then of lower flood basin areas were converted as they were drained and diked off from frequent floods. The floodplains of the Sacramento and San Joaquin Rivers were extensively cleared in the second half of the 19th century for dryland wheat farming, which occupied 3.75 million acres in 1880s (Kelley 1989). In the Sacramento Valley, rice growing developed since



Note: With natural floodplain functioning, much of the floodwaters are accommodated on the floodplain, where high hydraulic roughness leads to slower flows and thus slower downstream transmission of floodwaters (a). Levees concentrate floodwaters in the channel (b), resulting in deeper water and higher velocities, faster downstream transmission of floodwaters, and higher flood peaks downstream (d). Deeper and faster flows lead to higher shear stresses (force per unit area) on the channel bed (c), which may lead to bed incision (b).

Figure A-2: Effect of Levees on Floodflows and Channel Geomorphology

1910 with levee construction and availability of irrigation water, with 600,000 acres of rice in flood basins by 1981 (Bay Institute 1998).

Unfortunately, no reliable data exist on the actual extent of riparian forest before 1850, and estimates vary widely. The potential maximum area of riparian forest in the Sacramento Valley (based on soils and historically mapped riparian forest) was 364,000 acres. Only about 38,000 acres exist today, approximately 10% of the historical value. However, it is unlikely that the forest ever occupied the full 364,000 acres at one time (Bay Institute 1998). In the San Joaquin Valley, soils and historical accounts suggest a potential pre-1850 riparian zone of 329,000 acres, contrasting with a current 55,000 acres of wetlands and 16,000 acres of riparian forest (Bay Institute 1998). The area currently mapped as riparian forest includes areas of poor quality, heavily affected by human action. An illustration of a relatively recent conversion of floodplain habitats in the San Joaquin River basin is shown in Figure A-3. On the floodplain of the Merced River, a complex of side channel habitats was eliminated for agriculture between 1937 and 1967.

TIDAL MARSH CONVERSION. In the Delta and Suisun, San Pablo, and San Francisco Bays, similar transformations were underway, with most former tidal marsh and mudflats converted to agricultural lands (and some to urban uses). In the Delta, there was an estimated 380,000 acres of intertidal wetlands, 145,000 acres of nontidal wetland, and 42,000 acres of riparian vegetation on higher ground (Bay Institute 1998). Today, about 21,000 acres of wetland remain, of which about 8,200 acres are tidal (San Francisco Estuary Project 1992). The tidal wetland loss was largely finished by 1940 (Atwater et al. 1979).

The loss of these wetlands can be considered one of the most significant human-caused functional modifications of the Bay-Delta ecosystem. The Delta tidal marshes probably formed an important link in the nutrient transfer between the riverine and open-water estuarine components of the watershed. Delta tidal marshes had the highest primary productivity and biodiversity of any comparably sized area in pre-Columbian California. Although exports from marshes to adjacent open water systems have been difficult to demonstrate (Mitch and Gosselink 1993), it is likely that the Delta tidal marshes functioned as a filter that trapped sediment and removed inorganic nutrients supplied by the rivers from the upstream watershed and produced organic inputs that were transferred to the bay. Currently, tidal marshes probably still remove inorganic and organic compounds (including toxins) from the rivers, but this function has been greatly reduced because the existing river system largely bypasses the marshes.

The loss of networks of shallow dendritic slough channels in the tidal marsh has greatly reduced the length of the linear interface between open water and vegetated marsh. Historical topographic maps show that the drainage pattern in historical tidal marshes was much more complex than in current, remnant tidal marshes. Historically, tidal marshes probably provided important feeding and reproduction habitat for many vertebrate species. Restoration of tidal marsh will be most beneficial to vertebrate species if both tidal marsh area and habitat complexity are restored. Similarly, these shallow-water habitats were formerly exposed to a variable salinity regime to which native species were adapted.

RESERVOIRS AND DIVERSIONS. Dams constitute important discontinuities in rivers, altering riverflows, eliminating the continuity of aquatic and riparian habitat, and blocking migration of fish and other organisms. Reservoirs impound water for many reasons, such as generation of hydroelectric power; flood storage; and controlling flow to allow diversions, increased consumptive use, and export. Dams have cut off upper reaches of rivers, hydrologically isolating them (Figure A-4). One implication of this fact is that most of the channels of concern to CALFED lie downstream of large reservoirs and are thus hydrologically isolated from changes in runoff or sediment load in the upper reaches of the watersheds. For example, increased erosion from timber harvest or changes in water yield from changes in vegetative cover in the upper Feather River tributaries will not affect conditions in the ERP focus area downstream of Oroville Dam as long as the reservoir continues to trap sediment and regulate flows.

As barriers to migration, dams have had an especially hard impact on spring-run chinook

1937

1967

Figure A-3: Aerial Photographs of the Merced River Floodplain, Showing Loss of Floodplain Side Channel Habitats from 1937 to 1967.

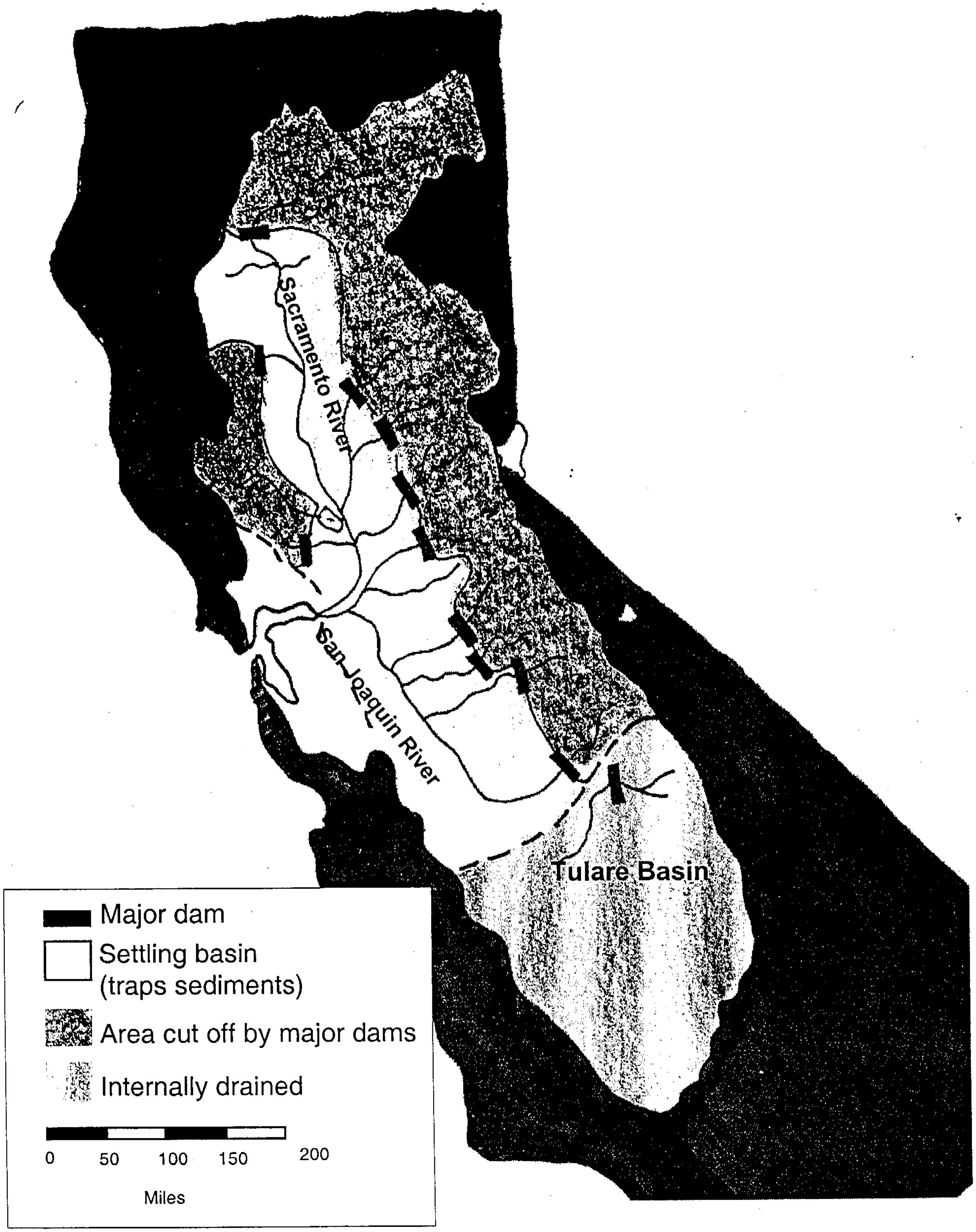


Figure A-4: Upper Watersheds in the CALFED Solution Area Cut off from the Lowland Alluvial Rivers by Dams salmon and steelhead trout, which formerly migrated to upstream reaches to spawn. In the San Joaquin Valley, Friant Dam delivered the entire flow of the upper San Joaquin River south, abruptly eliminating a major run of Chinook salmon. The extent of river channel inhabited by spring-run salmon has decreased dramatically since the early 19th century (Figure A-5). Overall, reservoirs were found to be the most important gaps in riparian habitat in rivers draining the Sierra Nevada (Kondolf et al. 1996). Diversions also entrain fish, resulting in direct mortality, especially of juveniles.

By 1940, most rivers in the Sacramento-San Joaquin River system had dams large enough to block fish passage, reduce flows during critical baseflow periods, and reduce frequent floods. However, reservoir size and cumulative reservoir storage increased dramatically with construction of the Central Valley Project, the State Water Project, and other large dams. From 1920 to 1985, total reservoir storage capacity increased from about 2 million acre-feet to 30 million acre-feet (Figure A-6) (San Francisco Estuary Project 1992, Bay Institute 1998). Reservoir storage in the Sacramento River system is now equivalent to 80% of annual average runoff; in the San Joaquin River system, reservoir storage is equivalent to 135% of runoff. As a result of dams, diversions, consumptive use, and export out of the watershed, the total runoff to the San Francisco Bay from the Delta has been reduced from pre-1940 runoff by 30-60% in all but wet years (Nichols et al. 1986, Bay Institute 1998). The seasonal distribution of flows has fundamentally changed, and flood magnitude and frequency profoundly decreased. The mean annual flood (the average of annual peak flows) has decreased by 20-65 % from pre-dam values (depending on reservoir capacity in relation to runoff) (Table A-1).

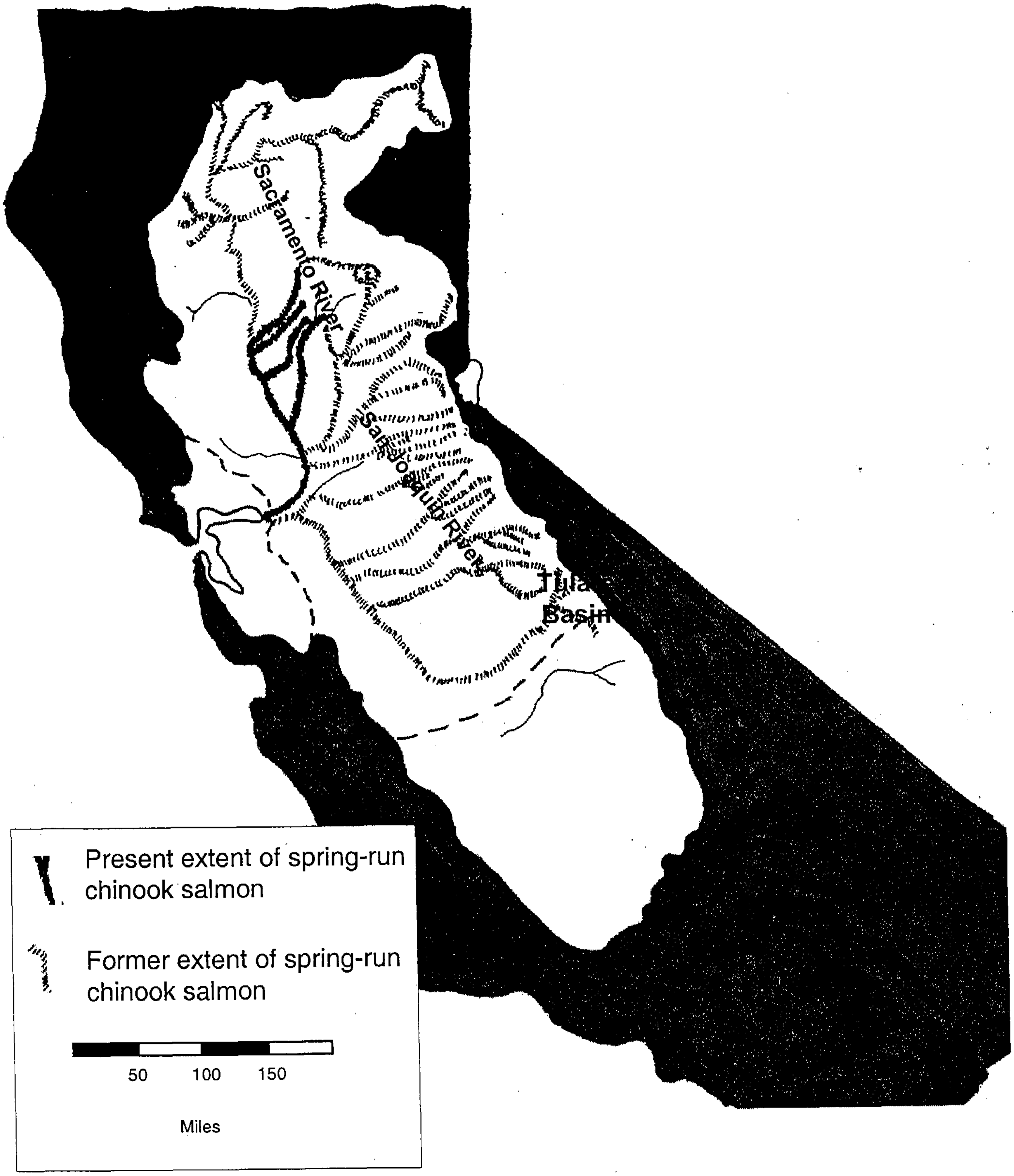
The reduction in floodflows has transformed river channels of the Sacramento-San Joaquin system. Rates of bank erosion and channel migration in the Sacramento River have declined because of dam construction and construction of downstream bank protection projects (Brice 1977, Buer 1984). The channel sinuosity (ratio of channel length to valley length) has also decreased because of numerous meander cutoffs (Brice 1977), reducing total channel length and thus total in-channel habitat. Moreover, the diversity of riparian and aquatic habitats is directly related to the processes of bank erosion, point bar building (creating fresh surfaces for riparian establishment), and overbank deposition, resulting in a mosaic of different-aged vegetation and contributing to the complexity of in-channel habitat and shaded bank cover (California State Lands Commission 1993). The reduction in active channel dynamics is compounded by the physical effects of riprap bank protection structures which typically eliminate shaded bank habitat and associated deep pools, as well as halting the natural processes of channel migration.

Reduced floodflows below dams have also rendered inactive much of the formerly active channel, "fossilizing" gravel bars and permitting establishment of woody riparian vegetation within the formerly active channel, narrowing the active channel and reducing its complexity (Peltzman 1973, Kondolf and Wilcock 1996). The reduced frequency of formerly periodic flood disturbance in channels downstream of dams has created conditions favorable to establishment of exotic species (Baltz and Moyle 1993).

Elimination of annual floodflows below dams may permit fine sediment to accumulate in gravel beds and cobble beds, reducing the quality of spawning and juvenile habitat for salmonids, and invertebrate production (Kondolf and Wilcock 1996). Reduced mobility of gravel beds may also favor invertebrate species less desirable as food for salmonids (Wootten et al. 1996).

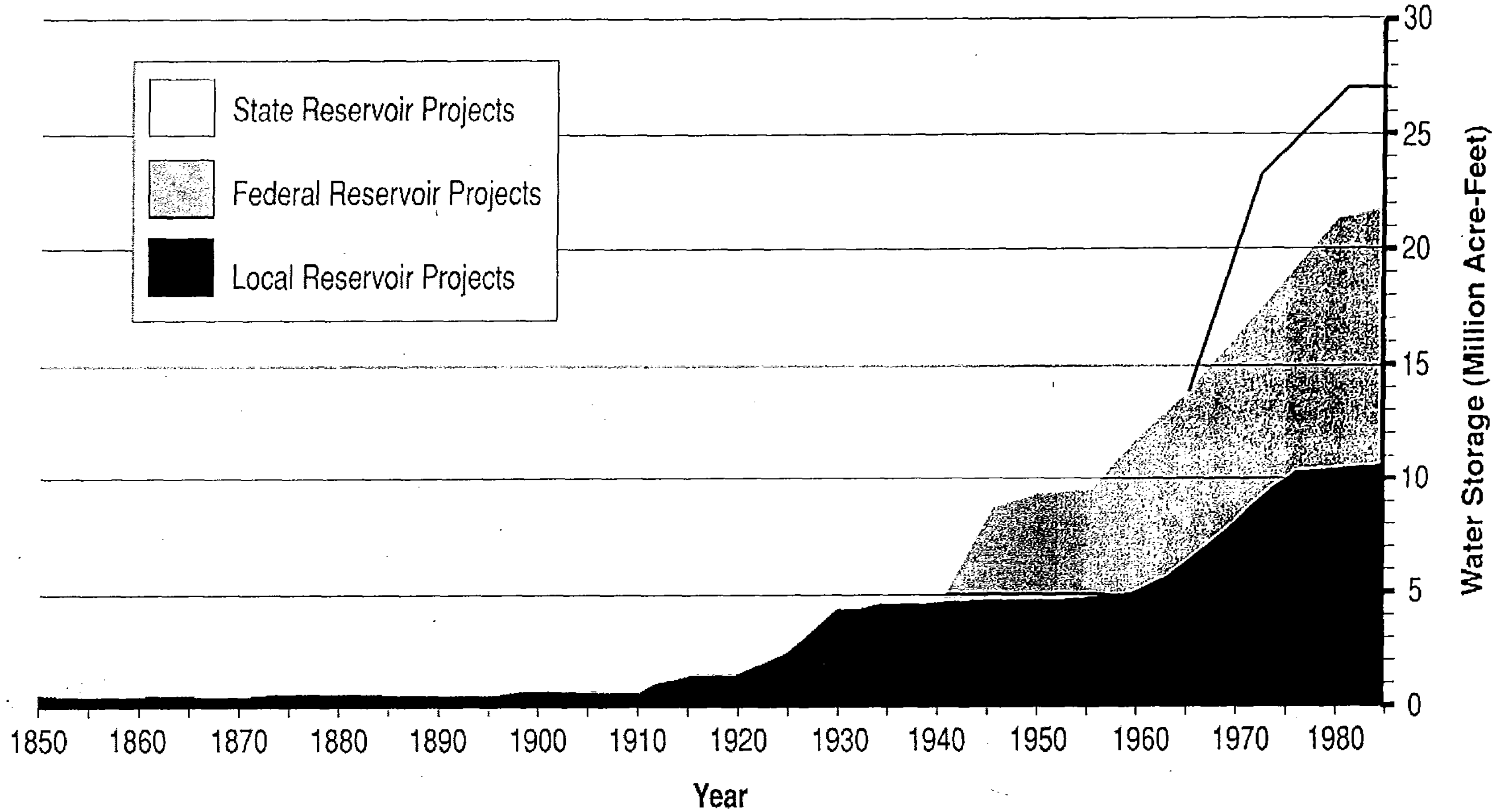
Dams also trap sediment derived from upstream, commonly releasing sediment-starved water downstream, as discussed below.

EXTRACTION OF SAND AND GRAVEL FOR CONSTRUCTION AGGREGATE. The rapid urbanization of California has required massive amounts of sand and gravel for construction aggregate (e.g., road fill, drain rock, concrete for highways, bridges, foundations), with annual production of more than 100 million tons, 30% of the national production (Tepordei 1992). Nearly all this sand and gravel is drawn from river channels and floodplains. Mining in channels disrupts channel form, causes a sediment deficit and channel incision, with resulting loss of



Source: Kondolf pers. comm.

Figure A-5: Present versus Historic Extent of Spring-Run Chinook Salmon



Source: San Francisco Estuary Project 1992.

Figure A-6: Cumulative Increase in Reservoir Storage in the Bay-Delta System

TABLE A-1. CHANGES IN MEAN ANNUAL FLOWS FOR SELECTED RIVERS IN THE SACRAMENTO-SAN JOAQUIN RIVER SYSTEM

River	Dam	Date Constructed	Gauge Number	Period of Gauge Record	Mean Annual Flood (cubic feet per second)		Percent Reduction
					Pre-dam	Post-dam	
Sacramento River	Shasta	1945	11377100	1938-1996	120,911	78,885	35
Feather River	Oroville	1968	11407000	1902-1996	69,641	22,929	66
American River	Folsom	1956	11446500	1904-1996	53,459	29,651	45
Stony Creek	Black Butte	1963	11388000	1955-1990	13,744	7,959	42
Mokelumne River	Camanche	1963	11323500	1904-1996	7,395	2,431	66
Stanislaus River	New Melones	1979	11302000	1957-1996	10,016	3,135	69
Merced River	New Exchequer	1967	11270900	1901-1996	8,287	4,560	45
San Joaquin River	Friant	1942	11251000	1908-1996	18,614	3,718	80

Source: U.S. Geological Survey.

spawning gravels and other habitats. Floodplain gravel pits commonly capture the river channel (i.e., the river changes course to flow through the pits). The pits are excellent habitat for warmwater species that prey on salmon smolts; the California Department of Fish and Game estimates that 70% of the smolts in the Tuolumne River are lost to predation annually (EA Engineering, Science, and Technology 1992). Refilling these pits to eliminate predator habitat and restore channel confinement is expensive, with $5 million recently budgeted to fix two such pits on the Tuolumne River.

SEDIMENT STARVATION FROM DAMS AND GRAVEL MINING. Dams and gravel mining can result in a sediment deficit downstream, especially when mining occurs downstream of dams. The cumulative effect of sediment trapping by dams has been enormous. Using published reservoir sedimentation rates, and assuming sand and gravel to be 10% of total sediment load, we estimate that the mountainous reaches of the Sacramento, San Joaquin, and tributary rivers formerly delivered an annual average of about 1.3 million cubic meters to the Sacramento and San Joaquin Valleys. (This is the estimated sediment yield to the large foothill reservoirs, or to the equivalent point in an unregulated river, near the transition from mountainous upland to valley floor.) Construction of reservoirs has cut this amount to about 0.24 million cubic meters, a reduction of about 83%. This does not account for the further reduction in sediment budget from gravel mining in the channels in the valley floor.

Overall, the rate of gravel mining from rivers in California is at least 10 times greater than the natural rates at which gravel and sand are eroded from the landscape and supplied to the rivers (Kondolf 1997). On the Merced River, an estimated 150,00-300,00 tons of sediment have been trapped behind the Exchequer Dam since 1926, and 7-14 million tons of sand and gravel have been excavated from the channel and floodplain since the 1950s (Kondolf et al. 1996). This constitutes a profound alteration in the regime of rivers tributary to the Bay-Delta. Although some of the sediment deficit is made up in the short term through bank erosion and channel downcutting and the transport capacity of most rivers has been reduced by reduced floodflows, the magnitude of the overall reduction in sediment supply to the system is such that long-term adjustments in channel, floodplain, and intertidal marsh/mudflat habitats are inevitable.

Dams, gravel mining, and bank protection have so reduced the supply of gravel in the Sacramento River system that many reaches of river that formerly had suitable gravels for salmon spawning are no longer suitable for spawning (e.g., Parfit and Buer 1980). In the CALFED area alone, millions of dollars have already been spent and will be spent to add gravels (and create spawning riffles) in the Sacramento, Feather, American, Mokelumne, Stanislaus, Tuolumne, and Merced Rivers and in Clear and Mill Creeks, all in attempts to compensate for the loss of spawning habitat (Kondolf and Matthews 1993, Kondolf et al. 1996).

OVERFISHING. Fish populations have been directly affected by harvest rate, most notably the intensive harvesting of the late 19th century, with development of major commercial fisheries for salmon in the estuary and the rivers. Gill nets strung across the Sacramento River at times completely blocked access to spawning grounds. Dozens of salmon canneries sprang up along the estuary, but the last one had closed by 1916, after the runs were depleted. Sturgeon were caught in the salmon nets in large numbers and most were killed and discarded because of the damage done to the nets. Commercial fisheries also developed to catch resident fishes, such as Sacramento perch, thicktail chub, and others, which were sold as fresh fish in the markets of San Francisco.

The early 1900s marked the beginning of the era of some of the first conservation legislation at state and national levels, the sturgeon fishery was banned, salmon populations were allowed to recover, and refuges were set aside for waterfowl.

EFFECTS OF WATER DIVERSIONS FROM THE DELTA ON NATIVE FISHES. Water diversions from the Delta affect fish in two principle ways, the direct diversion of fish and adverse effects on Delta channel hydraulics.

Delta diversions result in losses of all life stages of fish, particularly eggs, larvae, and juveniles as well as the loss of nutrients and primary and secondary production needed to support a healthy aquatic foodweb.

Changes in Delta channel hydraulics began in the mid-19th century with land reclamation that restricted flows to narrow channels defined with levees. These same channels later became conduits for carrying water to the water export facilities in the central and south Delta. In 1951, the CVP began to transport water from the south Delta to the Delta-Mendota Canal. Operation of the Delta Cross Channel in the north Delta began to allow Sacramento River water to flow through interior Delta channels from the north to the southern Delta export facilities. South Delta export facilities were increased with the addition of the SWP pumping plant in the late 1960s. Delta channel hydraulics in the June through September period were adversely affected by Delta diversions as early as the mid 1950s. In the 1960s, impacts extended into the April and May period. Delta channel hydraulics, particularly in the November through April period, were dramatically affected beginning in the early 1970s and continuing into the 1980s, a period of steep declines in the abundance of native fish species. In the San Joaquin Valley, Friant Dam delivered the entire flow of the upper San Joaquin River south, abruptly eliminating a major run of chinook salmon. The fish fauna of the rivers and Delta changed abruptly as well because resident non-native fishes were favored over native fishes, resident and anadromous. Thicktail chub and Sacramento perch gradually were driven to extinction in the system.

Existing Delta hydraulic conditions inhibit the ecological functions of the Delta as a migration corridor and rearing habitat for native species such as Chinook salmon and important non-natives such as striped bass. Native residents such as Delta smelt, which depend on natural hydraulic processes that help support spawning habitat and a productive foodweb, have been impacted by changed hydraulic conditions, particularly in the last two decades.

In the 1960s, the State Water Project went into operation with the completion of Oroville Dam on the Feather River (1967) and the construction of another set of big pumps in the south Delta. By this time, nearly every major river and creek feeding the Central Valley and the estuary was dammed. Not only was the water available for natural ecosystem processes increasingly diminished in amount, but it was increasingly polluted, the result of the ever-increasing urbanization of the region and more intensive agriculture.

Native resident and anadromous fishes continued to decline, as did the native flora and fauna of riparian areas and wetlands as water diversions increased and as wetland and riparian habitats continued to be diminished. (In dry years, migratory waterfowl were largely confined to artificial wetlands and showed marked downward trends as well.)

POLLUTION. Industrial, municipal, and agricultural wastes have been discharged into waters of the Bay-Delta system, with major historical point sources including wastes from fish and fruit/vegetable canneries and municipal sewage. The large-scale pollution of the estuary and rivers was partially relieved by the passage of the Clean Water Act, resulting in the construction of sewage treatment plants in all cities. Mines such as the Penn Mine on the Mokelumne River and the Iron Mountain Mine on the Sacramento River continue as serious sources of contaminants, with some releases from Shasta Dam made explicitly to dilute Iron Mountain leachate below lethal levels in the river to avoid fish kills. Nonpoint sources of pollution, such as urban runoff and agricultural runoff, continue to impair water quality. Agricultural drainage (often highest in summer from irrigation return flow) typically has elevated temperatures and contains excessive loads of constituents such as organic carbon, nitrates, phosphates, as well as herbicides and pesticides toxic to phytoplankton, invertebrates, and larval fish (Bailey et al. 1995).

INTRODUCTION OF NON-NATIVE SPECIES. As the native fishes became depleted in the late 19th century, non-native species were brought in (especially following the completion of the transcontinental railroad in 1872): American shad, striped bass, common carp, and white catfish. As their populations boomed, those of native fishes declined further. Introduction of non-native species accelerated in the 20th century through deliberate introductions of fish and unintended introductions of harmful invertebrates and fish, mainly through ballast water of ships. Establishment of non-native species was probably facilitated by altered hydrologic regimes and reduction in habitats suitable for native species.

Non-native birds have also adversely affected native bird species populations through competition, predation, and other means.

CHANGES IN POPULATIONS OF NATIVE SPECIES RESULTING FROM HUMAN ALTERATION TO THE ECOSYSTEM

Populations of a number of species have declined sufficiently since the 19th century to warrant their listing under the federal Endangered Species Act of 1973. Twenty-one species of plants, seven species of invertebrates, four fish species, one amphibian species, one reptile species, six bird species, and one mammal species present in the Bay and Delta region alone that are listed as threatened or endangered, with a number of others proposed for listing or listed under the equivalent state law. Perhaps the most significant of these listings have been those for winter-run chinook salmon, delta smelt, and steelhead trout because their recovery is likely only if there is a significant reallocation of water for environmental purposes, as well as significant improvements in their remaining habitats.

PRESENT CONDITIONS AND TRENDS

PRESENT CONDITIONS

The status of the ecosystem is described in detail in the affected environment chapters of the Fisheries and Aquatic Ecosystems Technical Appendix and Vegetation and Wildlife Technical Appendix to the CALFED Programmatic EIS/EIR.

ENVIRONMENTAL TRENDS. Specific currently discernable environmental trends are likely to continue during the next few decades. These trends would largely result in continued environmental degradation, although some positive trends are also apparent. Population growth will lead to an increase in the demands on water and other resources in California (e.g., gravel, petroleum, and wood products). Other possible sources of increased environmental degradation include conversion of agricultural lands to urban land uses, a likely shift in agricultural practices to more intensive crops, flood control activities, new introductions and expansion of non-native species, sea-level rise, and global climate change. On the positive side, several legislative and policy initiatives could result in improvements in habitat and water quality.

These trends in the demand for natural resources present constraints and opportunities on the extent to which CALFED can successfully rehabilitate elements of ecosystems that are critical to achieving the goals and objectives of the ERP (e.g., recovery of endangered species and maintenance of populations of other native species at levels sufficient to prevent potential future listings of species). The effect of these trends (along with the current commitment of land and natural resources to other uses) is to necessarily preclude wholesale rehabilitation of the ecosystem to a semblance of its historical condition. Instead, these trends will most likely limit CALFED to successful rehabilitation of representative "islands" within the Bay-Delta system in which most or all of the ecological processes associated with the historical ecosystem have been restored and to partial rehabilitation of some attributes historically associated with the ecosystem throughout the Bay-Delta system.

TRENDS IN POPULATION AND WATER USAGE. The California Department of Finance projects California's population to grow from its 1995 level of 32.1 million to 47.5 million in 2020, an increase of approximately 48%. Irrigated crop acreage is expected to decrease slightly from 9.5 million acres to 9.2 million acres. These factors (as well as changes in use rates) are expected to lead to a slight decrease in agricultural water use (from 33.8 MAF to 31.5 MAF), but significant increases in urban water uses over the same period (from 8.8 MAF to 12.0 MAF). These numbers are estimates from DWR's State Water Plan Update (California Department of Water Resources 1997) and are subject to different assumptions regarding the size and effectiveness of water conservation programs.

Increasing demand on water for urban uses will lead to increasing competition for water between agricultural, urban, and environmental uses, particularly during drought periods. Additionally, because the greatest population increases are projected to occur in southern California, an area dependent on water exported from the Delta, there is the potential to intensify the environmental impacts created by the existing water supply system. Population increases may also intensify environmental degradation through increased urbanization (conversion of natural and agricultural lands to urban uses) and increased demand for resources (such as sand and gravels, petroleum, wood products and other construction materials).

In view of this, attempts to restore the ecosystem in the future or increase the extent of natural habitats in the Bay-Delta system that are dependent on fresh water, including the physical processes associated with its flow, is likely to be more difficult than under current circumstances. Recognition that the availability of water for all uses is ultimately limited underscores the necessity of the ERP to focus the use of environmental water on rehabilitation of sufficient portions of the Bay-Delta system that are critical to meeting the goals and objectives of the ERP. Recognition of this trend also underscores the necessity for the ERP to secure sufficient environmental water in balance with other uses sooner, rather than later, to ensure success of the ERP.

CHANGES IN AGRICULTURAL CROPPING PATTERNS. Agricultural cropping patterns are expected to shift away from field and forage crops to higher intensity crops, such as vegetables, vineyards, and orchards, which typically provide less wildlife habitat for listed species such as the Swainson's hawk and greater sandhill crane. Because these more intensively managed crops are more profitable, agricultural land is expected to become more expensive and difficult to purchase for habitat restoration. These trends will place greater demands on remaining and restored native habitats to support displaced wildlife populations and constrain the quantity and location of habitat that can be restored.

INCREASES IN FLOOD PROTECTION. Periodic flooding is an important river function that sustains ecological functions by creating a matrix of diverse habitats, by replenishing nutrients in the system, and by transporting sediments and biota through the system. Plans for increased flood protection could lead to greater constraints on ecological structure and functions.

Increased flood protection can directly affect ecological functions by decreasing habitat diversity; creating barriers to the movement of sediment, nutrients, and species; removing riparian habitat; and reducing or eliminating floodplain inundation. Indirect impacts can also result. As the perceived threat of flooding is reduced, more floodplain lands are subject to urban and agricultural development. The increasing demand for flood control increases the urgency to provide innovative flood management solutions that increase the flood conveyance capacity of the rivers by restoring meander belts and enlarging the floodplain area.

NON-NATIVE SPECIES. As discussed elsewhere in this strategic plan, the introduction and spread of non-native species into the Bay-Delta system has affected native species by competing with them for food and habitat, preying on native species, and interfering with restoration efforts. For example, the non-native mitten crab can clog fish screens, reducing their effectiveness or completely blocking flows. In spite of efforts to address this problem, it is likely that new species will continue to be introduced into the ecosystem and that non-native species introduced in the past will continue to expand their range.

GLOBAL CLIMATE CHANGE AND SEA-LEVEL RISE. In spite of expectations of more extreme weather patterns, sea-level rise, and the potential for these changes to affect the structure and functioning of the ecosystem, the rate and nature of global climate change are still too poorly understood to be explicitly considered in this document, but as such information improves, it should accounted for in decision making under the adaptive management framework.

IMPORTANT LEGISLATIVE ACTIONS AFFECTING ENVIRONMENTAL TRENDS

Although the pressures created by increasing population and urbanization, by changes in agricultural cropping patterns, and the introduction and spread of non-native species will most likely continue to exert negative forces on the environment and on ecological processes in the

Bay-Delta system, several recent and important legislative actions have been initiated that will serve to moderate potential effects of these adverse trends.

CENTRAL VALLEY PROJECT IMPROVEMENT ACT. The Central Valley Project Improvement Act (CVPIA) is a federal law passed in 1992 that adds the maintenance of fish and wildlife to the list of objectives of the Central Valley Project (CVP). CVPIA provides resource managers with a large number of tools to aid in the recovery of fish and wildlife species, including the dedication of water to instream flows and Delta outflow, the creation of a fund to pay for further water purchases for habitat restoration, the allocation of CVP water supply to improve the reliability of deliveries to wildlife refuges, the retirement of agricultural lands to improve water quality, and the creation of a program to provide incentives for farmers to maintain habitat values on their lands. Among the goals of CVPIA is to double the population of naturally reproducing target fish species. Although it is not yet clear whether the tools provided by CVPIA will lead to the achievement of this goal or how the various provisions of it will ultimately be implemented, it is very likely that implementation will lead to improvement in habitat conditions for many fish and wildlife species.

1995 WATER QUALITY CONTROL PLAN. In 1995, the SWRCB adopted a water quality control plan for the Bay-Delta that includes rules governing Delta exports and Delta outflows. This plan intended to maintain salinity in the Delta at levels needed to maintain the health of the ecosystem. Since 1995, it has been the responsibility of CVP and the State Water Project (SWP) to comply with these rules, but SWRCB is now holding hearings to decide how the responsibility for compliance should be allocated among all water users in the Bay-Delta system. The results of these hearings will most likely lead to increases in instream flows in most, if not all, of the tributaries to the Delta. This change would improve conditions for fish and other aquatic species in those tributaries.

SACRAMENTO AND SAN JOAQUIN RIVER BASINS COMPREHENSIVE STUDY. The Comprehensive Study is being conducted by the U.S. Army Corps of Engineers and the California Reclamation Board with support from Department of Water Resources' staff and in cooperation with numerous other agencies and organizations. The study will cover a four-year period with Phase I being completed by April 1999. The study will initially identify problems, opportunities, planning objectives, constraints and measures to address flooding and ecosystem problems in the study area. It will ultimately develop a strategy for flood damage reduction and integrated ecosystem restoration along with identification of projects for early implementation. Solutions will include consideration of both structural and non-structural measures. The study objectives are expected to lead to innovative solutions to flooding and environmental problems in the Central Valley.

The Comprehensive Study reflects evolving policy at both state and federal agencies regarding the environment. Agencies that historically focused exclusively on improving flood protection are now incorporating the maintenance or enhancement of environmental values into their missions. This change in approach will most likely lead to more environmentally friendly solutions to water supply and flood control problems.

CLEANUP OF THE SOURCES OF TOXIC POLLUTANTS. The role of toxic pollutants in the decline of ecosystem functions in the Bay-Delta system is not yet well understood, but it is clear that these pollutants do contribute to morbidity and mortality in some aquatic species. Several efforts are currently underway under the EPA's Superfund program to clean up major sources of these pollutants. Although the solution to problems such as the Iron Mountain Mine will not easily be achieved, if successful, they could contribute considerably to restoring the health of the Bay-Delta system.

LAND USE PATTERNS AND TRENDS

The Bay-Delta system is undergoing major changes in land use and intensification (San Francisco Estuary Project 1992b). The San Francisco Bay itself and the central Delta are under the jurisdiction of the San Francisco Bay Conservation and Development Commission (BCDC) and the Delta Protection Commission, respectively. Land use in the periphery of the Delta and in the lower watersheds are the prerogative of local governments, with the federal government (U.S. Forest Service, U.S. Bureau of Land Management, National Park Service) managing a larger proportion of the upper watersheds.

Urbanization of the periphery and immediate watersheds of San Francisco Bay are relatively stable, but other areas are undergoing rapid change, especially the watershed of Suisun Marsh, eastern Contra Costa County and the western Delta (residential subdivisions, "New Towns"); the south-Delta/lower San Joaquin River historical floodplain ("New Town" proposals); the east-Delta periphery (low-density residential, "New Towns," and very-low-density residential). Fairfield, Oakley, Brentwood, Tracy, Lathrop, Stockton, Lodi, Elk Grove, Sacramento, Winters, and other cities within the periphery of the Delta are experiencing strong growth pressures. Rural areas above the Delta and below dams are expanding, with both residential subdivisions (e.g., three to five dwelling units/acre), and very low-density residential development (e.g., five to 20 acres/dwelling unit). Land use is also changing in the lower-watershed/intertidal zone where sea-level rise and flooding are an issue.

Urbanization and concomitant increased motor vehicle use are a major contributor of contaminants (especially heavy metals). Residential development, even at very low densities, raises important land use considerations, including habitat fragmentation, loss of the use of fire as a vegetation management tool, and increased demand for flood protection.

Although CALFED's focus is on state and federal activities in ecosystem restoration, the program must be cognizant of land use issues that may help or hinder these activities and work with those responsible to encourage and support land use patterns that are compatible with ecosystem protection and restoration. Collaborative work in flood management, waterfront development, stream-corridor management, park and recreation design, and watershed management and planning will be especially important.

♦ APPENDIX B. FURTHER EXAMPLES OF CONCEPTUAL MODELS

LANDSCAPE LEVEL MODEL

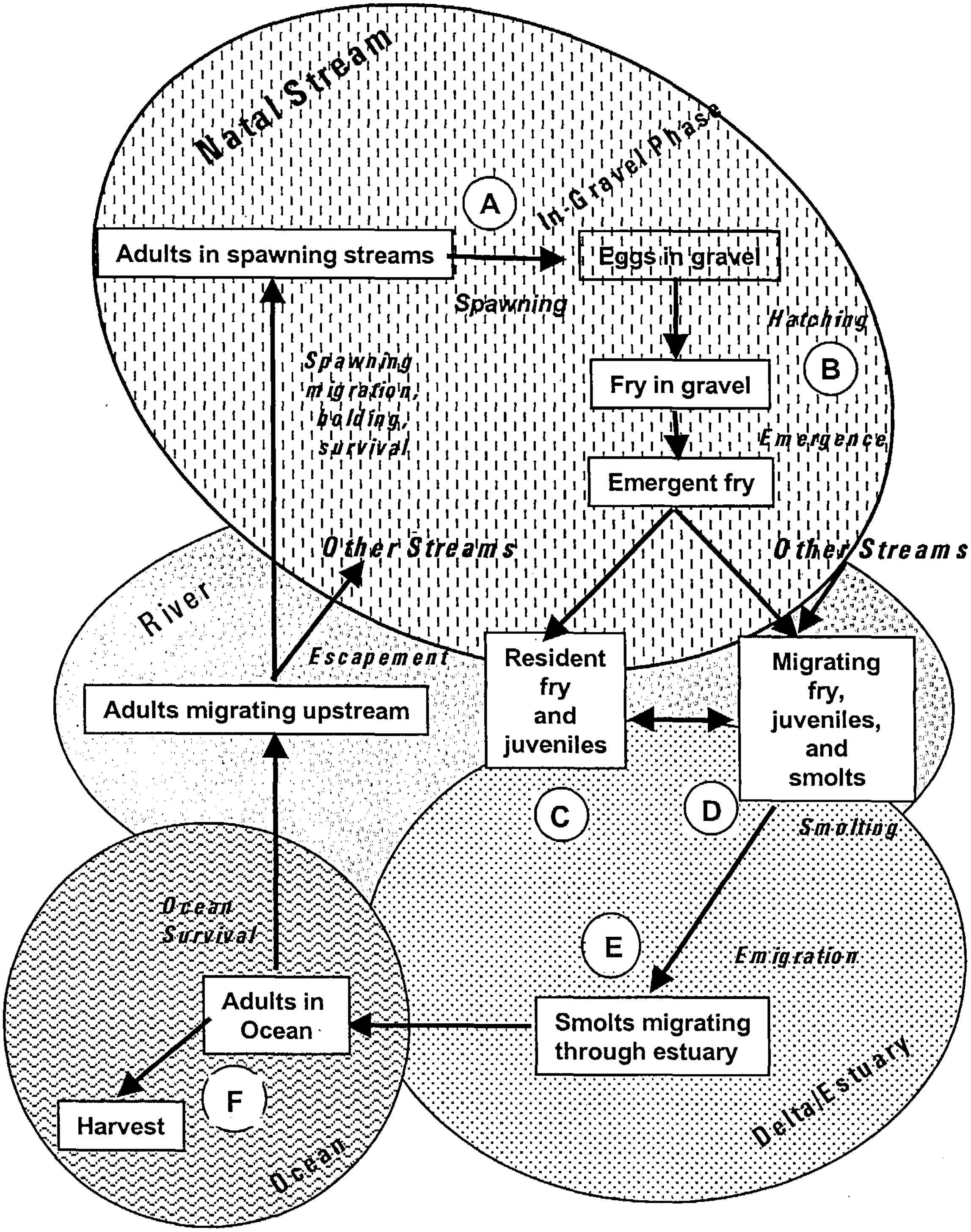
Figure B-1 illustrates a landscape level conceptual model. This model applies to chinook salmon, but its principles also could be applied to striped bass, other anadromous fish, and several species that spawn in the coastal ocean and rear in the estuary. These species link the system across boundaries by migrating between the rivers and the estuary or between the estuary and the ocean. Through their migrations, they expose themselves to variable human and environmental forces well outside the boundaries of the Bay-Delta ecosystem. The principal landscape level issue for managing these populations is the relative importance of events in each region in affecting their abundance. For example, chinook salmon experience rigorous conditions in their spawning and freshwater nursery regions, during migration through the Delta, and in the ocean. If the Delta causes a substantial fraction of their mortality, the opportunity exists for restoration that will be effective in reducing mortality and increasing salmon production. On the other hand, if mortality in the Delta is small, restoration of conditions there may have little effect on salmon production. Similar issues exist for the other species although the lack of direct human influence on oceanic conditions (except harvest) limit the opportunities for restoration in that region. A detailed example of ecosystem restoration for chinook that makes use of this model is discussed in Appendix C.

CONCEPTUAL MODEL OF ENTRAINMENT

We present two alternative conceptual models of how anadromous fish can be entrained in the state and federal water projects under low-flow conditions (Figure B-2). The upper part of the figure shows schematic maps of the Delta with the key nodes identified at which water and anadromous species diverge into separate pathways. Conceptual model A is the "old" model, in which the emphasis is on net flow. Water moves downstream in the rivers and either toward the ocean or toward the pumps in the Delta, including a landward net flow in the lower San Joaquin River ("QWEST").

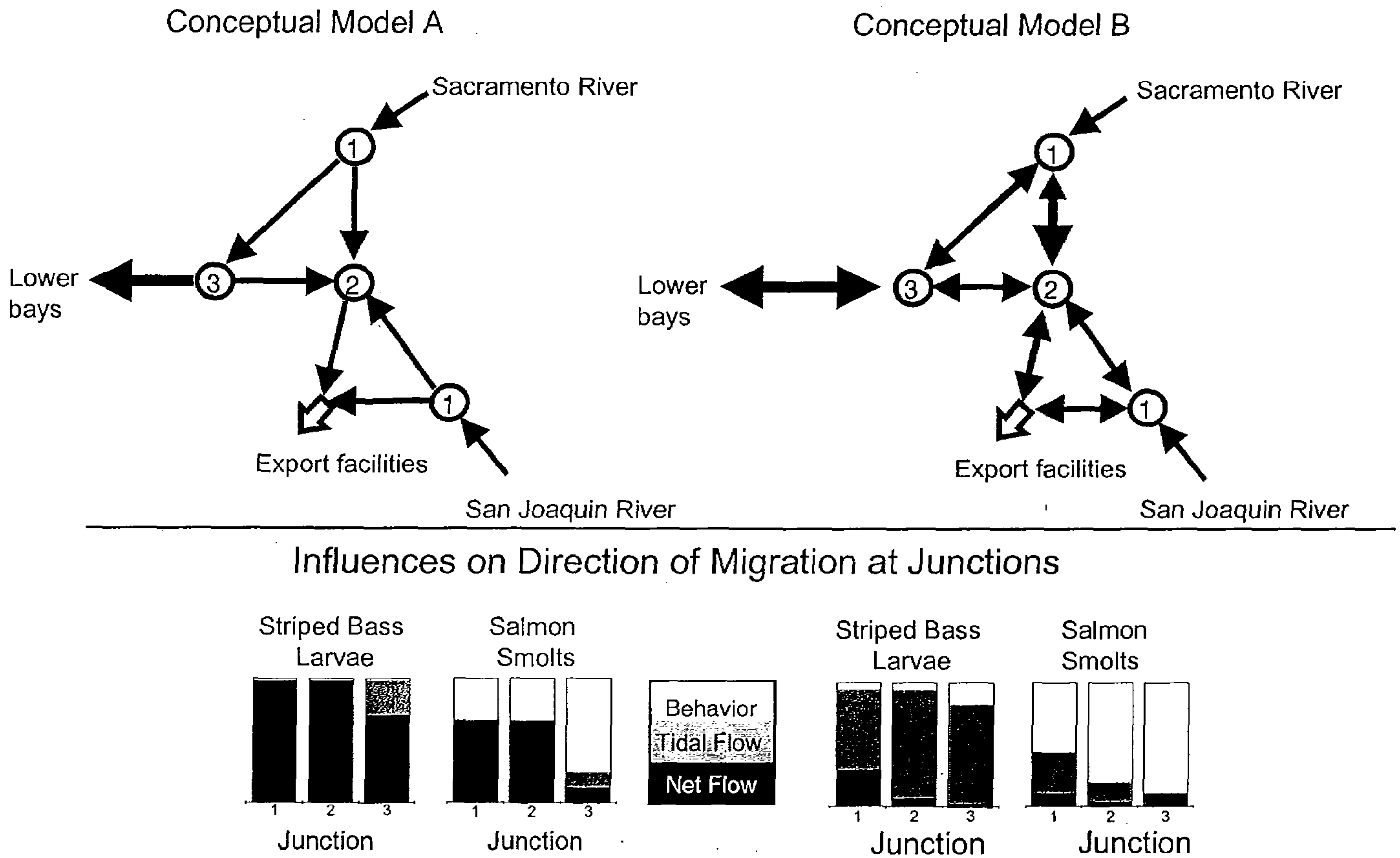
Conceptual model B is based on more recent developments in understanding of hydrodynamics of the Delta and on the realization that fish are not passive particles but are capable of quite complex behavior. Flow in the rivers is downstream, but as we move into the Delta, the flow becomes increasingly dominated by tides. The further west in the Delta we go, the more important the tides are and the less important is riverflow in terms of instantaneous velocity. For example, at Chipps Island under low-flow conditions, net flow is only 1-2% of tidal flow. The bottom panel in Figure B-2 illustrates how the selection of models determines the factors influencing the proportions of fish that take one course or another at each of the numbered nodes in the upper panel. Starting from the left-most bar chart, according to conceptual model A, striped bass larvae are largely subject to net flow, with tides affecting them to some degree at the confluence of the rivers (node 3). Salmon smolts, by contrast, are affected more by their own behavior. Still, the major influence is net (river) flow. Under conceptual model B, by contrast, striped bass larvae are affected mainly by tidal flows and to a lesser extent by net flows. Furthermore, the influence of net flows is nearly gone by the time the larvae reach node 3 (i.e., the low-salinity zone, which under low-flow conditions in late spring is at about the confluence). Behavior of the larvae plays an important role in this model, particularly when they reach brackish water and begin to migrate vertically.

In model B, the fate of salmon smolts is governed primarily by whether they migrate along the shore or distributed across the river. If they migrate



Note: The four oval areas represent the four major geographic regions. Arrows indicate a change of state of surviving salmon, with only ocean harvest mortality displayed explicitly. Terms in italics indicate the major transformations occurring in each phase.

Figure B-1: Landscape Level Conceptual Model of Chinook Salmon



Note: Arrows and circles comprise a schematic of the Delta, with the circles representing key nodes where flow and fish diverge. Single arrows indicate river inputs, and double arrows indicate flows that are partly or mostly tidal, with the sizes of the arrowheads reflecting relative flow velocities for each location. Conceptual model A depicts net flows, with arrows indicating how fish would move under the influence of these flows. Conceptual model B illustrates how water moves in response to both tides and net flow. Fish move under the influence of these flows and their own behavior. Bar charts in the bottom panel illustrate how these conceptual models differ in their prediction of the relative influence of fish behavior, tidal flow, and net flow on the proportion of fish taking alternative pathways at each of the nodes.

Figure B-2: Alternative Conceptual Models of Flow and Fish Movement in the Delta under Low-Flow, High-Export Conditions along the shore, they are more vulnerable to diversions such as at the Delta Cross-Channel than if they are distributed across the channel. In addition, we assume that, like other organisms living in tidal environments, salmon smolts are exquisitely sensitive to the tidal movements and phasing and are capable of moving downstream rapidly using the tidal currents. At the more landward modes, therefore, tidal flow rather than net flow has the most influence on smolt movement patterns.

These alternative models make radically different predictions about the effects of entrainment on salmon and the most effective measures to minimize these effects (Figure B-2). According to model A, losses can be minimized by reducing exports and maximizing flow. Moving the intake up into the Sacramento River would have a clear benefit. According to model B, on the other hand, export flows are not very important in killing salmon, and the most important issue is the strength of the environmental cues available to guide the salmon to sea. Note that this model is more consistent with recent statistical modeling results, which do not find that variation in salmon smolt survival is statistically related to export flows (Newman and Rice in prep.).

For young striped bass, model A again predicts that increasing flow and reducing exports would increase early survival. Model B, on the other hand, predicts a probability of entrainment that depends on the initial position of the fish and the strength of tidal and net flows, including export flows. The further seaward the larvae, the less likely it is to be entrained. Moving the salt field seaward (i.e., moving X2 seaward) reduces the exposure of the fish to entrainment and is therefore more effective than curtailing exports. Note the sharp contrast in the two models' predictions of the effects of moving the intake site.

For delta smelt, the picture is less clear. Under model A, minimizing exports is very important, and moving the intake facility would be very helpful for the species. Minimizing the ration of exports to inflows is believed to reduce the proportion of the smelt population that is entrained. Under model B, X2 determines the position of the bulk of the population and, therefore, the exposure to entrainment, while variation in export flow has little effect unless X2 is far upstream. Thus, moving the intake facility would have little effect except under very low-flow conditions.

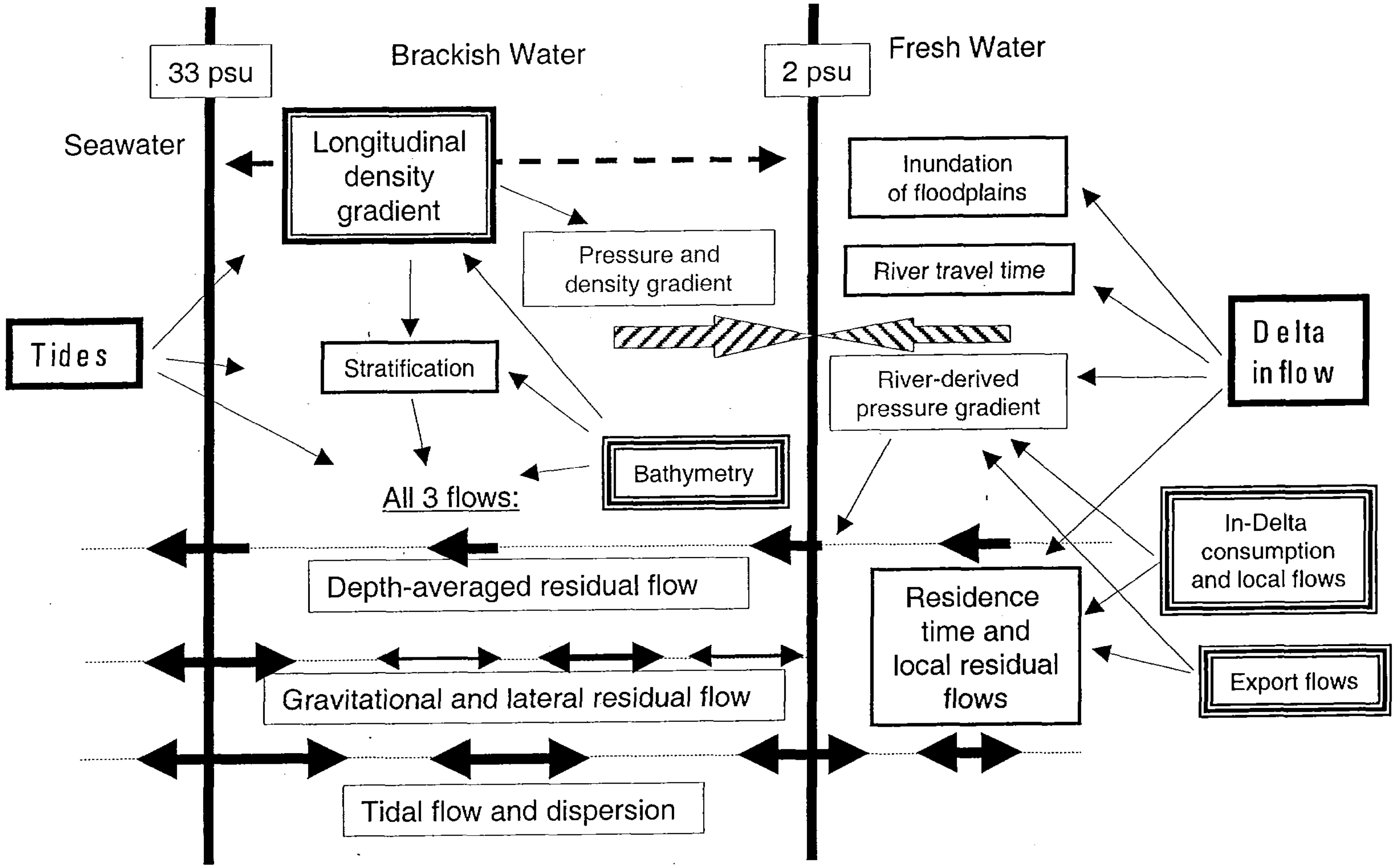
These models, along with the findings of the Diversion Effects on Fish Team (1998), suggest that we have a great deal to learn about entrainment effects before a decision can be made on the construction of large-scale water transfer facilities.

Model of Contrasting Mechanisms Underlying X2 Relationships

In this section, we contrast two mechanisms believed to be important for species that enter the estuary from the ocean as young or spawn in the lower bays and rear in the estuary. These models look in more detail at aspects of the Fish-X2 relationship described in the main body of the text. The two mechanisms are gravitational circulation and extent of physical habitat for rearing.

Recent developments in understanding of the physical characteristics of the estuary have altered our perception of how biota use their environment (e.g., Burau 1998 in Kimmerer 1998). Figure B-3 provides a conceptual model of estuarine circulation patterns designed to illustrate these concepts. For the purposes of this exercise, the main points are as follows. Flow in the brackish parts of the estuary can be considered to have three components as illustrated. First, there must be a cross-sectionally averaged residual (i.e., averaged over the tides) flow to seaward that is equal to the river flow. Second, vertical and lateral asymmetries in residual flow occur through the interaction between stratification, tides, and bathymetry. Third, the strongest flows in most of the estuary are reversing tidal flows, which induce strong longitudinal and lateral dispersion.

Freshwater flow introduces a pressure or level gradient that directs water seaward through the estuary. At the same time, tides drive the denser ocean water into the estuary through a combined pressure and density gradient. These opposing forces determine the length of the salinity gradient and therefore the density gradient. High



Notes: Freshwater inflow and tides are the major forcing functions. The principal role of freshwater input is in setting up a pressure (level) gradient along the axis of the estuary, which forces the depth-averaged residual flow throughout the estuary. Tides introduce a pressure gradient that varies in time, and the salinity gradient attributable to tidal mixing between fresh water and saltwater sets up a density gradient. This interacts with tidal mixing and bathymetry to produce various degrees of stratification and gravitational circulation.

psu = practical salinity units.

Figure B-3: Conceptual Model of Flow Effects with Emphasis on the Brackish Parts of the Estuary freshwater flow over a period of time compresses the longitudinal density gradient, enhancing stratification and possibly gravitational circulation. The opposing density gradient acts like a compressed spring, moving salt landward when freshwater flow (and the accompanying pressure gradient) declines.

Gravitational circulation (Figure B-4) can occur throughout the estuary if stratification occurs. This happens primarily in deep regions, such as beneath the Golden Gate Bridge, in the main channel through northern San Francisco and San Pablo Bays, and in Carquinez Strait. It is rare in the main channel of Suisun Bay (Burau 1998 in Kimmerer 1998). We assume (this theory has not been tested) that stratification is stronger when freshwater input is high because of the compression of the longitudinal density gradient (Figure B-3). Under low-flow conditions (Figure B-4, top), stratification is slight. Near-bottom currents are weaker than near-surface currents. Surface currents are stronger on the ebb than on the flood, whereas bottom currents are stronger on the flood than on the ebb. When freshwater flow is high, the density gradient is compressed and stratification is stronger, causing gravitational circulation to intensify. Under these conditions, the asymmetry in ebb-flood currents is greater, particularly near the bottom.

Certain species of bay organisms may use gravitational circulation to enter the estuary and to move landward. This is a common mode of transport for flatfish, crab, and shrimp larvae (e.g., Cronin and Forward 1979). Essentially, all they need to do is move down in the water column, and gravitational circulation will take them landward. Presumably, the stronger the gravitational flow the more rapid the movement and the larger the abundance of animals that will arrive at the rearing habitat. If correct, this model could explain the X2 relationships for bay shrimp, starry flounder, and possibly Pacific herring.

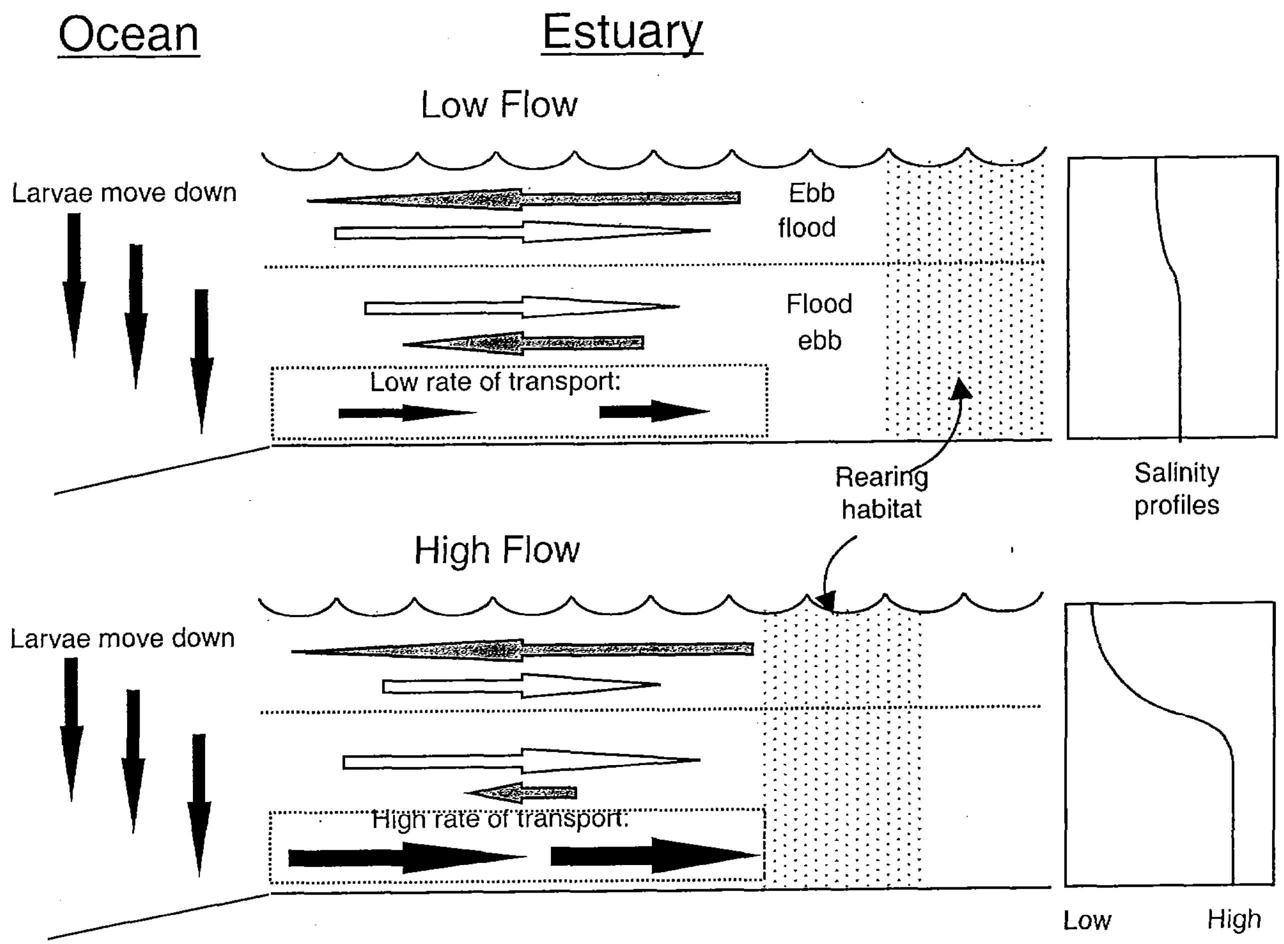
The alternative model holds that the physical extent of nursery habitat increases with increasing flow. This model is supported by a preliminary analysis of the area in the estuary encompassed by selected salinity values (Unger 1994). If habitat is limiting the development of some populations, and if it does indeed increase with flow, then this too could explain the observed relationships.

Actions to protect and enhance the abundance of these species that correlate with X2 (and the predatory species that depend on them) differ depending on which mechanism is most important. If the most important mechanism is gravitational circulation, little can be done to enhance these populations other than to increase freshwater flow (note that dredging channels also may accomplish this, but an additional result may be greater salt penetration). However, if limiting habitat is the key issue, then it may be possible to provide more, better, or more accessible habitat and achieve a suitable level of protection or enhancement with the same or less flow.

Conceptual Model of Meander Migration in a Regulated River

This conceptual model (Figure B-5) illustrates factors influencing meander migration, habitats created as a consequence of migration, and influence of management actions. River meanders migrate through a combination of eroding the outside (concave) bank and simultaneously depositing a point bar on the opposite (convex) bank. The highest velocity flows are concentrated on the outside of the bend, and a pool forms at the outside of the meander bend. Right and left bends alternate, with the highest current shifting from one side of the channel to the other at the "crossover" point between bends, where a gravel riffle forms (Figure B-6). As the meander bend migrates across the valley bottom, the channel dimensions remain essentially constant because erosion of the outside bend is compensated for by deposition on the point bar.

The process of meander migration is ecologically important because it creates and maintains channel and floodplain forms with a diversity of habitats (e.g., undercut banks, overhanging vegetation, scour pools, gravel riffles), delivers large woody debris to the channel, and maintains a diverse assemblage of riparian vegetation at different succession stages. As the outside bend erodes, late-stage successional riparian trees are typically eroded and fall into the channel, providing large



Note: Several species recruit from outside the estuary and must enter the bay to reach nursery areas; some other species reproduce in the bay but then move up the estuary for rearing. Tidal flows in the low-salinity and high-salinity layers are shown as arrows, with gray representing ebb and white representing flood. Black arrows indicate larval movement. Under low-flow conditions, stratification and gravitational circulation are weak; landward transport of larvae is slow. High flow compresses the longitudinal density gradient (Figure 5-3), increasing stratification and gravitational circulation and increasing the rate of larval transport. Note that this model has not been tested.

Figure B-4: Conceptual Model of the Mechanism for the X2 Effect Based on Gravitational Circulation

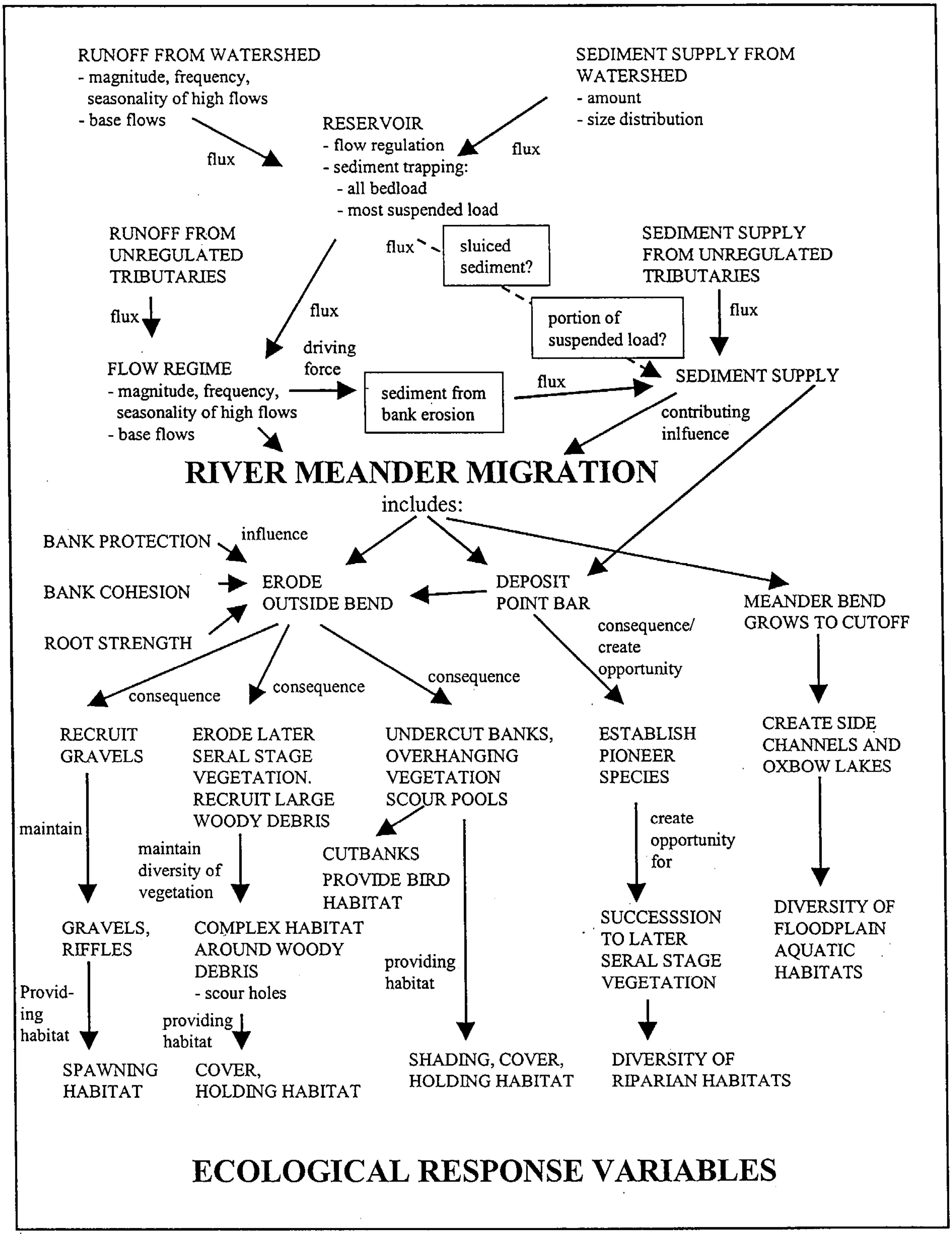
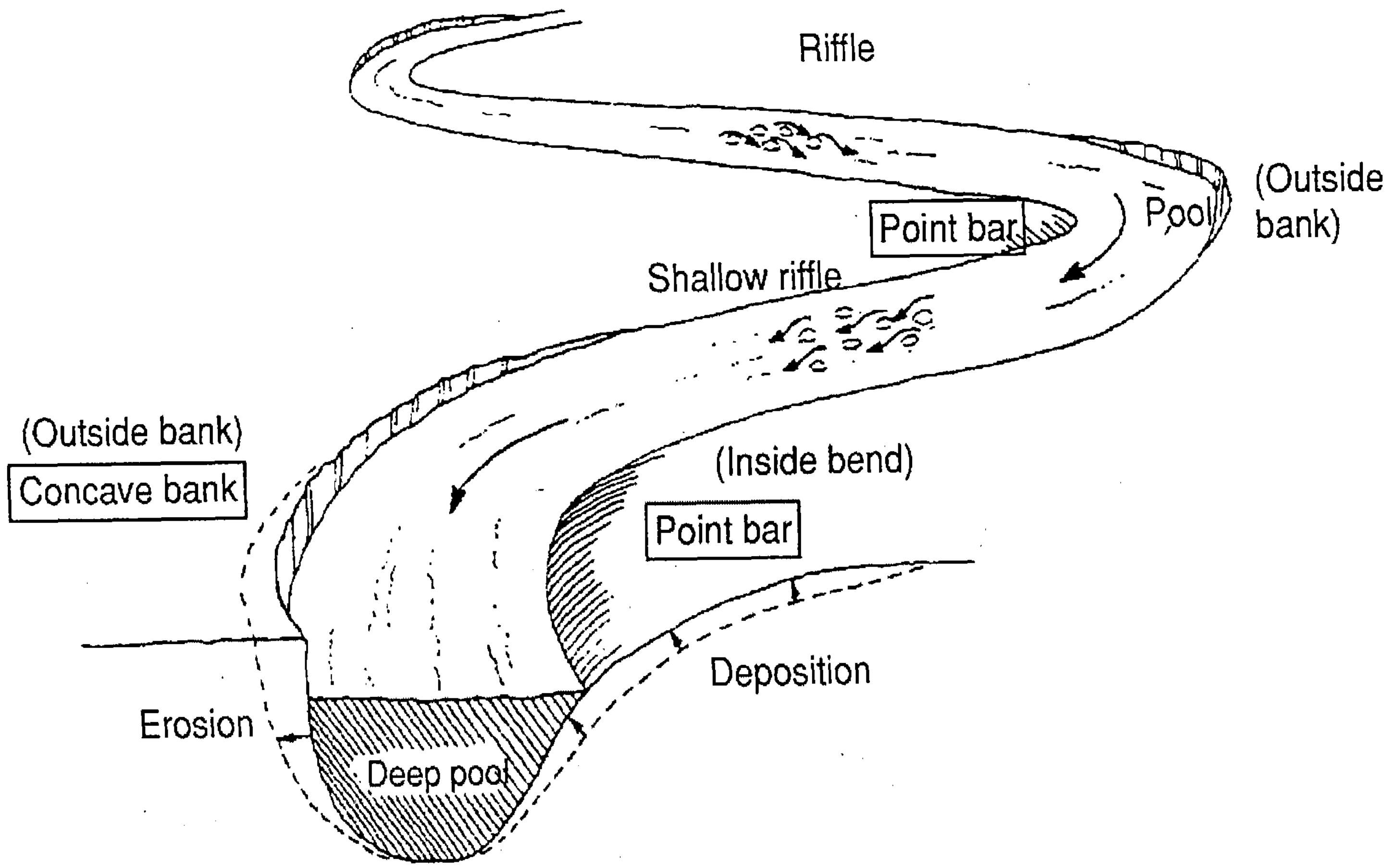


Figure B-5: River Meander Migration Model



Source: California State Lands Commission 1993.

Figure B-6: Diagram of Meander Bend, Showing Variety of Forms (and thus Habitats) Associated with Actively Migrating Meander Bend.

woody debris to the stream, which in turn increases channel complexity through providing cover and inducing scour. On the newly deposited point bar surface, pioneer riparian species establish and undergo gradual succession to species adapted to finer grained soils and less frequent inundation as the surface builds up through overbank sedimentation, which occurs as the channel migrates away from the site. The evolution from point bar to floodplain is accompanied by frequent inundation and a high connectivity with the channel.

Meander migration rate is driven largely by flow and is influenced by sediment supply. In an unregulated river, runoff and sediment load are derived from the watershed and upstream reaches. Below a reservoir, high flows are typically reduced, reducing the stream energy and slowing the rate of the erosion and deposition through which meander migration occurs. The system becomes less active overall although with distance downstream of the dam and increasing input from tributaries, the river typically becomes more dynamic because the effects of the dam are moderated by runoff from the drainage area downstream. Because the reservoir traps all gravel and sand from upstream, sediment supply is reduced, which can lead to channel enlargement as sediment-starved water erodes the bed and banks. Both of these effects are illustrated on the upper Missouri River below Harrison Dam. Rates of erosion and deposition were formerly high and roughly balanced, but after dam construction, the rates of erosion and deposition dropped sharply, and the erosion rates now greatly exceed deposition rates (Johnson 1992).

Management actions can influence meander processes and habitats in a variety of ways. In some cases, high flows can be released from dams to reactivate dynamic channel processes. However, if the high flows are not accompanied by an augmented supply of sand and gravel, the result may be further degrading of the channel and a paucity of gravel deposits. A recognition of the ecological importance of riparian zones (Gregory et al. 1991) and the role of dynamic channel-floodplain interactions (notably meander migration) suggests that restoration of salmon habitat should be undertaken, wherever possible, by restoring the dynamic river processes that create and maintain the desirable habitats.

♦ Appendix C. An Example of Adaptive Management Using Conceptual Models: Chinook Salmon and Deer Creek

Overview

This appendix provides an example of how Ecosystem Restoration Program (ERP) actions should be formulated and selected. The example given is for spring- and fall-run chinook salmon in the Deer Creek ecosystem (Figure C-1). Chinook salmon are a useful focus for this example because they are a valuable fish species, are sensitive to environmental conditions throughout the system, and integrate across the entire landscape of the Bay-Delta system. Spring-run salmon are of particular interest because their populations are a tiny fraction of their historical numbers and they have been proposed for listing as a threatened species. Fall-run chinook also have been proposed for listing, but their overall abundance is much higher than that of spring-run. The Deer Creek ecosystem is of interest because it is a relatively undisturbed stream, one of the last drainages in the Bay-Delta system to support spring-run chinook salmon, and because several specific restoration measures have been proposed for Deer Creek in recent years. In this appendix, we show how simple conceptual models can be used to evaluate various possibilities for rehabilitating salmon populations and habitat and how these might fit into the larger context of spring-run chinook life history and factors limiting its population.

Background

Species-Based vs. Ecosystem-Based Restoration

This example also illustrates the different assumptions underlying species-based and ecosystem-based restoration. Species-based restoration attempts to identify and remove limiting factors and bottlenecks to production. It requires specific knowledge about the species' life history and ecology that may be difficult to obtain and provides little progress toward ancillary objectives. On the other hand, it is easier to understand and justify and can capitalize on specific opportunities (e.g., harvest limits). Species-based approaches may be especially important for fishes such as chinook salmon that move between major ecosystems because removing limiting factors in one area may be offset by increased mortality in another area. Finally, state and federal endangered species legislation is essentially species based, although efforts are growing to apply them using ecosystem-based approaches.

Ecosystem-based restoration uses knowledge of the ecological context in which individual species thrive and attempts to restore that ecological context (structure and function) under the assumption that a species' well-being will emerge from a well-functioning ecosystem. It requires less knowledge about the species but incorporates the often-untested assumption that restoring the ecosystem will benefit the species. It can be used to achieve multiple objectives but also can be difficult to justify as a method for restoring individual species. As illustrated in this appendix, a comprehensive approach to ecosystem restoration, emphasizing an understanding and then restoration of physical and ecological processes affecting habitat, is likely to be more sustainable in the long term than attempts to create habitat features.

Deer Creek Chinook Salmon Life Histories

The life histories of spring- and fall-run chinook salmon are the same except for the seasonal timing of migration and spawning, the typical locations with the river system, and the length of time spent rearing in fresh water.

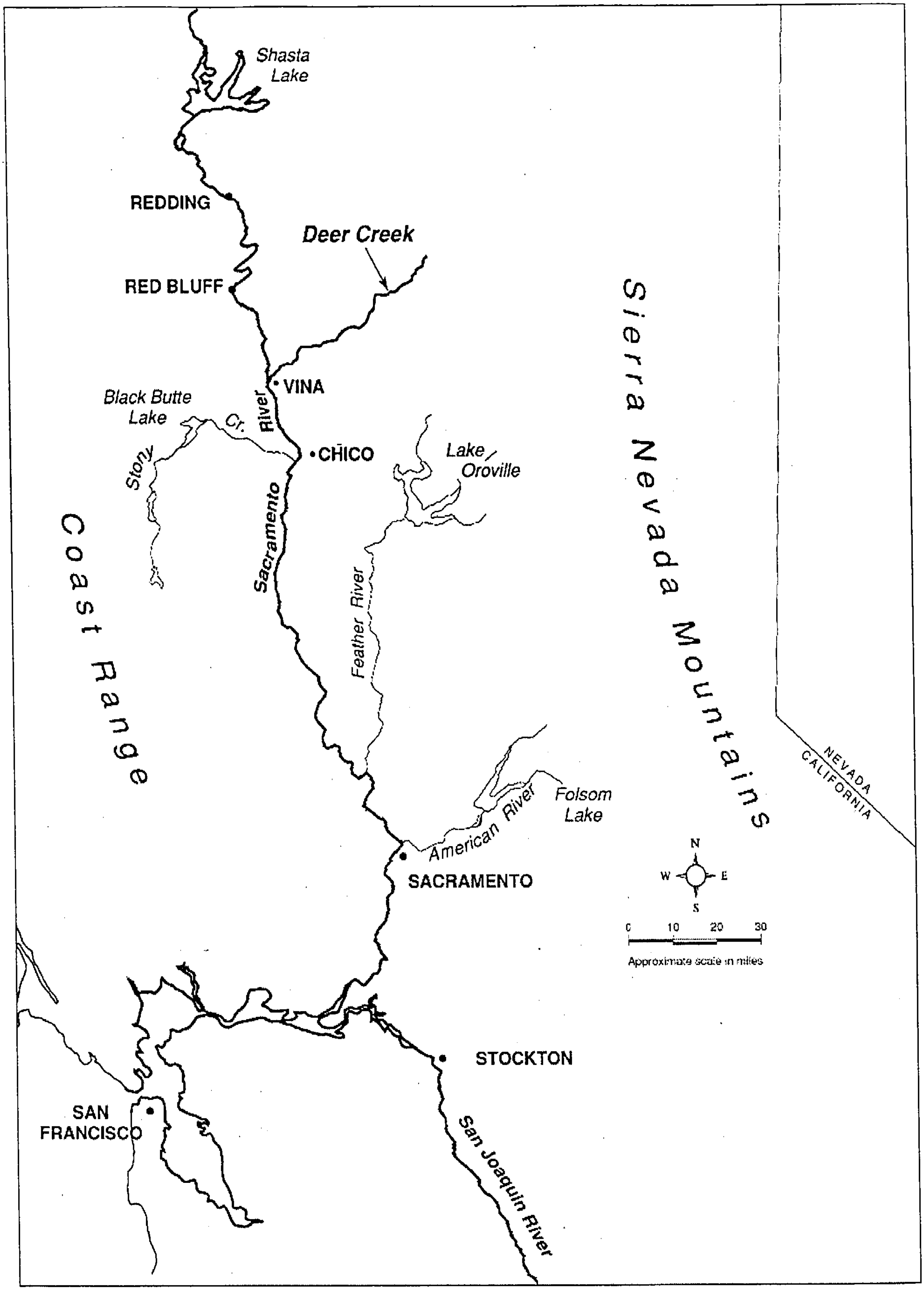


Figure C-1: Deer Creek Location Map

Spring-run chinook enter the rivers from the ocean from March through May. While migrating and holding in the river, spring-run chinook do not feed, relying instead on stored body fat reserves. They are fairly faithful to the home streams in which they were spawned, using chemical cues to locate these streams; however, some ascend other streams, especially during high-water years; in dry years, they may be blocked from their streams and forced to remain in main rivers.

Adult spring-run chinook migrate up Deer Creek from April through June (Vogel 1987a, 1987b), aggregate in the middle reaches (Airola and Marcotte 1985), and spawn from late August to mid-October. In Deer Creek, most hold and spawn between the Ponderosa Way bridge and upper Deer Creek falls, which is a natural barrier to migrating fish (Marcotte 1984). When they enter fresh water, spring-run chinook are immature; their gonads mature during the summer holding period (Marcotte 1984). Eggs are laid in large depressions (redds) hollowed out in gravel beds. The embryos hatch following a 5- to 6-month incubation period and the alevins (yolk-sac fry) remain in the gravel for another 2-3 weeks. After their yolk sac is absorbed, the juveniles emerge and begin feeding.

Historically, spring-run adults were a mixture of age classes ranging from 2 to 5 years old. Possibly because of fishing in the ocean, most of the fish now are probably 3 years old. During the summer holding period in freshwater pools, many large adult salmon may be caught by anglers (who snag them accidentally with spinning lures), and some by poachers. The importance of this source of mortality is indicated by the distribution of the fish; they are most abundant in the more remote canyon areas and scarce in pools close to roads.

Fall-run chinook salmon ascend Deer Creek from October through November (when they are sexually mature) and spawn immediately (October to early December), using gravels in lower elevation reaches, primarily in lower Deer Creek. Fall-run chinook spend less time in fresh water as adults and as juveniles, leaving their natal stream soon after emergence.

During most years, juvenile spring-run salmon in Deer Creek spend 9-10 months in the streams, where they feed on drift insects. The timing of emigration from Deer Creek has not yet been clearly determined, but it seems to be much more variable than for fall-run chinook. Some juveniles may move downstream soon after hatching in March and April, others may hold in the streams until fall, and still others may wait for more than a year and move downstream the following fall as yearlings (Harvey pers. comm.). The outmigrants may spend time in the Sacramento River or estuary to gain additional size before going out to sea, but most have presumably left the system by mid-May. Once in the ocean, salmon are largely piscivorous and grow rapidly. During downstream migrations in the Sacramento River and Delta, the smolts presumably stay close to the banks during the day (near cover) and then move out into open water at night, to migrate. Historically, they may have moved into flooded marshy areas in the Delta to feed, but there is little evidence of such activity today.

STATUS OF CHINOOK SALMON POPULATIONS

Spring-run chinook salmon are in a state of decline and are listed by the State as threatened species and are federally proposed for listing as endangered (see ERPP Volume I, Species and Species Groups Visions); therefore, actions likely to protect and enhance this stock should receive high priority. At the same time, actions to protect and improve habitat should help not only spring-run chinook, but also other fish, such as fall-run chinook, steelhead, Pacific lamprey eel, and a complete assemblage of native foothill fishes and native amphibians. Similarly, actions to benefit spring-run chinook habitat probably would achieve other objectives at the ecosystem level. The principal assumption is that restoration of habitat will be effective in improving conditions for this stock.

Spring-run chinook salmon of the Sacramento-San Joaquin River system historically comprised one of the largest set of runs on the Pacific coast. Campbell and Moyle (1991) reported that more than 20 "historically large populations" of spring-run chinook have been extirpated or reduced nearly to zero since 1940. The three largest remaining runs (Butte, Deer, and Mill Creeks) have exhibited statistically significant declines during the same period. The only substantial, essentially wild populations of spring-run chinook remaining in California are in Deer and Butte Creeks in the Sacramento River drainage and in the Salmon River in the Klamath-Trinity River drainage (Campbell and Moyle 1991).

In Deer Creek, spring-run chinook abundance has been low since the early 1980s (Figure C-2). The Mill and Big Chico Creek populations have suffered similar declines, but the Butte Creek population has not, for reasons that are uncertain.

Fall-run chinook populations have also declined, but not so precipitously. In large part, this decline has been less severe because, unlike for the spring-run chinook, access to the fall-run chinook's (lower elevation) spawning grounds has not been cut off.

Habitat Restoration Proposed for Deer Creek

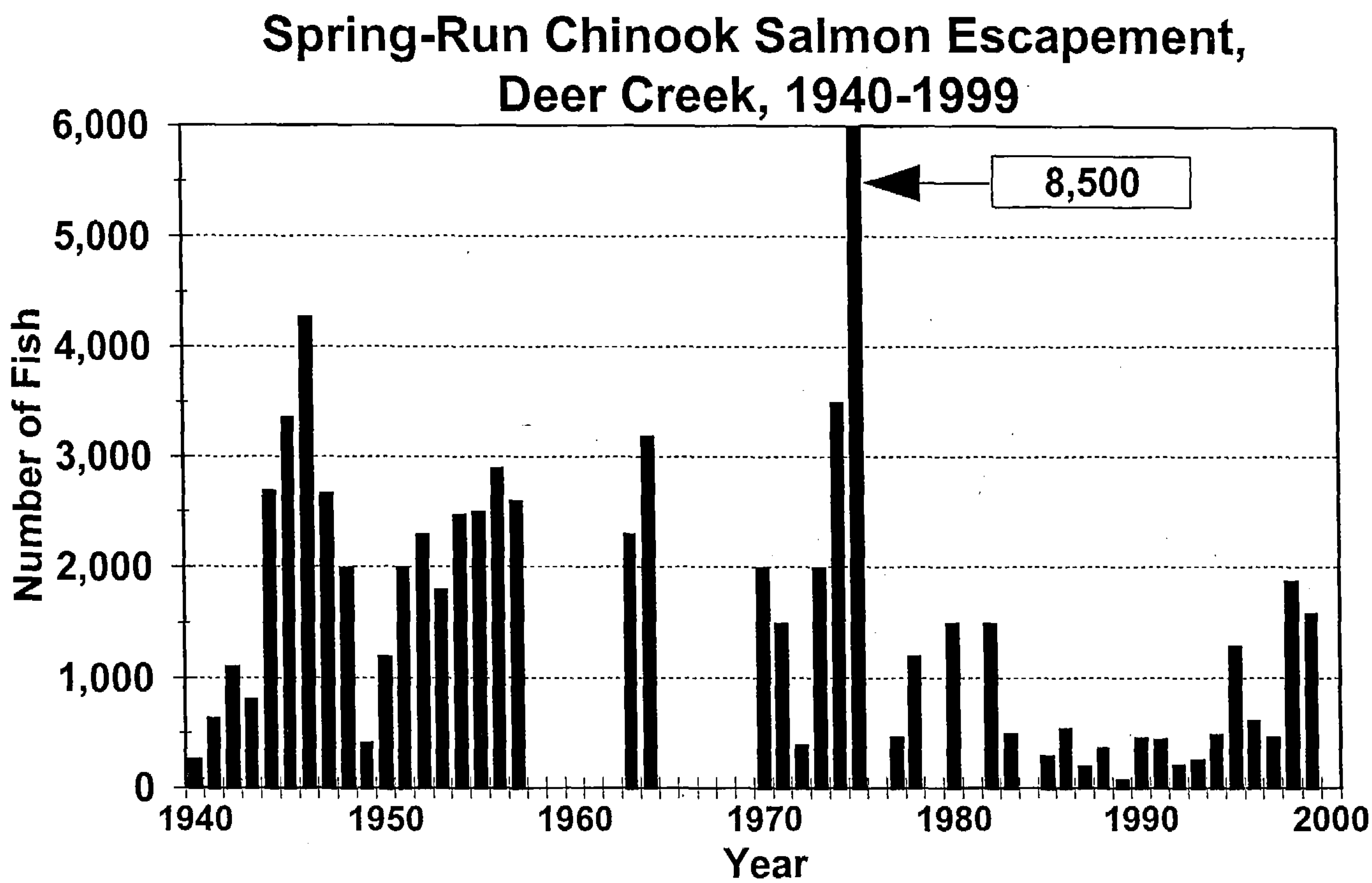
With declining salmon returns throughout the Bay-Delta system and the extinction of spring-run chinook in most of the rivers they formerly inhabited, Deer Creek and the other remaining spring-run chinook streams have attracted attention, and various proposals have been put forth to enhance salmon habitat and passage. These proposals have included measures such as minimum flow requirements in reaches formerly de-watered below irrigation diversions. Although there may be argument about the amounts of water needed, minimum flows in the reach are clearly required.

Other proposed measures have addressed the apparent armoring of the bed of Deer Creek, through mechanical ripping of the gravelbed, artificial addition of smaller gravel, and installation of log structures to hold the imported gravel in place (California Department of Fish and Game 1993, U.S. Fish and Wildlife Service 1995, CALFED Bay-Delta Program 1997). The relative lack of riparian vegetation on the banks along most of lower Deer Creek was addressed by the proposed planting of riparian trees. Although measures such as adding smaller gravel to the channel may provide short-term benefit, the shear stresses in the channel are so high that the gravels would be likely to wash downstream during the next flood. Similarly, in-channel structures and even riparian bank plantings may be washed out during high flows under present channel conditions.

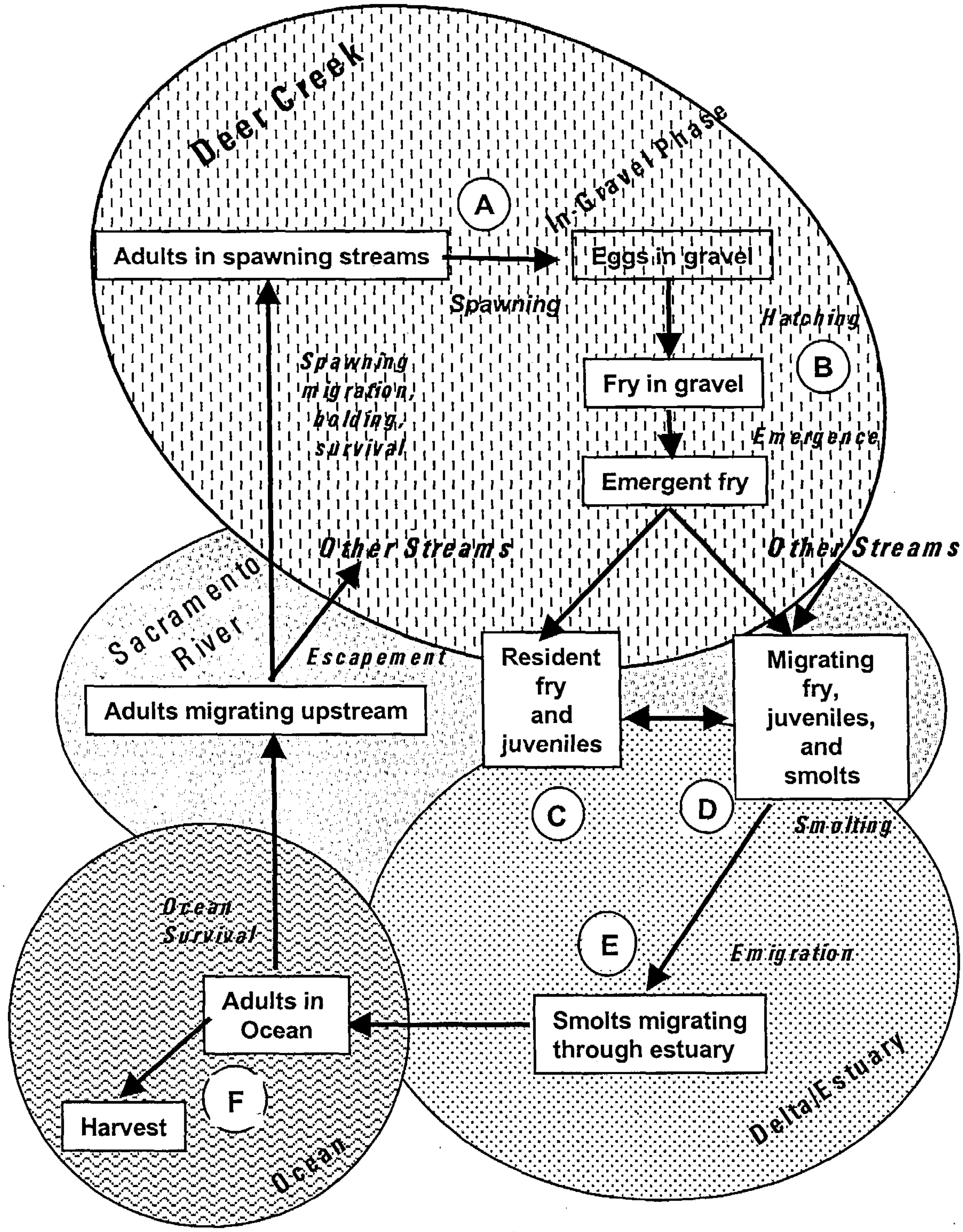
Overall Conceptual Model for Spring-Run Chinook Salmon

Figure C-3 shows a schematic diagram of the life cycle of spring-run chinook salmon in Deer Creek. Beginning with the ocean phase, surviving adults migrate upstream to hold through the summer and then spawn. Spawning, hatching, and initial rearing take place within Deer Creek. Rearing juveniles may remain in Deer Creek or begin moving downstream, some moving as far as the Delta. The distribution of spring-run juveniles that survive is not known. Spring-run salmon may smolt and migrate to sea in their first winter-spring, or the following winter as yearlings.

Efforts to restore habitat for spring-run chinook salmon within Deer Creek must be considered in the context of the species' life cycle. Restoration of habitat for one life stage may have little effect if other life stages are limiting. Furthermore, different stages in the life cycle could be limiting at different times, and releasing a limit at one part of the life cycle could result in another part of the life cycle becoming the limiting point. Circled letters on Figure C-3 show points in the life cycle at which interventions might be possible to restore habitat and conditions: (A) survival during migration to and holding near spawning areas, which may be affected by flow conditions or mortality including fishing; (B) spawning habitat, which may be affected by area of gravel of suitable quality in suitable hydraulic conditions, flow and variability in flow, and temperature; (C) rearing habitat including Deer Creek, the Sacramento River, and the Delta, which may be affected by flow, connection to floodplains, riparian vegetation, diversions, and temperature; (D) survival during migration down the river, which may be affected by flow, temperature, hatchery releases, predators, and diversions; (E) passage through the Delta, which may be affected by flow in the river, net flow across the Delta, temperature, contaminants, agricultural diversions, and possibly export flow; and (F) ocean survival, which is affected by ocean conditions and the percentage of salmon harvested.



Note: Data from Candidate Species Status Report 98-01 to the Fish and Game Commission.



Note: The four oval areas represent the four major geographic regions. Arrows indicate a change of state of surviving salmon, with only ocean harvest mortality displayed explicitly. Terms in italics indicate the major transformations occurring in each phase.

Density-dependent and density-independent factors affect salmon populations differently. Of the factors limiting the abundance of salmon, saturation of spawning habitat by high densities of redds, or possibly saturation of favorable rearing habitat by large numbers of juveniles, may result in density-dependent effects. In the case of spawners, this happens because females spawn in fairly restricted areas of high-quality habitat, and the resulting crowding, which can occur even at fairly low numbers of spawners, results in lower survival of the early-spawned eggs (superimposition). If this happens, providing more habitat or improving habitat quality should increase population size by increasing carrying capacity, thereby lifting the limit; however, if the population is too low for significant density-dependent mortality to occur, density-independent factors, mainly downstream, will predominate. In that case, habitat restoration upstream will have little if any effect on population size.

The current low abundance of spring-run salmon suggests that the population may not be greatly influenced by density-dependent effects, but until specific studies are made of this issue it cannot be resolved. In the meantime, ecosystem restoration can also be justified, along with actions designed to reduce density-independent mortality in other parts of the life cycle, because of other objectives (e.g., goal 2, ecological process objectives for high flows and floodplain inundation; goal 4, habitat objectives for tidal marsh and riparian wetlands).

A conceptual model of fall-run chinook salmon would be similar to that of spring-run except that the length of residence of juveniles and adults in the stream and use of the Delta for rearing by juveniles would be much less and the seasonal timing of migration would differ.

GEOMORPHIC AND HYDROLOGIC SETTING

Deer Creek drains 208 square miles of volcanic rocks on the west slope of Mount Lassen. It flows through canyons cut into volcanic strata before debouching onto the Sacramento Valley floor, flowing across its alluvial fan, and joining the Sacramento River near Vina (Figure C-1). For its first 2 miles, lower Deer Creek (the alluvial reach on the Sacramento Valley floor) migrates across an active channel 1,000-2,000 feet wide, bounded by bluffs (typically 5 meters [m] high) of older, cemented river gravels (Helley and Harwood 1985). Downstream of the bluffs, the multiple channels characteristic of alluvial fans can be clearly seen in the contour lines (Figure C-4). These contour lines reflect the process by which alluvial fans build up: A channel (or more than one channel) is active at a given time, carrying sediment from the watershed, and (because of the flattening of the gradient on the valley floor) aggrades (builds up with sediment) until the creek abandons that channel in favor of another channel, which now offers a higher gradient, until it too aggrades and the channel shifts again. Thus, over centuries or millennia, the locus of deposition shifts around the entire alluvial fan such that a low-gradient cone of sediment is created.

Strong, cold base flows are maintained in Deer Creek by springs in the volcanic rocks. The average flow at the U.S. Geological Survey gauge (located at the transition from the bedrock canyon to the valley floor) is 317 cfs (Mullen et al. 1991). Despite the base flows from the watershed, parts of Lower Deer Creek have been dry during the summer and fall of many years because of irrigation diversions. Dewatering of the stream no longer occurs thanks to voluntary releases by the irrigation districts, but the dewatered reach has been a barrier to migration until recently, and adequate flow to maintain cool temperatures remains an issue.

There is a high snowmelt flow virtually every year (forty percent of the Deer Creek watershed lies above 4,000 feet), but most big floods result from warm winter rains, and the biggest floods derive from warm rain on snow events. Deer Creek experienced such a rain-on-snow flood of 20,800 cfs in January 1997, which damaged farmland, and nearly washed out the under-sized Leininger Road bridge. The 1997 flood was only the third largest flood in the period of continuous record for the stream gauge, 1921-present, and is thus considered a 25-year flood (following standard formulae for flood frequency analysis) (Dunne and Leopold 1978). Other important floods occurred in December 1937 (23,800 cfs), 1940 (21,600 cfs), December 1964 (20,100 cfs), and 1970 (18,800 cfs) (published records and preliminary estimates of the U.S. Geological Survey). It is during such large floods that Deer Creek would historically shift

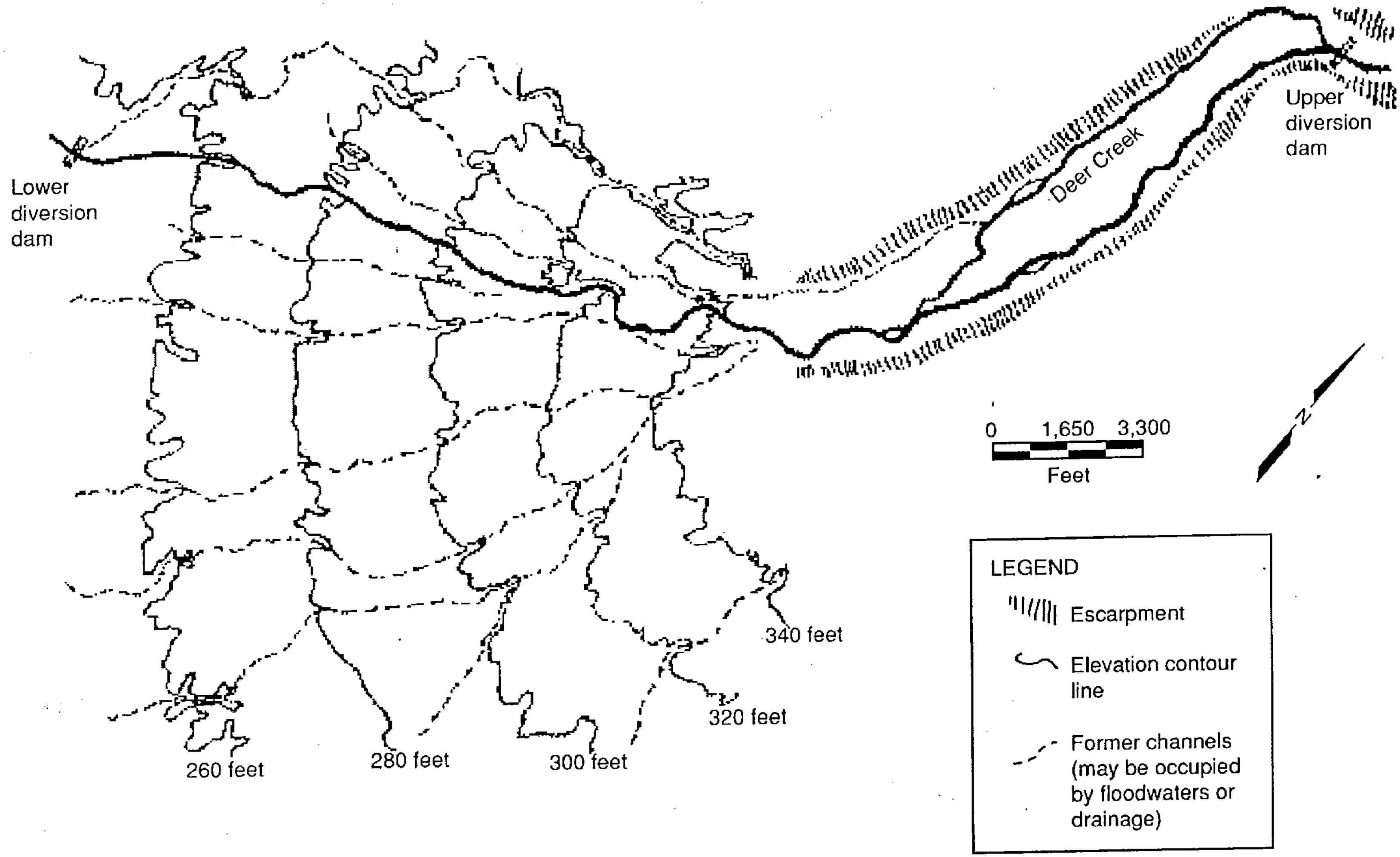


Figure C-4: Characteristic Multiple Channels Radiating from the Apex of the Alluvial Fan on Deer Creek channels. About ten miles of levees were built by the U.S. Army Corps of Engineers along Lower Deer Creek in 1949 to control flooding. During the 1997 flood and others, Deer Creek overflowed its banks, washing out levees on the south bank, and flowed across the floodplain for about 2 miles down to U.S. Highway 99, following another of the many distributary channels of the alluvial fan.

Habitat Change from Historical Geomorphic Analysis

Historical aerial photographs taken in 1939 clearly show Lower Deer Creek was highly sinuous, with small-scale bends, point bars, and alternating pools and riffles. For much of its course, the low-flow channel was against cut banks with overhanging trees, which provided the channel with habitat under cut banks and roots, shading of the stream, input of nutrients and carbon, and large woody debris. The bends in the channel created secondary circulations and complex flow patterns, which produced zones of higher and lower shear stress distributed through the channel, which in turn led to deposition of gravels and other sediments (Deer Creek Watershed Conservancy 1998). The complexity of channel form resulted in a diversity of microhabitats for invertebrates and fish. During floods, Deer Creek would regularly overflow its banks and inundate adjacent floodplains, a process which prevented continued build-up of water depth in the channel and thus limited the increase in shear stress on the channel bed. Inundation of the floodplain had numerous other ecological benefits, such as providing fish with refuge from high velocities, and abundant food sources on the floodplain, and watering the floodplain to maintain vegetation and floodplain water bodies (Stanford and Ward 1993, Sparks 1995).

Habitat conditions in Deer Creek were profoundly changed in 1949 by a U.S. Army Corps of Engineers flood control project, which built over 10 miles of levees along Deer Creek and straightened and cleared the low-flow channel. In effect, the flood control project sought to confine flood flows to the main channel, which required levees to prevent overflow, and increasing the capacity of the main channel by reducing its hydraulic roughness through straightening and clearing vegetation and large woody debris. Since 1949 there have been repeated efforts to maintain the flood control channel and levees by the U.S. Army Corps of Engineers, the California Department of Water Resources, and Tehama County Flood Control. After each major flood, heavy equipment was usually used to repair levees and clear the channel of gravel bars and large woody debris, with a particularly large gravel removal project after the 1983 flood by the Department of Water Resources (Deer Creek Watershed Conservancy 1998). Gravel removal and levee repair in the early 1980s cost about $1 million, and similar work in 1997 cost about half that amount.

Beginning with the aerial photographs of 1951 (the first available after the flood control project) and continuing to the present, the low-flow channel of Deer Creek is visibly less sinuous and less vegetated than it was in 1939. The alternating pool-riffle sequences visible on the 1939 aerial photographs have been largely replaced with long riffles and runs. There is less riparian vegetation bordering the low-flow channel, partly because there is less riparian vegetation on the banks and partly because there are fewer points where the (now straightened) low-flow channel is undercut at the base of a wooded bank.

Although there are no data on the bed material sizes before 1949, a number of reports have speculated that the gravels of Deer Creek are "armored" (California Department of Fish and Game 1993, U.S. Fish and Wildlife Service 1995, CALFED 1997). While Deer Creek probably does not fit the geomorphic definition of 'armored' (Dietrich et al. 1989), it is very likely true that the bed material is substantially coarser now than before 1949. The reason is that smaller gravels (which would be preferred by most spawning salmon) are now transported out of Deer Creek to the Sacramento River due to the increased shear stresses in the straightened and leveed channel.

The 1949 flood control project and subsequent maintenance efforts were undertaken with good intentions and reflected the best thinking at the time, but there is increasing recognition worldwide that channelization and other river control efforts are frequently detrimental to aquatic and riparian habitat, and often expensive to maintain because they are, in effect, "fighting" river processes. The literature is replete with evidence that natural, complex channels (i.e., channels with irregular banks, undulating bed morphology, and large roughness elements such as large woody debris) provide better aquatic habitat than simplified, channelized reaches (see Brookes 1988 for a review). It should come as no surprise that aquatic habitat is usually maximized with an unfettered, naturally migrating river channel (Ward and Stanford 1995), as these are the freshwater stream conditions with which the fish evolved.

Impacts of channelization include loss of aquatic habitat area and diversity, reduction in shading of the channel with attendant increase in water temperature, loss of riparian habitat for wildlife, specifically loss of undercut banks and overhanging vegetation, loss of pool-riffle structure, and loss of spawning habitat. These relations are visible from field observation on Deer Creek, and would probably be evident from detailed habitat mapping within channelized/leveed vs. more natural reaches of Deer Creek. One way in which channelization and levees reduce the quality of habitat in Deer Creek is by eliminating refuge from high flows: all the flow is concentrated between the levees, leading to increased shear stress in this narrow band. Not only do fish have no place to hide in such channelized/leveed reaches, but the resulting channel typically becomes simpler as well. Thus, the initial 1949 channelization project and subsequent channel clearing, gravel removal, and levee repairs (including post-1997-flood emergency work) were detrimental to aquatic habitat in Deer Creek.

Channel modifications are commonly accompanied by installation of rip-rap on banks. Rip-rapped banks lack bank overhangs, trees and roots, and other irregularities. Although the interstices of rip-rap can provide some habitat for juveniles, overall there is a loss of habitat when a natural bank is converted to rip-rap. Numerous studies have shown that rip-rapped banks support lower densities of fish (e.g., Cederholm and Koski 1977, Chapman and Knudsen 1980, Hortle and Lake 1983, Knudsen and Dilley 1987). Moreover, hardening river banks in one location typically produces a reaction elsewhere along the channel, because flows speed up, slow down, or change in direction. As a result, erosion is initiated elsewhere, and bank protection may be proposed for the new site of erosion, initiating a cycle of erosion and costly rip-rap projects, ultimately with substantial, negative, cumulative effects on aquatic habitat.

Channel maintenance for flood control has included removing accumulated gravel deposits and large woody debris. The gravel removed from the channel is important for building complexity of channel forms (e.g., point bars, riffles) and as part of the gravel delivered to the Sacramento River by Deer Creek. Large woody debris is increasingly recognized as providing important habitat in streams (Angermeier and Karr 1984, Dolloff 1986, Fausch and Northcote 1992, Fausch et al. 1995), so the loss of this wood from the system reduces habitat complexity and contributes to the rapid transmission of flow downstream.

Upstream reaches of Deer Creek most used for spawning and rearing by spring-run chinook salmon (the canyon reaches between the Lower Falls and the Ponderosa Way bridge) have remained largely unchanged since the 1930s. Farther upstream, the Deer Creek Meadows have experienced substantial erosion and channel widening and incision, which has caused the alluvial water table to drop, drying the meadow, and changing the distribution of pools, riffles, and other habitat features. The amount of sediment from the channel erosion, and from road construction, timber harvest, and landslides in the upper basin has no doubt increased in recent decades, and most of this sediment has passed downstream. However, important spring-run salmon habitats do not appear negatively affecting by excessive fine sediments at this time, implying that most of this sediment has been transported through the system during flows sufficiently high to maintain suspension.

A Systemic, Process-Based Strategy for Ecosystem Restoration of Lower Deer Creek

With an understanding of the effects of the flood control project (and its maintenance) on Deer Creek, we can see that many of the problems in Deer Creek are, in effect, symptoms of the underlying geomorphic effects of the flood control strategy. Many of the restoration actions proposed for Deer Creek can be viewed as treatments of these symptoms, rather than addressing the underlying problem. If the style of flood management were changed to set levees back, permit overbank flooding, and eliminate channel clearing, Deer Creek would, in the course of one or more floods, reestablish a more natural channel form with better habitat.

The Deer Creek Watershed conservancy is now exploring alternative flood management strategies. One concept is to let Deer Creek overflow its south bank at the same point it overflowed in 1997 (and in previous floods) and flow across a swath of the south bank floodplain (bounded along the south by set-back levees), through enlarged culverts under Highway 99, and past the town of Vina and into the Sacramento River through an enlarged China Slough. Vina, the Abbey of New Clairvaux, and other buildings on this floodplain would be protected by ring levees. This strategy would aim to manage floods rather than control them, to let Deer Creek release pressure during floods by overflowing as it has historically done, but to set back or protect vulnerable infrastructure.

Along many rivers and streams, it is too late to reestablish natural floodplain processes because intensive urbanization of the floodplain precludes its inundation, or upstream dam construction has reduced flood frequency. Fortunately, along Deer Creek, this is not the case, and a number of landowners have expressed willingness to consider periodic flooding of their agricultural lands. The Nature Conservancy and other organizations and programs could purchase easements or title to flood-vulnerable lands, compensating the landowners. Similarly, bank protection could be removed, destabilized, or not maintained, so that Deer Creek would become free to migrate across the floodplain. In the long run, this approach (of stepping back from the river and giving it a corridor in which to flood and erode) would reduce maintenance costs, in addition to improving habitat.

Because Deer Creek is a high energy channel with essentially unaltered flow and sediment yield from its watershed, it is capable of reforming its bed and banks from channelized to natural quickly, once the disturbing factors of levees and channel clearing were removed. We could expect to see substantial return to natural conditions in one large flood, as was illustrated by some of the channel changes effected by the 1997 flood.

Taking a systemic approach such as this need not preclude short-term measures such as planting riparian trees along de-vegetated channels, or even additions of spawning sized gravel to the channel, but these measures should be undertaken with the understanding that they are unlikely to be sustainable until the channel of Deer Creek can evolve to a more complex, natural form.

LIMITING FACTORS IN THE LIFE CYCLE OF SPRING-RUN AND FALL-RUN CHINOOK SALMON

SPAWNING. Gravels in Lower Deer Creek are used for spawning by fall-run chinook, despite grain sizes considered somewhat coarser than ideal. Spring -run spawning is concentrated upstream, where the gravels occur in smaller deposits. Restoration efforts in Lower Deer Creek would benefit spawning for fall-run chinook and rearing habitat for both runs. However, there may be other, less-visible, limitations on salmon at other stages of their life cycles. For example, if abundance is very low, spawning habitat may not be limiting, because even the limited spawning habitat is adequate for the depressed populations. In this case, restoration efforts directed at other parts of the life cycle may be more effective. This has probably been the case in some years of low abundance (Figure C-2). For some of these life cycle stages, ecosystem restoration seems like a logical and supportable way to proceed; for others, species- or even stock-specific actions are more likely to yield tangible results. Limitations at different stages of the life cycle are discussed below, with letters referring to Figure C-3.

FRY REARING IN RIVERS (C). In general, chinook fry tend to disperse downstream after emergence, taking up residence along edges of streams and rivers, and selecting habitat of increasing velocity as they develop (Chapman and Bjornn 1969, Lister and Genoe 1970, Reimers 1973, Healey 1991). Habitat characteristics seem to be important, particularly the availability of cover at the banks, and riprapped banks seem to provide especially poor habitat for rearing (Michny and Hampton 1984, Schaffter et al. 1983, Brusven et al. 1986). Under the assumption that these characteristics apply equally well to Deer Creek spring-run salmon, then restoration activities in both the creek and the Sacramento River should increase growth and survival of Deer Creek spring-run by an unknown amount. These improvements may include increasing the extent of meander belts, increasing riparian vegetation and woody debris, and reducing the effect of structures that impede migration and concentrate predators. Continuing to maintain Red Bluff Diversion Dam gates open will eliminate what had been believed to be an important concentration of predators.

HABITAT CONDITIONS IN THE DELTA (D). Data on conditions for juvenile salmon in the Delta is largely confined to fall-run smolts and, to a lesser extent, fry. Although many brackish estuaries provide important rearing habitat for chinook salmon (Healey 1982), spring-run races tend to rear more in rivers. Rearing of fall-run salmon in the Sacramento-San Joaquin estuary is believed to occur in freshwater regions of the Delta (Kjelson et al. 1982). Survival of migrating hatchery-reared smolts is lower if they are released in the interior Delta than if they are released on the Sacramento River, suggesting poor conditions for survival within the Delta (USFWS data). To the extent that these poor conditions are due to inadequate habitat, ecosystem-based restoration efforts may help smolt survival as well as that of fry. Too many unknown factors exist, however, to suggest large-scale restoration efforts on behalf of salmon (e.g., the extent and importance of rearing in the Delta, the characteristics of favorable habitat, and the degree to which habitat may be occupied by either salmon or their predators). This suggests that a stepwise, adaptive-management approach to this restoration be used to begin to test assumptions about how habitat in the Delta may be improved and what affect that has on key species such as salmon.

FISH PASSAGE THROUGH THE DELTA (E) Although this is included as an illustration of potential effects on salmon, improvement of fish passage through the Delta is an ecosystem-level action which should benefit other species and stocks. Most of the emphasis in the Delta has been on survival of fall-run salmon smolts passing through on their seaward migration (Newman and Rice in prep.). The principal factors affecting survival appear to be flow in the Sacramento River, salinity distribution, and Delta cross-channel gate position (Newman and Rice in prep.). If spring-run salmon respond similarly to conditions in the Delta (except that temperature should not be a factor), there may be opportunities for improving their survival. Proposals in the Central Valley Improvement Act Anadromous Fish Restoration Plan included closing the Delta Cross-Channel gates in winter, and conducting adaptive management experiments (as in the Vernalis Adaptive Management Program), manipulating flow and exports during experimental releases of tagged late-fall-run fish to represent spring-run. Additional actions that improve the effectiveness of directional cues should benefit all salmon stocks as well.

ADULT PASSAGE AND SURVIVAL (A) Adult passage into Deer Creek is probably not a limiting factor under most flow conditions. However, high temperature in the Sacramento River could result in physiological damage or exhaustion with resulting poor survival or egg viability. Because adults hold in the stream through summer, spring-run chinook may be particularly vulnerable to poaching, which may have contributed to their decline (Sato and Moyle 1989).

OCEAN CONDITIONS (E) Survival of salmon in the ocean is reduced by natural mortality (an ecosystem condition) and fishery mortality (largely a species-based condition). Natural mortality is a function of ocean conditions, out of the control of CALFED. The fraction of fall-run salmon caught (harvest fraction) has been increasing by 0.5% per year for the last 40 years to values over 70% (based on data in Mills and Fisher 1994). This value seems excessive if it applies also to spring-run salmon, given their population size. Thus an obvious management option is to reduce harvest, particularly if it can be done in a way that uses the different migratory patterns to reduce impacts on spring-run fish.

ALTERNATIVE CONCEPTUAL MODELS FOR SALMON RESTORATION IN DECISION MAKING

With these limiting factors in mind, we now illustrate the application of conceptual models to formulating ERP actions, by identifying key events in the life cycle that affect production. We first present alternative models for spring-run chinook salmon system-wide, which lead to alternative restoration approaches, depending on the relative importance of each life stage. Second, we present a conceptual model of fall-run spawning in Lower Deer Creek, which provides a basis for choosing restoration actions in Deer Creek.

EXAMPLE 1: CONCEPTUAL MODELS FOR SPRING-RUN SALMON

ALTERNATIVE POINTS IN THE LIFE CYCLE. For illustration, we have selected just two qualitatively different models of the life cycle of spring-run chinook salmon (Figure C-5). These models are briefly summarized in Table C-1. According to Model A, spring-run salmon could be restored through control of poaching in the streams and improvement of rearing habitat in the streams and river. Model B suggests restoration by improving spawning habitat and Delta rearing habitat, and reducing ocean harvest. Both models indicate a moderate improvement through reduction of mortality on passage through the Delta. Delta conditions are discussed further below.

Clearly the expected benefits due to improvements in different locations differ greatly among these and other possible alternatives. The only way to resolve these issues is through modeling of the life cycle. With a model containing the various mortality factors, their expected response to restoration actions, and the degree of uncertainty about each, one could estimate the effectiveness of various actions and how well that effectiveness is known. The principal output of such a modeling effort would be a set of constraints on the improvement to be expected from each action. The model would not need to be very complicated, and in this case a simple model would most clearly distinguish among scenarios.

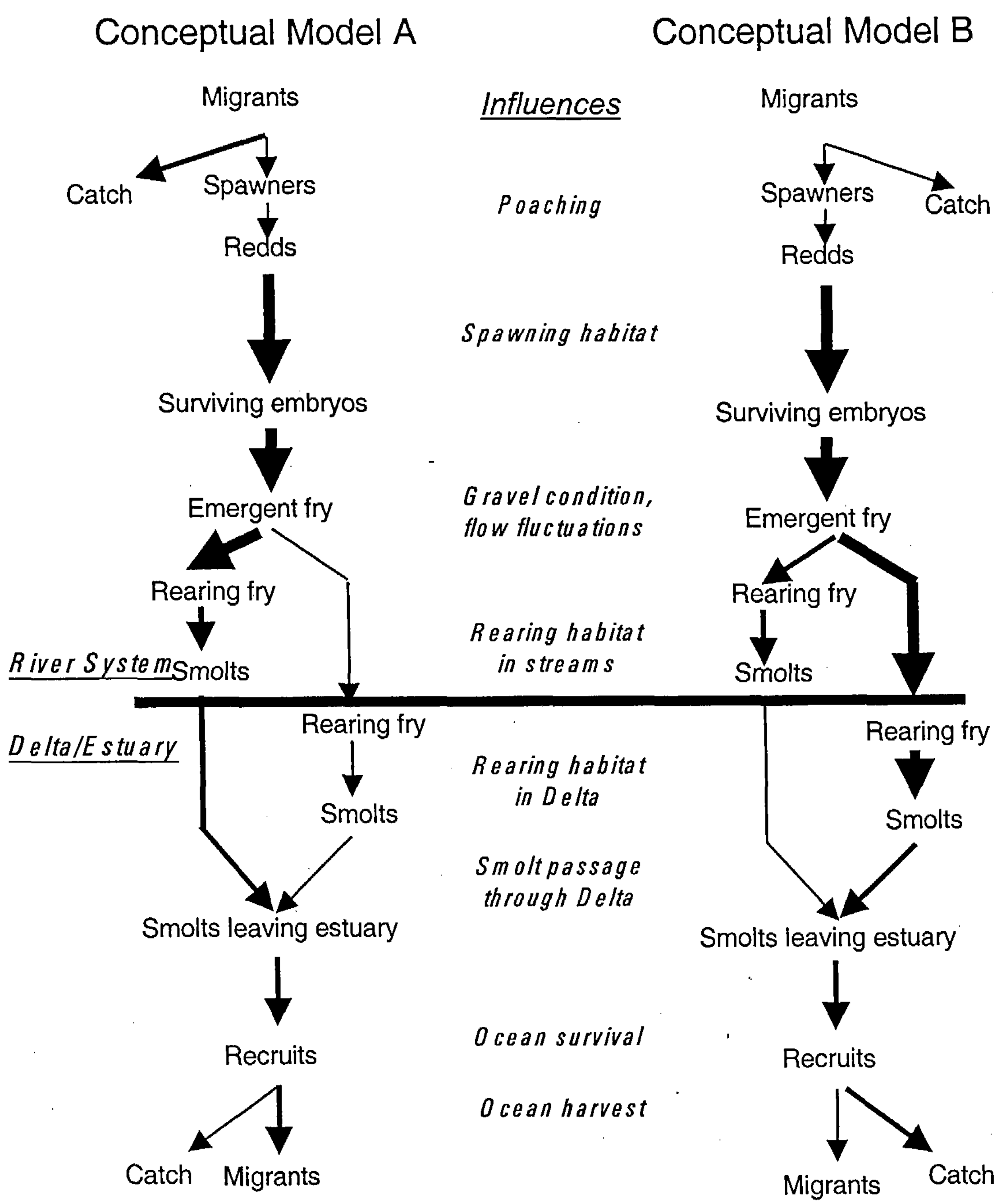
SURVIVAL IN THE DELTA. Because conditions in the Delta have received a lot of attention, and because this is the centerpiece of CALFED, we illustrate several important issues regarding survival and passage through the Delta.

Again, we use alternative conceptual models, but in this case the models differ in only one important respect: the degree of importance of tidal vs. net flows within the Delta channels (Figure C-6). Conceptual model N (for Net) holds that net flows are more important than tidal flows. According to this model, young salmon are diverted off the Sacramento River mainstem in approximate proportion to estimated net flow splits. Reverse flows such as QWEST (net flow in the lower San Joaquin River) are important either in drawing young fish toward the export pumps, or in altering salinity or other cues, confusing migrating fish as to the correct direction in which to migrate. The influence of Delta agricultural diversions (not shown in the figure) is to remove salmon in approximate proportion to the diversion flow. This model has predominated over the last few decades, despite a lack of data suggesting a strong influence of reverse flows, results of a recent study showing low abundance of salmon in agricultural diversion flows, and relatively low rates of capture of tagged salmon at the export pumps.

TABLE C-1. SUMMARY OF DIFFERENCES BETWEEN ALTERNATIVE CONCEPTUAL MODELS A AND B IN FIGURE C-5 IN RELATIVE IMPORTANCE OF VARIOUS LIFE STAGES TO POTENTIAL IMPROVEMENT IN PRODUCTION OF DEER CREEK SPRING-RUN CHINOOK SALMON.

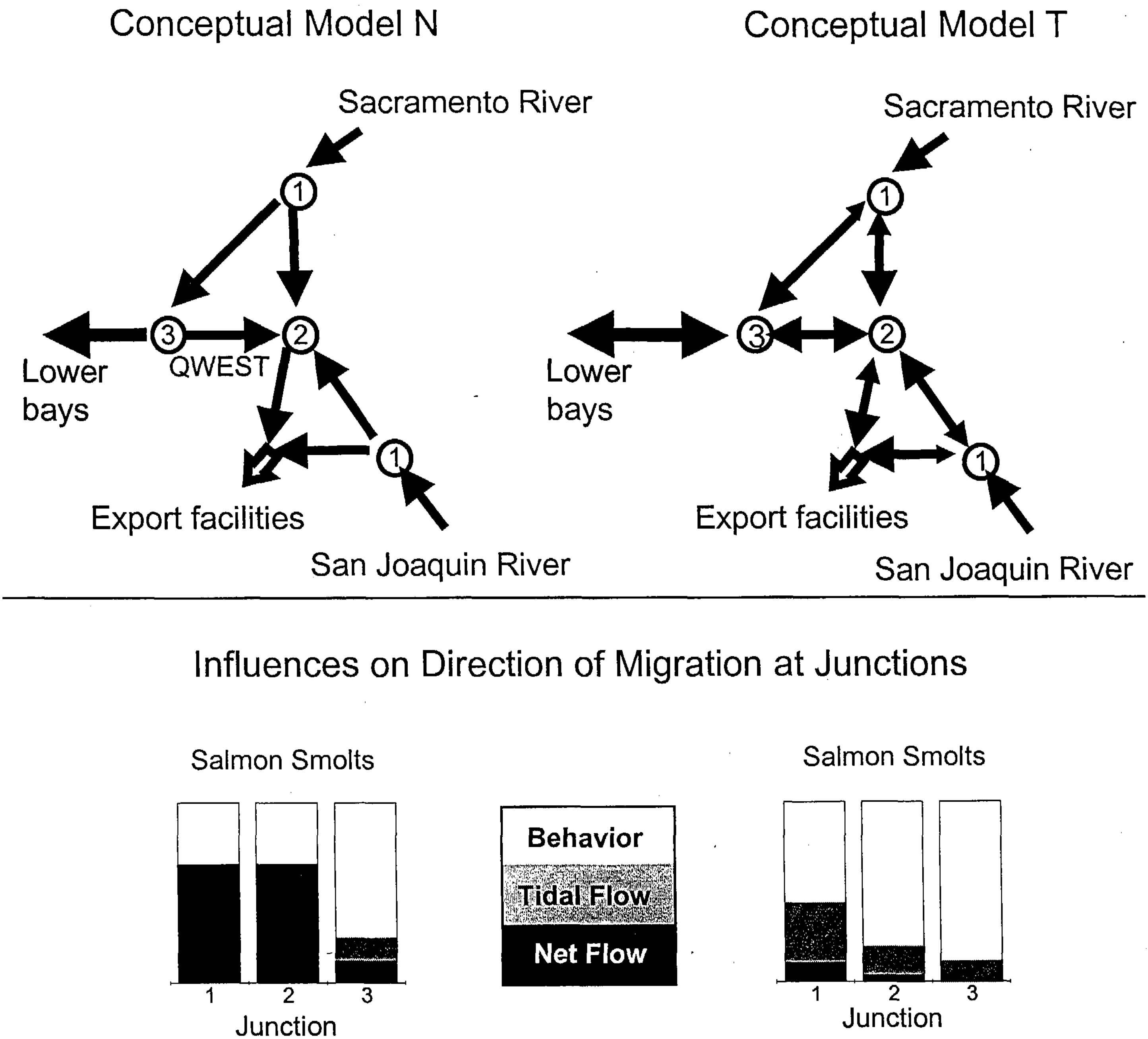
Life Stage or Event	Density-Dependent	Relative Importance	
		Model A	Model B
Poaching	Yes?	High	Low
Availability of spawning habitat	Yes	Low	High
Rearing in stream/river	No?	High	Low
Rearing in the Delta	No	Low	High
Passage through the Delta	No	Moderate	Moderate
Ocean harvest	No?	Low	High

The alternative model T (for Tides) holds that water movement is asymmetric, with dominance by ebb or flood due to net flow and tidally-driven residual flow; the further west in the Delta, and the lower the freshwater flow, the more predominant



Note: Arrows represent transformations of fish from one life stage to the next, and thickness of arrows indicates relative magnitude of population undergoing transformation. Conceptual models A and B differ in the importance of effects at several stages of the life cycle (Table C-1).

Figure C-5: Alternative Conceptual Models of Salmon Smolt Production for Deer Creek Spring-Run Chinook



Note: Arrows and circles comprise a schematic of the Delta, with the circles representing key nodes where flow and fish diverge. Single arrows indicate river inputs, and double arrows indicate flows that are partly or mostly tidal, with the sizes of the arrowheads reflecting relative flow velocities for each location. Conceptual model A depicts net flows, with arrows indicating how fish would move under the influence of these flows. Conceptual model B illustrates how water moves in response to both tides and net flow. Fish move under the influence of these flows and their own behavior. Bar charts in the bottom panel illustrate how these conceptual models differ in their prediction of the relative influence of fish behavior, tidal flow, and net flow on the proportion of fish taking alternative pathways at each of the nodes.

Figure C-6: Alternative Conceptual Models of Flow and Salmon Movement in the Delta Under Low-Flow, High-Export Conditions the tidal effects. A passive particle released in the Sacramento River has a high probability of eventually moving into Suisun Bay, a moderate probability of entering the central Delta or being entrained in Delta agricultural diversions, and a low but non-zero probability of being entrained in the pumping plants. Salmon behavior complicates this in unknown ways: e.g., splits at Delta channel junctions are a complex, at present unpredictable, function of tidal flow splits and fish behavior. Furthermore, adult salmon (and probably juveniles) use tides to assist in migration. Net flows probably have little effect except where they set up or obliterate gradients (e.g., in salinity) that may provide cues for seaward migration. QWEST and other small (relative to tidal) net flows have little or no effect, although they may be related to the environmental gradients referred to above. Finally, losses to agricultural diversions depend on the size and location, as well as the flow rate, of each diversion, and because of avoidance by fish these losses may be generally low.

In the conceptual models presented thus far, we have referred to habitat restoration in a general way, implicitly assuming that restoration projects will actually benefit salmon. However, the effectiveness of restoration projects is highly variable, depending upon the degree to which their design accounts for physical and ecological processes. In the following conceptual model, we consider in more detail the factors affecting spawning success of fall-run chinook salmon, and potential strategies for restoration.

EXAMPLE 2: A CONCEPTUAL MODEL FOR FALL-RUN CHINOOK SALMON SPAWNING HABITAT RESTORATION IN LOWER DEER CREEK

Although Deer Creek is probably most important as habitat for spring-run chinook salmon, Lower Deer Creek also provides spawning habitat for fall-run chinook (and, potentially, rearing habitat for spring-run). A number of the proposed restoration measures in Deer Creek (e.g., gravel ripping, addition of spawning gravels, installation of retaining structures) relate to spawning habitat for fall-run. Thus, an understanding of the processes and factors controlling the distribution of this habitat, and how management decisions can affect them, is important.

The conceptual model shown in Figure C-7 lays out the life stage functions involved in migration, spawning, incubation, fry emergence from gravels, and juvenile rearing. The model also discusses management and restoration actions in light of their effects on the requirements of each life stage. Under Upstream Migration, the fish must be able to swim from the ocean to their natal spawning grounds, which requires a path free of migration barriers. Barriers include dams, diversions, dewatered reaches, or reaches with high temperatures, contaminant concentrations, or low dissolved oxygen. For management, this implies that all dams and diversions below potential spawning grounds be evaluated for passage or removal, and adequate flows be provided to insure sufficient water quantity and quality to permit migration.

Under Digging Redds, the fish must be able to move the gravel, which is mostly a question of gravel size. Larger fish can move larger gravels, with the maximum size (median grain diameter) moveable being about 10 percent of the fish's body length. The sizes of gravel available is largely a function of the balance between the amount and size of gravel supplied by the watershed and local channel transport capacity. Below dams, the supply of gravel is usually reduced, so gravel may need to be added to make up for the lack of supply from upstream. In channelized and leveed reaches, the transporting power is locally increased, so gravels that might formerly have been stable are likely to be washed downstream.

Under "Incubation" in Figure C-7, the eggs must have their metabolic wastes removed and adequate dissolved oxygen, both of which depend on adequate intragravel flow past the eggs, which in turn depend on sufficient hydraulic gradient to drive the flow and sufficient permeability in the gravels to permit the flow. The hydraulic gradient depends upon the location within the longitudinal profile and local channel geometry, with the pool-riffle transition typically creating an excellent gradient for intragravel flow (water wells down into the bed at the tail of the pool, upwells from the riffle). For ecological management, this implies that undulations in the streambed are important

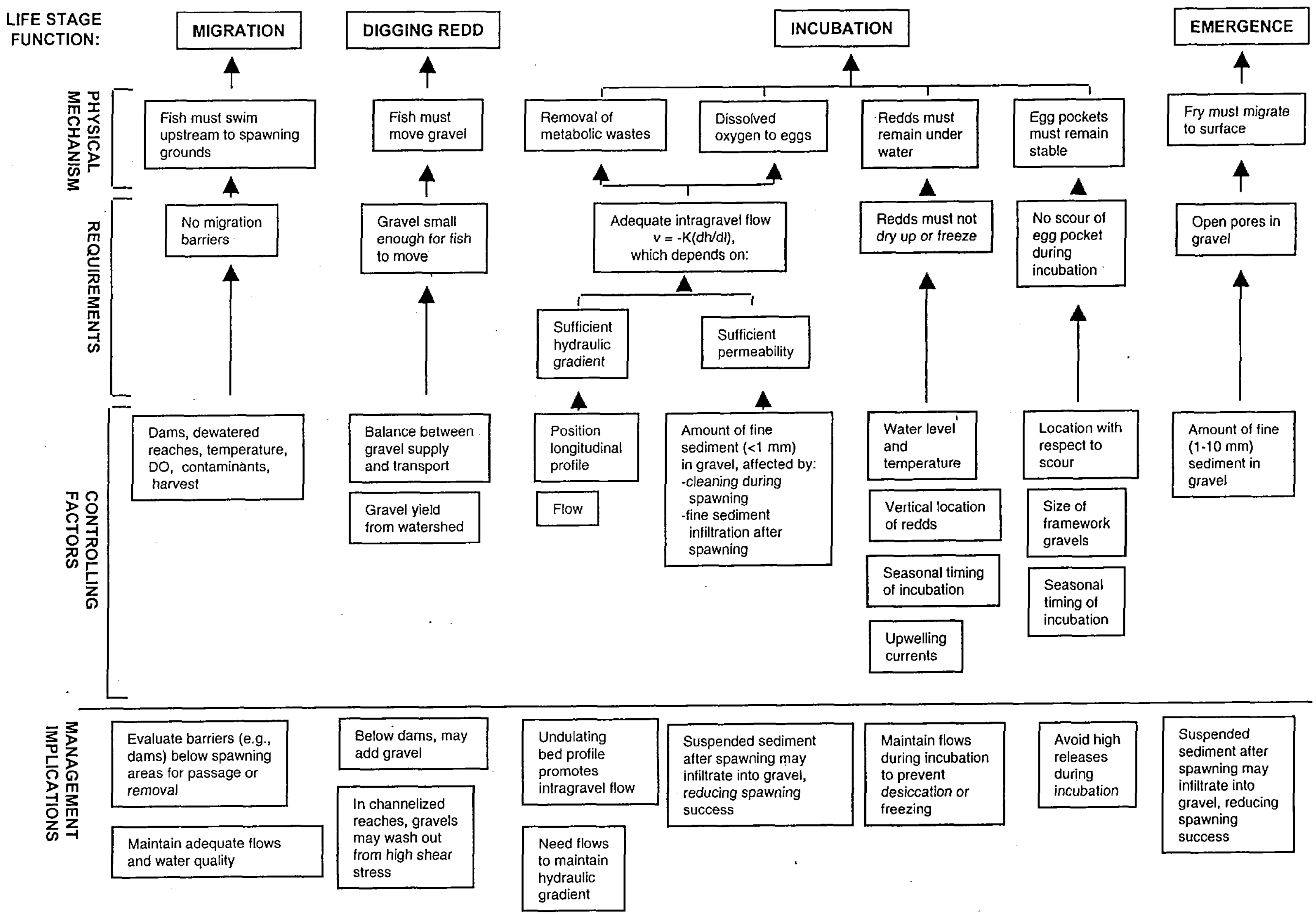


Figure C-7: Conceptual Model of Salmon Spawning, Showing Factors Affecting Success at Various Life Stages ecologically, and should be maintained. The permeability depends upon the amount of fine sediment (finer than 1 mm) in the gravel, which in turn is affected by the amount of fine sediment present before the fish spawned, the cleaning effect of the fish, and fine sediment infiltration after spawning. This implies that gravels with initially high levels of fine sediment can be improved during spawning, but subsequent high suspended sediment concentrations can be detrimental. Thus, the timing of fine sediment delivery to the channel may be as important as the amount.

Also under Incubation, redds must remain underwater, so they must be located where they do not dry up (or, in other climates, freeze). This is controlled by the streamflow (especially any drops during incubation), the location of individual redds with respect to seasonal low water levels, and the timing of incubation with respect to seasonal flows. For management this implies that adequate flows are needed during the spawning and incubation season. For successful incubation, the egg pockets of the redds must remain stable, i.e., the gravel must not be scoured (at least down to the depth of the egg pocket), because salmon eggs are vulnerable to crushing if the gravel moves. This is controlled by the location of redds in the channel with respect to bed mobility, the size of the gravel, and the timing of incubation with respect to high flows. For management, this implies that on channelized reaches with increased shear stress for a give discharge, redds are more likely to be scoured than in unchannelized, natural reaches.

Under Emergence, the fry must be able to migrate through interstices in the gravel upward to the surface, so the interstices must not be filled with fine sediment (1-10 mm). This depends on the amount of fine sediment (1-10 mm) in the gravel, which is controlled by the factors discussed above.

Under rearing, the juveniles require habitats with suitable temperatures, adequate cover, refugia from high velocity flows, and food. The habitats provided by a sinuous channel, with an undulating bed and dense riparian trees along the banks and floodplain are ideal for rearing, as they meet these requirements. For management, this implies that either the characteristics of natural, sinuous channels be artificially recreated and maintained, or that the processes which maintained those conditions be reestablished.

Implementing Adaptive Management

In adaptive management, we select actions, implement, and monitor ecosystem response. However, because our primarily target species in Deer Creek, chinook salmon, is affected by many factors besides the physical habitat we modify, we should not only monitor salmon population levels in Deer Creek and nearby drainages (which is already done). We need to monitor a suite of ecosystem responses, such as growth and survival of juvenile salmon, abundance of amphibians, abundance of native fishes, sprouting and establishment of cottonwoods.

The two spring-run chinook salmon conceptual models lead to very different choices of restoration actions. For example, Model N would suggest that moving the point of diversion might be effective in reducing losses in the Delta, and that screening agricultural diversions is an obviously effective means of improvement. By contrast, Model T implies that survival may be more a function of flow in the Sacramento River and tidal and possibly habitat conditions in the interior Delta, so that moving the point of diversion would have no measurable effect. Furthermore, agricultural diversions may have a small effect on salmon, and altering the intakes or diversion schedules to account for salmon behavior may be as effective as the far more expensive alternative of screening diversions.

The fall-run chinook spawning conceptual model illustrates the needs of different freshwater life stages of fall-run chinook salmon, and can be used to evaluate various restoration actions. For example, adding gravel to the specific sites in the channel may provide localized, short-term benefits to spawning habitat, but a more sustainable approach to increase habitat lies in re-establishing natural processes of channel migration, erosion, and deposition, overbank flooding, natural establishment of riparian vegetation, and transport of large woody debris.

The conceptual models also help to identify gaps in our understanding, and thus focused research and adaptive probing that would help resolve uncertainties to improve future management. For example, proportional entrainment of salmon in agricultural diversions and its dependence on location of intakes and timing of water withdrawal is not well understood and should be the subject of focused research before a large commitment of funds is made to expensive screening projects. Similarly, more needs to be known about spring-run adult mortality during summer, which can be approached by mark-recapture or other techniques. If mortality is significant, we should evaluate the potential magnitude of poaching, and design strategies to limit poaching if it is appreciable. In addition, the extent to which salmon, particularly spring-run, use the Delta for rearing should be investigated, and salmon passage through the Delta under winter conditions should be modeled using various alternative assumptions about behavior in response to environmental cues.

If ecosystem restoration is undertaken by setting back levees and permitting a dynamic, irregular channel to develop on Lower Deer Creek, the evolution of channel form should be carefully monitored. After each flood capable of moving bed material, the channel should be resurveyed, and the distribution of habitats inventoried from detailed aerial photographs and compared with similar information from 1939 aerial photographs as a way to measure recovery back to the favorable conditions that existed before the flood control project.

Improvements to freshwater habitat should be accompanied by reductions in ocean harvest to a level consistent with restoration, and we should monitor both harvest and total escapement of salmon to gauge success.

Conclusions

Implementing an effective restoration program will require more than developing site-specific restoration projects. It is essential that we step back and look at the big picture, and the big picture can be defined in more than one way. Conceptual models can provide a useful approach to look at the big picture. We have illustrated species-based and river-ecosystem-based conceptual models and demonstrated their use in decision making. Each kind of approach is useful, and each provides different information.

In any restoration program, the complex nature of river systems and multiple causes for declines in populations of important must be acknowledged and planned for. Because of this complexity, restoration actions may not yield the anticipated results. For example, habitat restoration measures for fall-run chinook salmon may not result in increased populations due to downstream factors such as over-harvesting, but the habitat restoration may increase populations of yellow-legged frogs. If the downstream problems are addressed, eventually salmon populations may increase as a delayed result of habitat improvements. Meanwhile, there are other benefits from habitat restoration, including, for example, hydrologic benefits from restoration of meadows in the upper watershed.

On Deer Creek, spawning and rearing habitat for spring run (in the canyon reaches) is in generally good condition. This implies that we should not undertake habitat enhancements in this reach to increase populations, but also that protection of this habitat becomes a top priority. One potential threat to spring-run habitat would be spills of hazardous materials into the creek from trucks on Highway 32 (upstream of the best spring-run habitat). In the past, diesel fuel has spilled into the creek, demonstrating the potential for more serious accidents. Restrictions on or elimination of truck traffic in hazardous materials on this highway should be considered.

APPENDIX D. DRAFT STAGE 1 ACTIONS

This chapter describes at a programmatic level of detail the draft list of priority ERP actions that will be implemented in the first 7 years of the CALFED program. The draft Stage 1 actions describe:

- the critical processes, habitats and species that will be addressed for key tributary watersheds,
- the rationale for the selection of actions to be implemented during Stage 1,
- actions already being implemented as part of CALFED's Restoration Coordination Program, CVPIA, or other restoration programs, and
- uncertainties about ecosystem structure and function that can be answered by designing restoration actions to maximize their information value.

DRAFT SACRAMENTO-SAN JOAQUIN DELTA STAGE 1 ACTIONS

DESCRIPTION OF THE SACRAMENTO-SAN JOAQUIN DELTA REGION

The Sacramento-San Joaquin River Delta (Delta) is the tidal confluence of the Sacramento and San Joaquin rivers. Once a vast maze of interconnected wetlands, ponds, sloughs, channels, marshes, and extensive riparian strips it is now islands of reclaimed farmland protected from flooding by hundreds of miles of levees. Remnants of the tule marshes are found on small "channel" islands or shorelines of remaining sloughs and channels.

Despite many changes, the Delta remains a productive region for many species of native and non-native fish, waterfowl, shorebirds, and wildlife. All anadromous fish of the Central Valley migrate through the Delta or spawn in, rear in, or are dependent on the Delta for some critical part of their life cycle. Native resident fish including delta smelt and splittail spend most of their lives within the Delta. Many of the Pacific Flyway's waterfowl and shorebirds pass through or winter in the Delta. Many migratory songbirds and raptors migrate through the Delta or depend on it for nesting or wintering habitat. Considerable areas of waterfowl and wildlife habitat occur along the channels and sloughs and within the leveed agricultural lands. The Delta also supports many plants with restricted distribution and some important plant communities.

Factors having the greatest influence on Delta ecological health include:

1. Hydrologic regime altered by reduced inflow, reduced seasonal and inter-annual hydrologic variability and large in-Delta diversions;
2. Hydraulics and hydrodynamics altered by leveed islands, channel dredging, and south Delta pumping;
3. Food web altered by introduced species, reduced inputs of organic carbon and decreased residence time of water and organisms;
4. Conversion of agricultural land (which provides surrogate habitat for many avian species) to low habitat value crops or to urban development.
5. Tidal marsh and riparian habitats lost to island reclamation to agriculture, levee construction and maintenance (rip-rapping), wave and boat wake erosion;
6. Water quality degraded from industrial, agricultural and residential pollutants;
7. Elevated water temperatures; and
8. Entrainment of fishes in power plants and south Delta State and Federal diversions.

STAGE 1 APPROACH

Stage 1 actions in the Delta have been selected to address the following key issues (described earlier in Chapter 5):

- The impact of introduced species and the degree to which they may pose a significant threat to reaching restoration objectives.
- Development of an alternative approach to manage floods by allowing river access to more of their natural floodplains and integrating ecosystem restoration activities with the Comprehensive Study.
- Increasing the ecological benefits from existing flood bypasses, such as the Yolo Bypass, so that they provide improved habitat for waterfowl, fish spawning and rearing, and possibly as a source of food and nutrients for the estuarine foodwebs.
- Thoroughly testing the assumptions that shallow water tidal and freshwater marsh habitats are limiting the fish and wildlife populations of interest in the Delta.
- The need to better understand the underlying mechanisms of the X2 salinity standard in the Delta and the resultant effects on aquatic organisms.
- The need to better understand the linkage between the decline at the base of the estuarine foodweb and the accompanying decline of some higher level species and trophic groups.
- Clarify the extent to which entrainment at the CVP and SWP pumping plants affects population sizes of fish and invertebrate species; and
- Clarifying the suitability and use of the Delta for rearing by juvenile salmon and steelhead.

The proposed Stage 1 approach for the Sacramento-San Joaquin Delta is to broadly design and implement actions that will make a substantial contribution to developing aquatic and terrestrial habitat through the Delta which connect with upstream areas. In addition to the focus on the corridor concept, a variety of general actions will be implemented, ranging from large-scale tidal marsh restoration and research projects (Frank's Tract, Little Holland Tract and Liberty and Prospect islands), floodplain restoration, and control and eradication of introduced species. Implementation of these actions and linking them through adaptive management to the Comprehensive Monitoring, Assessment and Research Program will be major steps toward resolving the important Stage 1 issues and will set the direction for subsequent implementation stages.

The three major habitat corridors envisioned include the following:

- **THE NORTH DELTA HABITAT CORRIDOR** will provide a contiguous habitat corridor connecting the mosaic of tidal marsh, seasonal floodplain, riparian and perennial grassland habitats in the Yolo Bypass, Cache Slough Complex, Prospect Island, Little Holland Tract, Liberty Island and Steamboat Slough.
- **THE EAST DELTA HABITAT CORRIDOR** will restore a large, contiguous corridor containing a mosaic of habitat types including tidal perennial aquatic, riparian and riverine aquatic habitat, essential fish habitat, and improved floodplain-stream channel interactions. The focus area includes the South Fork of the Mokelumne River, East Delta dead-end sloughs, Georgiana Slough, Snodgrass Slough, and the Cosumnes River.
- **THE SAN JOAQUIN RIVER HABITAT CORRIDOR** will provide a contiguous habitat corridor of tidal perennial aquatic habitat, freshwater fish habitat, essential fish habitat and improved river-floodplain interactions.

NORTH DELTA HABITAT CORRIDOR STAGE 1 ACTIONS

Major features of the North Delta are the Yolo Bypass, the Sacramento Deep Water Ship Channel, the Sacramento River downstream of Sacramento to Rio Vista, and sloughs connecting the Sacramento River to the Cache Slough complex at the base of the Yolo bypass.

The Stage 1 proposal for the North Delta is to restore a large, contiguous habitat corridor connecting a mosaic of tidal marsh, seasonal floodplain, riparian, and upland grassland habitats. This involves:

- Increasing the quantity and quality of seasonal and perennial wetlands,
- Improving flows, riparian and seasonal wetlands and fish passage in the Yolo Bypass,
- Restoring Prospect Island to tidal and seasonal wetlands to connect with the Cache Slough complex,
- Restoring Little Holland Tract to tidal wetlands to connect with the Cache Slough complex,
- Restoring Liberty Island to tidal and seasonal wetlands to connect with the Cache Slough complex, and
- Protection and enhancement of riparian habitat in Steamboat Slough.

These actions are a high priority because there is the potential to effectively restore and connect multiple habitat types into a functional habitat corridor. The habitat corridor will improve an important rearing, migration, and spawning area for anadromous and resident fishes as well as important habitat for waterfowl, special-status plants, reptiles, and other species. This suite of actions provides a unique opportunity to restore the only functional floodplain ecosystem in the Delta at a large scale, low cost, and with high information and learning potential. Restoration at this location offers the ability to address major restoration issues and uncertainties including:

- Evaluation of species utilization of flood bypasses,
- Ability to control introduced aquatic and riparian plants,
- Evaluation of mercury methylization potential,
- Experimentation of tidal marsh restoration techniques, and
- Experimentation of the relationship between variable salinity regimes, physical habitat and species.

The Restoration Coordination Program has funded many projects that are critical to restoring this habitat corridor and may fund additional projects during 1999. Before major actions are taken in Stage 1, the results of the previously funded projects will be assessed and the proposed Stage 1 actions may be refined accordingly. Many of the projects listed below will require planning studies and outreach to local landowners, recreation interests, and coordination with other agency and CALFED Program activities.

The proposal for the Yolo Bypass is to coordinate planning with the Yolo Bypass foundation to restore permanent flows, fish passage, and seasonal wetland habitat consistent with flood management requirements. The Yolo Bypass is a managed floodway that provides extremely important habitat when flooded for splittail spawning and salmon rearing. When not flooded, the Yolo Basin wetlands provide critical habitat along the Pacific Flyway for tens of thousands of migratory waterfowl and wading birds. This habitat could be enhanced at a low-cost and large scale because restoration will not have significant impacts to existing agricultural practices, bypass land is either publicly owned or privately owned land with flood easements, and restoration actions can be bundled with flood control improvements. There is an unknown, potential benefit by improving salmon passage through the major Bypass slough, the Tule Canal/Toe Drain, to connect with the Sacramento River and Cache Creek.

Potential restoration actions in the Yolo Bypass must be modeled for potential flood control impacts and will only go forward if compatible with flood control requirements or if the impacts are mitigated. For example, the increased channel roughness caused by new riparian habitat in Tule Canal/Toe will have to be offset by increased flood capacity.

ACTION 1: Increase the duration of Yolo Bypass flooding in winter and spring by modifying the Fremont Weir to allow lower-stage flows of the Sacramento River to pass through the Yolo Bypass.

- Install an inflatable barrier to induce overbank flooding out of the Tule Canal/Toe Drain or modify the Tule Canal/Toe Drain as described in Action 3 to create an excavated, shallow flooded region.

RATIONALE: Before the Yolo Basin was developed as a flood bypass system, flow from the Sacramento River entered the basin at much lower flows than the Fremont Weir currently allows to reduce flood risk associated with the Sacramento and American rivers; consequently, the Bypass only receives flow from the Sacramento River during very high flow events.

Floodplains, and in particular the Yolo Bypass, are seasonally important habitats for native fishes including splittail and chinook salmon and may provide a large source of food and nutrients for the estuarine food web. The beneficial impacts of bypass flooding can be increased without sacrificing flood control capabilities and not interfering with agricultural practices. Lowering the height of a portion of the Fremont Weir (and possibly the Sacramento Weir) would allow lower-stage Sacramento River flows in winter and spring to flood a portion of the Bypass. Because the basin slopes toward the East, additional flows may simply concentrate in the Tule Canal/Toe Drain rather than inundate the floodplain. To increase the extent of floodplain inundation, an inflatable barrier can be installed at the base of the Toe Drain channel to induce overbank flooding. Increased flood duration would also improve fish passage to Cache and Putah creeks.

ADAPTIVE MANAGEMENT CONSIDERATIONS:

- Evaluate use of inflatable barrier to induce overbank flooding of the Tule Canal/Toe Drain.
- Study invasion of exotic plants such as Arundo and tamarisk. Develop control measures.
- Evaluate potential for mercury methylization potential (from Cache Creek).
- Evaluate potential flood control impacts and mitigation alternatives.
- Value for splittail spawning.
- Value of improved chinook salmon survival.
- Contribution to total organic carbon and phytoplankton growth.
- Potential adverse effects of total organic carbon on drinking water supplies.

CURRENT OR RECENT RESTORATION ACTIVITIES OR INVESTIGATIONS:

The Yolo Basin Foundation recently completed wetland restoration in the Yolo Bypass that is now being managed by the Department of Fish and Game. CALFED FY 98 Restoration Coordination Program funds were provided for Lower Putah Creek watershed planning and Yolo Bypass restoration planning.

CALFED FY 97 Restoration Coordination Program funds were provided for an assessment of the capacity of different Delta habitats to support the nutritional requirements of the invertebrate biota that sustain upper trophic level organisms. FY 97 funds were also provided to evaluate the potential of mercury methylization produced through wetland restoration.

ACTION 2: Construct a fish ladder at Fremont Weir to provide for fish passage through the Tule Canal/Toe Drain to the Sacramento River.

RATIONALE: Improved flows through the Bypass will attract adult anadromous fish that must navigate past the weir to reach their natal spawning habitat on the upper Sacramento River. Providing passage around the Fremont Weir will help prevent migratory fish from being stranded.

ADAPTIVE MANAGEMENT CONSIDERATIONS:

- The ladder must be evaluated for effectiveness of adult and juvenile fish passage including white sturgeon, green sturgeon, American shad, striped bass and lamprey.

ACTION 3: Evaluate the feasibility and benefits of widening the Tule Canal/Toe Drain channel, restoring riparian vegetation and improving year-round flows. Potential actions include:

- Excavate a wider channel to convey winter and spring flows from the Fremont Weir;

- Allocate water to sustain higher summer and fall flows (non-flood) through the Tule Canal/Toe Drain;

- Better connect the channel by enlarging existing culverts, etc. to allow fish passage at low flows;

- Construct new channels connecting the Tule Canal/Toe Drain with Putah Creek, Cache Creek and the Fremont Weir fish ladder; and

- Restore riparian habitat along the Tule Canal/Toe Drain, including on the Sacramento Ship Channel levee.

RATIONALE: The Tule Canal/Toe Drain is a slough along the east side of the Bypass (the slough is referred to as "Tule Canal" from the Fremont Weir to the Yolo Causeway and as the "Toe Drain" from the causeway to Cache Slough). During most of the year when the bypass is not flooded, the Tule Canal/Toe Drain does not provide migratory fishes access to Putah Creek, Cache Creek and the Sacramento River. However, when the bypass is flooded, fish can migrate through the Bypass to Cache and Putah creeks and the Sacramento River. In 1997 and 1998, adult chinook salmon spawned in Putah Creek. Outmigration of juveniles from Putah Creek may be impeded or impossible in the absence of better-connected channels to the Toe Drain.

Tule Canal/Toe Drain channel improvements and restored riparian, in conjunction with increased winter and spring flows from Action 1 and a fish ladder at Fremont Weir from Action 2, will enable year-round fish passage and longer-duration seasonal floodplain habitat.

It may also be beneficial to improve summer and fall flows through the Bypass to allow for fish passage to Cache and Putah Creeks and the Sacramento River. It may also serve as a better migration corridor than the Sacramento River for migratory fishes. If it is determined that additional flow would primarily benefit non-native fishes, this action will not be implemented.

ADAPTIVE MANAGEMENT CONSIDERATIONS: Evaluate native and non-native species utilization of the bypass.

ACTION 4: Evaluate potential flood conveyance impacts from actions 1 to 3. Conduct a feasibility analysis to increase flood flow capacity in the Yolo Bypass to compensate for lost flood capacity from Bypass restoration.

- Enlarging the openings of the railroad causeway may be an alternative to increase capacity.

RATIONALE: Restored riparian habitat in Tule Canal/Toe Drain will increase the roughness of the Bypass, reducing its flood conveyance capacity. The railroad causeway restricts the flow of floodwaters through the Bypass and also creates conditions that tend to strand larval, juvenile, and occasionally adult fish when the water recedes. The small openings through the railroad causeway can be enlarged to increase net flood capacity of the Bypass and reduce stranding effects.

ACTION 5: Conduct a feasibility analysis of opportunities to reduce fish stranding in the Bypass. Refine Actions 1, 3 and 4 accordingly.

RATIONALE: The Bypass tends to drain quickly after flooding, potentially stranding a significant number of salmon, Delta smelt and other fishes. Fish stranding can be reduced by creating new channels through ponded areas to improve drainage to the Tule Canal/Toe Drain and by re-grading land to provide better connectivity with distributary sloughs.

TARGETED RESEARCH: Evaluate conditions favorable to splittail spawning (wetted perimeter, depth, timing, and duration).

RATIONALE: Splittail are known to use the Bypass and other flooded seasonal habitats to spawn, but the optimal spawning conditions are unknown. By studying spawning behavior and habitat preferences in different water year floods, the knowledge gained may be used to better manage Bypass flows to benefit splittail.

The Department of Water Resources has been conducting these types in the Yolo Bypass. These studies need to continue and include the development of conceptual models.

ADAPTIVE MANAGEMENT CONSIDERATIONS:

- Through Action 1, vary flow rates from Fremont Weir to study splittail spawning.

ACTION 6: Plan and implement restoration of shallow water habitat on Little Holland Tract.

ACTION 7: Plan and implement restoration of shallow water habitat and seasonal wetlands on Prospect Island.

ACTION 8: Plan and implement restoration of shallow water habitat and seasonal wetlands on Liberty Island.

ACTION 9: Plan and implement restoration of shallow water habitat in the lower Yolo Bypass.

RATIONALE: Prospect, Liberty, and Little Holland are ideal locations to restore tidal marshes. Most of the land is or will soon be publicly owned, therefore it will reduce the need to convert additional agricultural land to habitat. Since they are located at the outlet of the Yolo Bypass, they are more susceptible to flooding. The islands are not as subsided as other Delta islands, so they will require less effort to construct suitable land elevations for habitat. Restoration can build upon existing tidal marsh habitat on the margins of these islands. Tidal marsh restored on these islands will connect with the important riparian and seasonal floodplain habitats in the Yolo Bypass, tidal marsh and riparian habitats in the Cache Slough complex, Steamboat Slough, and the Sacramento River.

ADAPTIVE MANAGEMENT CONSIDERATIONS:

- Evaluate multiple tidal marsh restoration techniques.
- Evaluate species colonization and succession.
- Study native vs. non-native species use of shallow-water habitats.
- Develop control measures for non-native aquatic plants.

CURRENT OR RECENT RESTORATION ACTIVITIES OR INVESTIGATIONS:

CALFED FY 97 and 98 Restoration Coordination Program funds were provided for acquisition and restoration of Prospect Island, acquisition of Liberty Island, restoration of SRA, tidal slough habitat, and perennial grasslands along/adjacent to Barker Slough and Calhoun Cut, restoration of SRA habitat along a Cache Slough levee, and relocation and screening of diversions on Hastings Tract to reduce the entrainment of delta smelt.

Category III funds were provided for a North Delta salmon rearing study.

PILOT PROJECT/TARGETED RESEARCH: Develop a plan to design and evaluate tidal marsh restoration of Prospect, Liberty and Little Holland in the North Delta. Study the relationship between salinity gradients, salinity variability, and physical habitat and the effect on species in the tidal North Delta.

- Modify physical habitat configurations to vary salinity gradients and evaluate effects on species.

RATIONALE: Restoration in the North Delta provides an opportunity to learn about species utilization of shallow-water, tidal marsh habitats and salinity gradients. The seasonal and inter-annual variations in Delta inflow created a variable salinity regime. Construction of reservoirs, water diversions, and modification of Delta islands have reduced the variability of flow and salinity conditions. Native plant, wildlife and fish species evolved with the variable flow and salinity regimes. Reducing the variability may have provided competitive advantage to non-native species. Developing a plan to experiment with flows and salinity gradients may identify conditions that benefit native species.

ADAPTIVE MANAGEMENT CONSIDERATIONS:

- Extent to which physical habitat may be limiting native and introduced species.
- How salinity gradients and variability affect conditions and species in shallow-water habitats.

- Calibration of models to evaluate changes in Delta hydraulics resulting from wetland restoration.

CURRENT OR RECENT RESTORATION ACTIVITIES OR INVESTIGATIONS:

CALFED FY 97 funds were provided for a Delta sediment transport and availability study.

Category III funds were provided for a North Delta salmon rearing study.

ACTION 10: Develop and implement measures to rehabilitate and restore a riparian and shaded riverine aquatic habitat corridor along Steamboat Slough.

RATIONALE: Steamboat Slough is an important migratory corridor for Sacramento River salmon. Habitat conditions are more favorable in Steamboat than the Sacramento River, and there is little opportunity to restore riparian habitat on the large, federal levees of the Sacramento River. Attempts should be made to protect existing habitat from boat wakes and other activities associated with heavy recreational use on Steamboat Slough. Existing boat speed restrictions have not been effective in stopping degradation of existing habitat.

ADAPTIVE MANAGEMENT CONSIDERATIONS:

- Evaluate Sacramento salmon smolt survival through Coded Wire Tag (CWT) (paired) experiments to assess baseline survival and survival after restoration.

EAST DELTA HABITAT CORRIDOR STAGE 1 ACTIONS

Major features of the East Delta are the North and South Forks of the Mokelumne River, the Cosumnes River and floodplain, dead-end sloughs adjoining the South Fork, and Georgina Slough. For purposes of Stage 1 action grouping, Snodgrass Slough of the North Delta region is considered a functional unit of this habitat corridor. The East Delta is an important region for its diversity of plant, fish and avian species, and a functioning floodplain on the Cosumnes River.

The objective for the East Delta is to restore a large, contiguous corridor containing a mosaic of habitat types. Restoration in the East Delta offers the best opportunity to evaluate and restore natural ecological functions in the Delta. Stage 1 actions will focus on tidal marsh and riparian habitat restoration on the South Fork of the Mokelumne River, East Delta dead-end sloughs, Georgiana Slough, Snodgrass Slough and the Cosumnes River floodplain.

ACTION 1: Restore and rehabilitate a contiguous corridor of riparian, shaded riverine aquatic, tidal freshwater, and seasonal and perennial habitats along the South Fork of the Mokelumne River.

RATIONALE: Restoration of this corridor may improve rearing and migration of salmon from the Mokelumne and Cosumnes rivers. It is an opportunity to restore critical ecological processes including flood processes. Land elevations are suitable for tidal marsh and riparian restoration.

ADAPTIVE MANAGEMENT CONSIDERATIONS:

- Evaluate the benefits of large-scale restoration of ecological processes on the Mokelumne.

CURRENT OR RECENT RESTORATION ACTIVITIES OR INVESTIGATIONS:

CALFED FY 97 and 98 Restoration Coordination Program funds were provided for acquisition of property along the lower Cosumnes River floodplain, community-based planning for the lower Mokelumne River watershed, construction of a 3.4 mile long, 400 foot levee setback on the Mokelumne River, and fish passage and fish screen improvements at Woodbridge Dam. FY 98 funds are being used to acquire McCormack-Williamson Tract

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ACTION 2: Restore tidal marsh and riparian habitats on McCormack-Williamson Tract in conjunction with other flood control measures.

RATIONALE: McCormack-Williamson, a highly flood-prone tract, is planned to be acquired in FY 99. Breaching McCormack-Williamson levees and restoring the tract to tidal marsh and riparian habitat in conjunction with other flood control efforts can relieve flooding pressure in the North Delta and improve habitat connectivity with the Cosumnes River floodplain. The tract is ideal for restoration to tidal and riparian habitats due to favorable land elevations.

Adaptive Management Considerations:

- Evaluate species colonization and succession.
- Evaluate the effects of natural process restoration on the evolution of riparian and tidal marsh habitats.

Current or Recent Restoration Activities or Investigations:

CALFED FY 97 Restoration Coordination Program funds were provided for acquisition and planning for restoration of 4,600 acres of property adjacent to the Cosumnes River and FY 98 funds are being used to acquire McCormack-Williamson Tract.

Sacramento County Flood Control Agency (SAFCA) and North Delta Flood Management will be consulted with on restoration efforts.

Action 3: Restore tidal marsh and riparian habitats on Georgiana Slough.

Rationale: Georgiana Slough is a major migration corridor for salmon. Substantial losses to salmon may occur due to predation and entrainment in the slough.

Adaptive Management Considerations:

- Evaluate benefits of restoring additional habitats in areas of high predation and entrainment

Current or Recent Restoration Activities or Investigations:

CALFED FY 97 Restoration Coordination Program funds were provided for restoration of SRA and riparian habitat along 2,000 ft of Georgiana Slough and 3,000 ft along the North Fork of the Mokelumne River on Tyler Island.

Action 4: Restore tidal marsh and riparian habitats on East Delta sloughs in conjunction with control of non-native aquatic plants.

Rationale: Backwater habitats are critical habitat for Delta native fishes. The dead-end sloughs tend to be clogged with non-native plants like water hyacinth. Restoration of riparian and wetland habitats will provide food and cover for native fishes. Restoration of these sloughs to benefit native fishes and plants must include eradication of non-native plants.

Adaptive Management Considerations:

- Evaluate native vs. non-native species use prior to and after restoration.

Action 5: Restore mid-channel islands and experiment with multiple techniques to allow natural sediment accretion to create new mid-channel islands and to protect mid-channel shallow-water habitat from boat wakes.

Rationale: Boat wakes and other stressors have significantly reduced the quantity and quality of mid-channel habitat. Multiple approaches should be used to protect existing mid-channel islands including limiting boat speeds in sensitive areas, installing wave attenuation structures, and also to encourage natural creation of islands.

Adaptive Management Considerations:

- Experiment with techniques to reduce erosion.
- Relationship to Delta sediment transport and depositional processes.

Current or Recent Restoration Activities or Investigations:

CALFED FY 97 funds were provided for a Delta sediment transport and availability study and for an in-channel islands restoration demonstration project (Little Tinsley, Webb Tract 3, 10 and 21).

Action 6: Develop and implement incentives for wildlife-friendly agriculture on Staten Island.

Rationale: Agricultural fields provide surrogate habitat for resident and migratory wildlife. Incentives could include not harvesting crop to improve forage value for wildlife or changing cropping patterns.

ADAPTIVE MANAGEMENT CONSIDERATIONS:

- Monitor the use of lands in the incentive program by waterfowl and other species.
- Prepare an economic analysis of the most cost-effective means to fully support the agricultural industry while increasing the value for wildlife.
- Evaluate the relationship of bioenergetics and nutrients to migratory species

SAN JOAQUIN RIVER HABITAT CORRIDOR STAGE 1 ACTIONS

The San Joaquin is an important region for many native fishes including delta smelt, splittail and salmonids. Little shallow-water and riparian habitat remains on the San Joaquin River. The habitat that does remain in-channel and along levees is being degraded by wind and boat waves and levee maintenance. Water quality is poor for much of the year; there is low dissolved oxygen, high salinity, agricultural, residential and industrial contaminants, and water temperature is often elevated. Restoration opportunities are limited by the requirements of flood control, levee maintenance and dredging for ship navigation.

The Stage 1 proposal for the San Joaquin River is to restore a contiguous habitat corridor of tidal marsh, shaded riverine aquatic, riparian, and floodplain habitats. Reconnaissance studies should be initiated to evaluate opportunities for wetland and floodplain habitat in the river channel, on levees, on shallow levee berms, and for incorporation into the design of levee upgrades. CALFED Water Quality Program actions will also enhance the San Joaquin River restoration efforts in Stage 1.

ACTION 1: Conduct a feasibility study and, as appropriate, construct setback levees or shallow water berms along the San Joaquin River between Stockton and Mossdale where practicable to restore floodplain and riparian habitats and to increase channel capacity.

RATIONALE: Restoration of the San Joaquin River corridor can improve an important rearing and migration corridor for fishes and would provide information on our ability to reestablish floodplain processes in the Delta. There is the potential to utilize clean dredge material available from other areas in the Delta for in-channel restoration. As floodplains are restored splittail spawning and delta smelt and salmon usage will be evaluated.

ADAPTIVE MANAGEMENT CONSIDERATIONS:

- Determine the feasibility of larger-scale restoration of riparian floodplain habitat and flood processes in the Delta.
- Evaluate species utilization of riparian and floodplain habitats, including benefits to splittail spawning and outmigrant San Joaquin salmon mortality.

CURRENT OR RECENT RESTORATION ACTIVITIES OR INVESTIGATIONS:

FY '97 Category III funds have been used to purchase fee title or easements on over 6,000 acres of land adjacent to the San Joaquin National Wildlife Refuge and have been used to help screen Banta-Carbona Irrigation District's diversion.

- Vernalis Adaptive Management Plan (VAMP)
- San Joaquin River Management Plan
- CALFED Levee Program
- Comprehensive Study

TARGETED RESEARCH: Evaluate species utilization of shallow-water wetlands on Venice Tip and McDonald Tip.

RATIONALE: Knowledge of the habitat preferences and utilization of shallow-water and floodplain habitats along the San Joaquin River by fish such as splittail (for spawning) and juvenile salmon (for rearing) is limited.

ADAPTIVE MANAGEMENT CONSIDERATIONS:

- Determine San Joaquin River salmon smolt survival through Coded Wire Tag (CWT) (paired) experiments to assess baseline survival and the change in survival following restoration.

- Determine the residence time and rearing of San Joaquin River salmon, delta smelt, and other native species.

Current or Recent Restoration Activities or Investigations:

CALFED FY 98 funds were provided for a study to identify the movement of adult chinook salmon in the lower Delta and lower San Joaquin River and evaluate the impacts of barrier operations and dissolved oxygen (DO) levels.

The DFG has conducted studies of chinook salmon smolt migration.

- VAMP

Action 2: Restore mid-channel islands and experiment with multiple techniques to allow natural sediment accretion to create new mid-channel islands and to protect mid-channel shallow-water habitat from boat wakes.

Rationale: Restoration of mid-channel islands may be the most effective means to improve habitat continuity along the San Joaquin. There is some existing mid-channel habitat (although diminished from boat wakes and channel modifications) that can be enhanced and a considerable amount of new habitat can be accommodated in the wide channel of the San Joaquin River. Existing mid-channel habitat can be augmented and new habitat created using Stockton Ship Channel dredge material and by encouraging natural sediment deposition.

Adaptive Management Considerations:

- Experiment with techniques to reduce erosion including the need to armor mid-channel islands.
- Relationship to Delta sediment transport and depositional processes.
- Identify species colonization and succession rates.

Current or Recent Restoration Activities or Investigations:

CALFED FY 97 funds were provided for a Delta sediment transport and availability study and in-channel islands restoration demonstration projects (Little Tinsley, Webb Tract 3, 10 and 21).

- CALFED Levee Program

Central and West Delta Stage 1 Actions

Major features of the Central and West Delta are the flooded Frank's Tract and Big Break, the Sacramento and San Joaquin Rivers to Collinsville, and Delta islands, including many islands subsided over twenty feet in many places.

Action 1: Restore Frank's Tract to a mosaic of habitat types using clean dredge materials and natural sediment accretion. Control or eradicate introduced, nuisance aquatic plants.

Rationale: Frank's Tract is a flooded Delta island that can be restored to a mosaic of habitat types with no impact to agriculture. Frank's Tract levees were breached and the island has been flooded since the early 1900s. The deep bed of the island does not provide good quality habitat for native fish. Parts of the island bed could be elevated through a combination of dredge material placement, natural sediment accretion, and peat accumulation. Frank's Tract will be a functional component of the San Joaquin River corridor, a major fish rearing and migration area, as well as provide continuity with existing and proposed habitats in the western Delta. Developing the tract must also occur in conjunction with the control or eradication of introduced, nuisance aquatic plants for restoration to be most beneficial to native species.

Adaptive Management Considerations:

- Use multiple techniques to restore tidal habitats, including physical creation and natural sediment accretion.
- Use of dredge material to build wetlands.

Current or Recent Restoration Activities or Investigations:

CALFED FY 98 funds were provided for planning and design of a 45 acre pilot tidal wetland restoration project in Frank's Tract. CALFED FY 97 funds were provided for a Delta sediment transport and availability study and in-channel islands restoration demonstration projects (Little Tinsley, Webb Tract 3, 10 and 21).

- CALFED Water Quality Program.

Action 2: Restore Decker Island to tidal wetlands.

Rationale: Restoration of tidal wetlands on Decker Island will provide habitat along the Sacramento River for migrant Sacramento salmon, for delta smelt, and many other fishes. Some or all of the dredge spoils located on Port of Sacramento half of the island may have to be removed to return the island to tidal elevations.

Action 3: Restore seasonal wetlands on Twitchell Island.

Rationale: Restoration of seasonal wetlands on Twitchell Island will provide habitat for migratory birds.

Current or Recent Restoration Activities or Investigations:

CALFED FY 97 funds were provided for a tidal wetland and shaded riverine habitat demonstration project on Twitchell Island.

Action 4: Restore seasonal wetlands on Sherman Island.

Rationale: Restoration of seasonal wetlands on Sherman Island will provide habitat for migratory birds.

Action 5: Restore mid-channel islands in the Central and Western Delta.

Rationale: Mid-channel islands are important habitats that do not require acquisition of easements or land. Natural sediment transport processes can be used to create and maintain these habitats.

Adaptive Management Considerations:

- Use multiple techniques to protect existing habitats from boat wakes and use natural processes to create and maintain mid-channel habitats.

Current or Recent Restoration Activities or Investigations:

CALFED FY 97 funds were provided for a Delta sediment transport and availability study and in-channel islands restoration demonstration projects (Little Tinsley, Webb Tract 3, 10 and 21).

- CALFED Levee Program and Conveyance element.

Targeted Research: Evaluate species utilization of tidal wetlands on Big Break.

Rationale: Big Break is a flooded Delta tract with a large expanse of shallow-water habitat. The region can serve as a reference site for species utilization of shallow-water habitat.

Adaptive Management Considerations:

Evaluate the utilization, residence time, and rearing of San Joaquin River salmon, delta smelt, and other native species.

General Delta Stage 1 Actions

Action 1: Prevent introductions of exotic species throughout the Bay-Delta system through multiple strategies including: educating the public of harmful impacts, outlawing the sale or transportation of nuisance species .

Rationale: Introduced species have had a profound, adverse impact on the entire Bay-Delta watershed and its species.

Current or Recent Restoration Activities or Investigations:

CALFED FY 98 funds were provided to help develop the California State Management Plan for Aquatic Nuisance Species.

ACTION 2: Develop and implement control strategies for nuisance aquatic plants in the Delta.

RATIONALE: Introduced plants such as water hyacinth, Egeria, and Elodia have taken over large areas of the Delta, clogging water diversion intakes, hampering navigation, and providing vegetative cover preferred by non-native, predatory fishes. Control of these plants will have benefits to multiple beneficial uses of the Delta and may create conditions more favorable to native species.

ADAPTIVE MANAGEMENT CONSIDERATIONS:

- Ability to control nuisance aquatic plants.
- Extent to which non-native plants favor non-native fishes over natives.

CURRENT OR RECENT RESTORATION ACTIVITIES OR INVESTIGATIONS:

- California Department of Boating and Waterways hyacinth and Egeria control programs.

ACTION 3: Evaluate the feasibility of re-vegetating levees on the Sacramento River between Verona and Collinsville (also listed under Sacramento Basin actions).

RATIONALE: Current levee maintenance operations remove vegetation from levees to maintain channel capacities. Providing riparian habitat along the levees could benefit several wildlife species and provide valuable SRA habitat for aquatic species. Because riparian vegetation reduces channel capacity by increasing roughness, re-vegetation must proceed with improved flood management that reduces peak flows in the basin, or with setback levees that increase channel capacity.

ADAPTIVE MANAGEMENT CONSIDERATIONS:

- Evaluate local water temperatures in levee reaches with restored riparian habitat versus levee reaches without riparian habitat.
- Compare the quantity and quality of aquatic and riparian habitat for levee reaches with restored riparian habitat versus levee reaches without riparian habitat.

TARGETED RESEARCH: Evaluate the feasibility of propagating special-status Delta plants species.

RATIONALE: There are numerous plants in the Delta, including many endemic species, which are listed as threatened, endangered or other special-status. In many cases the ecological requirements of the plants are unknown. Experimental propagation may identify the species' ecological requirements. It may be more feasible to reintroduce propagated plants rather than replicate the habitat requirements to encourage natural recruitment of the plants.

TARGETED RESEARCH/PILOT PROJECT: Develop a sediment budget (fine and coarse sediments) for the Delta. Monitor the effects of different flow events and other upstream events on sediment transfer to the Delta.

RATIONALE: Sediment supply to the Delta has decreased due to a loss of coarse sediment supply caused by dams, gravel mining, disconnection of floodplains, and water quality improvement actions. This loss of sediment may contribute to diminishment of Delta wetland habitats.

CURRENT OR RECENT RESTORATION ACTIVITIES OR INVESTIGATIONS:

CALFED FY 97 funds were provided for a Delta sediment transport and availability study.

TARGETED RESEARCH/PILOT PROJECT: Determine the relationship between turbidity, primary productivity and potential eutrophication in the Bay and Delta.

RATIONALE: The relationship between turbidity, primary productivity and potential eutrophication in the Bay and Delta is not well understood. One hypothesis suggests that the decrease in turbidity from water quality improvement actions may increase light penetration, potentially leading to eutrophication.

CURRENT OR RECENT RESTORATION ACTIVITIES OR INVESTIGATIONS:

CALFED FY 97 Restoration Coordination Program funds were provided for an assessment of the capacity of different Delta habitats to support the nutritional requirements of the invertebrate biota that sustain upper trophic level organisms. Tasks include sampling to measure the quantity and quality of organic matter available among the different habitats and the amount derived from the primary sources, describing the nutritional budgets in the Delta, and developing nutrient-phytoplankton dynamic models.

TARGETED RESEARCH: Evaluate the effectiveness of pulse flows from the San Joaquin River to improve salmon outmigration and to move juvenile salmon away from the South Delta pumps.

RATIONALE: There are conflicting hypotheses as to survival of outmigrant San Joaquin salmon. Current management emphasizes pulse flows intended to reduce entrainment in South Delta pumps. Conversely, pulse flows may reduce juvenile salmon survival rates by pushing them away from rearing areas too quickly.

ADAPTIVE MANAGEMENT CONSIDERATIONS:

- Track indicator of salmon smolt survival through CWT (paired) experiments to assess baseline survival and survival after pulse flows.

CURRENT OR RECENT RESTORATION ACTIVITIES OR INVESTIGATIONS:

VAMP is experimenting with pulse flows.

TARGETED RESEARCH/PILOT PROJECT: Evaluate residence time of rearing and outmigration of San Joaquin River juvenile salmon.

RATIONALE: The relationship of habitat quality, quantity and distribution to the residence time of chinook salmon on the San Joaquin River is unknown. Determining impact of additional habitat to residence time will help determine to what extent habitat restoration will benefit salmon and how restoration efforts can be optimized.

ADAPTIVE MANAGEMENT CONSIDERATIONS:

- Conduct a distribution survey.
- Conduct a habitat preference and utilization survey.

CURRENT OR RECENT RESTORATION ACTIVITIES OR INVESTIGATIONS:

- VAMP

TARGETED RESEARCH/PILOT PROJECT: Evaluate the need to screen small diversions in the Delta.

RATIONALE: Unlike in riverine environments where unscreened diversions may affect a large portion of fish, the benefit of screening small diversions throughout the Delta is unknown. An evaluation should be undertaken to identify diversion effects on species and locations in the Delta where screening small diversions is a high priority.

DRAFT SUISUN MARSH AND NORTH SAN FRANCISCO BAY STAGE 1 ACTIONS

SUISUN MARSH STAGE 1 ACTIONS

ACTION 1: Restore tidal wetlands in Suisun Marsh and Van Sickle Island.

RATIONALE: Restoration of tidal wetlands can provide habitat for native fishes, rare plants and wildlife.

ADAPTIVE MANAGEMENT CONSIDERATIONS:

- Evaluate the effects of tidal marsh restoration on estuarine productivity.

CURRENT OR RECENT RESTORATION ACTIVITIES OR INVESTIGATIONS:

CALFED FY 98 Restoration Coordination Program funds have been provided for planning for tidal restoration in Hill Slough West. FY 97 funds were also provided for restoration planning at the Martinez Regional Shoreline and for public outreach to reduce the use and disposal of toxic pesticides in Suisun Bay.

ACTION 2: Develop and implement control strategies for nuisance marsh and upland plants in the Suisun Marsh and North Bay.

RATIONALE: Introduced plants such as *Lepidium latifolium*, and English cordgrass have invaded the marshes of North Bay and Suisun Bay, displacing native plants and animals. Control of these plants may create conditions more favorable to native species.

ADAPTIVE MANAGEMENT CONSIDERATIONS:

- Ability to control nuisance plants.
- Extent to which non-native plants favor non-native fishes over natives.

TARGETED RESEARCH: Develop and implement a plan to analyze the mechanisms underlying the X2 relationships.

RATIONALE: Current management of the Bay-Delta system is based largely on a salinity standard (the "X2" standard). This standard is based on empirical relationships between various species of fish and invertebrates and X2 (or freshwater flow in the estuary). As with all empirical relationships, these are not very useful to predict how the system will respond after it has been altered by various actions in the Delta, including altered conveyance facilities. This implies a need to determine the underlying mechanisms of the X2 relationships so that the effectiveness of various actions in the Delta can be put in context with this ecosystem-level restorative measure.

CURRENT OR RECENT RESTORATION ACTIVITIES OR INVESTIGATIONS:

IEP Estuarine Ecology Team conducts ongoing studies of the relationship of fish and X2.

TARGETED RESEARCH: Study the effects of *Potamocorbula amurensis* on the foodweb and, as appropriate, develop and implement control strategies.

RATIONALE: *Potamocorbula* have decreased estuarine primary productivity, the effects of which have traveled throughout the foodweb, including upper trophic level species. Restoration of marshes may offset some of this lost productivity, but may not be great enough to overcome the effects of the clam unless its population abundance is reduced. There are presently no known, viable control methods for this species.

ADAPTIVE MANAGEMENT CONSIDERATIONS:

- Extent to which *Potamocorbula* are limiting to restoration of native species.
- Extent to which effects of *Potamocorbula* can be overcome with other measures.
- Ability to control *Potamocorbula*.

NORTH BAY STAGE 1 ACTIONS

ACTION 1: Develop and implement a ballast water management program to halt the introduction of introduced species into the estuary.
RATIONALE: The single largest source of nuisance species in the Bay-Delta is from ship ballast water discharged to San Francisco Bay.

CURRENT OR RECENT RESTORATION ACTIVITIES OR INVESTIGATIONS:

CALFED FY 97 funds were provided for an education and outreach program to prevent introduction of introduced species from ballast water.

ACTION 2: Acquire and restore floodplains and tidal marsh along the Napa/Sonoma Marsh.

RATIONALE: Protection, enhancement and restoration of North Bay tidal marsh and floodplain will benefit clapper rail, black rail, salt marsh harvest mouse and other salt marsh species. In high outflow years, Delta fishes also utilize North Bay habitats.

ADAPTIVE MANAGEMENT CONSIDERATIONS:

- Evaluate species utilization of restored habitats.

CURRENT OR RECENT RESTORATION ACTIVITIES OR INVESTIGATIONS:

CALFED FY 97 Restoration Coordination Program funds were provided for management support and assist in implementing restoration actions in the Sonoma Creek Watershed and the Napa River watershed.

ACTION 3: Acquire and restore floodplains and tidal marsh along the Petaluma Marsh.

RATIONALE: Protection, enhancement and restoration of North Bay tidal marsh and floodplain will benefit clapper rail, black rail, salt marsh harvest mouse and other salt marsh species. In high outflow years, Delta fishes also utilize North Bay habitats.

ADAPTIVE MANAGEMENT CONSIDERATIONS:

- Evaluate species utilization of restored habitats.

CURRENT OR RECENT RESTORATION ACTIVITIES OR INVESTIGATIONS:

CALFED FY 97 and 98 Restoration Coordination Program funds were provided for the acquisition, protection and restoration of 181 acres of tidal wetlands adjacent to the Petaluma River and for restoration planning on the Hamilton Wetland near Novato. Funds were also provided for Petaluma River watershed restoration planning.

ACTION 4: Acquire and restore floodplains and tidal marsh along the Napa River.

RATIONALE: Protection, enhancement and restoration of North Bay tidal marsh and floodplain will benefit clapper rail, black rail, salt marsh harvest mouse and other salt marsh species. In high outflow years, Delta fishes also utilize North Bay habitats.

ADAPTIVE MANAGEMENT CONSIDERATIONS:

- Evaluate species utilization of restored habitats.

CURRENT OR RECENT RESTORATION ACTIVITIES OR INVESTIGATIONS:

CALFED FY 97 and 98 Restoration Coordination Program funds were provided for acquisition and restoration of over 1,000 acres of wetlands adjacent to the Napa River and for management support and assist in implementing restoration actions in the Sonoma Creek Watershed and the Napa River watershed.

ACTION 5: Develop and implement control strategies for nuisance marsh and upland plants in the Suisun Marsh and North Bay.

RATIONALE: Introduced plants such as *Lepidium latifolium*, and English cordgrass have invaded the marshes of North Bay and Suisun Bay, displacing native plants and animals. Control of these plants may create conditions more favorable to native species.

ADAPTIVE MANAGEMENT CONSIDERATIONS:

- Ability to control nuisance aquatic plants.
- Extent to which non-native plants favor non-native fishes over natives.

TARGETED RESEARCH/PILOT PROJECT: Study the effects of *Potamocorbula amurensis* on the foodweb and, as appropriate, develop and implement control strategies.

RATIONALE: *Potamocorbula* have decreased estuarine primary productivity, the effects of which have traveled throughout the foodweb, including upper trophic level species. Restoration of marshes may offset some of this lost productivity, but may not be great enough to overcome the effects of the clam unless its population abundance is reduced. There are presently no known, viable control methods for this species.

ADAPTIVE MANAGEMENT CONSIDERATIONS:

- Extent to which *Potamocorbula* are limiting to restoration of native species.
- Extent to which effects of *Potamocorbula* can be overcome with other measures.
- Ability to control *Potomocorbula*.

DRAFT SACRAMENTO RIVER BASIN STAGE 1 ACTIONS

SACRAMENTO RIVER BASIN DESCRIPTION

The Sacramento River and its tributaries are a vital component of the Bay-Delta ecosystem. As California's largest river, the Sacramento River provides the bulk of the Bay-Delta water supply, and it contributes approximately 80% of the inflow to the Delta. Despite human disturbances that have disrupted ecological processes in the basin, the Sacramento River and its tributaries continue to provide important spawning, rearing, nesting, and wintering habitat for a variety of species.

Factors most influencing the ecological health of tributaries in the Sacramento River Basin include:

1. Reductions in the magnitude, frequency, duration, and variability of river flows because of dam construction and diversions.

2. Reductions in the amount of coarse sediment available to create and maintain important aquatic and riparian habitat because of dam construction, aggregate mining in active river channels, and relatively narrow levees that increase shear stress applied to channel bed sediments.

3. Reductions in the amount of spawning and rearing habitat available to anadromous fish because of dams that block access to historical habitat ranges.

4. Reductions in the amount and contiguity of riparian habitat because of urban and agricultural encroachment and levee construction.

5. Elevated water temperatures because of dam construction, diversions, return flows, and the loss of riparian habitat.

6. Degradation of spawning and rearing habitat because of excessive loads of fine sediments and urban, industrial, and agricultural discharges of pollutants.

7. Loss of river-floodplain interactions because of levee construction.

8. Stranding of adult and juvenile anadromous and resident fish because of straying and the lack of hydraulic connectivity to river channels as flood waters recede.

9. Loss of seasonal wetlands because of levee construction and urbanization.

STAGE 1 APPROACH

Local watershed groups are active in many of the tributary watersheds of the upper Sacramento River basin. The ERP will work with these local watershed groups—as well as local, state and federal agency personnel—to implement and monitor Stage 1 actions.

Since many of the tributaries in the Sacramento River basin are regulated by large dams, it will be necessary to conduct targeted research and to monitor Stage 1 actions to determine the optimal combinations of flow and sediment that will best restore aquatic and riparian habitat in light of the regulated flow regime.

The primary species that will benefit from Stage 1 actions implemented in the upper Sacramento River basin are spring-run chinook salmon, fall-run chinook salmon, and steelhead trout. Both spring-run chinook salmon and steelhead trout have relatively stringent habitat requirements that upper basin tributaries can satisfy. Fall-run chinook salmon populations are distributed more widely throughout the Central Valley because of their less stringent habitat requirements. Populations of white and green sturgeon, American shad, striped bass and splittail will benefit primarily from actions implemented in lower Sacramento River Basin tributaries.

Stage 1 actions also focus on two tributaries that have been selected as demonstration streams: Clear Creek and Deer Creek. The objective for each demonstration stream is to fully restore the tributary within existing constraints (such as large dams) so that each becomes a healthy, resilient haven of continuous riparian and aquatic habitat to optimize endemic plant and animal populations. Restoring these two tributaries into healthy riparian corridors during Stage 1 will help recover and maintain large populations of fish species to endure severe ecological conditions such as droughts. Both of these tributaries offer high-quality habitat in upstream reaches to satisfy the relatively stringent habitat requirements of spring-run chinook salmon and steelhead trout. Both creeks also provide habitat for fall-run chinook salmon in their lower reaches.

MAINSTEM SACRAMENTO RIVER STAGE 1 ACTIONS

ACTION 1: Protect, enhance and restore the meander belt between Red Bluff and Chico Landing.

RATIONALE: The Sacramento River still meanders freely for more than 50 miles between Red Bluff and Chico Landing, dynamically eroding existing banks and forming new banks. Meandering rivers help to sustain several critical ecological processes including gravel recruitment and transport, riparian succession, and the creation of diverse and valuable aquatic habitat such as cutbanks, pools, and spawning riffles. The SB 1086 planning process has developed the Upper Sacramento River Fisheries and Riparian Habitat Management Plan and the Sacramento River Conservation Area Handbook, which delineates a conservation area and provides guidelines for preserving and restoring riparian and aquatic habitat in the upper Sacramento River. Purchasing fee title, flood easements, or conservation easements on riparian lands within the conservation area will provide the river with room to meander and help to reduce flood damage by relocating economic activities and development from vulnerable floodplains.

ADAPTIVE MANAGEMENT CONSIDERATIONS:

- Compare the quantity and quality of aquatic and riparian habitat for freely meandering river reaches and reaches protected by rip-rap.
- Determine the rate of gravel recruitment to the river from eroding banks.

CURRENT OR RECENT RESTORATION ACTIVITIES OR INVESTIGATIONS:

FY '97 and '98 CALFED Restoration Coordination Program funds have been provided to allow the acquisition of fee title or easement on several hundred acres of riparian land along the upper Sacramento River. Additional funds have been provided to actively restore riparian habitat on selected lands.

ACTION 2: In conjunction with the USACE and Reclamation Board Comprehensive Study, evaluate the feasibility of setting back levees on the Sacramento River between Chico Landing and Verona.

RATIONALE: The Army Corps of Engineers, in conjunction with DWR and the State Reclamation Board, is currently engaged in a comprehensive study to enhance flood management in the Central Valley by evaluating alternative flood management strategies such as floodplain storage. Setting back levees along the Sacramento River could reconnect the river with a portion of its floodplain, with the attendant ecological benefits, while simultaneously reducing flood risk. Setting back levees would enlarge the channel capacity to transport flood flows and provide floodplain storage, thereby reducing flood risk by reducing the pressure placed upon levees and by reducing peak flows.

ADAPTIVE MANAGEMENT CONSIDERATIONS:

If it is feasible to setback levees, then:

- monitor and compare the amount and quality of aquatic and riparian habitat available in reaches narrowly confined by levees and reaches where the creek can meander within setback levees.
- monitor rates of gravel recruitment, transport, and retention in leveed vs. non-leveed reaches.
- compare flood stage levels and associated flood risk with historical levels for a given amount of inflow.

CURRENT OR RECENT RESTORATION ACTIVITIES OR INVESTIGATIONS:

The U.S. Army Corps of Engineers, California Reclamation Board and the Department of Water

Resources are conducting the Sacramento and San Joaquin River Basins Comprehensive Study to reduce flood damage and integrate ecosystem restoration. The measures that will be identified through the Comprehensive Study may have the potential to help meet or be compatible with the goals and objectives for the Ecosystem Restoration Program.

ACTION 3: Evaluate the feasibility of re-vegetating levees on the Sacramento River between Verona and Collinsville (also listed under Delta actions).

RATIONALE: Current levee maintenance operations remove vegetation from levees to maintain channel capacities. Providing riparian habitat along the levees could benefit several wildlife species and provide valuable SRA habitat for aquatic species. Because riparian vegetation reduces channel capacity by increasing roughness, re-vegetation must proceed with improved flood management that reduces peak flows in the basin, or with setback levees that increase channel capacity.

ADAPTIVE MANAGEMENT CONSIDERATIONS:

- Evaluate local water temperatures in levee reaches with restored riparian habitat versus levee reaches without riparian habitat.
- Compare the quantity and quality of aquatic and riparian habitat for levee reaches with restored riparian habitat versus levee reaches without riparian habitat.

ACTION 4: Evaluate the need to screen all diversions smaller than 100 cfs on both the mainstem Sacramento River and selected tributaries.

RATIONALE: There are numerous small diversions of water from the Sacramento River and its tributaries. While many large diversions have fish screens to reduce the entrainment of fish, many small diversions are unscreened. The individual and cumulative losses of fish from these small diversions are unknown. Estimating the entrainment losses at small diversions, and comparing the effectiveness of fish screens with changes in the timing or location of small unscreened diversions will help to quantify and balance the benefits of potentially reduced entrainment with the costs of fish screening facilities. (CVPIA actions include screening all diversions on the Sacramento River greater than 250 cfs.)

ADAPTIVE MANAGEMENT CONSIDERATIONS:

- Evaluate the effectiveness of timing diversions to reduce impacts upon juvenile anadromous fish
- Study the loss of juvenile anadromous fish to entrainment in smaller diversions

CURRENT OR RECENT RESTORATION ACTIVITIES OR INVESTIGATIONS:

FY '98 CALFED Restoration Coordination Program funds have been provided to study entrainment losses at twin diversions (20 cfs each) in which one diversion is screened and the other is unscreened.

ACTION 5: Evaluate and implement alternative structural and operational actions to reduce or prevent fish from straying into the Colusa Basin Drain with low habitat value.

RATIONALE: Agricultural return flows draining from the Colusa Drain into the Sacramento River can attract adult anadromous fish migrating upstream to spawn. There is no spawning habitat in the Colusa Drain, so adults that stray into the Colusa Drain subsequently become stranded and are lost to the spawning population. Creating a migration barrier will prevent adult anadromous fish from straying into the Drain.

ADAPTIVE MANAGEMENT CONSIDERATIONS:

- Compare numbers of anadromous fish stranded in Colusa Drain before and after implementation of various alternatives.

DEER CREEK STAGE 1 ACTIONS

Deer Creek has the potential to be a demonstration stream, representative of northern Sacramento Valley tributaries that drain the Cascade and Sierra Nevada Ranges. Demonstration streams will be selected for large-scale implementation of restoration actions to significantly restore ecological processes and resources while simultaneously testing restoration hypotheses as part of an adaptive management approach. The objective for demonstration streams is to fully restore the tributary within existing constraints (such as large dams) by accounting for all major stressors that affect the ecological health of the tributary. Lessons learned restoring Deer Creek will help the design and refinement of future restoration actions on the Deer Creek and other Bay-Delta tributaries.

Deer Creek has potential as a demonstration stream for several reasons. It has a relatively undeveloped watershed, which reduces human impacts upon the ecosystem. Deer Creek also provides habitat for a number of special-status species including, spring-run and fall-run chinook salmon and steelhead trout; indeed Deer Creek presents one of the best opportunities for recovering populations of spring-run chinook salmon because of the amount of holding and spawning habitat available in the upstream reaches. Deer Creek may also provide an opportunity to demonstrate the value of restoring habitat by restoring ecological processes rather than continued management intervention. Levees border the lower 10 miles of the creek channel, inhibiting channel meander, disrupting sediment transport, preventing floodplain inundation, and reducing riparian and aquatic habitat. Setting back or breaching levees could yield valuable information about restoring fluvial processes and associated habitats. Deer Creek may also demonstrate the benefits of alternative flood management if it is feasible to setback Deer Creek levees, thereby providing more floodplain storage of flood flows.

Such restoration of ecological processes will require broad public support from local stakeholders. CALFED will work with the local watershed conservancy and local landowners to pursue restoration opportunities in Deer Creek.

ACTION 1: Evaluate the feasibility of setting back levees along portions of Deer Creek to re-connect the creek channel with a portion of its floodplain and to allow the creak to meander more freely. Set back levees if feasible.

RATIONALE: In the interest of flood control, the Army Corps of Engineers channelized and constructed levees along Deer Creek in the 1940s. These levees, in addition to private levees, separate the creek channel from its floodplain, prevent the creek from meandering, and prevent the formation of valuable aquatic habitat associated with naturally meandering streams. The relatively narrow levees also concentrate flow and increase shear stress on the channel bed so that spawning gravels are often flushed from the creek channel during high flows. During the '97 floods, Deer Creek levees were breached in several places, which provided floodplain storage of flood flows that attenuated downstream flood peaks. Setting back levees along Deer Creek could improve aquatic and riparian habitat by providing the creek more room to meander, which helps to create diverse aquatic habitat such as cutbanks (valuable to rearing juvenile fish), pools (valuable to spring-run chinook salmon and steelhead trout holding through warm summer temperatures), and point bar deposits (valuable for colonization by riparian plant species). Setback levees could also increase the amount of floodplain available to store floodflows, helping to reduce downstream flood risk by reducing the height of flood peaks. It will be necessary to study the feasibility of setting back Deer Creek levees to determine the expense and potential impacts to flood management in the lower reaches. The feasibility study would also need to account for the need to purchase floodplain land or flood easements from private landowners in the vicinity of the setback levees.

ADAPTIVE MANAGEMENT CONSIDERATIONS:

- If it is feasible to setback levees, then monitor and compare the amount and quality of aquatic and riparian habitat available in reaches narrowly confined by levees and reaches where the creek can meander within setback levees.
- If it is feasible to setback levees, then monitor rates of gravel recruitment, transport, and retention in leveed vs. non-leveed reaches.
- If it is feasible to setback levees, then compare flood stage levels and associated flood risk with historical levels for a given amount of inflow.

CURRENT OR RECENT RESTORATION ACTIVITIES OR INVESTIGATIONS:

The Deer Creek Watershed Conservancy received FY 97 Funds to develop a Deer Creek watershed strategy.

There is a potential future linkage with the Comprehensive Study.

ACTION 2: Re-connect the creek channel with a portion of its floodplain by purchasing flood easements from willing sellers.

RATIONALE: Levees along Deer Creek were breached during the flood of 1997. Purchasing flood easements from willing sellers along Deer Creek could help reconnect the stream with a portion of its floodplain while simultaneously providing flood storage to attenuate downstream peaks.

ADAPTIVE MANAGEMENT CONSIDERATIONS:

- If it is feasible to re-connect the stream channel with a portion of its floodplain through setback levees or flood easements, then monitor the amount of floodplain storage and rates of water percolation to groundwater.
- Monitor the flow of nutrients from floodplain lands to the stream channel.
- Determine the extent to which anadromous fish species use floodplain land for refuge, spawning, or rearing.
- Monitor the level of stranding of adult and juvenile anadromous fish.

CURRENT OR RECENT RESTORATION ACTIVITIES OR INVESTIGATIONS:

The Deer Creek Watershed Conservancy received FY 97 Funds to develop a Deer Creek watershed strategy.

There is a potential future linkage with the Comprehensive Study.

ACTION 3: Acquire water from willing sellers or develop alternative water supplies to provide sufficient instream flows to allow the upstream migration of adult anadromous fish. (Note: this water will be part of the 100 TAF of water purchased to improve flows in the Sacramento and San Joaquin Basins.)

RATIONALE: In the past, water diversions from lower Deer Creek have de-watered the stream channel and prevented the upstream migration of adult anadromous fish. In recent years, landowners have worked with DFG and DWR to provide instream flows, in part by developing alternative water supplies for the water diverters. To ensure long-term water supplies that will provide adequate passage flows of suitable temperatures, it will be necessary to acquire water from willing sellers or to work with local diverters to develop alternative water supplies that will allow more water to stay in the channel.

ADAPTIVE MANAGEMENT CONSIDERATIONS:

- Determine the flows necessary to provide fish passage over obstacles
- Evaluate the relationship between flows and water temperatures
- Determine the flows necessary to transport and cleanse spawning gravels.

ACTION 4: Protect and restore riparian habitat to create a continuous riparian corridor in the valley reach of Deer Creek.

RATIONALE: In addition to providing habitat for a variety of wildlife species, riparian buffers can help to trap fine sediments from reaching the stream channel. Riparian vegetation can also help reduce stream temperatures by providing shading, especially for pools that adult spring-run chinook salmon and steelhead trout use for holding during the summer. Riparian vegetation also helps create cutbanks that provide important rearing habitat for juvenile salmonids. Riparian vegetation also provides nutrients and woody debris to the creek channel, helping to stimulate food production and to provide diverse aquatic habitat.

Riparian vegetation can also help to retain stormwater runoff, helping to reduce peak flows in the channel and the concomitant flood risk to downstream reaches. Retention of stormwater runoff can also help increase the amount of water that percolates into groundwater aquifers, which can in turn help to increase groundwater discharge to the stream channel that enhances base flows.

CURRENT OR RECENT RESTORATION ACTIVITIES OR INVESTIGATIONS:

FY '97 and '98 CALFED Restoration Coordination Program funds were provided to allow the purchase of fee title or conservation easement on riparian properties that will protect existing riparian habitat or allow restoration of degraded or absent riparian habitat.

ACTION 5: In conjunction with the local watershed conservancy and local, state, and federal agencies, develop an implement a watershed management plan to reduce the transport of fine sediments to the creek channel, to protect and restore riparian habitat to improve base flows, to reduce water temperatures, and to reduce the ecological risk associated with catastrophic events.

RATIONALE: Activities in the Deer Creek watershed can increase erosion rates and introduce excessive loads of fine sediments to the creek channel. Untimely pulses of fine sediments can clog or bury spawning gravels, suffocating the incubating eggs of anadromous fish or preventing salmonid fry from emerging from the gravels. Fine sediments can also fill in the deep water pools that adult spring-run chinook salmon and steelhead trout require to survive high summer temperatures. Developing a watershed management plan to manage road construction, timber harvest and cattle grazing in the watershed can help prevent the introduction of too many fine sediments to the creek channel. Managing the fuel load in the watershed can also help prevent catastrophic wildfires that can denude vast areas of vegetation.

ADAPTIVE MANAGEMENT CONSIDERATIONS:

- determine the relative contribution of fine sediments to the channel from natural and human disturbances in the watershed
- evaluate how the restoration of upland and riparian habitat affects the transport of fine sediments to the stream channel
- as riparian vegetation is restored, evaluate the volume of stormwater runoff retained, rates of water percolation to groundwater, and groundwater discharge to the channel during base flow
- as riparian vegetation is restored, evaluate its effects upon water temperatures

CURRENT OR RECENT RESTORATION ACTIVITIES OR INVESTIGATIONS:

FY '97 and '98 CALFED Restoration Coordination Program funds were provided to help manage erosion caused by road construction in the watershed. Funds have also been provided for the development of a watershed management plan that includes:

- managing grazing and meadow restoration to help prevent erosion in the watershed,
- managing of fuel loads to help prevent catastrophic wildfires, and
- developing a contingency plan to address spills of hazardous material into the creek channel.

CLEAR CREEK STAGE 1 ACTIONS

Clear Creek has the potential to be a demonstration stream, representative of northern Sacramento Valley tributaries that drain the Coast Range. Demonstration streams will be selected for large-scale implementation of restoration actions to significantly restore ecological processes and resources while simultaneously testing restoration hypotheses as part of an adaptive management approach. The objective for demonstration streams is to fully restore the tributary within existing constraints (such as large dams) by accounting for all major stressors that affect the ecological health of the tributary. Lessons learned restoring Clear Creek will help the design and refinement of future restoration actions on Clear Creek and other Bay-Delta tributaries.

Clear Creek has potential as a demonstration stream for several reasons. Clear Creek provides habitat for several special-status species, including spring-run and fall-run chinook salmon and steelhead trout. Whiskeytown Reservoir offers the potential to release flows of cold water, which is important for providing fish passage and maintaining holding and rearing habitat for special-status fish species. Much of the land surrounding lower Clear Creek is publicly owned and managed by state and federal agencies, which generally provides greater restoration opportunities by minimizing conflicts with private land use. For instance, there is relatively little development along lower Clear Creek so that allowing the creek to meander across a portion of its floodplain will not require displacing homes or infrastructure. Clear Creek may also offer the opportunity to release channel maintenance flows that reactivate fluvial processes as a means of sustaining habitat conditions. Clear Creek also has an active watershed group composed of local landowners and local, state and federal agency personnel, which can help to catalyze restoration efforts.

ACTION 1: Remove the McCormick-Saeltzer diversion dam to provide greater access to upstream habitat, to restore sediment transport processes, and to reduce predator habitat.

RATIONALE: Saeltzer Dam is located on Clear Creek roughly 6 miles upstream of the confluence with the Sacramento River, and approximately 10 miles downstream of the much larger Whiskeytown Reservoir. The dam is approximately 15 feet tall, so during periods of low flow, it impedes the upstream migration of adult anadromous fish. In the past, the dam has been equipped with fish ladders to provide upstream passage, but they have been largely ineffective. The dam also interrupts the transport of sediment by trapping coarse sands and gravels derived from upstream reaches, thereby depriving lower Clear Creek of important spawning gravels. Purchasing the water right and removing the dam, or replacing the dam with a screened diversion, can restore fish access to upstream habitat and the transport of coarse sediments to downstream reaches.

The upstream reaches of Clear Creek between Whiskeytown Dam and Saeltzer Dam provide habitat that can meet the relatively stringent needs of adult spring-run chinook salmon and steelhead trout, two species that require deep cold-water pools to survive high summer temperatures as they hold in the creek waiting to spawn. Since there are few streams in the Central Valley that can provide the summer holding habitat that spring-run chinook and steelhead trout need, improving access to nearly 10 miles of upstream habitat in Clear Creek is an important opportunity.

Fall-run chinook salmon generally spawn in the lower reaches of Clear Creek downstream of Saeltzer Dam, so the dam does not impede their access to spawning habitat. However, the dam does degrade downstream spawning habitat by trapping gravel that would otherwise help replenish and maintain spawning habitat in lower Clear Creek. Replacing the current dam with an alternative diversion structure that allows the transport of sediment will allow gravels that have accumulated behind the dam to be transported to downstream reaches of the creek and eventually to the Sacramento River.

By impounding water at low flows, the dam can also provide warm water habitat that favors non-native or invasive species that prey upon rearing or emigrating juvenile salmonids.

ADAPTIVE MANAGEMENT CONSIDERATIONS:

- Compare use of available spawning habitat upstream of the dam by anadromous fish before and after re-configuration of the diversion facilities.

CURRENT OR RECENT RESTORATION ACTIVITIES OR INVESTIGATIONS:

Both CVPIA and FY '97 CALFED Restoration Coordination Program funds have been provided to allow the evaluation, design and construction of an alternative water diversion that would allow removal of Saeltzer Dam.

ACTION 2: Augment the supply of spawning-sized gravel in the Clear Creek channel.

RATIONALE: Clear Creek has been deprived of its historical sediment load by dams that trap coarse sediment from upstream sources and by extensive gravel mining in the lower reaches of the creek. In recent years, gravel mining operations have been moved from the active channel by a county ordinance, which has improved downstream aquatic habitat. However, Whiskeytown Reservoir will continue to trap all of the coarse sediment derived from the upper watershed. Several gravel augmentation projects have been completed or proposed for Clear Creek; however, as high flows transport introduced gravels down the creek channel into the Sacramento River, it will be necessary to introduce additional gravels to the channel. During Stage 1, it will be important to monitor the availability of spawning gravels and to augment gravel supplies as needed.

ADAPTIVE MANAGEMENT CONSIDERATIONS:

- Monitor the transport and deposition of spawning gravels.
- Evaluate introduced spawning gravels to see if they are suitably sized for spawning habitat for anadromous fish.

ACTION 3: Fill instream mining pits and isolate floodplain gravel mining pits from the active channel.

RATIONALE: The extraction of gravel from instream and floodplain deposits has formed large pits that can strand juvenile salmonids emigrating from the creek and eliminate a clearly defined channel for adult upstream migration. The instream pits and captured floodplain pits provide warm water habitat for non-native and invasive species that prey upon juvenile salmonids attempting to emigrate from the creek. Filling instream and captured floodplain pits, or bolstering levees and berms that protect floodplain mining pits, will reduce the warm water habitat that favors predators.

ADAPTIVE MANAGEMENT CONSIDERATIONS:

- Monitor the transport and deposition of spawning gravels.
- Evaluate introduced spawning gravels to see if they are suitably sized for spawning habitat for anadromous fish.

CURRENT OR RECENT RESTORATION ACTIVITIES OR INVESTIGATIONS:

FY '98 CALFED Restoration Coordination Program funds were provided to fill in and isolate downstream gravel pits to prevent the predation and stranding of juvenile anadromous fish by using dredger tailings from upstream reaches which will allow the restoration or riparian habitat on the upper reach.

ACTION 4: Provide sufficient scouring flows to periodically remove vegetation that has encroached within the active channel in lower Clear Creek, and mechanically remove vegetation if necessary.

RATIONALE: Whiskeytown Dam has altered the Clear Creek flow regime by reducing peak flows. As a result, riparian vegetation has encroached into the active creek channel since the reduced peak flows are insufficient to naturally scour the vegetation. The encroaching vegetation helps to prevent the creek from meandering much like levees do. A naturally meandering river helps to create and maintain important aquatic habitat such as cutbanks and pools (valuable to rearing juvenile fish) and point bar deposits (valuable for colonization by riparian plant species). Periodically increasing peak flows in the downstream channel will provide the energy required to drive channel migration and to restore the natural process of riparian succession, which can provide more diverse aquatic and riparian habitat. Much like levees, vegetation that has encroached upon the active channel can confine flows to a relatively narrow channel, thereby increasing water velocity and the shear stress applied to sediments on the channel bed. This increased shear stress can flush spawning gravels downstream, thereby depriving the local reach of important habitat material.

Since years of reduced peak flows have allowed vegetation to firmly establish in the active channel, it may be necessary to mechanically remove encroaching vegetation to assist the natural scouring process.

ADAPTIVE MANAGEMENT CONSIDERATIONS:

- Determine flows necessary to scour encroaching vegetation from the active channel.
- Determine channel maintenance flows necessary to scour and transport sediment to provide surfaces for riparian vegetation succession.

ACTION 5: Refine and implement a watershed management plan to reduce the transport of fine sediment to the creek channel and to protect and restore riparian habitat in conjunction with local landowners and local, state and federal agencies active in the watershed.

RATIONALE: Activities in the Clear Creek watershed can increase erosion rates and introduce excessive loads of fine sediments to the creek channel. Untimely pulses of fine sediments can clog or bury spawning gravels, suffocating the incubating eggs of anadromous fish or preventing salmonid fry from emerging from the gravels. Fine sediments can also fill in the deep water pools that adult spring-run chinook salmon and steelhead trout require to survive high summer temperatures. Developing a watershed management plan to manage road construction, timber harvest and cattle grazing in the watershed can help prevent the introduction of too many fine sediments to the creek channel. Managing the fuel load in the watershed can also help prevent catastrophic wildfires that can denude vast areas of vegetation.

Current land use practices in the upper watershed increase rates of erosion, introducing excessive loads of fine sediments that degrade habitat in the upper tributaries of Clear Creek. Re-introducing steelhead trout above Whiskeytown Reservoir will require better management of activities to decrease the transport of fine sediments to stream channels.

Developing a watershed management plan that protects and restores riparian vegetation can provide several ecological benefits. In addition to providing habitat for a variety of wildlife species, riparian buffers can help to trap fine sediments from reaching the stream channel. Riparian vegetation can also help reduce stream temperatures by providing shading, especially for pools that adult spring-run chinook salmon and steelhead trout use for holding during the summer. Riparian vegetation also helps create cutbanks that provide important rearing habitat for juvenile salmonids. Riparian vegetation also provides nutrients and woody debris to the creek channel, helping to stimulate food production and to provide diverse aquatic habitat.

Riparian vegetation can also help to retain stormwater runoff, helping to reduce peak flows in the channel and the concomitant flood risk to downstream reaches. Retention of stormwater runoff can also help increase the amount of water that percolates into groundwater aquifers, which can in turn help to increase groundwater discharge to the stream channel that enhances base flows.

An active watershed management group, the Lower Clear Creek Watershed Conservancy, has already developed a watershed management plan that will help to guide restoration efforts in lower Clear Creek.

ADAPTIVE MANAGEMENT CONSIDERATIONS:

- determine the relative contribution of fine sediments to the channel from natural and human disturbances in the watershed
- evaluate how the restoration of upland and riparian habitat affects the transport of fine sediments to the stream channel
- as riparian vegetation is restored, evaluate the volume of stormwater runoff retained, rates of water percolation to groundwater, and groundwater discharge to the channel during base flow
- as riparian vegetation is restored, evaluate its effects upon water temperatures

CURRENT OR RECENT RESTORATION ACTIVITIES OR INVESTIGATIONS:

NRCS conducted an evaluation of the Lower Clear Creek watershed.

ACTION 6: Evaluate the need to augment flows in Clear Creek and acquire water from willing sellers. (This water will be part of the 100 TAF acquired to improve streamflow in the Sacramento and San Joaquin Basins.)

RATIONALE: Whiskeytown Reservoir provides a source of water to help provide minimum instream flows necessary to allow fish passage over obstacles and to reduce stream temperatures. CVPIA provides for flows necessary to maintain ecological resources. It may be necessary to augment these flows to achieve more optimal conditions by purchasing water from willing sellers.

ADAPTIVE MANAGEMENT CONSIDERATIONS:

- Determine the flows necessary to provide fish passage over obstacles
- Evaluate the relationship between flows and water temperatures
- Determine the flows necessary to transport and cleanse spawning gravels

CURRENT OR RECENT RESTORATION ACTIVITIES OR INVESTIGATIONS:

CVPIA allocates flow releases from Whiskeytown and Clair Hill Reservoirs.

MILL CREEK STAGE 1 ACTIONS

Mill Creek is a relatively healthy tributary since its upper reaches flow through an inaccessible, undeveloped canyon. Since it drains volcanic lands surrounding Mount Lassen, Mill Creek has relatively higher flows throughout the summer and fall because it is fed by underground springs of cold water, which helps to provide important holding habitat for spring-run chinook salmon and steelhead trout. Indeed, Mill Creek is one of the few Central Valley streams that provides appropriate habitat conditions for spring-run chinook salmon and steelhead trout.

ACTION 1: Reduce or eliminate the need to reconstruct Clough Dam by providing an alternative diversion structure that does not impede the migration of anadromous fish.

RATIONALE: Clough Dam is one of three diversion structures on Mill Creek that can delay or impede the migration of anadromous fish. Clough Dam was breached during the floods of '97, providing an opportunity to remove the dam by developing an alternative diversion structure that does not impede fish migration.

ADAPTIVE MANAGEMENT CONSIDERATIONS:

Since the dam has already been breached naturally, there is relatively little opportunity to design an adaptive management experiment to improve our knowledge of local ecological relationships and functions related to fish obstruction, other than continuing to monitor escapement rates and compare against historical data.

CURRENT OR RECENT RESTORATION ACTIVITIES OR INVESTIGATIONS:

FY '98 CALFED Restoration Coordination Program Funds have been provided for the design, evaluation and construction of an alternative diversion structure that will eliminate the need to reconstruct the dam.

ACTION 2: Acquire water from willing sellers or develop alternative water supplies to provide sufficient instream flows to allow the upstream migration of adult anadromous fish. (Note: this water will be part of the 100 TAF of water purchased to improve stream flows in the Sacramento and San Joaquin Basins.

RATIONALE: In the past, water diversions from lower Mill Creek have de-watered the stream channel and prevented the upstream migration of adult anadromous fish. In recent years, landowners have worked with DFG and DWR through the Four Pumps Agreement to provide instream flows, in part by developing alternative water supplies for the water diverters. To ensure long-term water supplies that will provide adequate passage flows of suitable temperatures, it will be necessary to acquire water from willing sellers or to work with local diverters to develop alternative water supplies that will allow more water to stay in the channel.

ADAPTIVE MANAGEMENT CONSIDERATIONS:

- Determine the flows necessary to provide fish passage over obstacles
- Evaluate the relationship between flows and water temperatures
- Determine the flows necessary to transport and cleanse spawning gravels

ACTION 3: In conjunction with the local watershed conservancy and local, state, and federal agencies, develop and implement a watershed management plan to reduce the transport of fine sediments to the creek channel, to protect and restore riparian habitat to improve base flows, and to reduce water temperatures.

RATIONALE: Activities in the Mill Creek watershed can increase erosion rates and introduce excessive loads of fine sediments to the creek channel. Untimely pulses of fine sediments can clog or bury spawning gravels, suffocating the incubating eggs of anadromous fish or preventing salmonid fry from emerging from the gravels. Fine sediments can also fill in the deep water pools that adult spring-run chinook salmon and steelhead trout require to survive high summer temperatures. Developing a watershed management plan to manage road construction, timber harvest and cattle grazing in the watershed can help prevent the introduction of too many fine sediments to the creek channel. Managing the fuel load in the watershed can also help prevent catastrophic wildfires that can denude vast areas of vegetation.

Developing a watershed management plan that protects and restores riparian vegetation can provide several ecological benefits. In addition to providing habitat for a variety of wildlife species, riparian buffers can help to trap fine sediments from reaching the stream channel. Riparian vegetation can also help reduce stream temperatures by providing shading, especially for pools that adult spring-run chinook salmon and steelhead trout use for holding during the summer. Riparian vegetation also helps create cutbanks that provide important rearing habitat for juvenile salmonids. Riparian vegetation also provides nutrients and woody debris to the creek channel, helping to stimulate food production and to provide diverse aquatic habitat.

Riparian vegetation can also help to retain stormwater runoff, helping to reduce peak flows in the channel and the concomitant flood risk to downstream reaches. Retention of stormwater runoff can also help increase the amount of water that percolates into groundwater aquifers, which can in turn help to increase groundwater discharge to the stream channel that enhances base flows and helps reduce water temperatures.

ADAPTIVE MANAGEMENT CONSIDERATIONS:

- determine the relative contribution of fine sediments to the channel from natural and human disturbances in the watershed
- evaluate how the restoration of upland and riparian habitat affects the transport of fine sediments to the stream channel
- as riparian vegetation is restored, evaluate the volume of stormwater runoff retained, rates of water percolation to groundwater, and groundwater discharge to the channel during baseflow
- as riparian vegetation is restored, evaluate its effects upon water temperatures

CURRENT OR RECENT RESTORATION ACTIVITIES OR INVESTIGATIONS:

FY '97 and '98 CALFED Restoration Coordination Program funds were provided to help manage erosion caused by road construction in the watershed, and to purchase fee title or conservation easements for riparian properties that will protect or restore riparian habitat.

BATTLE CREEK STAGE 1 ACTIONS

ACTION 1: Improve fish migration by removing diversion dams, upgrading fish passage facilities, and screening diversions.

RATIONALE: PG&E owns and operates two small reservoirs and seven unscreened diversions on Battle Creek and its tributaries. The facilities can impede the migration of juvenile and adult anadromous fish, and the unscreened diversions can entrain juvenile anadromous fish. Before hydropower development, Battle Creek was one of the most important spawning streams in the Central Valley for several species of chinook salmon. Various species of chinook salmon and steelhead trout still utilize spawning habitat in lower Battle Creek; however, generally there is too little habitat available for the available populations of fish. Removing diversion dams or upgrading their fish ladders can provide access to upstream habitat and relieve pressure on the over-utilized downstream reach of the creek. Battle Creek is one of the few Central Valley streams that provides the cold-water pool habitat that spring-run chinook and steelhead trout require for surviving high summer temperatures.

As greater access to upstream habitat is provided to adult anadromous fish, it will be necessary to screen the several unscreened diversions that can entrain juvenile salmonids.

ADAPTIVE MANAGEMENT CONSIDERATIONS:

- Compare escapement rates and use of spawning habitat upstream of diversion facilities before and after removal.
- Compare use of available spawning habitat above hydropower facilities before and after construction of fish passage facilities.

CURRENT OR RECENT RESTORATION ACTIVITIES OR INVESTIGATIONS:

FY '97 CALFED Restoration Coordination Program funds were provided for the evaluation and design of several screened diversions on Battle Creek and its tributaries.

ACTION 2: Improve instream flows in lower Battle Creek to provide adequate passage flows.

RATIONALE: The PG&E hydropower facilities on Battle Creek were capable of diverting up to 98% of the streamflow, which impeded fish passage and elevated stream temperatures. An interim agreement provided for re-operation of the hydropower facilities to provide a greater volume of flow. It is important to provide a long-term solution to ensure adequate streamflows downstream of the hydropower facilities.

ADAPTIVE MANAGEMENT CONSIDERATIONS:

- Determine the flows necessary to provide fish passage over obstacles
- Evaluate the relationship between flows and water temperatures
- Determine the flows necessary to transport and cleanse spawning gravels

CURRENT OR RECENT RESTORATION ACTIVITIES OR INVESTIGATIONS:

CVPIA funds have helped to provide interim flows until a long-term flow agreement is reached.

ACTION 3: Develop and implement a watershed management plan to reduce the amount of fine sediments introduced to the creek channel, to protect and restore riparian habitat, to improve base flows, and to reduce water temperatures

RATIONALE: Activities in the Battle Creek watershed can increase erosion rates and introduce excessive loads of fine sediments to the creek channel. Untimely pulses of fine sediments can clog or bury spawning gravels, suffocating the incubating eggs of anadromous fish or preventing salmonid fry from emerging from the gravels. Fine sediments can also fill in the deep water pools that adult spring-run chinook salmon and steelhead trout require to survive high summer temperatures. Developing a watershed management plan to manage road construction, timber harvest and cattle grazing in the watershed can help prevent the introduction of too many fine sediments to the creek channel. Managing the fuel load in the watershed can also help prevent catastrophic wildfires that can denude vast areas of vegetation.

Developing a watershed management plan that protects and restores riparian vegetation can provide several ecological benefits. In addition to providing habitat for a variety of wildlife species, riparian buffers can help to trap fine sediments from reaching the stream channel. Riparian vegetation can also help reduce stream temperatures by providing shading, especially for pools that adult spring-run chinook salmon and steelhead trout use for holding during the summer. Riparian vegetation also helps create cutbanks that provide important rearing habitat for juvenile salmonids. Riparian vegetation also provides nutrients and woody debris to the creek channel, helping to stimulate food production and to provide diverse aquatic habitat.

Riparian vegetation can also help to retain stormwater runoff, helping to reduce peak flows in the channel and the concomitant flood risk to downstream reaches. Retention of stormwater runoff can also help increase the amount of water that percolates into groundwater aquifers, which can in turn help to increase groundwater discharge to the stream channel that enhances base flows.

Creating a watershed management group can help bring together private landowners and local stakeholders with local, state, and federal agency personnel to help develop and coordinate watershed management activities. The watershed group can provide a focused forum for the exchange of ideas and for building consensus among stakeholders, helping to provide a structure for continued public participation in decision making and to help build public support for long-term ecosystem restoration and management.

CURRENT OR RECENT RESTORATION ACTIVITIES OR INVESTIGATIONS:

Category III funds were provided to help establish a Battle Creek Watershed Conservancy.

ACTION 4: Improve the fish passage facilities at the Coleman National Fish Hatchery.

RATIONALE: Coleman National Fish Hatchery has a weir equipped with a fish ladder. The fish ladder provides access to upstream spawning habitat for spring-run and winter-run chinook salmon. The weir is designed to prevent fall-run chinook salmon from migrating upstream to spawn to prevent hybridization of the species. Improving the weir to better block upstream access to fall-run chinook salmon will help to preserve the genetic integrity of Battle Creek salmonids.

ACTION 5: Improve hatchery management and release practices at the Coleman National Fish Hatchery to better protect the genetic integrity of wild anadromous fish populations.

RATIONALE: Fish hatcheries in the Central Valley help to mitigate for fisheries losses attributed to dams that block access to historical spawning grounds and the degradation of habitat. Hatcheries can provide a valuable function by helping to maintain commercial and sport fisheries and by augmenting wild populations of fish that decline during adverse conditions such as droughts, thereby helping to ensure the survival of the species. However, hatchery produced fish can compete with wild populations for available resources such as food and spawning and rearing habitat. Hatchery produced fish may also prey upon wild populations of juvenile anadromous fish. The selection of fish used as hatchery stock may not represent an appropriate cross section of the population, which can reduce genetic diversity. Hatchery-produced fish also spawn with wild populations, reducing threatening the genetic integrity of wild populations of fish.

Reducing the number of hatchery-produced fish released into Bay-Delta tributaries in years when the natural production of fish is high can help prevent competition among wild and hatchery-reared fish and help populations of wild fish to rebound naturally. It can also help to reduce inter-breeding and the genetic contamination of the wild population. Selecting an appropriate cross section of adult spawners can also help to preserve genetic diversity in the species. Tagging hatchery-produced fish could allow for selective commercial and sport fishery harvest, reducing the impacts of harvest upon wild populations of fish.

COTTONWOOD CREEK STAGE 1 ACTIONS

ACTION 1: Relocate gravel mining operations from the active channel and nearby floodplain to higher terraces.

RATIONALE: Since the completion of Shasta Dam, Cottonwood Creek has become the single greatest source of coarse sediment for the Sacramento River, supplying approximately 85% of the gravel introduced into the river between Redding and Red Bluff. Cottonwood Creek drains a portion of the Coast Range, which is composed of geologic deposits that generally produce greater quantities of coarse sediment per unit of area than the Sierra Nevada or Cascade Ranges. Cottonwood Creek also provides the cold water pool habitat that spring-run chinook salmon and steelhead trout require.

Instream and floodplain gravel mining in the lower reaches of Cottonwood Creek represent the greatest stressor upon ecological processes in the creek's watershed. The removal of sand and gravel from the creek channel deprives the Sacramento River of important gravels necessary to create and maintain spawning habitat for anadromous fish. Dams on the mainstem Sacramento River (Shasta) and Clear Creek tributary (Whiskeytown and Clair Hill) prevent the transport of coarse sediment; however, there are no major dams on Cottonwood Creek or its tributaries. Relocating gravel mining operations from the active channel and nearby floodplain will restore the important ecological process of sediment transport and allow Cottonwood Creek to contribute a greater load of coarse sediment to the gravel-starved Sacramento River.

Gravel mining practices on lower Cottonwood Creek can also prevent or delay the upstream migration of adult anadromous fish. Gravel mining operations can spread gravel over a wide area to reduce the velocity of streamflow, which encourages greater deposition of coarse sands and gravels, thereby making more material available for mining. Spreading the flow over a larger area often eliminates the low-flow channel and reduces water surface elevations so that adult anadromous fish are impeded from migrating upstream to valuable holding and spawning habitat. Relocating gravel mining operations from the active channel and nearby floodplains will allow a low-flow channel to form, providing greater access to upstream habitat.

The extraction of gravel from floodplain deposits can form large pits that are separated from the main river channel by relatively narrow levees or berms. High flows can often breach the levees or berms and capture the deep gravel pits, which then provide warm water habitat for non-native and invasive species that prey upon juvenile salmonids attempting to emigrate from the creek. Relocating gravel mining operations from the nearby floodplain will help prevent the capture of mining pits and thereby reduce the risk of predation for emigrating juvenile salmonids.

By disturbing and removing the gravel substrate of the channel, instream gravel mining operations can also reduce the production of aquatic invertebrates that are an important component of the foodweb.

ADAPTIVE MANAGEMENT CONSIDERATIONS:

- Evaluate rates of gravel recruitment to the channel from channel erosion of bank deposits and events in the watershed such as wildfires and landslides

ACTION 2: Develop and implement a watershed management plan in concert with local stakeholders and local, state, and federal public agencies to reduce the amount of fine sediments introduced to the creek channel, to protect and restore riparian habitat, to improve base flows, and to reduce water temperatures.

RATIONALE: Activities in the Cottonwood Creek watershed can increase erosion rates and introduce excessive loads of fine sediments to the creek channel. Untimely pulses of fine sediments can clog or bury spawning gravels, suffocating the incubating eggs of anadromous fish or preventing salmonid fry from emerging from the gravels. Fine sediments can also fill in the deep water pools that adult spring-run chinook salmon and steelhead trout require to survive high summer temperatures. Developing a watershed management plan to manage road construction, timber harvest and cattle grazing in the watershed can help prevent the introduction of too many fine sediments to the creek channel. Managing the fuel load in the watershed can also help prevent catastrophic wildfires that can denude vast areas of vegetation.

Developing a watershed management plan that protects and restores riparian vegetation can provide several ecological benefits. In addition to providing habitat for a variety of wildlife species, riparian buffers can help to trap fine sediments from reaching the stream channel. Riparian vegetation can also help reduce stream temperatures by providing shading, especially for pools that adult spring-run chinook salmon and steelhead trout use for holding during the summer. Riparian vegetation also helps create cutbanks that provide important rearing habitat for juvenile salmonids. Riparian vegetation also provides nutrients and woody debris to the creek channel, helping to stimulate food production and to provide diverse aquatic habitat.

Riparian vegetation can also help to retain stormwater runoff, helping to reduce peak flows in the channel and the concomitant flood risk to downstream reaches. Retention of stormwater runoff can also help increase the amount of water that percolates into groundwater aquifers, which can in turn help to increase groundwater discharge to the stream channel that enhances base flows.

Creating a watershed management group can help bring together private landowners and local stakeholders with local, state, and federal agency personnel to help develop and coordinate watershed management activities. The watershed group can provide a focused forum for the exchange of ideas and for building consensus among stakeholders, helping to provide a structure for continued public participation in decision making and to help build public support for long-term ecosystem restoration and management.

ADAPTIVE MANAGEMENT CONSIDERATIONS:

- determine the relative contribution of fine sediments to the channel from natural and human disturbances in the watershed
- evaluate how the restoration of upland and riparian habitat affects the transport of fine sediments to the stream channel
- as riparian vegetation is restored, evaluate the volume of stormwater runoff retained, rates of water percolation to groundwater, and groundwater discharge to the channel during base flow
- as riparian vegetation is restored, evaluate its effects upon water temperatures

CURRENT OR RECENT RESTORATION ACTIVITIES OR INVESTIGATIONS:

In the FY '98 round of funding for CALFED Restoration Coordination Program, funds were provided to assist the formation of a Cottonwood Creek Watershed Group. It is anticipated that this group will help to stimulate the development of a watershed management plan.

FY '98 Category III funds have been provided to allow the formation of the Cottonwood Creek Watershed Group.

BUTTE CREEK STAGE 1 ACTIONS

ACTION 1: Improve fish passage at diversion dams either by providing alternative diversion structures that will allow removal of existing dams or by upgrading fish ladders and screen diversions.

RATIONALE: Several diversion dams on Butte Creek currently delay or impede the upstream migration of adult anadromous fish and entrain juvenile salmonids emigrating from the system in unscreened diversions. Improving fish passage and reducing entrainment at each of the diversions will help provide better access to upstream spawning habitat and increase the number of juvenile escaping to the Sacramento River.

CURRENT OR RECENT RESTORATION ACTIVITIES OR INVESTIGATIONS:

FY '97 CALFED Restoration Coordination Program funds, as well as earlier Category III funds, have been provided to help fund the design, evaluation, and construction of alternative diversion structures or upgraded fish ladders, as well as screened diversions, at the Adams Dam and Gorrill Dam diversions. Earlier Category III funds helped to finance alternative diversion structures, upgraded fish ladders, and screened diversions at the Durham Mutual Dam, Parrot-Phelan Dam, and Western Canal Water District diversions.

ACTION 2: Improve instream flows by purchasing water from willing sellers or providing alternative water supplies that will allow diverters to reduce diversions. (Note: this water will be part of the 100 TAF of water purchased to improve stream flows in the Sacramento and San Joaquin Basins.

RATIONALE: In dry years, insufficient flows in Butte Creek can impede the upstream migration of adult anadromous fish because there is too little water in the channel to provide passage over obstacles or because elevated water temperatures create a temperature barrier. Low flows and elevated water temperatures can also stress or kill juvenile salmonids rearing or emigrating through Butte Creek. To ensure long-term water supplies that will provide adequate passage flows of suitable temperatures, it will be necessary to acquire water from willing sellers or to work with local diverters to develop alternative water supplies that will allow more water to stay in the channel during dry years. It will also be necessary to balance the ecological benefits of water diverted from Butte Creek for seasonal wetlands on state and federal refuges and private duck clubs with the benefits of water left in Butte Creek to benefit salmonids.

ADAPTIVE MANAGEMENT CONSIDERATIONS:

- Determine the flows necessary to provide fish passage over obstacles
- Evaluate the relationship between flows and

water temperatures

- Determine the flows necessary to transport and cleanse spawning gravels

ACTION 3: Develop and implement a watershed management plan to reduce the amount of fine sediments introduced to the creek channel, to protect and restore riparian habitat to improve base flows, and to reduce water temperatures.

RATIONALE: Activities in the Butte Creek watershed can increase erosion rates and introduce excessive loads of fine sediments to the creek channel. Untimely pulses of fine sediments can clog or bury spawning gravels, suffocating the incubating eggs of anadromous fish or preventing salmonid fry from emerging from the gravels. Fine sediments can also fill in the deep-water pools that adult spring-run chinook salmon and steelhead trout require to survive high summer temperatures. Developing a watershed management plan to manage road construction, timber harvest and cattle grazing in the watershed can help prevent the introduction of too many fine sediments to the creek channel. Managing the fuel load in the watershed can also help prevent catastrophic wildfires that can denude vast areas of vegetation.

Developing a watershed management plan that protects and restores riparian vegetation can provide several ecological benefits. In addition to providing habitat for a variety of wildlife species, riparian buffers can help to trap fine sediments from reaching the stream channel. Riparian vegetation can also help reduce stream temperatures by providing shading, especially for pools that adult spring-run chinook salmon and steelhead trout use for holding during the summer. Riparian vegetation also helps create cutbanks that provide important rearing habitat for juvenile salmonids. Riparian vegetation also provides nutrients and woody debris to the creek channel, helping to stimulate food production and to provide diverse aquatic habitat.

Riparian vegetation can also help to retain stormwater runoff, helping to reduce peak flows in the channel and the concomitant flood risk to downstream reaches. Retention of stormwater runoff can also help increase the amount of water that percolates into groundwater aquifers, which can in turn help to increase groundwater discharge to the stream channel that enhances base flows and helps reduce water temperatures.

ADAPTIVE MANAGEMENT CONSIDERATIONS:

- determine the relative contribution of fine sediments to the channel from natural and human disturbances in the watershed
- evaluate how the restoration of upland and riparian habitat affects the transport of fine sediments to the stream channel
- as riparian vegetation is restored, evaluate the volume of stormwater runoff retained, rates of water percolation to groundwater, and groundwater discharge to the channel during base flow
- as riparian vegetation is restored, evaluate its effects upon water temperatures.

CURRENT OR RECENT RESTORATION ACTIVITIES OR INVESTIGATIONS:

FY '97 and FY '98 CALFED Restoration Coordination Program funds have been provided for the acquisition and restoration of riparian habitat along Butte Creek as well as watershed planning. Earlier Category III funds were provided for the development of the Butte Creek Watershed Management Strategy.

BIG CHICO CREEK

ACTION 1: Develop and implement a watershed management plan to reduce the amount of fine sediments introduced to the creek channel, to protect and restore riparian habitat, to improve base flows, to reduce water temperatures, and to balance recreational uses with plant and wildlife requirements.

RATIONALE: Activities in the Big Chico Creek watershed can increase erosion rates and introduce excessive loads of fine sediments to the creek channel. Untimely pulses of fine sediments can clog or bury spawning gravels, suffocating the incubating eggs of anadromous fish or preventing salmonid fry from emerging from the gravels. Fine sediments can also fill in the deep water pools that adult spring-run chinook salmon and steelhead trout require to survive high summer temperatures. Developing a watershed management plan to manage road construction, timber harvest and cattle grazing in the watershed can help prevent the introduction of too many fine sediments to the creek channel. Managing the fuel load in the watershed can also help prevent catastrophic wildfires that can denude vast areas of vegetation.

The Big Chico Alliance is developing a watershed management plan for protecting and restoring riparian vegetation to provide several ecological benefits. In addition to providing habitat for a variety of wildlife species, riparian buffers can help to trap fine sediments from reaching the stream channel. Riparian vegetation can also help reduce stream temperatures by providing shading, especially for pools that adult spring-run chinook salmon and steelhead trout use for holding during the summer. Riparian vegetation also helps create cutbanks that provide important rearing habitat for juvenile salmonids. Riparian vegetation also provides nutrients and woody debris to the creek channel, helping to stimulate food production and to provide diverse aquatic habitat.

Riparian vegetation can also help to retain stormwater runoff, helping to reduce peak flows in the channel and the concomitant flood risk to downstream reaches. Retention of stormwater runoff can also help increase the amount of water that percolates into groundwater aquifers, which can in turn help to increase groundwater discharge to the stream channel that enhances base flows.

Existing and future recreational uses of Big Chico Creek must be balanced with the needs of plant and animal species. Recreational areas should be located away from sensitive or important fish habitat.

Current or Recent Restoration Activities or Investigations:

FY '97 CALFED Restoration Coordination Program funds were provided to help develop the Big Chico Watershed Plan. The Big Chico Watershed Alliance is facilitating the development of this plan and is hosting a series of public workshops to prioritize watershed goals and issues and concerns.

Feather River Stage 1 Actions

Action 1: Screen the Sunset Pumps diversion to prevent entrainment of juvenile salmonids.

Rationale: Several species of anadromous fish spawn in the Feather River. Juvenile salmonids attempting to emigrate from the river can be entrained by unscreened or poorly screened diversions. Upgrading the Sunset Pumps diversion screens will help reduce entrainment losses for several species of anadromous fish.

Action 2: Improve hatchery management and release practices at the Feather River Hatchery to better protect the genetic integrity of wild anadromous fish populations.

Rationale: Fish hatcheries in the Central Valley help to mitigate for fisheries losses attributed to dams that block access to historical spawning grounds and the degradation of habitat. Hatcheries can provide a valuable function by helping to maintain commercial and sport fisheries and by augmenting wild populations of fish that decline during adverse conditions such as droughts, thereby helping to ensure the survival of the species. However, hatchery produced fish can compete with wild populations for available resources such as food and spawning and rearing habitat. Hatchery produced fish may also prey upon wild populations of juvenile anadromous fish. The selection of fish used as hatchery stock may not represent an appropriate cross section of the population, which can reduce genetic diversity. Hatchery-produced fish also spawn with wild populations, reducing threatening the genetic integrity of wild populations of fish.

Reducing the number of hatchery-produced fish released into Bay-Delta tributaries in years when the natural production of fish is high can help prevent competition among wild and hatchery-reared fish and help populations of wild fish to rebound naturally. It can also help to reduce inter-breeding and the genetic contamination of the wild population. Selecting an appropriate cross section of adult spawners can also help to preserve genetic diversity in the species. Tagging hatchery-produced fish could allow for selective commercial and sport fishery harvest, reducing the impacts of harvest upon wild populations of fish.

YUBA RIVER STAGE 1 ACTIONS

ACTION 1: Evaluate options to improve fish passage upstream and downstream of Daguerre Point Dam. Conduct a feasibility study of removing or modifying Daguerre Point Dam.

RATIONALE: Daguerre Point Dam is a debris dam constructed primarily to trap excessive sediment caused by upstream mining operations. The dam can delay or impede the upstream migration of adult anadromous fish, thereby reducing reproductive success. The dam has been equipped with fish ladders in the past, but their success in providing access has been minimal. The dam can also disrupt the downstream migration of emigrating juvenile salmonids, which are subject to predation by non-native and invasive fish species in the warm water habitat created by the dam's impoundment of water. Removing the dam could improve access to nearly 12.5 miles of river channel and reduce predation losses of juvenile anadromous fish.

ADAPTIVE MANAGEMENT CONSIDERATIONS:

- If it is feasible to remove Daguerre Point Dam, compare escapement rates and use of spawning habitat upstream of the dam before and after removal.
- Compare rates of predation of juvenile anadromous fish downstream of the dam before and after removal.

CURRENT OR RECENT RESTORATION ACTIVITIES OR INVESTIGATIONS:

There is a potential future linkage with the Comprehensive Study.

ACTION 2: Evaluate options to reintroduce steelhead and spring-run chinook salmon upstream of Englebright Dam.

RATIONALE: Englebright Dam is a debris dam constructed primarily to trap excessive sediment caused by upstream mining operations, though the dam also provides for important re-regulation of hydropower releases from upstream reservoirs. The dam is currently the upstream limit of anadromous fish migration. The feasibility study would need to evaluate the potential quantity and quality of upstream habitat that would be provided, as well as the potential mercury contamination of sediments behind Englebright Dam.

ADAPTIVE MANAGEMENT CONSIDERATIONS:

- Evaluate the suitability of upstream habitats.
- Evaluate mercury levels in the sediments behind the dam.

CURRENT OR RECENT RESTORATION ACTIVITIES OR INVESTIGATIONS:

There is a potential future linkage with the Comprehensive Study.

AMERICAN RIVER STAGE 1 ACTIONS

ACTION 1: Control or eradicate non-native riparian plants and re-vegetate with native plants.

RATIONALE: *Arundo donax* (giant reed) has become established in the American River. Arundo can alter ecological processes by inducing greater deposition, by evapotranspiring greater quantities of water than native riparian vegetation, and by altering soil chemistry. Arundo provides little habitat for native wildlife species, and because it grows vertically and doesn't overhang the stream channel, it doesn't provide the SRA habitat for aquatic species that native riparian vegetation does. Replacing Arundo with native riparian vegetation may also enhance base flows. Another non-native plants of concern is scarlet wisteria.

ADAPTIVE MANAGEMENT CONSIDERATIONS:

- Evaluate different removal and re-vegetation techniques to identify the most effective and cost-effective methods for controlling or eradicating non-native or invasive riparian plant species.
- Monitor the rate of re-colonization by native, non-native, and invasive species.
- Determine the ecological conditions or processes that favor native species over non-native species.

- Determine invertebrate and wildlife use of non-native riparian plant species.
- Determine the extent to which non-native riparian species alter ecological processes.

CURRENT OR RECENT RESTORATION ACTIVITIES OR INVESTIGATIONS:

SWRCB funds have been provided for erosion and sediment control demonstration project on Cache Creek.

ACTION 2: In balance with public safety, manage the removal of or introduce instream woody debris on selected river reaches to enhance aquatic habitat for salmonids.

RATIONALE: Woody debris is cleared from the American River channel for recreational and public safety purposes. However, woody debris provides important rearing and resting habitat for salmonids. Allowing woody debris to stay in selected reaches of the channel may enhance patches of salmonid rearing habitat without affecting recreation significantly.

ADAPTIVE MANAGEMENT CONSIDERATIONS:

- Compare salmonid use of aquatic habitat in reaches with woody debris and reaches cleared of woody debris.

ACTION 3: Improve hatchery management and release practices at the Nimbus Hatchery to better protect the genetic integrity of wild anadromous fish populations.

RATIONALE: Fish hatcheries in the Central Valley help to mitigate for fisheries losses attributed to dams that block access to historical spawning grounds and the degradation of habitat. Hatcheries can provide a valuable function by helping to maintain commercial and sport fisheries and by augmenting wild populations of fish that decline during adverse conditions such as droughts, thereby helping to ensure the survival of the species. However, hatchery produced fish can compete with wild populations for available resources such as food and spawning and rearing habitat. Hatchery produced fish may also prey upon wild populations of juvenile anadromous fish. The selection of fish used as hatchery stock may not represent an appropriate cross section of the population, which can reduce genetic diversity. Hatchery-produced fish also spawn with wild populations, reducing threatening the genetic integrity of wild populations of fish.

Reducing the number of hatchery-produced fish released into Bay-Delta tributaries in years when the natural production of fish is high can help prevent competition among wild and hatchery-reared fish and help populations of wild fish to rebound naturally. It can also help to reduce inter-breeding and the genetic contamination of the wild population. Selecting an appropriate cross section of adult spawners can also help to preserve genetic diversity in the species. Tagging hatchery-produced fish could allow for selective commercial and sport fishery harvest, reducing the impacts of harvest upon wild populations of fish.

CACHE CREEK STAGE 1 ACTIONS

ACTION 1: Control or eradicate non-native riparian plants and re-vegetate with native plants.

RATIONALE: Tamarisk has become established in the Cache Creek watershed. Tamarisk can alter ecological processes by inducing greater deposition, by evapotranspiring greater quantities of water than native riparian vegetation, and by altering soil chemistry. Tamarisk provides little habitat for native wildlife species, and because it grows vertically and doesn't overhang the stream channel, it doesn't provide the SRA habitat for aquatic species that native riparian vegetation does. Controlling or eradicating tamarisk from the Cache Creek watershed will help prevent its spread into Yolo Bypass and the Delta. Replacing tamarisk with native riparian vegetation may also enhance base flows.

ADAPTIVE MANAGEMENT CONSIDERATIONS:

- Evaluate different removal and re-vegetation techniques to identify the most effective and cost-effective methods for controlling or eradicating non-native or invasive riparian plant species.
- Monitor the rate of re-colonization by native,

non-native, and invasive species.

- Determine the ecological conditions or processes that favor native species over non-native species.
- Determine invertebrate and wildlife use of non-native riparian plant species.
- Determine the extent to which non-native riparian species alter ecological processes.

CURRENT OR RECENT RESTORATION ACTIVITIES OR INVESTIGATIONS:

SWRCB Proposition 204 funds have been provided for a demonstration project to control soil erosion in the Cache Creek watershed to help prevent the release of contaminants into the stream channel.

GENERAL SACRAMENTO BASIN STAGE 1 ACTIONS

ACTION 1: Restore seasonal wetlands and encourage wildlife-friendly agricultural practices to support the Central Valley Habitat Joint Venture restoration goals for resident and migratory birds in Sutter, Colusa, Butte, and American Basins.

RATIONALE: The ERP embraces the goals of the Central Valley Habitat Joint Venture, which has a goal of protecting, enhancing, and restoring seasonal wetlands for the benefit of migratory bird species. The ERP will focus on actions to enhance existing but degraded seasonal wetland habitat and in promoting wildlife-friendly agricultural practices.

ACTION 2: Acquire at least 100,000 acre-feet of water from willing sellers for environmental uses in the Sacramento Basin, San Joaquin Basin and the Delta. (Note: action also listed as San Joaquin Basin action.)

RATIONALE: Alteration of the flow regime in Bay-Delta tributaries and changes in Bay-Delta hydrodynamics have contributed to ecosystem degradation. Purchasing water from willing sellers will provide water that can be used to:

- Provide passage flows for adult anadromous fish;
- Provide pulse flows for emigrating juvenile salmonids;
- Improve habitat conditions by reducing water temperatures;
- Prevent diversion effects on fish through exchange agreements with diverters;
- Provide flushing flows to maintain the quality of aquatic habitat;
- Provide flows for riparian habitat maintenance, regeneration, and succession;
- Provide flows to inundate floodplains.

This 100 TAF is not a part of CVPIA flows; rather, it is additional water necessary to meet the broader objectives of the CALFED Ecosystem Restoration Program and will be coordinated with the Environmental Water Account.

DRAFT SAN JOAQUIN RIVER BASIN STAGE 1 ACTIONS

SAN JOAQUIN RIVER BASIN DESCRIPTION

The San Joaquin River and its tributaries are an important component of the Bay-Delta ecosystem. The tributaries in the basin can be restored to provide important spawning, rearing, nesting, and wintering habitat for a variety of species.

Factors most influencing the ecological health of tributaries in the San Joaquin River Basin include:

1. Reductions in the magnitude, frequency, duration, and variability of river flows because of dam construction and diversions.

2. Reductions in the amount of coarse sediment available to create and maintain important aquatic and riparian habitat because of dam construction, aggregate mining in active river channels, and relatively narrow levees that increase shear stress applied to channel bed sediments.

3. Disruption of sediment transport and expansion of habitat that favors non-native and invasive species from excavation pits formed by aggregate mining operations.

4. Reductions in the amount and contiguity of riparian habitat because of urban and agricultural encroachment and levee construction.

5. Elevated water temperatures because of dam construction, diversions, return flows, captured excavation pits, and the loss of riparian habitat.

6. Degradation of spawning and rearing habitat because of excessive loads of fine sediments and urban, industrial, and agricultural discharges of pollutants.

7. Loss of river-floodplain interactions because of levee construction.

STAGE 1 APPROACH

Since most of the tributaries in the San Joaquin River basin are regulated by large dams, it will be necessary to conduct targeted research and to monitor Stage 1 actions to determine the optimal combinations of flow and sediment that will best restore aquatic and riparian habitat in light of the regulated flow regime.

The primary species that will benefit from Stage 1 actions implemented in the San Joaquin River basin are fall-run chinook salmon.

Stage 1 actions also focus on the Tuolumne River as a demonstration stream. The objective for each demonstration stream is to fully restore the tributary within existing constraints (such as large dams) so that each becomes a healthy, resilient haven of continuous riparian and aquatic habitat to optimize endemic plant and animal populations. Restoring the Tuolumne River into a healthy riparian corridor during Stage 1 will help recover and maintain large populations of fall-run chinook salmon to endure severe ecological conditions such as droughts. The Tuolumne River was selected as a demonstration stream because it generally offers the best habitat conditions in the basin for fall-run chinook salmon, and it has a well-organized stakeholder group to help implement restoration actions.

TUOLUMNE RIVER STAGE 1 ACTIONS

The Tuolumne River has potential to be a demonstration stream representative of tributaries of the San Joaquin Basin. Demonstration watersheds will be selected for large-scale implementation of restoration actions to significantly restore ecological processes and resources while simultaneously testing restoration hypotheses as part of an adaptive management approach. Lessons learned restoring the Tuolumne River will help the design and refinement of future restoration actions on the Tuolumne River and other Bay-Delta tributaries.

The Tuolumne has potential to be a demonstration stream for several reasons. It generally has the highest volume of inflow (1.9 MAF) of the three tributaries to the San Joaquin River; therefore it generally provides greater opportunity to release flows for ecological benefits. Historically, the Tuolumne River also contributed a larger percentage to Central Valley salmon escapement than the other tributaries to the San Joaquin River, so emphasizing restoration in this river has the potential to provide more benefits to stabilizing populations of anadromous fish. The Tuolumne River also has an organized watershed group, Tuolumne River Technical Advisory Committee (TRTAC), to facilitate implementation of restoration actions. TRTAC has already begun preparing the site-specific environmental documentation and acquiring permits for several restoration actions; consequently, it may be feasible to implement a larger number of actions in the first seven years of implementation as compared to other watersheds.

ACTION 1: Fill in in-channel excavation pits.

RATIONALE: Past aggregate mining operations excavated deep pits in the Tuolumne River channel. The size of the excavation pits reduces the velocity of water flow and increases ambient water temperatures, creating conditions that favor both non-native (large- and small-mouth bass) and native (Sacramento pikeminnow) species that prey upon juvenile anadromous fish. Since most of the spawning habitat for anadromous fish in the Tuolumne River is located upstream of these excavation pits, juvenile anadromous fish emigrating to the Bay-Delta and ocean are subject to increased risk of predation. The excavation pits also serve as sediment traps by capturing coarse bedload material transported from upstream reaches, thereby depriving downstream reaches of important spawning gravels. Filling in the excavation pits will eliminate habitat that favors non-native or invasive fish species and reduce the risk of predation upon juvenile anadromous fish, and it will also be a prerequisite to restoring sediment transport processes

ADAPTIVE MANAGEMENT CONSIDERATIONS:

- As in-channel excavation pits are filled in, monitor the number of large-mouth bass (the principal predator for juvenile anadromous fish) and the number of juvenile anadromous fish that escape from the river to help assess the relative effect of predation upon population size.
- Monitor ambient water temperatures to assess the relative contribution of excavation pits to elevated water temperatures in the Tuolumne River.

CURRENT OR RECENT RESTORATION ACTIVITIES OR INVESTIGATIONS:

CALFED Restoration Coordination funds have been provided to fill one of the larger instream excavation pits on the Tuolumne River.

ACTION 2: Fill in floodplain excavation pits and remove or setback protective berms and levees that isolate floodplain excavation operations.

RATIONALE: Aggregate mining activities on floodplains of the Tuolumne River excavate deep pits that are usually separated from the main river channel by relatively narrow berms and levees. Relatively moderate flood flows can breach these protective levees and berms, allowing the river to capture the floodplain pits that provide habitat for non-native and invasive fish species that prey upon juvenile anadromous fish. The berms and levees that isolate floodplain excavation pits from the main river channel can also concentrate flows and increase the shear stress applied to the channel bed, thus scouring important spawning gravels and incising the channel. Filling floodplain excavation pits in danger of being captured by peak flows will help eliminate potential habitat for non-native and invasive fish species that prey upon juvenile anadromous fish. Filling the pits will also allow confining levees and berms to be removed or set back, which will re-connect the river with a portion of its floodplain, thereby increasing flood storage and conveyance capacity and providing room for the river channel to meander. Removing or setting back the protective levees and berms will also reduce shear stress on the channel bed and help prevent spawning gravels from being flushed from the system. Strengthening setback levees and berms will also help to better protect continuing aggregate mining operations.

ADAPTIVE MANAGEMENT CONSIDERATIONS:

- Monitor the availability and distribution of spawning-sized gravel in reaches where levees are removed or set back.

CURRENT OR RECENT RESTORATION ACTIVITIES OR INVESTIGATIONS:

CALFED Restoration Coordination funds have been provided to fill floodplain excavation pits and to set back protective levees and berms along one section of the Mining Reach of the Tuolumne River.

ACTION 3: Introduce spawning-sized gravel to the Tuolumne River channel.

RATIONALE: Dams in the Tuolumne River watershed trap all of the gravel derived from upstream reaches, thereby depriving downstream reaches of important material required to maintain aquatic and riparian habitat. Introducing spawning-sized gravel into the river channel will help to improve and increase the amount of spawning habitat available for anadromous fish by compensating for the coarse sediment load trapped behind dams.

ADAPTIVE MANAGEMENT CONSIDERATIONS:

- Restoring spawning habitat in the river will likely require the introduction of a large supply of spawning-sized gravel initially to compensate for past deficits caused by sediment trapping behind dams and past aggregate mining activities in the active channel. It will be necessary to determine the amount of gravel required for this initial infusion of gravel in light of the regulated flow regime of the river.

- Long-term river management will require balancing the river's sediment budget in light of the regulated flow regime of the river, which will require periodic infusions of gravel to compensate for sediment trapped behind dams. It will be necessary to determine the amount of gravel to be introduced periodically, as well as a schedule for gravel augmentation, to restore the river's sediment budget.

CURRENT OR RECENT RESTORATION ACTIVITIES OR INVESTIGATIONS:

CALFED Restoration Coordination funds have been provided to place spawning-sized gravel in the Tuolumne River channel between La Grange Dam and Basso Bridge.

ACTION 4: Purchase flood easements or floodplain land from willing sellers.

RATIONALE: Re-connecting the river channel with a portion of its floodplain can provide several ecological benefits. In conjunction with sufficient flows to mobilize fine sediments, restored floodplains can trap fine sediments, thereby preventing them from being stored in the river channel where they can degrade spawning habitat. Floodplains also contribute woody debris and organic material to the river channel, helping to create diverse aquatic habitat and to stimulate food web production. The purchase of flood easements or floodplain lands can also provide room for the river to meander by eliminating or setting back levees and by eliminating bank protection activities that degrade riparian habitat. The purchase of conservation easements or floodplain land can also allow the protection and restoration of riparian habitat.

ADAPTIVE MANAGEMENT CONSIDERATIONS:

- Monitor floodplain storage of flood flows.
- Monitor the introduction of nutrients and organic material to the channel downstream of restored floodplains.
- Compare groundwater levels and groundwater discharges to the channel in reaches with restored floodplains with reaches confined by relatively narrow levees.

CURRENT OR RECENT RESTORATION ACTIVITIES OR INVESTIGATIONS:

CALFED Restoration Coordination funds have been provided to purchase 42 acres of floodplain land and a conservation easement on 140 acres of floodplain land on the Tuolumne River downstream of La Grange Dam to protect riparian habitat.

ACTION 5: Purchase water from willing sellers to increase the magnitude of fall flows. (Note: this water will be part of the 100 TAF of water purchased to improve stream flows in the Sacramento and San Joaquin Basins.)

RATIONALE: The Tuolumne River contributes a significant portion of the Central Valley's fall-run chinook salmon. The FERC Settlement Agreement for the New Don Pedro Project establishes a schedule for releasing minimum streamflows throughout the year, based upon the type of water year. Scheduled releases during the adult migration period include a 2-3 day attraction pulse flow (except in critically dry and dry water years) followed by fall base flows ranging from 100 cfs in critically dry water years to 300 cfs in above normal and wet water years. The superimposition of redds—the creation of spawning nests on top of already created spawning nests—suggest that the fall base flows are inadequate to distribute spawning throughout the channel, especially in dry and critically dry years. Increasing fall base flows by purchasing water from willing sellers will expand the wetted perimeter of the channel and make more aquatic habitat available for spawning. It will also allow fall-run chinook salmon to use spawning gravels located further away from the center of flow in the channel (the thalweg), which will make the redds less susceptible to scour during moderate floods while the eggs are incubating.

ADAPTIVE MANAGEMENT CONSIDERATIONS:

- As fall base flows are increased, monitor the rate of redd superimposition and the distribution of spawning habitat used.
- Monitor the proportion of redds scoured by moderate floods.

CURRENT OR RECENT RESTORATION ACTIVITIES OR INVESTIGATIONS:

The FERC Settlement Agreement has established a schedule of minimum flow releases based upon the type of water year, which has increased the amount of flow released to the lower Tuolumne River and helped to improve habitat conditions.

ACTION 6: Explore actions to reduce ambient water temperatures, including increasing flows by purchasing water from willing sellers or developing new water supplies, as well as protecting and restoring riparian habitat.

RATIONALE: Elevated ambient water temperatures in the Tuolumne River can be stressful or lethal to the early life stages of anadromous fish. Filling or isolating instream and floodplain excavation pits will help to reduce ambient water temperatures, but additional measures may be necessary to further reduce water temperatures. Purchasing water from willing sellers or developing new water supplies will allow increasing flows to reduce water temperatures during periods of egg incubation and juvenile anadromous fish emigration. Protecting and restoring riparian habitat will also help to increase the amount of shaded pool habitat, which is important temperature refugia for juvenile anadromous fish.

ADAPTIVE MANAGEMENT CONSIDERATIONS:

- Evaluate the effectiveness of filling or isolating excavation pits on ambient water temperatures and determine if they are still stressful or lethal to anadromous fish.
- Evaluate the role of temperature refugia created by riparian habitat in reducing the effects of elevated water temperatures on anadromous fish.
- Evaluate the relative contribution of agricultural return flows upon elevated water temperatures.
- Evaluate the effectiveness of increased groundwater discharge associated with restored floodplains upon elevated water temperatures.

CURRENT OR RECENT RESTORATION ACTIVITIES OR INVESTIGATIONS:

The Vernalis Adaptive Management Program (VAMP) includes provisions to release water from San Joaquin River tributaries to evaluate the effects of flow upon San Joaquin River water quality.

ACTION 7: Evaluate entrainment rates at small diversions and assess their affect upon population size of native and anadromous fish.

RATIONALE: DFG has identified 36 diversions on the lower Tuolumne River; however, it is unknown if these diversions significantly affect, both individually and cumulatively, the population size of anadromous fish species. Evaluating entrainment rates at these small diversions will help assess their relative impact upon populations of anadromous fish species. If it is determined that the individual or cumulative impact of these diversions is significant, then ERP managers will work with willing local diverters to change the timing of diversions and to evaluate its effectiveness in reducing entrainment rates. If these diversions still produce a significant individual or cumulative impact upon fish populations, then ERP managers will work with willing diverters to consolidate, relocate, or screen the diversions.

ADAPTIVE MANAGEMENT CONSIDERATIONS:

- Determine the individual and cumulative effects of diversions upon population size of fish species.
- Evaluate the effectiveness of changing the timing of diversions upon reducing entrainment rates.
- Evaluate the effectiveness of consolidating diversions or relocating diversions to areas less sensitive to fish species.

ACTION 8: Increase enforcement to reduce illegal harvest of fish.

RATIONALE: Several factors affect the population of adult anadromous fish that return to the Tuolumne River to spawn each year, including hydrologic conditions in previous years, ocean conditions, and harvest rates. Illegal harvest of fish reduces the number of adult spawners. Especially during years when the population of adult spawners is already low, poaching can constitute a significant threat to the viability of a species. Increasing enforcement can help discourage poaching.

ADAPTIVE MANAGEMENT CONSIDERATIONS:

- Determine the relative impact of poaching upon the population size of anadromous fish species.

TARGETED RESEARCH : Conduct a feasibility study of expanding the reservoir release capacity of New Don Pedro Dam.

RATIONALE: The current reservoir release capacity of New Don Pedro Reservoir is 14,500 cfs. Expanding the release capacity of New Don Pedro Reservoir could increase the flexibility of managing the flood pool. In addition to enhancing flood protection, expanding the release capacity could also provide greater energy to initiate downstream channel migration in conjunction with restoration actions intended to re-connect the river channel with its floodplain (such as setback levees or levee removal, and the purchase of floodplain land or flood easements).

ADAPTIVE MANAGEMENT CONSIDERATIONS:

- Determine the flow necessary to drive channel migration in the lower Tuolumne River, and use this flow as a target release capacity for the feasibility study.

TARGETED RESEARCH: Evaluate the feasibility of re-operating flood releases from New Don Pedro Reservoir to improve channel maintenance flows, in balance with downstream flood protection.

RATIONALE: Threshold flows of a certain magnitude are required to mobilize and distribute coarse sediments, to scour vegetation that has encroached into the active channel, and to flush fine sediments onto floodplains. Re-operating flood releases from New Don Pedro Reservoir may be able to provide flows sufficient to sustain these important ecological processes without significantly affecting water supply.

ADAPTIVE MANAGEMENT CONSIDERATIONS:

- The magnitude of channel maintenance flows will vary based upon changing conditions in: the amount and size of coarse sediments (both natural and introduced sources) available for transport and distribution; the age and density of encroaching vegetation; and the amount of fine sediments stored in the channel.

MERCED RIVER STAGE 1 ACTIONS

ACTION 1: Isolate dredger pits from the active river channel.

RATIONALE: Old gravel mining operations created large pits in Merced River floodplains. Insufficient levees designed to separate the mining pits from the river have been breached during high flow events. The dredger pits can elevate water temperatures, and they provide habitat for both native and exotic fish species that prey upon juvenile anadromous fish. Isolating these pits from the active channel could help to reduce water temperatures and the loss of juvenile fish to unnaturally high levels of predation

ADAPTIVE MANAGEMENT CONSIDERATIONS:

- Estimate rates of predation upon juvenile anadromous and resident fish species by non-native, warm water fish species.
- Evaluate water temperatures in the channel before and after dredger pits are isolated from the main channel.
- Evaluate rates of gravel recruitment and transport before and after dredger pits are isolated from the main channel.
- Compare interaction between surface flow and groundwater flow in vicinity of isolated dredger pits with reaches not bordered by dredger pits to estimate the amount of surface water lost from the stream channel to dredger pits.

CURRENT OR RECENT RESTORATION ACTIVITIES OR INVESTIGATIONS:

FY' 97 Category III funds were provided to help fill in or isolate gravel mining pits

MAINSTEM SAN JOAQUIN RIVER STAGE 1 ACTIONS

ACTION 1: Improve instream flows by purchasing water from willing sellers or providing alternative water supplies that will allow diverters to reduce diversions. (Note: this water will be part of the 100 TAF of water purchased to improve stream flows in the Sacramento and San Joaquin Basins.)

RATIONALE: Additional water is needed to augment flows on the San Joaquin River below the Merced River to provide attraction flows for adult salmonids and out-migration flows for juvenile salmonids. Additional flows may also have the benefit of diluting pollutants and reducing diversion effects in the South Delta.

ADAPTIVE MANAGEMENT CONSIDERATIONS:
- VAMP

CURRENT OR RECENT RESTORATION ACTIVITIES OR INVESTIGATIONS:
- VAMP

ACTION 2: Develop a cooperative strategy to acquire floodplain easements along the lower San Joaquin River consistent with the Sacramento and San Joaquin River Basins Comprehensive Study.

RATIONALE: The U.S. Army Corps of Engineers, the California Reclamation Board and the Department of Water Resources is conducting the Comprehensive Study to develop a strategy to reduce flood damage while incorporating ecosystem restoration through structural and non-structural measures. This is an opportunity to cost-effectively restore large expanses of ecologically important floodplains while improving flood protection by through cost sharing and integrated project design and implementation. A variety of measures including levee setbacks and riparian restoration on the mainstem San Joaquin River would meet objectives of the Comprehensive Study and the Ecosystem Restoration Program.

GENERAL SAN JOAQUIN BASIN STAGE 1 ACTIONS

ACTION 1: Acquire at least 100,000 acre-feet of water from willing sellers for environmental uses in the Sacramento Basin, San Joaquin Basin and the Delta. (Note: action also listed as Sacramento Basin action..)

RATIONALE: Alteration of the flow regime in Bay-Delta tributaries and changes in Bay-Delta hydrodynamics have contributed to ecosystem degradation. Purchasing water from willing sellers will provide water that can be used to:
- Provide passage flows for adult anadromous fish;
- Provide pulse flows for emigrating juvenile salmonids;
- Improve habitat conditions by reducing water temperatures;
- Prevent diversion effects on fish through exchange agreements with diverters;
- Provide flushing flows to maintain the quality of aquatic habitat;
- Provide flows for riparian habitat maintenance, regeneration, and succession;
- Provide flows to inundate floodplains.

This 100 TAF is not a part of CVPIA flows; rather, it is additional water necessary to meet the broader objectives of the CALFED Ecosystem Restoration Program and will be coordinated with the Environmental Water Account.

Appendix E: Strategic Plan for Managing Nonnative Invasive Species:

A CALFED Bay-Delta Program Strategic Plan for Managing Nonnative Invasive Species in the San Francisco Bay-Delta Estuary/Sacramento-San Joaquin Rivers and Associated Watersheds

July 2000

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SUMMARY

The purpose of this Non-native Invasive Species (NIS) Strategic Plan is to provide guidance for management actions to prevent introductions, provide control and mitigate impacts of non-native species that have invaded or may invade the ecosystems of the San Francisco Bay-Delta, the Sacramento/San Joaquin Rivers and their watersheds. This document has been developed for the CALFED Bay-Delta Program. It is an important first step in the coordinated response to this serious problem and communicates the scope of activities necessary to effectively deal with NIS.

The plan discusses the problem and identifies the goals and major issues relevant to feasible, cost-effective management practices and measures to be taken by federal, state, local and other programs to prevent and control NIS infestations in a manner that is environmentally sound. It is important to note that the information developed by NIS activities will be provided to the CALFED Program Managers and the Comprehensive Monitoring, Assessment and Research Program in order to assist these CALFED elements to more effectively achieve CALFED goals and objectives.

The focus of this plan is directed at the San Francisco Bay-Delta estuary, the Sacramento-San Joaquin Rivers and the associated watersheds in California, though it is recognized that the solution area may be statewide and beyond.

This strategic management plan is based on the following three goals:

- Goal I: Preventing new introductions and establishment of NIS into the ecosystems of the San Francisco Bay-Delta, the Sacramento/San Joaquin Rivers and their watersheds.
- Goal II: Limiting the spread or, when possible and appropriate, eliminating populations of NIS through management.
- Goal III: Reducing the harmful ecological, economic, social and public health impacts resulting from infestation of NIS through appropriate management.

The template for much of this document comes from the efforts to develop a State Plan for California. Contributions for that effort came from the California Resources Agency, California Department of Food and Agriculture, US Fish and Wildlife Service, US Department of Agriculture - Agricultural Research Service and US Army Corps of Engineers. Also contributing to this document were staff from the CALFED agencies and participants from academia, non-profit groups, stakeholder groups and individuals with technical experience with NIS. The information contained in the Strategic Plan for the Ecosystem Restoration Program (September 30, 1998) and the draft Ecosystem Restoration Program Plan, Volume I (October 1, 1998), both CALFED Bay-Delta Program documents, provided further information for this plan. Public comments also will be solicited from local governments and regional entities, and public and private organizations that have expertise in the control of NIS. Comments will be considered and revisions made to the plan, as appropriate.

While this plan provides guidance, it does not stand alone as an instrument to deal with the problem. With this coordinated effort, California will have a more efficient approach for implementing California NIS strategies. Besides the CALFED Bay-Delta Program, California entities should find the document useful for designing projects,

preparing proposals, and prioritizing activities related to the NIS issue.

INTRODUCTION

Most often, the suitability of environmental conditions determines a species range. Normal changes in a species range can also occur over great distances as a result of transport mechanisms such as wind and ocean currents and dispersion by migrating species. Some NIS establish new ranges with little effect on their new surroundings. However, some NIS have established themselves, spread unimpeded and caused substantial negative economic and ecological impacts.

Over the past one hundred years, many NIS have been introduced to the San Francisco Bay-Delta. Within the last few decades, the frequency of intra- and international transfer has been greatly accelerated by various human activities. Some scientists fear that the international trend is toward species homogeneity. Some of the species introductions have been intentional, such as ornamental plants, certain agricultural crops and livestock. Others have been inadvertent; introduced through releases from the horticulture trade, pet trade, aquaculture activities, dumping of ballast water, escapees, etc.

NIS affect ecosystems in several ways that are of concern. The extinction of native species can be attributed first to habitat destruction and secondly to introduced species, whose impacts may include habitat alteration, trophic alteration, community spatial alteration, gene pool deterioration, introduction of diseases and parasites, and contaminant dynamics (Kohler and Courtenay).

One of the many underestimated affects of NIS is the potential for contaminants to be consumed, resuspended and incorporated into the food chain by organisms that have been introduced. In the Great Lakes, there are reports that PCBs and cadmium are being cycled from the water column and sedimented to the bottom of the lakes due to the presence of zebra mussels. In a similar fashion, Asian clams are bioaccumulating contaminants at a remarkable level (Cd and Se in particular) in northern San Francisco Bay. Since its arrival, there are much higher levels of Se in the livers of demersal feeders (diving ducks and sturgeon) in Northern San Francisco Bay.

Genetic pollution refers to the process by which NIS threaten natives with alien genes. Though this is not a new phenomenon, comprehensive treatments of invasion ecology in the mid-1980s did not include genetic competition as a threat. Increasing numbers of NIS and their inter-fertility mean that hybridization is a substantial threat to native biotas.

Ecological engineers are species with particularly great habitat effects; they change the physical and chemical environment through various means. This often results in rendering the habitat unsuitable for historic use, often leading to habitat loss for native species. A good example of this is the plant *Spartina alterniflora*, which invades mudflats and converts them into extensive stands of cordgrass. This alteration disturbs sediment dynamics and reduces shorebird feeding and reproduction habitat.

Some species may find themselves adapting to NIS as a matter of necessity. When riparian habitats are taken over by giant reed or aquatic habitats are taken over by water hyacinth or Egeria, the animals that use these environments to reproduce, feed or escape predation must develop the means to utilize the diminished habitats to survive. This can complicate strategies to remove or otherwise manage non-native invasive plant species, especially if listed wildlife species are observed using the undesirable vegetation.

Strategies to remove or control NIS must consider possible conflicts of this nature to avoid causing unnecessary, significant harm to special status species or other species of concern.

THE PROGRAM

This Strategic Plan has been made possible through the funding of CALFED and the support of CALFED agency, academic, non-profit and stakeholder participants. As CALFED has developed the goals and objectives of their program, they have come to recognize that NIS is a significant stressor of the Bay-Delta. The result has been the initiation of a CALFED NIS Program charged with the responsibility to develop a long-term Strategic Plan, an Implementation Plan, directed projects, an open solicitation for proposals, and coordination of the resulting projects. The U. S. Fish and Wildlife Service has agreed to develop and coordinate this program, in cooperation with CALFED programs and members. The initial funding is $1.25 million, which will be allocated over FY99 and FY 00. It is anticipated that at least $1,050,000 will be available for on-the-ground work over this two year period and that CALFED funding will become available in future years to continue with implementation actions as identified in the Plans.

In May 1995, the CALFED Bay-Delta Program was established to Arestore the ecological health and improve water management for beneficial uses in the Bay-Delta system. To accomplish this, a draft Ecosystem Restoration Program Plan has been developed to increase aquatic and terrestrial habitats, improve ecosystem functions and reduce the effects of stressors, which includes non-native invasive species.

Management actions of this Strategic Plan will be consistent with the objectives identified in the **STRATEGIC PLAN FOR ECOSYSTEM RESTORATION PROGRAM** (ERP) dated September 30, 1998. Goal 5 of the ERP plan is "Prevent establishment of additional non-native invasive species and reduce the negative biological and economic impacts of established non-native species."

The ERP objectives identified for this goal are to:

Objective 1: Eliminate further introductions of new species in ballast water of ships.

Objective 2: Eliminate the use of imported marine baits.

Objective 3: Halt the introduction of freshwater bait organisms into the waters of Central California.

Objective 4: Halt the deliberate introduction and spread of potentially harmful species of fish and other aquatic organisms in the Bay-Delta and the Central Valley.

Objective 5: Halt the release of fish and other organisms from aquaculture operations into Central California waters, especially those imported from other regions.

Objective 6: Halt the introduction of invasive aquatic and terrestrial plants into Central California.

Objective 7: Halt the release and spread of aquatic organisms from the aquarium and pet trades into the waters of Central California.

Objective 8: Reduce the impacts of exotic mammals on native birds and mammals.

Objective 9: Develop focused control efforts on those introduced species for which control is most feasible and of greatest benefit.

Objective 10: Prevent the invasion of the zebra mussel into California.

The NIS program will work to develop close linkages with the CALFED Program Elements and CMARP. These linkages will enable those programs to take advantage of the information generated by the NIS program activities and facilitate recognition of the special issues and concerns that NIS present to the estuary in general and to specific Program Elements. This insight will allow development of a better understanding of effective ways to address NIS as the work to accomplish the CALFED goals and objectives proceeds.

The purpose of this strategic plan is to provide a planned approach for management actions to address prevention, eradication, control and impacts of NIS that have invaded or may invade the ecosystems of the San Francisco Bay-Delta estuary, the Sacramento/San Joaquin Rivers and their watersheds. This plan should serve as a basic model for resource managers responsible for implementing programs to protect and enhance ecosystems in California.

THE MISSION

The mission of the CALFED Nonnative Invasive Species Program:

PREVENT ESTABLISHMENT OF ADDITIONAL NON-NATIVE SPECIES AND REDUCE THE NEGATIVE ECOLOGICAL AND ECONOMIC IMPACTS OF ESTABLISHED NON-NATIVE SPECIES.

The mission is consistent with Goal #5 of the ERP Strategic Plan.

THE GOALS

Following are the three goals of the CALFED NIS Program with a brief explanation of the problem and some insight into the issues, current activities and necessary actions.

GOAL I: PREVENT NEW INTRODUCTIONS OF NIS INTO THE ECOSYSTEMS OF THE SAN FRANCISCO BAY-DELTA, THE SACRAMENTO/SAN JOAQUIN RIVERS AND THEIR WATERSHEDS.

PROBLEM: The introduction of NIS into California, including inland state waters, frequently causes environmental, socioeconomic, and public health impacts. The severity of these impacts is not widely known or recognized which impedes the investment of resources needed to prevent new NIS introductions. Also, a delayed "crisis-response" approach often limits the vision and opportunity for the prevention of new introductions, leaving California with NIS management problems that are economically costly, technically challenging, if not infeasible to solve, and frequently irreversible. Although numerous NIS already have been introduced into California ecosystems, new introductions continue to occur. The prevention of new introductions is critical in the amelioration of NIS problems in California.

California has a long and successful history of preventing the introduction of exotic invasive pests that threatened California agricultural and natural resources. The strategy of CDFA's Pest Prevention System is consistent with the strategies of the Aquatic Nuisance Species Plans currently developed by other states (Washington, Ohio, New York, etc.) and regions (Colorado River Basin). A major component of CDFA's Pest Prevention systems is the Pest Exclusion Program which includes a statewide network of border station and port inspection activities. Although these areas of inspection concentrate on agricultural pests, they have intercepted non-native aquatic species. For example, California border station employees have intercepted 18 vessels, from eastern and mid-western states, that contained zebra mussels. Three of these vessels contained live zebra mussels. A fourth vessel was so heavily infested that live specimens were probably present and treatment was recommended prior to allowing the vessel into California waters.

Detection of zebra mussels and other NIS at the border stations has potentially saved hundreds of millions of dollars in economic losses associated with impacts to water conveyance systems, hydroelectric power plants and loss or alteration of natural aquatic habitats. California will benefit by expanding CDFA's Exclusion Program to include NIS. The US Department of Agriculture and US Department of Interior should enter into partnership with CDFA and the California Resource Agency to identify ways to expand CDFA's Exclusion Program and obtain the needed funding to accomplish this task. The CALFED Program could play a vital role in facilitating this effort.

Multiple mechanisms transport NIS into California's waters and some mechanisms transcend the authority of a single state to control. A prime example is ballast water discharge from transoceanic shipping, the largest source of nonindigenous aquatic species invasions worldwide {Carlton 1985}. Cooperative efforts are necessary between state, federal (i.e., Coast Guard and USDA), and international agencies to promulgate and enforce regulations to ensure that ballast management practices and other related transport mechanisms are employed to prevent NIS introductions. There is much attention currently directed at the efforts in the San Francisco Bay to encourage responsible ballast water management practices through the use of existing regulations. There is more extensive discussion of these activities in the Policy Background section.

Current technology is frequently inadequate to prevent new introductions of NIS into California ecosystems. Research on prevention strategies to minimize NIS transport, such as innovative ballast water management technology, is critical in the effective prevention of NIS introductions. Ongoing studies by the U.S. and Canadian Coast Guards indicate that it is especially important to deal with the difficult problem posed by vessels entering the coastal and major navigable waters with residual unpumpable ballast water and sediment in their tanks. This medium, potentially harboring a variety of NIS, is often mixed with California's fresh water and discharged at another California location or port. In order to achieve more effective emptying or flushing of these tanks, the feasibility of altering the current design of ballast tanks needs to be examined. Other significant transport mechanisms increasing the potential for new introduction of NIS into California include the aquaculture business, commercial barge traffic, recreational boating, the bait industry, the pet shop trade, plant nurseries, and fish stocking activities- all of which have the potential to introduce NIS as well as associated parasites and other disease organisms. The pet shop and aquatic plant nurseries trade are quite problematic, offering increasing numbers of easily introduced aquatics like Hydrilla. In some cases, such activities are subject to little or no regulation. In cases where laws and regulations do exist, they are frequently not well publicized or enforced. There are often gaps in the current laws. There is further explanation of the existing laws in the Policy section. An extensive effort must be made to reach out to user groups that could potentially introduce NIS into California and are generally not adequately informed of NIS prevention practices.

GOAL II: LIMIT THE SPREAD OR, WHEN POSSIBLE AND APPROPRIATE, ELIMINATING POPULATIONS OF NIS THROUGH MANAGEMENT.

PROBLEM: The spread of established populations of NIS into uninfested areas is often via human activity, such as boat transfers, ballast exchange, bait handling, water transport, intentional introduction by anglers, and ornamental and landscape practices. Limiting the spread of such populations is problematic due to the numerous pathways of dispersal, the complex ecological characteristics associated with NIS populations, and the lack of technology that is needed to limit the spread.

Many public and private resource user groups are not aware of existing infestations of NIS in San Francisco Bay, Sacramento-San Joaquin Estuary, or the inland waters of California, and why they cause problems. The probability of NIS spread to other waters can increase when resource user groups are not aware of the consequences of illegal introductions of NIS, or how their routine activities can cause the dispersal of NIS into uninfested areas. An information and education program is needed to provide information on why the spread of NIS populations needs to be limited, how the NIS populations can be reduced, and also the value of healthy ecosystems that support a diverse native community. Information and education is also critical to strengthening public and private support for statewide participation in NIS management strategies.

It is also difficult to manage the spread of NIS since infestation frequently occurs in watersheds that occupy more than one county. Cooperation among all counties in California sharing NIS infested watersheds is needed to implement consistent management strategies that will effectively limit the spread of NIS populations.

GOAL III: REDUCE THE HARMFUL ECOLOGICAL, ECONOMICAL, SOCIAL AND PUBLIC HEALTH IMPACTS RESULTING FROM INFESTATION OF NIS THROUGH APPROPRIATE MANAGEMENT.

PROBLEM: The NIS infestations in California can have ecological, economic, social and public health impacts. Strategies to control NIS and efforts to abate their impacts are not always known or technically and/or economically feasible. It should be recognized that these efforts are no substitute for prevention, which should always be the highest priority.

The NIS infestations in California's aquatic ecosystems can alter or disrupt existing ecological processes. Without co-evolved parasites and predators, some NIS out-compete and even displace native plant or animal populations. As part of this process, the invading species can also influence the foodwebs, nutrient dynamics, and biodiversity of the ecosystems. To abate the ecological impacts of the invading organism, it is necessary to understand the mechanisms by which the species disrupts the natural balance of the ecosystem.

Some introduced NIS to California have provided economic benefits, such as those supporting the aquaculture business and sportfishing industry. However, several NIS have been found to cause adverse economic impacts. Organisms invading California's waters can threaten public health through the introduction of disease, concentration of pollutants, contamination of drinking water, and other harmful human health effects. An extensive abatement system for these NIS needs to be established to prevent human health problems from occurring in California.

It is often difficult to assess the ecological, socio-economic and public health impacts of NIS in terms that are meaningful to decision makers and the general public. Actions to abate NIS impacts through control strategies are frequently impeded by circumstances, such as the absence of political support and the lack of resources needed to effectively develop and implement control strategies.

The strategic approach to this plan recognizes prevention as the most practical, economic and environmentally safe method for dealing with new or incipient infestations. An effective prevention program must include an exclusion component to prevent introductions into California, a detection component to identify incipient infestations and an integrated pest management component to eradicate or control species with minimal or transitory impact to the habitat and nontarget species. All three components need to have strong research, public information and awareness support to be effective, timely and responsive. For NIS already widely established and distributed, this plan emphasizes an ecosystem approach to management, (as opposed to a species by species approach) utilizing integrated pest management methods that are flexible and environmentally sound.

NIS IN THE BAY-DELTA

In the last one hundred years, there have been over 212 introductions of species into the Sacramento-San Joaquin Estuary. Many of these species are believed to have traveled here via ballast water of ships. The incidence grows with the increase in trade between Pacific Rim nations because many species are carried in the ballast water of ocean-crossing vessels. Since 1970, many new species of zooplankton, clams, amphipods, crabs and fish have become established in the Sacramento-San Joaquin Estuary (Cohen and Carlton, 1995).

Aquatic ecosystems such as the Sacramento-San Joaquin Delta are comprised of many interrelated organisms which include phytoplankton (algae), macrophytes (vascular plants), invertebrates, fish, birds and mammal. These organisms require a certain set of chemical and physical conditions to exist, such as oxygen, light, nutrients adequate movement of water and adequate space.

Scientists and other NIS experts have recognized the fact that healthy ecosystems are impacted by the establishment and spread of exotic species. A habitat that is disturbed seems to be at even higher risk for establishment and negative impacts due to introduced species. The CALFED program includes an aggressive and expensive effort to increase shallow water habitats in the Delta, as well as restore the health of those already in existence. Failure to identify and develop a comprehensive strategic approach to the problem associated with invasive aquatic species could negate or undermine benefits gained from these efforts (increasing flows, reclaiming agricultural lands and eliminating or redistributing levees) to improve and expand habitat for native, beneficial, and endangered aquatic species.

In the last hundred years, human mobility has greatly accelerated and with this movement plants and animals have been introduced, either deliberately or accidentally into new environments with unforeseen consequences. Starlings, the boll weevil, rats in Hawaii, the zebra mussel and sea lamprey in the Great Lakes, and water hyacinth in California's Sacramento-San Joaquin Delta are some of the infamous cases of species becoming pests when introduced into new environments. The Nature Conservancy in a recent report entitled "America's Least Wanted" details how approximately 4000 exotic plant and 2300 exotic animal species have threatened native species and how some of these exotics have ended up costing the economy an estimated $97 billion.

AQUATIC PLANTS

Submersed, emersed, and floating aquatic plants are natural and important components of aquatic ecosystems. In a well balanced aquatic ecosystem, aquatic plants provide protective cover for fish as well as habitat and a source of food for organisms consumed by fish. Aquatic plants also provide nesting sites and food for birds and other animals. In addition, aquatic plants can increase water clarity and quality and improve the appearance of a water body.

The spread of nonnative flowering aquatic plants has increased dramatically over the past 25 years in California and has created many economic and ecological impacts. Demands on the state's water resources, which include irrigation water delivery, recreational and domestic (drinking) uses, and fisheries and waterfowl habitats, have exacerbated these impacts. The introductions of NIS have consistently upset the delicate ecological balance of many aquatic systems. Furthermore, large-scale infestations of aquatic NIS have proven to be a severe impediment to boating, fishing, swimming, water delivery, and generation of hydroelectric power. The hallmark of aquatic invaders is their ability to grow in low light levels and their rapid, prolific, and varied reproductive abilities.

According to the California Department of Food and Agriculture, the aquatic plant species causing most of the problems in California are: *Eichhornia crassipes* (water hyacinth), *Egeria densa* (Egeria), and *Myriophyllum spicatum* (Eurasian water milfoil). There is also an intensive *Hydrilla verticullata* (Hydrilla) control program underway to limit the spread and reduce the impacts from this aquatic plant. This program intends to contain this pest and prevent it from causing widespread problems.

Water hyacinth has been under management for 15 years, and a bill authorizing the management of Egeria passed the state legislature in 1996. The combined costs of these efforts to control fewer than 25% of the infestations will probably equal or exceed the $1 million annual Hydrilla eradication expenditures. Management of water hyacinth and Egeria by using biological control agents may be the long-term goal, yet safe and effective herbicides and mechanical control strategies need to be used in the interim to prevent further spread of these weeds.

Wetland Plants

Several invasive plant species on the California Exotic Pest Plant Council's (CALEPPC) list of plants of greatest ecological concern threaten the wetland habitats of the Bay-Delta system. Cordgrass introduced from the Atlantic coast has spread very rapidly in Pacific estuaries in northern California, Oregon, Washington, and British Columbia and now invades the San Francisco Estuary. The introduction of smooth cordgrass (*Spartina alterniflora)* has led to dense coverage of about 30% of the intertidal area in Willapa Bay, Washington. The introduction to San Francisco Bay has resulted in rapid colonization of the south end of the bay. It is now known to hybridize with *Spartina foliosa*, the native cordgrass, which confounds the problem of identification and eradication.

Spartina alternaflora and *S. densiflora* are the introduced cordgrass species of greatest concern (Grossinger and Cohen,1998). *Spartina patens* and *S. anglica* are of secondary concern according to this report based on input from regional wetland scientists and managers.

Smooth cordgrass is a substantial threat to wildlife, fisheries, and traditional uses of Pacific estuaries. Replacing the naturally open mud of Pacific estuaries with monospecific grass prairie, the dense canopy and tightly interlocked rootmats of these weeds exclude shorebirds, native vegetation, fish, and many invertebrates. Scientists that study and document these impacts, sometimes refer to NIS which invade in this manner, altering the physical characteristics of the habitat, as ecological engineers.

Other wetland invasive species include those found in upland-wetland transitions, but are now invading high-marsh terraces. Pepperweed (*Lepidium latifolium*) is a particularly aggressive invader and is proving difficult to eradicate. Its rhizomes can be resistant to herbicide applications and it is fairly euryhaline. *Salsola soda,* a member of the Chenopodiaceae family, is another plant that threatens native pickleweed marshes. In a recent survey Tamasi (1998) reports *S. soda* in the Bay-Delta system from Calhoun Cut near Hastings Tract down to the southern end of the South Bay. Grossinger and Cohen (1998) cite both of these species as needing attention.

Riparian Plants

Recent introduction and spread of purple loosestrife *(Lythrum salicaria)* threaten the state's riparian systems. It has recently been observed invading some Delta levees (e.g. White Slough). According to CALEPPC's 1996 list of exotic pest plants of greatest concern, purple loosestrife status is red alert. Giant reed (*Arundo donax*) is another species that is receiving considerable attention both nationally and in California. There are now five regional teams dedicated to control and eradication of giant reed in the state. This plant is known to aggressively displace native riparian vegetation and is so disruptive that it affects water quality and quantity, exacerbates flooding, and alters the geomorphology of the waterway it invades. Giant reed is widespread throughout the CALFED problem and solution areas.

Other plants that threaten our riparian or wetland systems include blue gum eucalyptus (*Eucalyptus globulus*), salt cedar (*Tamarix* spp.), Russian olive (*Eleagnus angustifolia*), Himalayaberry (*Rubus discolor*), Cape ivy (*Delairea odorata*; formerly known as German ivy, *Senecio mikanioides*), hoary cress (*Cardaria draba*), tree of heaven (*Ailanthus altissima*), thistles (*Cirsium arvense* and *C. vulgare*), and periwinkle (*Vinca major*).

The above species are only a few of the approximately 80 species listed as Aproblem exotic plants reported in California wetlands from a survey of resource managers representing six bioregions of the state (Dudley,1998). Clearly, much work remains to be done in identifying the threats to wetland and riparian habitats posed by these invasions, prioritizing research and eradication, and monitoring progress.

CLAMS AND ZOOPLANKTON

One species having a major impact is the small Asian clam, *Potamocorbula amurensis*. After it first appeared in 1986, the clam rapidly colonized the brackish water portion of the estuary throughout San Francisco Bay to the western edge of the Delta. It was the dominant bivalve south of San Mateo Bridge by 1991. The clam has affected the base of the food web by removing much of the algae, which is food for zooplankton. This clam is so abundant that calculations indicate that the population can filter a volume of water equal to the entire water column in 24 hours. It has apparently greatly reduced abundance of the native copepod *Eurytemora affinis*, a dominant zooplankton species providing food for many larval fish. Ironically, some recently accidentally introduced zooplankton species now provide food for young fish and may help fill the void caused by the decline in *Eurytemora affinis*. The mysid *Acanthomysis bowmani* was first reported here in 1993 and has increased in abundance, while the native mysid *Neomysis mercedis*, another important food item for young fish may have been greatly reduced in abundance through competition for food with the Asian clam.

CRABS

Two exotic crabs, the Chinese mitten crab *Eriocheir sinensis* from Asia and the green crab *Carcinus maenas* native to Europe, have also become established in the Estuary. The mitten crab, first found in South San Francisco Bay in 1992, was collected in the Delta in the fall of 1996 and since then has traveled upstream in the Sacramento River north of Colusa and upstream in the San Joaquin to Gustine. The mitten crab may have been deliberately and illegally introduced or it may have been introduced via ballast water. It is known to damage rice crops in China, and it is a potential competitor of crayfish, which supports a commercial fishery and is an important forage species for fish in the Delta. The mitten crab potentially could burrow into and weaken the levee system in the Delta if it becomes more abundant. The green crab is non-burrowing but inhabits the intertidal zone in San Francisco Bay, San Pablo Bay and has been found in Suisun Bay where it may compete with shorebirds and other crabs for food. The green crab is a voracious predator of shellfish and native shore crabs, and it is believed that it could fundamentally alter Bay-Delta invertebrate species distributions, and imperil aquaculture such as oyster farming. It has apparently spread rapidly from San Francisco Bay, where it was first captured in 1989 or 1990 (Cohen and Carlton, 1995), up the coast of California to Willapa Bay and Grays Harbor, Washington.

FISH

It is well known that a number of introduced fish have become established in this estuary over the past one hundred years. They include striped bass, catfish and several members of Centrarchidae. Some of these fish now support popular fisheries and are considered by many to be a valued recreational feature of the watershed. Outside of the Sacramento-San Joaquin Delta, unauthorized planting of the Inland silverside, *Menidia beryllina*, into Clear Lake occurred in 1967, and it was likely dispersed into the Delta from Clear Lake by high winter flows. The fish was established in the estuary by 1975. It is suspected to prey upon larvae of other fish and may compete for food with the delta smelt, *Hypomesus transpacificus*, a threatened species. The delta smelt is also faced with the threat of hybridization and competition with a morphologically similar smelt species, the wakasagi, *Hypomesus nipponensis*. A growing problem in California is ill-advised anglers who desire and introduce exotic species. Intentional illegal introductions can have great economic consequences. The white bass, *Morone americana*, a species native to the Midwest, was eradicated from Kaweah Reservoir in Tulare County with rotenone in 1987. Northern pike, *Esox lucius*, another species native to the Midwest, was illegally stocked into Frenchman Reservoir, Plumas County, in the 1980s. In March 1991, the Department of Fish and Game treated Frenchman Reservoir and successfully eradicated northern pike. A similar program was conducted in 1997 to eradicate northern pike from Lake Davis in Plumas County. Biologists were concerned that if these two predatory fish species became established throughout the watershed, they would decimate populations of salmon, trout and other fish, including some that are threatened or endangered. These eradication efforts cost over one million dollars each. These expenditures are necessitated by the irresponsible behavior of a few individuals who either do not understand or do not care about the environmental and economic consequences of their illegal actions.

NONNATIVE WILDLIFE

Nonnative wildlife is present throughout the Sacramento-San Joaquin Valleys in a variety of habitats. These include aquatic, riparian scrub, woodland and forest habitats; valley oak woodland; grassland and agricultural land. Non-native wildlife species negatively impact native organisms mainly through predation or competition. These nonnatives often have a competitive advantage because of their location in hospitable environments where the normal controls of disease and natural enemies are missing. The result is diminished abundance of native species. Some of the common but harmful species found in the Bay-Delta area are:

- The European red fox, which threatens many native endangered wildlife species, such as the clapper rail and several other San Joaquin Valley animals.
- The Norway rat, which threatens ground-nesting wildlife, has experienced large increases in the populations living along the bay shores.
- The feral cat which is a major predator to bird and mammal populations in the wetland areas of the Bay-Delta estuary.

IMPLEMENTATION ISSUES

The development of this Plan has led to the conclusion that there is one element that is necessary to the success of any program which addresses the prevention, management and eradication of NIS. That essential element is a group of individuals that come together to form an advisory council to monitor and coordinate the efforts of the program. For this Plan, the formation of this group is identified as a Programmatic Action below.

PROGRAMMATIC ACTION

PROGRAMMATIC ACTION: FORMATION OF AN INTERAGENCY NON-NATIVE INVASIVE SPECIES ADVISORY COUNCIL (NISAC) TO MONITOR MANAGEMENT EFFORTS AND ASSURE EFFECTIVE COORDINATION OF THIS PROGRAM WITH CALFED AND OTHER NIS PROGRAMS.

California natural and man made water conveyance and impoundment systems are available and utilized for multiple purposes. In addition, there is a complex mosaic of federal, state and local laws and regulations which not only address intended use of these resources but will impact efforts to prevent the introduction, establishment and management of NIS. To facilitate accomplishment of the strategic goals, this program must coordinate with jurisdictions within and outside the state and build tasks and actions upon sound science. Therefore, mechanisms will be established to ensure that all prevention, control and abatement tasks and actions developed and implemented by this program under this plan are (1) done in cooperation with federal agencies, local governments, interjurisdictional organizations and other entities, as appropriate (2) based upon the best scientific information available, (3) conducted in an environmentally-sound and conscientious manner and (4) coordinated through NISAC.

As presented in the Implementation Section on page 7, there are also a number of major issues critical to achieving the goals as presented in this plan. These issues are discussed below and will be addressed as objectives of the Implementation Plan with specific Tasks and Actions.

LEADERSHIP, AUTHORITY AND ORGANIZATION

As the program develops, one of the components essential to actual implementation will be to identify the leadership, authority and organization that are necessary to accomplish each goal. In some cases, there will be existing organizations that have the leadership and authority to carry out the actions identified in the plan. The CALFED NIS Program will develop relationships and support the efforts of these organizations. It may be that other tasks and actions determined to be essential to the success of the program do not have the leadership, authority or organization in place. In these instances, we will work to identify and/or develop the appropriate component needed to carry out the work as a part of the CALFED NIS Program.

COORDINATION, COOPERATION AND PARTNERSHIP

For all of the work undertaken as part of this program, the value and necessity of the elements of coordination, cooperation and partnership to the success of the program can not be overstated. At all times and in all aspects of the work, priority will be given to these ideals and we will strive to incorporate them into every aspect of plans made and actions taken. There are many entities and organizations developing or operating programs to address NIS, including local, regional, state and national. The programs and organizations that deal with the issues and organisms that are of concern to the CALFED objectives will be identified and cooperative relationships will be developed with these entities. Emphasis will be given to projects where partnerships can be developed to improve efficiency, support and effectiveness of activities. There is further discussion of this issue in the Policy Background section.

EDUCATION AND OUTREACH

A comprehensive awareness and education program is critical for an effective NIS management program. Except for isolated cases that have attracted substantial media attention, the general public does not understand how NIS negatively impact the environment, the economy and the use of the natural aquatic resources that are important to them. Therefore, a strategic approach to NIS must include an education and awareness component for all actions and tasks presented. Developing and implementing a coordinated and comprehensive information program will expand understanding by all California citizens of the impacts and risks associated with the introduction and spread of NIS.

Information about the nature, characteristics, and the impacts of NIS on the environment, economy, and quality of life needs to be made more available. This information should be presented concurrently with information about related issues such as threatened and endangered species, water quality, habitat restoration, and ecosystem health. An important aspect of this program will be developing outreach to inform and educate not only the public, but also private entities that may be contributing to the problems and/or may be affected by project actions. The need for understanding and managing NIS should be institutionalized in public and environmental education curricula. A well-coordinated effort is needed because of the costs and complexities associated with developing and delivering a comprehensive, high caliber outreach program.

A successful education and information program must utilize individuals and institutions with expertise on raising public awareness and influencing attitudes towards NIS management. Public information specialists can be utilized to develop, distribute and coordinate information statewide. In addition, information specialists can enhance public interest and improve citizen and organizational involvement to reduce the spread of NIS. Raising awareness can be achieved via television spots, ad campaigns, outreach to schools, and public service announcements.

An increased awareness and concern of California citizens should precipitate an increased level of commitment by elected officials toward NIS management. Many federal and state legislators have little understanding of the risks associated with NIS and this has had a negative impact on obtaining sufficient long-term funding. An immediate priority should be the development of briefing packages and presentations for national, state, and local officials and interest groups.

FUNDING AND RESOURCES

In California, the funding for management of NIS is not reliable or consistent and in many cases is inadequate or nonexistent. This is especially true in the areas of exclusion, education, emergency response, research and management. Funds are generally available on a reactive basis and do not effectively deal with infestations before they become unmanageable. Except for the Hydrilla Program conducted by California Department of Food and Agriculture, or the Northern Pike Program conducted by California Department of Fish and Game, funds for NIS are usually provided only after the problems become widespread, provide resources for only limited control efforts and do very little to prevent further spread to uninfested areas.

Costs associated with this management plan and associated implementation plans must be identified. The CALFED Program has provided initial funding for development of the NIS Program and to begin high priority projects. It is the intent of the CALFED Program that as future funding becomes available, the CALFED NIS Program will continue to receive support to carry out the NIS projects that will contribute to the success of the CALFED Program objectives. Also, traditional sources of financial support which will be pursued include the US Fish and Wildlife Service, ANS Task Force, US Army Corps of Engineers, US Environmental Protection Agency, Natural Resource Conservation Service and the National Fish and Wildlife Foundation. For federal agencies, allocations of discretionary funds will likely be inadequate. It is necessary to acquire dedicated funding to assure the continuity and viability of this Program. At the state level, one or more agencies may have to submit Budget Change Proposals to obtain long-term funding in support of a statewide management program. It should be recognized that discretionary funding would not be adequate to address the full scope of this problem. Funding needs are substantive and appropriations will be necessary to carry out this Plan.

In addition to traditional funding sources, a working group within the NISAC, should develop a number of nontraditional funding options for NISAC consideration and recommendation. These funding options should recognize that management of NIS benefits all Californians and will actually prove cost-effective over the long term.

Other nontraditional sources of revenue and resources involve cooperative agreements and partnerships. Federal, state, local agencies and private organizations with NIS management responsibilities should be encouraged to coordinate, share, or pool resources. This can include shared purchase of supplies and use of equipment, savings for bulk purchases of chemical supplies, use of staff and other human resources, sharing of mapping and monitoring data and expertise, biological control and educational materials.

MONITORING, MAPPING AND ASSESSMENT

As part of the CALFED program, a Comprehensive Assessment, Monitoring and Research Program (CMARP) is under development to address the needs of CALFED's common programs and related agency programs regarding monitoring, research and assessment. The CALFED NIS Program will communicate and coordinate with all pertinent CMARP programs and activities.

Ecosystems infested with NIS are not consistently identified and delineated. Complete up- to-date maps, displaying the distribution and severity of NIS infestation are available in only a few areas. Knowledge of which species are located where is paramount for: 1) increasing public awareness and concern, 2) obtaining support and funding for developing a strategic program, 3) accurately predicting where new infestation may occur from already infested areas and, 4) developing effective integrated management and prevention plans with specific actions to mitigate or prevent NIS impacts.

Risk assessment involves identifying geographic areas that may be at risk for successful establishment of particular species. This type of assessment can be an essential element of a successful prevention program by identifying areas of specific concern and affording the opportunity to direct resources in the most beneficial and efficient manner.

A georeferenced ecosystem inventory, mapping and monitoring system will be based on standards which allow for easy exchange of information among federal, state and local agencies as well as private organizations and form the basis of a Bay-Delta GIS for NIS.

An integral component of the goals to prevent and limit spread of NIS is early detection monitoring and rapid response. It is important to identify and monitor susceptible areas on a regular basis in an effort to detect invasions early and allow the best possible chance of successful management for the least cost and disruption. Examples of areas more susceptible to invasions include those in close proximity to ports with ballast water discharges and areas of physical ecosystem disturbance such as newly restored areas.

Research and Technology Transfer

A strong commitment to research and information/technology transfer is critical towards achieving the goals presented in this management plan. The CALFED NIS Program will communicate and coordinate with CMARP, the coordinating entity for the common programs of monitoring, research and assessment, in their efforts to identify research needs. A subcommittee within NISAC will meet annually to review and prioritize research needs already identified by various entities, as well as newly identified research gaps relative to the goals and objectives of the plan. A report and recommendations, including suggested opportunities for funding critical research should be submitted to the NISAC and other interested groups following the annual review. This commitment also extends to the transfer of information to a wide audience through many venues to assure coordination and cooperation with others involved in the same type of endeavors.

Enforcement and Compliance

In those areas where enforcement and compliance are identified as an issue, this program will develop the information base to illustrate and define the issue, describe possible approaches, and make recommendations to appropriate agencies to enhance the adherence to regulations. As programs to prevent, control, and manage NIS are cooperatively developed, certain practices or prohibitions may emerge as mandatory requirements for specific entities in order for the three management goals to be accomplished. It will be necessary for responsible agencies to monitor the compliance with such requirements. In these cases, enforcement mechanisms will be essential to encourage compliance with recognized standard practices.

Program Evaluation

To be effective and responsive this management program and associated implementation plans must include an evaluation component to identify progress, evaluate implementation problems and needs, and make necessary corrections at any time. The adaptive management strategy will be highlighted. The evaluation process will include:

1. Develop a peer review process for program evaluation using the technical expertise and experience of the national, regional, and local groups identified in this report as entities familiar with the issues of NIS.

2. Coordinate and communicate with CMARP for the CALFED program evaluation process.

3. Establishment of an evaluation subcommittee within NISAC responsible for reviewing performance measures, conducting the evaluation efforts, reporting the results to NISAC and others if required, and identifying program or plan adjustments that address projected outcomes.

4. The three program goals, as previously presented, provide the focal point for evaluation. Quantifiable milestones for each goal and objective will be developed and have realistic, feasible time frames.

5. The evaluation process will involve those with implementation responsibility, resource user groups, and others affected by the program implementation.
6. An annual report highlighting progress and achievements will be prepared and distributed. The annual report will include evaluation of the efficacy of the program strategies and tasks and identify revisions as needed. The annual report will be readily available on the Internet and distributed to local and federal agencies and

legislative decision-makers and CALFED program managers.

POLICY BACKGROUND

The complex environmental and economic impacts posed by the intrusion of NIS require policies and programs to address prevention and control at various levels of government. In addition, improved coordination of new and existing policies could more effectively focus attention on the problems and achieve more positive results. The following overview describes the basic role of the federal, regional and state governments in implementation of efforts to address NIS. The contents of this section includes:

- The CALFED role in implementing restoration of the San Francisco Bay-Delta estuary and Sacramento-San Joaquin Rivers and their watersheds and the objectives of that program with regard to nonnative invasive species.

- The federal Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 (NANPCA, Public Law 101-646) and the reauthorization of The National Invasive Species Act of 1996 (NISA).

- Executive Order on Invasive Species issued by President Clinton in February of 1999 which was intended to coordinate a federal strategy to address the growing environmental and economic threat of NIS.
- An assessment of California's existing laws and programs that address prevention and control of NIS.

Immediate and strategic coordinated federal and state action is critical for effective NIS prevention and control in North American waters. For example, over 212 aquatic nuisance species have already become established in the San Francisco Bay-Delta estuary watershed alone. The rate of invasion appears to be increasing due in part to expanded national trade and travel. Reducing the acceleration of invasions will require managing transport mechanisms including the discharge of ship ballast water, aquaculture activities, global trade in aquarium organisms, live seafood and live bait. Prevention of new NIS introductions coupled with long-term research on control strategies are priorities.

CALFED ROLE

The CALFED Bay-Delta Program was established to develop a long-term solution to the problems affecting the Bay-Delta system. Building on the spirit of cooperation reflected in the December 1994 Bay-Delta Accord, a group of state and federal agencies have come together to work cooperatively at developing and implementing a long-term comprehensive plan that will restore the ecological health and improve water management for beneficial uses of the Bay-Delta system.

The Ecosystem Restoration Program (ERP) is the principal Program component designed to restore the ecological health of the Bay-Delta ecosystem. The ERP represents one of the most ambitious and comprehensive ecosystem restoration projects ever undertaken in the United States. The goal of the ERP is to restore or mimic ecological processes and to increase and improve aquatic and terrestrial habitats to support stable, self-sustaining populations of diverse and valuable species.

As part of the ERP, the U.S. Fish and Wildlife Service has accepted the responsibility of developing, implementing, managing, and coordinating a non-native invasive species program in the San Francisco Bay-Delta estuary which will include terrestrial as well as aquatic species. This program, with the contributions of CALFED staff, agencies, academia, non-profits and interested stakeholders, will focus on the San Francisco Bay-Delta, the Sacramento and San Joaquin Rivers and their watersheds.

CALFED MEMBER AGENCIES:

STATE:

The Resources Agency
- Department of Fish and Game
- Department of Water Resources

California Environmental Protection Agency
- State Water Resources Control Board

Department of Food and Agriculture

FEDERAL:

Environmental Protection Agency

Department of the Interior
- Fish and Wildlife Service
- Bureau of Reclamation
- U.S. Geological Survey
- Bureau of Land Management

U.S. Army Corp of Engineers
Department of Agriculture
Natural Resources Conservation Service
Department of Commerce
National Marine Fisheries Service
Western Area Power Administration

FEDERAL ROLE

INVASIVE SPECIES COUNCIL

The expanded federal effort to address NIS includes the Executive Order on Invasive Species signed by President Bill Clinton on February 3, 1999. This action is intended to build upon existing laws such as the National Environmental Policy Act, NANPCA, The Lacy Act, Federal Plant Pest Act, Federal Noxious Weed Act, and the Endangered Species Act. The order creates an Invasive Species Council which has eighteen months to develop a comprehensive plan to minimize the economic, ecological, and human health impacts of invasive species and determine the steps necessary to prevent the introduction and spread additional invasive species. This council will be co-chaired by Secretary of the Interior, Secretary of Agriculture, and Secretary of Commerce and will work in cooperation with the Secretary of State, Department of Defense, Secretary of Transportation, the Administrator of the Environmental Protection Agency, states, tribes, scientists, universities, shipping interests, environmental groups and farm organizations to combat invasive plants and animals. In addition, the President's fiscal year 2000 budget proposes an additional $29 million to support these efforts.

NONINDIGENOUS AQUATIC NUISANCE PREVENTION AND CONTROL ACT

NANPCA was primarily a federal response to the Great Lakes invasion of the zebra mussel which has caused extensive ecological and socioeconomic impacts. Although the zebra mussel issue played a key role in prompting passage of the legislation, NANPCA clearly was established to prevent the occurrence of new unintentional introductions of aquatic nuisance species (ANS) and to limit the dispersal and adverse impacts of invasive species currently in United States waters.

The actions identified in NANPCA are a first line of defense against aquatic nuisance invasions. The Act provides an institutional framework that promotes and coordinates research, develops and applies prevention and control strategies, establishes national priorities, educates and informs citizens, and coordinates public programs. The Act calls upon states to develop and implement comprehensive state management plans to prevent introduction and control the spread of aquatic nuisance species (ANS). Section 1002 of NANPCA outlines five objectives of the law, as follows:

- To prevent further unintentional introductions of nonindigenous aquatic species;
- To coordinate federally funded research, control efforts and information dissemination;
- To develop and carry out environmentally sound control methods to prevent, monitor, and control unintentional introductions;
- To understand and minimize economic and ecological damage; and
- To establish a program of research and technology development to assist state governments.

Section 1201 of the Act established the national Aquatic Nuisance Species Task Force (ANSTF), co-chaired by the U.S. Fish and Wildlife Service (USFWS) and the National Oceanic and Atmospheric Administration (NOAA). The Task Force is charged with coordinating governmental efforts related to prevention and control of ANS. The ANSTF (consisting of seven federal agency representatives and eight ex-officio members representing nonfederal governmental agencies) has adopted the ANS program under Section 1202 of NANPCA. This program recommends the following elements:

- Prevention: Establish a systematic risk identification, assessment and management process to identify and modify pathways by which ANS spread.
- Detection and Monitoring: Create a national ANS information center to coordinate efforts to detect the presence and monitor the distributional changes of all nonindigenous ANS,

identify and monitor the impacts to native species and other effects, and serve as a repository for that information.

- Control: The Task Force or any other potentially affected entity may recommend initiation of a nonindigenous ANS control program. If the Task Force determines that the species is a nuisance and control is feasible, cost effective and environmentally sound, a control program may be approved.

The ANSTF recommends research, education and technical assistance as strategies to support the elements listed above. The Task Force also provides national policy direction as a result of protocols and guidance that have been developed through the efforts of working committees. The ANSTF currently has two regional panels, the Great Lakes Panel and the Western Regional Panel. The latter was added as part of a 1996 amendment to NANPCA. The new law of 1996 (NISA) expanded the focus of the original legislation from zebra mussels to all potential ANS and enlarged the area of concern from the Great Lakes/Hudson River to all of the U.S. In addition, NISA requires that the Coast Guard (USCG) draft regulations to implement a ballast water management program nation-wide. This new program was to be patterned after the program established under NANPCA for the Great Lakes/Hudson River.

The USCG regulations will apply to all vessels with ballast on board that enter U.S. waters from outside the Exclusive Economic Zone (EEZ). These vessels will be encouraged to *voluntarily* comply with the International Maritime Organization=s (IMO) guidelines for ballast exchange at sea, and will be *required* to submit a report form to the USCG documenting where, when and how they dealt with their ballast.
Ballast procedures allowed under the proposed regulations:

1. open ocean exchange in at least 500 meters of water, or
2. retain ballast on board, or
3. obtain approval for using an alternate method in a given situation, or
4. discharge ballast in an approved Aalternate exchange zone.

Reporting requirements under the new regulations:

1. record ballast procedures on the IMO form;
2. fax the information to the USCG upon arrival in port;
3. retain records on board for at least 2 years.

The USCG regulations have been circulated for public review and comment. It is anticipated that the rule will become final in April 1999. The voluntary guidelines will become mandatory if vessels fail to comply with ballast exchange procedures or fail to submit the report forms to the USCG. The statute requires the USCG to report to Congress within 18 months of the effective date of the regulations, providing information on the level of voluntary compliance. It is anticipated that a mandatory program, if needed, would be implemented in 2000 or 2001.
The USCG will establish a Clearinghouse to retain the report forms and to be a central repository for ballast management-related information/studies. Such information will include; patterns of invasion, measures of compliance and effectiveness of IMO procedures, a national database of exotic species, the economic and environmental impacts of the invaders, and the economic impacts of control measures. The Smithsonian Environmental Research Center (SERC) will maintain the Clearinghouse.

Locally, the proposed federal project to deepen the Oakland Harbor Channel to allow larger ships into the Port of Oakland has raised concerns about increases in ballast water releases. San Francisco Baykeeper and the Center for Marine Conservation have been actively encouraging the Port of Oakland, the Army Corp. of Engineers and the consulting agencies, (U.S. Fish and Wildlife Service and the National Marine Fisheries Service) to fully evaluate the potential impacts of non-native species introduction into the San Francisco Bay. The Port of Oakland has agreed to require that all ships calling at the Port exchange their ballast water at sea, except in emergencies. While applauding this step as a positive effort to reduce introductions, a full consultation under the Endangered Species Act is desired by these groups, as they feel that it may result in more information and more effective and stable control measures.

CLEAN WATER ACT

The objective of the Clean Water Act (CWA) is to restore and maintain the chemical, physical, and biological integrity of the Nation's waters, and where attainable, to achieve a level of water quality that provides for the protection and propagation of fish, shellfish, and wildlife, and for recreation in and on the water.

Discharges of pollutants and fill material to waters of the United States are regulated under various sections of the CWA. In California, the U.S. Environmental Protection Agency (EPA) has delegated the authority to implement the CWA to the State Water Resources Control Board (SWRCB), which in turn has designated the nine Regional Water Quality Control Boards (RWQCBs), established under the State's Porter-Cologne Water Quality Control Act, as the implementing agencies.

The mission of RWQCBs, under the State's Porter-Cologne Act, is consistent with the objective of the CWA, namely, to protect beneficial uses of waters of the state. To accomplish this objective, RWQCBs use various planning and permitting programs authorized under the CWA. Section 402 authorizes the National Pollutant Discharge Elimination System (NPDES), which is a permit program intended to reduce and eliminate the discharge of pollutants from point sources that threaten to impair beneficial uses of water bodies. The State's Waste Discharge Requirements, discussed below, incorporate the authority of the federal NPDES permitting program for discharges of wastes to surface waters.

The CWA defines point sources to include vessels (Section 502(14)); and prohibits all point source discharges of pollutants into U.S. waters unless a permit has been issued either under Section 402 (NPDES) or Section 404 (dredge and fill activities). The CWA provides a narrow exemption from the usual CWA regulations for certain discharges (including ballast water) only for Armed Forces vessels (Section 502(6)(A)). However, these discharges are to be regulated by an EPA- and DOD-sponsored proposed rule under Section 312(n) of the CWA, Uniform Discharge Standards for Vessels of the Armed Forces.

Under Section 305(b) of the CWA, RWQCBs are required to assess water bodies for attainment of beneficial uses every two years, and report to the EPA. In cases where beneficial uses of water bodies are shown to be impaired, Section 303(d) requires the RWQCBs to list the impaired water bodies and "establish a priority ranking for such waters, taking into account the severity of the pollution and the uses to be made of such waters." Section 502(6) defines "pollutant" as dredged spoil, solid waste, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt and industrial, municipal, and agricultural waste discharged into water.

Ballast water is considered to be a "waste" by the RWQCBs, based on the above definition and definitions in the State Water Code, described below. Based on these federal and state definitions and scientific evidence, the San Francisco Bay RWQCB has made a finding that ballast water has created "pollution" in the estuary. In February 1998, the San Francisco Bay RWQCB listed the waters of the San Francisco Bay-Delta Estuary as impaired under Section 303(d) because of introductions of NIS.

Section 303(d) of the CWA requires implementing agencies to establish and allocate "a total maximum daily load (TMDL) for those pollutants which the (EPA) Administrator identifies under Section 304(a)(2) as suitable for such calculation." This section of the CWA was developed to support a water quality-based system of effluent limits for chemical pollutants, and the interpretation of what an allowable load of invasive species has not been defined. Historically, for instance for sewage treatment plants, the regulations of the CWA have supported a permitting sequence of (1) technology-based effluent limits, and (2) water quality-based effluent limits. Water quality-based limits, of which TMDL is an example, are considered necessary if technology-based limits do not lead to attainment of adequate water quality to protect beneficial uses.

100TH MERIDIAN INITIATIVE

The U.S. Fish and Wildlife Service is developing the 100th Meridian Initiative: A Control Plan to Prevent the Westward Spread of Zebra Mussels and other

Aquatic Species. The goal of this initiative is to prevent the spread of zebra mussels and other ANS west of the 100th meridian. It is comprised of 6 components: 1) information and education 2) voluntary boat inspections and boater surveys 3) commercial boat hauling 4) monitoring 5) rapid response 6) evaluation. This initiative will be coordinated with the jurisdictions that straddle the 100th meridian and those further west, tribes and private entities such as water and power companies.

The CALFED NIS Program will work with the 100th Meridian Initiative in an effort to address the CALFED Strategic Plan Objective #10) Prevent the invasion of zebra mussel into California.

Federal agencies with regulatory authority over introduction and transport of aquatic species which may be invasive or noxious include, US Department of Agriculture Animal Plant Health Inspection Service (USDA-APHIS), USDA Agricultural Marketing Service (USDA-AMS), US Fish and Wildlife Service (USFWS), US Department of Commerce (USDC) and US Coast Guard (USCG).

Regional Role

On July 8 and 9, 1997 the Western Regional Panel on Aquatic Nuisance Species held their first organizational meeting. The general goals of the WRP are to prevent nuisance species introductions, coordinate activities of the western states among federal, local, and tribal agencies and organizations and minimize impacts of already established nuisance species. Though much emphasis to date has been on the zebra mussel, there is a general recognition of the need to limit introductions of all non-native species.

The WRP will eventually include representatives from the 17 western states, several federal agencies, native Americans and Canada. The panel which meets annually, is chaired by an executive committee consisting of a state, federal, and at-large representatives. The basic structure of the Panel reflects the varying interests and concerns of the western states and is comprised of two elements, the Coastal committee and the Inland committee. It appears that the potential for this group to help California minimize impacts of introduced aquatic species is could be substantial. The purposes of the WRP are to:

- identify western region priorities for responding to aquatic nuisance species;
- make recommendations to the Task Force regarding an education, monitoring (including inspection), prevention, and control program to prevent the spread of the zebra mussel west of the 100th Meridian;
- coordinate, where possible, other aquatic nuisance species program activities in the West not conducted pursuant to the Act;
- develop an emergency response strategy for Federal, State, and local entities for stemming new invasions of aquatic nuisance species in the region;
- provide advise to public and private individuals and entities concerning methods of preventing and controlling aquatic nuisance species infestations;
- submit an annual report to the Task Force describing activities within the western region related to aquatic nuisance species prevention, research and control.

State Role

State and regional management plans for ANS are addressed in Section 1204 of NANPCA. The intent of this Strategic Plan is to focus on the identification of feasible, cost-effective management practices and measures to be taken by various entities to prevent and control NIS infestations of the San Francisco Bay-Delta and its watersheds in an environmentally sound manner. Section 1204 also states that in the development and implementation of the management plans, the state or region needs to involve appropriate local, state, and regional entities as well as public and private organizations that have expertise in ANS prevention and control. These management plans should also identify federal activities dealing with prevention and control measures, including direction of how these activities should be coordinated with state and local efforts. This CALFED NIS Strategic Plan and the Implementation Plan which will follow will be submitted to the ANS Task Force as a Regional Management Plan for the San Francisco Bay-Delta estuary and its watersheds. It is anticipated that a State Management Plan will also be developed and submitted that will include and expand upon the information in this document. There is a Colorado River Basin Regional Plan currently under development as well.

The State of California currently has several statutory and regulatory authorities that address or potentially can address the issue of prevention and control of NIS that impact aquatic and riparian ecosystems. All of these authorities have been developed over time in response to individual target species and their associated concerns. Therefore, no comprehensive, coordinated and vigorously enforced policy framework to deal with problem species and their impacts exists. Clearly, gaps must be identified within the state's policies and statutes and recommendations made. Such improvements may entail developing methods for improving enforcement, coordination, and information dissemination regarding new or existing authorities.

The following existing authorities and policies have been identified relative to California's management of NIS that impact aquatic and riparian ecosystems. Some of these deal more broadly with all species that may invade terrestrial or transitional ecosystem, as well as aquatic ecosystems.

PORTER-COLOGNE WATER QUALITY CONTROL ACT (CALIFORNIA WATER CODE)

The Porter-Cologne Act (also known as the California Water Code or CWC) establishes the system of water quality regulation for the State, including the State Water Resources Control Board (SWRCB) and the nine Regional Water Quality Control Boards (RWQCBs). The Porter-Cologne Act establishes the authority of these agencies to develop statewide water quality control plans and regional basin plans. These plans designate the beneficial uses for specific water bodies, the water quality objectives to protect those uses, and the implementation plans for the attainment of uses and associated water quality objectives. NPDES permits, described above under Clean Water Act, are an important element of the implementation plans of all California basin plans.

Section 13260 of the CWC authorizes RWQCBs to issue waste discharge requirements (WDR) to dischargers of waste into waters of the state, which include ground waters. For discharges to surface waters, WDR are federal NPDES permits, discussed above, which implement both the Clean Water Act and the Porter-Cologne Water Quality Control Act.

Section 13050(l) of the Porter-Cologne Act defines "pollution" as "an alteration of the quality of the waters of the state by waste to a degree which unreasonably affects either beneficial uses or facilities which serve the beneficial uses." Section 13050(d) defines "waste" as sewage and any and all other waste substances, liquid, solid, gaseous, or radioactive, associated with human habitation, or of human or animal origin, or from any producing, manufacturing, or processing operation of whatever nature, including waste placed within containers of whatever nature prior to, and for the purposes of, disposal."

Ballast water is considered to be a "waste" by the RWQCBs, based on the above definitions and definitions in the Clean Water Act. Based on these federal and state definitions and scientific evidence, the San Francisco Bay RWQCB has made a finding under its Clean Water Act authority that ballast water has created "pollution" in the estuary and that it threatens beneficial uses. Therefore, vessels discharging ballast water could be required to obtain WDR/NPDES permits which may contain conditions that could result in requirements for open ocean exchange or treatment of ballast water.

CALIFORNIA ENVIRONMENTAL QUALITY ACT

Requires that agencies adopt feasible mitigation measures in order to substantially lessen or avoid the otherwise significant environmental impacts of a proposed project. This act could be used to ensure appropriate mitigation of projects which result in increased discharges of ballast water.

CODE REGULATIONS

IMPORTATION, TRANSPORTATION AND POSSESSION OF WILD ANIMALS (PROHIBITED SPECIES) (Sections 671-671.7, Title 14, California Code of Regulations, Sections 2116-2118, Fish and Game Code)

Sections 2116-2118 define wild animals, provide a list of prohibited wild animals, provide specific restrictions regarding Atlantic salmon in the Smith

River, extend authority to the Fish and Game Commission to prohibit animals not listed in Sections 2116-2118 and to adopt certain other restrictions which appear in Sections 671-671.7, Title 14, CCR.

Section 671 Title 14, CCR, lists animals designated by the Fish and Game Commission as members of one of two classes of animals which are prohibited: AW or welfare animals (listed to prevent their depletion and/or to assure their welfare), and AD, or detrimental animals (listed because they pose a threat to native wildlife, the agricultural interests of the State, or to public health or safety). Live animals listed in Section 671 may not be imported, transported or possessed, except under special permits issued pursuant to Sections 671.1 through 671.7.

IMPORTATION OF LIVE AQUATIC PLANTS AND ANIMALS (Section 236, Title 14, California Code of Regulations)

Section 236 requires an importation permit for the importation of live aquatic plants and animals, except:
(1) Mollusks and crustaceans intended directly for the live seafood market, and which will not be introduced to waters of the State nor held in waters discharged to waters of the State,

(2) Live ornamental tropical plants or animals not utilized for human consumption or bait, which are maintained in closed systems for personal, pet industry or hobby purposes, and which will not be placed into waters of the State, and

(3) Brine shrimp.

The Department regulates importation of live aquatic plants and animals through review and approval or disapproval of permit applications. Permit applications must be submitted at least ten day before the proposed date of importation. When importation's are approved by the Department they are permitted by either a Standard Importation Permit or a Long-Term Importation Permit. The type of permit issued is determined by the species and by its proposed use.

Standard Importation Permits are issued for importations which are normally inspected by Department of Fish and Game pathologists. Examples are salmon, trout, largemouth bass and other species destined for stocking into aquaculture facilities. An approved Standard Importation Permit permits only one shipment, and the date of shipment and inspection scheduling information is on the permit.

Long-Term Importation Permits are issued for importations which are not normally inspected by Department pathologists and which generally represent little environmental risk. Examples include largemouth bass or Sacramento blackfish destined for direct sale in the live food markets. Long-Term Permits are issued for a period of up to one year, and the number of shipments permitted is normally unlimited.

STOCKING (Sections 6400 and 6431, Fish and Game Code)

Section 6400 prohibits the stocking of plants or animals into State waters without permission of the Department. Amendments to this section in 1998 provided new, severe penalties for violation of this section. Penalties are more severe when the violation involves a nuisance species. Section 6431 defines Anuisance species.

ASSEMBLY BILL 1625 (Sections 12023, 12024, and 12026, Fish and Game Code)

Assembly Bill 1625: This Act, approved by the Governor on September 12, 1998, adds Sections 12023, 12023, and 12026 to the Fish and Game Code.

Section 12023: Any person that violates Section 6400 through the use of aquatic nuisance species, as defined in Section 6431, is guilty of a misdemeanor punishable by all of the following:

1) Imprisonment in county jail for not less than six months or more than one year, a fine of not more than fifty thousand dollars for each violation or both imprisonment and fine.

2) Revocation of all of the defendant's licenses and permits issues pursuant to this code.

A defendant is also liable to the owner of any private or publicly owned property for any monetary damages directly, indirectly and proximately caused by the violation. This also covers escape of aquatic nuisance species, but exempts release through discharge or exchange of ballast water. Also exempt are persons unaware that he or she is in possession of a plant.

Section 12024: A person that violates Section 6400 is liable for all public and private response, treatment, and remediation efforts resulting from the violation, including administrative, legal and public relations costs.

Section 12026: Any person that provides information or evidence leading to the arrest and conviction of a person or persons found guilty of violating Section 6400 is eligible to obtain a reward of up to fifty thousand dollars.

BALLAST WATER (Sections 6432, 6433, Fish and Game Code)

Section 6432: Requires the adoption of International Maritime Organization guidelines for ballast water exchange for all vessels prior to entering California waters.
Section 6433: Requires the department to adopt a ballast water control report form, consistent with the U. S. Coast Guard (USCG) to monitor compliance and shall assist with distributing these forms to vessels.

This has been deferred at the suggestion of USCG pending release of their regulations, expected in April 1999. The State of California (OSPR) and USCG have signed a cooperative agreement affecting various maritime programs; ballast water programs would be subject to such an agreement.

Sale And Transportation Of Aquatic Plants And Animals (Section 238, Title 14, California Code of Regulations)

Section 238 regulates the sale and transportation of live aquaculture products by requiring sales invoices and waybills and requiring that all aquaculture products be killed before leaving retail sale premises.

Stocking Of Aquaculture Products (Section 238.5, Title 14, California Code of Regulations)

Section 238.5 is designed to prevent the unwanted introduction of exotic species, by regulating the private stocking of live fish. It requires a stocking permit for the private stocking of all waters except (1) lakes operated under a Cooperative Stocking Agreement with the Department, and (2) private ponds in the central valley and southern California when the species are limited to certain species designated in this section (common game fish species already established in these parts of the State).

TRIPLOID GRASS CARP STOCKING (Section 238.6, Title 14, California Code of Regulations, Sections 6450-6458, Fish and game Code)

These regulations and statutes regulate the private stocking of triploid grass carp for the control of nuisance aquatic vegetation. Restrictions include stocking permit application review requirements to assure stocking only in safe areas, testing and verification of triploidy (sterility), tagging requirements, monitoring of stocked areas to prevent unauthorized movement of fish, and other restrictions.

BAIT FISH (Sections 4.00 through 4.30, 200, 200.10, 200.12, 200.13, 200.29 and 200.31, California Code of Regulations).
Sections 4.00 through 4.31 provide general statewide restrictions on the species allowed for use as live bait, specific restrictions by regulation district, and in some cases, specific restrictions by water body. Sections 200 through 200.12 provide license requirements for live freshwater bait dealers and restrictions on the transportation and sale of live bait. Sections 200.13 and 200.31 restrict the species sold by live bait. Section 200.29 provides restrictions by species and location on the sources of live bait.

CONTROL MEASURES FOR NON-NATIVE FLORA AS PART OF MANAGEMENT PLANS FOR DFG MANAGED ECOLOGICAL RESERVES AND WILDLIFE AREAS (FISH AND GAME COMMISSION POLICY; Ccr, Title 14 ' 550 AND 630)

Each ecological reserve and wildlife area is managed by the Department of Fish and Game by separate specific plan. The management plans are written in conformance with the California Environmental Quality Act, usually as mitigated Negative Declarations. The Department of Fish and Game's goals to manage and control impacts of prohibited/detrimental species on natural ecosystems in California through (a) leading efforts to eradicate detrimental animal and plant species from wildlife communities and (b) seeking legislation to reduce the number of exceptions in the law that allow prohibited species to be imported and to increase fines and penalties for the introduction of illegal species into the wild.

Taking Of Harmful Fish (Section 5501, Fish and Game Code)

The department may, or prescribe the terms of a permit to, take any fish that is unduly preying upon any bird, mammal or fish or is harmful to other species and should be reduced in numbers.

Hydrilla (Food And Agricultural Code Sections 6048-6049)

These code sections deal specifically with the aquatic plant Hydrilla (*Hydrilla verticullata*). The codes specifically prohibit the production, propagation, harvest, possession, selling or distribution of Hydrilla. Fines and penalties are described for unlawful activities. The director of CDFA is also required to conduct an ongoing survey and detection program for Hydrilla. When discovered, the director is directed to immediately investigate the feasibility of eradication and do so if determined feasible.

In cooperation with the University of California, the U.S. Department of Agriculture or other agencies, the director of CDFA may develop and implement biological control methods to eradicate or control Hydrilla in any area of the State and may conduct studies for these purposes.

In addition to exercising its statutory and regulatory authorities, the State also fosters research and education/outreach programs through various State and federal agencies and local organizations and institutions. Examples include the US Department of Agriculture-Agricultural Research Service, University of California and California State University system, the San Francisco Bay-Delta Interagency Ecological Program, the San Francisco Bay Institute and the Water Education Foundation. Implementation of this management plan is intended to assist the State in enhancing and better coordinating these programs and activities.

Implementation Plan

A CALFED NIS Implementation Plan will be developed in accordance with this strategic management plan. Strategies will be identified to address prevention, management, control and eradication. The Implementation Plan will develop and define objectives for every applicable major issue identified above, as well as the tasks and activities necessary to address the major issues and achieve the three goals, including development of priorities and criteria. It will address these issues in a manner that identifies the who, what, when, where, and how for proposed tasks or actions.

Each year a new implementation plan will be developed to direct and focus future activities. These plans will adopt the adaptive management strategy identified by CALFED, reflecting an evaluation of progress made, new information learned, and necessary actions remaining as projects are completed.

Appendix F: Managing Nonnative Invasive Species

A CALFED Bay-Delta Program Implementation Plan for Managing Nonnative Invasive Species in the San Francisco Bay-Delta Estuary/Sacramento-San Joaquin Rivers and Associated Watersheds

JULY 2000

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SUMMARY

The purpose of this Nonnative Invasive Species (NIS) Implementation Plan is to provide guidance for the specific management actions necessary to address the prevention, control and impacts of nonnative invasive species that have invaded or may invade the ecosystems of the San Francisco Bay-Delta, the Sacramento/San Joaquin Rivers and their watersheds.

The content of this plan focuses on a detailed outline of the Tasks and Actions to be accomplished in an effort to achieve the goals and address the major issues identified in the **STRATEGIC PLAN FOR MANAGING NONNATIVE INVASIVE SPECIES**, dated July, 2000.

The three goals on which the Strategic Plan and this Implementation Plan are based are as follows:

- Goal I: Preventing new introductions and establishment of NIS into the ecosystems of the San Francisco Bay-Delta, the Sacramento/San Joaquin Rivers and their watersheds.
- Goal II: Limiting the spread or, when possible and appropriate, eliminating populations of NIS through management.
- Goal III: Reducing the harmful ecological, economical, social and public health impacts resulting from infestation of NIS through appropriate mitigation.

Program implementation will be guided by the Implementation Plan. The plan focuses on the early period of implementation when needed actions are better known, but also provides a long-term vision for continuing implementation for future years. Adaptive management will adjust future implementation to accommodate what we learn about the system and the response to the early efforts of the NIS Program. It is important to note that, as the efforts to rehabilitate the estuary progress, they should include the establishment and stewardship of native populations.

Contributing to this document were the CALFED agencies and participants from academia, non-profits, stakeholder groups and individuals with technical experience with NIS. The information contained in the Strategic Plan for the Ecosystem Restoration Program (September 30, 1998) and the draft Ecosystem Restoration Program Plan, Volume I (October 1, 1998), both CALFED Bay-Delta Program documents, provided further information for this plan. Public comments also will be solicited from local governments and regional entities, and public and private organizations that have expertise in the control of NIS. Comments will be considered and revisions made to the plan, as appropriate.

WHILE THIS PLAN PROVIDES GUIDANCE, IT DOES NOT STAND ALONE AS AN INSTRUMENT TO DEAL WITH THE PROBLEM. WITH THIS COORDINATED EFFORT, CALIFORNIA WILL HAVE A MORE EFFICIENT APPROACH FOR IMPLEMENTING CALIFORNIA NIS STRATEGIES. BESIDES THE CALFED BAY-DELTA PROGRAM, CALIFORNIA ENTITIES SHOULD FIND THE DOCUMENT ESSENTIAL FOR DESIGNING PROJECTS, PREPARING PROPOSALS, AND PRIORITIZING ACTIVITIES RELATED TO THE NIS ISSUE.

INTRODUCTION

The purpose of this implementation plan is to provide a standard approach for formulating management actions to address prevention, eradication, control and impacts of NIS that have invaded or may invade the ecosystems of the San Francisco Bay-Delta estuary, the Sacramento/San Joaquin Rivers and their watersheds. This plan will serve as a basic model for resource managers responsible for implementing programs to protect and restore natural and modified ecosystems in California.

The primary focus of this plan will be directed at the San Francisco Bay-Delta estuary/Sacramento-San Joaquin Rivers and associated watersheds in California, though actions may be identified that need to be taken on a statewide basis.

In May 1995, the CALFED Bay-Delta Program was established to restore the ecological health and improve water management for beneficial uses in the Bay-Delta system. The mission of CALFED is: to develop a long-term, comprehensive plan that will restore ecosystem health and improve water management for beneficial uses of the Bay-Delta system. CALFED addresses problems in four resource areas: ecosystem quality, water quality, levee system integrity and water supply reliability. The Nonnative Invasive Species Program has been developed under the Ecosystem Quality, Ecosystem Restoration Program, though we recognize that NIS negatively impact all of the CALFED resources areas.

Goal for Ecosystem Quality: The goal for ecosystem quality is to improve and increase aquatic and terrestrial habitats and improve ecological functions in the Bay-Delta system to support sustainable populations of diverse and valuable plant and animal species. To accomplish this, a draft Ecosystem Restoration Program Plan has been developed with goals to increase aquatic and terrestrial habitats, improve ecosystem functions and reduce the effects of stressors which included non-native invasive species. Management actions of this Implementation Plan will be consistent with the objectives identified in the **STRATEGIC PLAN FOR ECOSYSTEM RESTORATION PROGRAM** (ERP) dated September 30, 1998. Goal 5 of that plan is "Prevent establishment of additional nonnative invasive species and reduce the negative biological and economic impacts of established nonnative species." The objectives identified under this goal are:

Objective 1: Eliminate further introductions of new species in ballast water of ships.

Objective 2: Eliminate the use of imported marine baits.

Objective 3: Halt the introduction of freshwater bait organisms into the waters of Central California.

Objective 4: Halt the deliberate introduction and spread of potentially harmful species of fish and other aquatic organisms in the Bay-Delta and the Central Valley.

Objective 5: Halt the release of fish and other organisms from aquaculture operations into Central California waters, especially those imported from other regions.

Objective 6: Halt the introduction of invasive aquatic and terrestrial plants into Central California.

Objective 7: Halt the release and spread of aquatic organisms from the aquarium and pet trades into the waters of Central California.

Objective 8: Reduce the impacts of exotic mammals on native birds and mammals.

Objective 9: Develop focused control efforts on those introduced species for which control is most feasible and of greatest benefit.

Objective 10: Prevent the invasion of the zebra mussel into California.

THE MISSION

The mission of the CALFED non-native invasive species program:

PREVENT ESTABLISHMENT OF ADDITIONAL NON-NATIVE SPECIES AND REDUCE THE NEGATIVE BIOLOGICAL AND ECONOMIC IMPACTS OF ESTABLISHED NON-NATIVE SPECIES.

This mission is consistent with Strategic Goal 5 of the ERP Strategic Plan.

THE GOALS

The three goals on which this implementation plan is based are as follows:

- **GOAL I: PREVENTING NEW INTRODUCTIONS OF NIS INTO THE ECOSYSTEMS OF THE SAN FRANCISCO BAY-DELTA, THE SACRAMENTO/SAN JOAQUIN RIVERS AND THEIR WATERSHEDS.**

- **GOAL II: LIMITING THE SPREAD OR, WHEN POSSIBLE AND APPROPRIATE, ELIMINATING POPULATIONS OF NIS THROUGH MANAGEMENT.**

- **GOAL III: REDUCING THE HARMFUL ECOLOGICAL, ECONOMICAL, SOCIAL AND PUBLIC HEALTH IMPACTS RESULTING FROM INFESTATION OF NIS THROUGH APPROPRIATE MANAGEMENT.**

In development of the outline approach of this plan, it is recognized that prevention is the most practical, economic and environmentally safe method for dealing with new or incipient infestations. For NIS already widely established and distributed, this plan emphasizes an ecosystem approach utilizing integrated pest management methods that are flexible and environmentally sound. The long-term benefits of control or eradication must justify the short-term impacts. Supported research and information/awareness is critical toward maintaining a long-term control or containment program.

In order to achieve the goals set forth in this plan for NIS, a number of major issues must be addressed. These issues are critical to the establishment of a successful program. These issues as described in the **STRATEGIC PLAN FOR MANAGING NONNATIVE INVASIVE SPECIES**, July, 2000 are:

- Leadership, Authority and Organization
- Coordination, Cooperation and Partnership
- Education and Outreach
- Funding and Resources
- Monitoring, Mapping , Assessment
- Research
- Technology and Information Transfer
- Enforcement and Compliance
- Program Evaluation

Implementation plans developed in accordance with the CALFED NIS strategic management plan should identify the who, what, when, where, and how for the proposed tasks or actions. This CALFED NIS Implementation Plan will develop objectives from each of the major issues identified above for each of the three goals of the NIS Strategic Plan. The Implementation Plan will develop and expand detailed Tasks and Activities necessary to address the major issues and achieve the three goals.

Funding for this program has been provided through CALFED to the U.S. Fish and Wildlife Service in the amount of $1.25 million with fiscal year 1998 funds. The Service has agreed to develop and coordinate the development of a long-term Strategic Plan, an Implementation Plan and fund projects through three possible processes with this funding:

- Directed projects
- Expansion or extension of existing projects
- Proposal solicitation process

It is anticipated that at least $1.05 million will be available for actual on-the-ground work when the planning process is complete. The funding time period for funds already committed to this program is through fiscal year 2000. It is anticipated that this plan will continue to be supported and implemented through the continued contributions and support of the various agencies and entities responsible for rehabilitation of the San Francisco Bay-Delta, the Sacramento/San Joaquin rivers and their watersheds.

IMPLEMENTATION ISSUES

As presented, there are a number of major issues critical to achieving the goals as presented in this plan. These issues are discussed below and will be addressed as objectives of the Implementation Plan with specific Tasks and Actions.

California natural and man made water conveyance and impoundment systems are available and utilized for multiple purposes. In addition, there is a complex mosaic of federal, state and local laws and regulations which not only address intended use of these resources but will impact efforts to prevent the introduction, establishment and management of NIS. To facilitate accomplishment of the strategic goals, this program must coordinate with jurisdictions outside the state and build its tasks upon sound science. Therefore, mechanisms will be established to ensure that all prevention, control and abatement tasks developed and implemented by this program under this plan are (1) done so in cooperation with federal agencies, local governments, interjurisdictional organizations and other entities, as appropriate (2) based upon the best scientific information available, and (3) conducted in an environmentally-sound and conscientious manner and (4) coordinated through an interagency advisory council that will monitor management efforts and assure effective coordination of this program with CALFED, Comprehensive Assessment, Monitoring and Research Program (CMARP) and other NIS programs.

LEADERSHIP, AUTHORITY AND ORGANIZATION

As the program develops, one of the components essential to actual implementation will be to identify the leadership, authority and organization that is necessary to accomplish each of our goals. In some cases, there will be existing organizations that have the leadership and authority to carry out the actions identified in the plan. It may be that other tasks and actions determined to be essential to the success of the program do not have the leadership, authority or organization in place. In these instances, we will work to identify and/or develop the appropriate component needed to carry out the work as a part of this planning process. The formation of an interagency advisory council to monitor management efforts and assure effective coordination of this program with CALFED and other NIS programs is essential to the success of these efforts. This council will be referred to hereafter as the Nonnative Invasive Species Advisory Council (NISAC).

COORDINATION, COOPERATION AND PARTNERSHIP

In all of the work undertaken as part of this program, the value and necessity of the elements of coordination, cooperation and partnership to the success of the program can not be overstated. At all times and in all aspects of the work, priority will be given to these ideals and we will strive to incorporate them into every aspect of the plans made and actions taken.

EDUCATION AND OUTREACH

A comprehensive awareness and education program is critical for an effective NIS management program. Except for isolated cases that have attracted substantial media attention, the general public does not understand how NIS negatively impact the environment, the economy and the utilization of the natural aquatic resources that are important to them. Therefore, a strategic approach to NIS must include education and awareness component for all actions and tasks presented. Developing and implementing a coordinated and comprehensive information program will expand understanding by all California citizens of the impacts and risks associated with the introduction and spread of NIS.

Information about the nature, characteristics and the impacts of NIS on the environment, economy and quality of life needs to be made more available. This information should be presented concurrently with information about related issues such as threatened and native species, natural history, endangered species, water quality, habitat restoration, and ecosystem health. An important aspect of this program will be developing outreach to inform and educate public and private entities that may be affected by project actions. The need for understanding and managing NIS should be institutionalized in public and environmental education curricula. A well-coordinated effort is needed because of the costs and complexities associated with developing and delivering a comprehensive, high caliber outreach program.

A successful education and information program must utilize individuals and institutions with expertise on how to raise public awareness and influence attitudes towards NIS management. Public information specialists can be utilized to develop distribute and coordinate information state-wide. In addition, information specialists can enhance public interest and improve citizen and organizational involvement toward reducing the spread of NIS. Raising awareness can be achieved via television spots, ad campaigns and public service announcements. All of these efforts will make extensive use of existing agencies and pursue cost-effective strategies.

An increased awareness and concern of California citizens should precipitate an increase in level of commitment by elected officials toward NIS management. Many federal and state legislators have little understanding of the risks associated with NIS and this has had a negative impact on obtaining sufficient long term funding. An immediate priority should be the development of briefing packages and presentations for national, state, and local official and interest groups.

FUNDING AND RESOURCES

Reliable consistent funding in California for management of NIS is generally fragmented and in many cases inadequate or nonexistent. This is especially true in areas of exclusion, education, emergency response, research and management. Funds are generally available on a reactive basis and do not effectively deal with infestations before they become unmanageable. Except for the Hydrilla Program conducted by California Department of Food and Agriculture, or the Northern Pike Program conducted by California Department of Fish and Game, funds for NIS are provided after the problems become widespread. Generally these funds provide resources for limited control efforts and do very little to prevent further spread to uninfested areas.

Costs associated with this management plan and associated implementation plans must be identified. Once costs are determined, sources of revenue should be investigated and pursued. Traditional sources include but are not limited to the US Fish and Wildlife Service, ANS Task Force, US Army Corps of Engineers, US Environmental Protection Agency, Natural Resource Conservation Service and the National Fish and Wildlife Foundation. For federal agencies, allocations of discretionary funds may be necessary if dedicated funding by decision makers (Congress) can not be achieved. At the state level, one or more agencies may have to submit Budget Change Proposals to obtain long term funding in support of a statewide management program.

In addition to traditional funding sources, a working group within the NISAC, should develop a number of nontraditional funding options for NISAC consideration and recommendation. These funding options should recognize that management of NIS benefits all Californians and will actually prove cost-effective over the long term. It should not tax or levy fees in a manner that unfairly impacts one, two or three user groups. In other words, a balance between general fund revenue and user group revenue should be achieved.

Other nontraditional source of revenue and resources involve cooperative agreements and partnerships. Federal, state, local agencies and private organizations with NIS management responsibilities will be encouraged to coordinate, share or pool resources. This can include shared purchase of supplies and use of equipment, use of staff and other human resources, sharing of mapping and monitoring data and expertise and to achieve potential purchase savings for bulk purchases of chemical supplies, biological control and educational materials.

MONITORING, MAPPING AND ASSESSMENT

Ecosystems infested with NIS are not consistently identified and delineated. Complete up to date maps, displaying the distribution and severity of NIS infestation are available only in a few areas. Knowledge of which species are located where is paramount for: 1) increasing public awareness and concern, 2) obtaining support and funding for developing a strategic program, 3) accurately predicting where new infestation may occur from already infested areas and, 4) developing effective integrated management and prevention plans with specific actions to mitigate or prevent impacts caused by NIS, 5) Establishing the costs of eradication/control efforts.

As part of the CALFED program, a Comprehensive Assessment, Monitoring and Research Program (CMARP) is under development to address the needs of CALFED's common programs and related agency programs. The CALFED NIS Program will communicate and coordinate with CMARP programs and activities.

An ecosystem inventory, mapping and monitoring system should be based on standards which allow for easy exchange of information among federal, state and local agencies as well as private organizations. Compatible systems and software will be utilized and GIS will be integrated into this process.

Research and Technology Transfer

A strong commitment to research and information/technology transfer is critical towards achieving the goals presented in this management plan. A working group with NISAC should review research needs already developed by various entities, identify new areas of research relative to the various actions and tasks presented in the plan, prioritize areas of research and opportunities for funding and submit a report to NISAC. This should be done on at least an annual basis. This commitment also extends to the transfer of information developed to a wide audience through many venues to assure coordination and cooperation with others involved in the same type of endeavors.

Enforcement and Compliance

In those areas where enforcement and compliance are identified as an issue, this program will develop the information base to illustrate and define the issue and possible approaches and make recommendations to appropriate agencies to enhance the adherence to regulations.

Program Evaluation

To be effective and responsive this management program and associated implementation plans must include an evaluation component to identify progress, evaluate implementation problem/needs and make necessary corrections at anytime. The adaptive management strategy will be highlighted. The evaluation process will include:

1. Establishment of an evaluation subcommittee within NISAC responsible for reviewing performance measures, conducting the evaluation efforts, reporting the results to NISAC and others if required, and identifying program or plan adjustments that address projected outcomes.

2. The three program goals, as previously presented, provide the focal point for evaluation. Ways to assign measurable objectives to these goals should be developed to provide meaningful evaluation.

3. The evaluation process should be inclusive, involving those with implementation responsibility, resource user groups and others affected by the program and/or plan implementation.

4. An annual report highlighting progress and achievements will be prepared and distributed. The annual report will include evaluation of the efficacy of the programs strategies and tasks and identify revisions as needed. The annual report will be readily available on the Internet and distributed to local and federal agency and legislative decision makers.

5. Work with CALFED program managers to evaluate the NIS component/impact to their program actions and how NIS may affect the overall goal of the program.

6. Work with CALFED management through CMARP to provide NIS information as it applies to management decisions.

Implementation Objectives and Actions

The three goals of the CALFED Nonnative Invasive Species Program are:

Goal I: Preventing new introductions and establishment of NIS into the ecosystems of the San Francisco Bay-Delta, the Sacramento/San Joaquin Rivers and their watersheds.

GOAL II: LIMITING THE SPREAD OR, WHEN POSSIBLE AND APPROPRIATE, ELIMINATING POPULATIONS OF NIS THROUGH MANAGEMENT ACTIONS.

GOAL III: REDUCING THE HARMFUL ECOLOGICAL, ECONOMICAL, SOCIAL AND PUBLIC HEALTH IMPACTS RESULTING FROM INFESTATION OF NIS THROUGH APPROPRIATE MITIGATION.

The Objectives that follow are identified beginning on page 8 of this document and within the draft NIS Strategic Plan as Major Issues of concern for the NIS Program. Under each Objective, specific Actions and Tasks have been identified which are considered essential elements of the implementation of this program.

OBJECTIVE 1: LEADERSHIP, AUTHORITY AND ORGANIZATION:

DEVELOP AND IDENTIFY THE LEADERSHIP, AUTHORITY AND ORGANIZATION NECESSARY TO PREDICT, PREVENT AND REDUCE THE IMPACTS OF NIS INTRODUCTIONS IN THE ECOSYSTEMS OF THE SAN FRANCISCO BAY-DELTA, THE SACRAMENTO/SAN JOAQUIN RIVERS AND THEIR WATERSHEDS.

ACTION 1A: Form an Interagency Nonnative Invasive Species Advisory Council (NISAC) to develop the leadership, authority and organization necessary to effectively promote the NIS goals.

1. NISAC will coordinate and streamline the authorities to regulate NIS between state and federal agencies. Specific problems will be identified and pathways evaluated.

2. NISAC will develop and analyze information and recommendations to go to CALFED and program elements specific to areas of CALFED concern.

    A. NIS Technical Review Team assist with preparation of requests for proposals and coordinate peer review of proposal solicitation responses and evaluate the potential of the action in encouraging the establishment of NIS.

    B. Provide information for CALFED management decisions on the prevention NIS introductions.

    C. Develop interface with CMARP for information exchange and coordination aimed at the prevention of the introduction of NIS.

3. Develop Rapid Response Plan to address early infestations of NIS.

4. Develop and implement standard reporting procedures for NIS.

5. NISAC will develop the resources necessary to carry on the council activities beyond FY 2000.

ACTION 1B: Identify existing authorities, leadership and areas which could benefit from further support and leadership and link this information to CALFED actions and management decisions. In particular, identify those with the authority to prevent the introduction of species through:

- Ballast Water releases
- Bait use (marine and freshwater).
- Deliberate introductions
- Aquaculture releases
- Aquarium and pet trades
- Water features industry
- Landscape and nursery industry
- Urban forestry
- Urban entomology
- Road/Highway construction/repair/mitigation
- Animal feeds
- Off-road vehicles
- Boating practices

1. Identify existing species specific workgroups and authorities of NIS not yet present in the CALFED area and work with those groups to determine if that species presents a threat to reaching CALFED areas of concern. Work with those groups to determine measures which can prevent the introduction of the species into the CALFED study area.

ACTION 1C: Identify gaps in existing authorities that would affect CALFED interests and coordinate with appropriate bodies to meet CALFED needs.

ACTION 1D: Develop and implement a program to systematically apply available resources to the support of viable regulations and authorities to prevent introductions of NIS.

1. Support improvements to exclusionary activities (ballast management, clean lists and border station programs).

2. Support efforts to designate ballast water as a pollutant to be regulated under existing state law (regarding the release of point source pollution and the uptake of ballast in infested waters.)

3. Recommend and provide protocols for improved detention and quarantine procedures (Cargo, packing materials, dredge spoils).

4. Review and make recommendations to improve routine inspections programs and processes of entities that may transfer NIS such as:
   - Retail outlets
   - Commodity transfers
   - Commercial activities
   - Public Venues
   - Irrigation districts

ACTION 1E: Utilize a technical working group within NISAC to review and recommend statutory and regulatory changes for state legislation to limit spread, prioritize control strategies and evaluate approaches that may limit spread of NIS.

ACTION 1F: Identify the organization(s) with the expertise and experience necessary to implement control strategies for NIS.

ACTION 1G: Develop a process through NISAC to review, recommend and coordinate control and management plans.

ACTION 1H: Provide a forum for CMARP, CALFED program managers, and stakeholders to discuss CALFED actions and the possibility of these actions encouraging the establishment or spread of NIS. Facilitated discussions of project or action modification to avoid encouraging NIS establishment will be part of the forum. Relate the impacts of NIS on CALFED actions and facilitate discussions of methods of reducing or eliminating the NIS impacts.

ACTION 1I: Establish interjurisdictional approaches to facilitate legislative, regulatory and other actions to prevent NIS introductions.

1. Pacific States Fisheries Legislative Task Force

2. Pacific States Marine Fisheries Commission

OBJECTIVE 2: COORDINATION, COOPERATION AND PARTNERSHIP.

ESTABLISH AND SUPPORT COALITIONS AND INTERJURISDICTIONAL APPROACHES TO FACILITATE PARTNERSHIP, COORDINATION AND COOPERATION IN THE EFFORTS TO PREVENT NIS INTRODUCTIONS, CONTROL NIS POPULATIONS AND REDUCE THEIR NEGATIVE IMPACTS.

ACTION 2A: NISAC will monitor NIS management efforts and assure effective coordination between CALFED and other NIS programs.

ACTION 2B: Develop partnerships with regional and national programs to facilitate the recognition of NIS threatening to spread to CALFED solution area such as:

1. Western Regional Panel
2. Aquatic Nuisance Species ask Force
3. National and California Sea Grant
4. Pacific States Marine Fisheries Commission
5. Invasive Species Council
6. Water agencies, including NAQA, etc.
7. California Interagency Noxious Weed Coordinating Committee
8. California Exotic Pest Plant Council
9. Grassroots organizations
10. Irrigation districts
11. University of California Cooperative Extension
12. Pacific Ballast Water Group
13. Weed Management Areas

ACTION 2C: Initiate and maintain a communication network of NIS scientists and resource managers via NISAC and the work teams to encourage information exchange and coordination of effort.

ACTION 2D: Establish and support interjurisdictional process to ensure compatibility and consistency between western states and between states, public, private and semi-public agencies and federal agencies. (Federal consistency, a tool implemented by coastal management programs to ensure that federal activities/projects are compatible with enforceable policies of the state, is recommended to facilitate interjurisdictional endeavors.)

ACTION 2E: Establish and support coalitions among the western states including agricultural, natural resource agencies, state universities, the Coastal State Organization, coastal managers, tribal groups, recreational boaters, nurserymen, pet industry, angler groups and other concerned resource users. Assist coalitions in promoting state and federal legislation and programmatic support for the prevention of new NIS introductions or the spread of existing populations that could impact CALFED objectives.

ACTION 2F: Implement a watershed approach as a basic organizational structure limiting the spread of NIS but with the understanding that current water transport facilities and modes of transportation transcends traditional watershed patterns of distribution.

1. Establish cooperative policies with counties (and other entities) sharing watersheds and water transport facilities to limit the spread of NIS.

2. Establish a network of coastal counties and regional interests sharing coastal access to limit the spread of NIS.

ACTION 2G: Establish and maintain cooperative relationships with groups working to limit spread of NIS and work to coordinate and complement those efforts.

1. Team Arundo

2. Spartina Technical Control Committee

3. Department of Food and Ag (Hydrilla program and others)

4. Boating and Waterways (Egeria, Hyacinth and others)

5. ANS Task Force European Green Crab Workgroup

6. IEP Chinese mitten crab Project Work Team

7. Pacific Ballast Water Group

ACTION 2H: Support and enhance the operations and projects of the organizations responsible for ongoing programs to prevent, mitigate, control, or eradicate NIS populations.

OBJECTIVE 3: EDUCATION AND OUTREACH:

DEVELOP AND IMPLEMENT A COORDINATED AND COMPREHENSIVE INFORMATION AND EDUCATION PROGRAM TO EXPAND THE UNDERSTANDING OF THE BENEFITS OF PREVENTION, THE RISKS AND IMPACTS ASSOCIATED WITH INTRODUCTIONAND SPREAD OF NIS, CONTROL STRATEGIES, ASSOCIATED ENVIRONMENTAL IMPACTS AND THE POSSIBLE MODIFICATION OF HUMAN BEHAVIOR AND ACTIVITIES THAT MAY REDUCE HARMFUL IMPACTS.

ACTION 3A: Provide the most up to date information in a format useful in CALFED management and program decisions:

1. Develop for CALFED managerial use, fact sheets on life history, environmental, economic impacts and preventative measures, etc for species that threaten to establish in the CALFED area of concern. The information on this sheet is more specific than those for general public distribution.

2. Provide a quarterly newsletter on potential NIS introductions, range distribution changes, unexpected beneficial and detrimental impacts of NIS, etc. The target audience will be CALFED managers and those making policy decisions for the CALFED program.

ACTION 3B: Acquire or develop and distribute appropriate information to educate and inform appropriate resource user groups about NIS and their harmful impacts in cooperation with existing resources.

1. Develop a CALFED NIS web page to educate the resource users and the public about introductions.

2. Create NIS exhibits and supply materials to public facilities interpretive displays such as state parks, boat launches, the DWR State Water Project visitors centers, and public libraries.

3. Include information in boater registration mailer.

4. Utilize existing environmental and resource newsletters and other educational materials to publish and publicize appropriate NIS information.

ACTION 3C: Acquire or develop and distribute appropriate information to educate and inform appropriate businesses and other entities that may contribute to the introduction, establishment and spread of NIS.

1. Work with business and industry involved in the development of new technologies to reduce the transfer and movement of NIS.

2. Identify methods to prevent inadvertent "hitchhiking" of NIS during transport of commercial products.

3. Promote the use and inspection of packaging materials to reduce transport of NIS.

4. Acquire or develop and distribute Best Management Practices and regulation and compliance information to reduce the risk of activities which contribute to the introduction, establishment or spread of NIS. Such businesses and entities include:
   - Fishing (sport and commercial)
   - Live Seafood Dealers/ Sellers
   - Pet Stores
   - Nursery industry
   - Bait Dealers/Sellers
   - Aquatic Plant Distributors
   - Aquascape/Landscape Designers
   - Public venues (aquariums, zoos, botanical gardens)
   - Aquaculture operations.

5. Distribute information on regulations and enforcement that may apply to activities that contribute to introduction of NIS.
   - Immigration
   - Customs
   - Military

ACTION 3D: Acquire from partners or develop and distribute appropriate information to educate and inform the public about NIS and their harmful impacts.

1. Participate in and support the 100th Meridian Initiative to prevent the westward spread of zebra mussels.

2. Promote and utilize existing public education materials such as the zebra mussel traveling trunk.

3. Support development of materials specifically designed to educate the public about the hazards of intentional/accidental introduction in cooperation with other outreach efforts and organizations like UC Cooperative Extension.
   - Aquaria/Pet stores
   - Aquatic plant/nursery
   - Fishermen
   - Boaters.

4. Support development of a K-12 curricula in conjunction with the State Department of Education in cooperation with other interested parties such as county advisors of UC Cooperative Extension, Sea Grant.

5. Support the development and distribution of appropriate information to educate and inform the public about public health risks identified by public health agencies as associated with NIS.

ACTION 3E: In cooperation with other groups, develop identification materials to facilitate participation by the public and others in recognizing and reporting spread of NIS.

ACTION 3F: Inform and educate user groups and the public about the management strategies that are necessary to limit spread of NIS.

ACTION 3G: Coordinate community volunteer groups, fishermen, sport divers. Shell collectors, school groups and others in and around the Bay-Delta habitats to act as an early warning system and to communicate "sightings" of NIS to NISAC.

ACTION 3H: Develop and distribute appropriate information to educate and inform the public and appropriate resource users groups about control strategies, associated environmental impacts and the rationale for implementing such programs.

1. Utilize existing groups/programs responsible for information dissemination when appropriate and feasible such as:
   - UC Cooperative Extension
   - National and California Sea Grant
   - Western Regional Panel
   - California Exotic Plant Pest Council

ACTION 3I: Establish monitoring, tracking, survey programs to evaluate the effectiveness of information/education efforts.

OBJECTIVE 4: FUNDING AND RESOURCES

INVESTIGATE, IDENTIFY AND DEVELOP SOURCES OF FUNDING TO SUPPORT PREVENTION ACTIVITIES, CONTROL EFFORTS AND ACTIONS TO REDUCE NEGATIVE IMPACTS.

ACTION 4A: As information is developed about potential species that may impact CALFED actions, identify public and private entities that may also be specifically impacted by the species for program support.

ACTION 4B: Submit the CALFED NIS Strategic and Implementation Plan and a request for support to the ANS Task Force as a regional management plan.

ACTION 4C: Identify sources of Rapid Response Funds to address emergency actions taken to attack a relatively new infestation of NIS that may possibly be eradicated with early intervention.

ACTION 4D: Create a matrix of funding programs vs. types of NIS prevention needs.

ACTION 4E: Develop support for NIS prevention programs by state and federal agencies, environmental groups, academic institutions, and others.

ACTION 4F: Develop criteria for identifying and prioritizing funding needs both for short term rapid response and long term for more sustained funding.

OBJECTIVE 5: MONITORING, MAPPING, AND ASSESSMENT

DEVELOP AND ENHANCE MONITORING AND EXCLUSION PROGRAMS TO PREVENT INTRODUCTIONS, PROVIDE FOR EARLY DETECTIONS, LIMIT SPREAD AND REDUCE IMPACTS IN COOPERATION WITH CMARP AND OTHER NIS PROGRAMS. THIS OBJECTIVE IS CLOSELY LINKED TO RESEARCH, OBJECTIVE 6.

ACTION 5A: Establish new and participate in and/or review existing monitoring programs to detect new introductions and detect the spread of existing populations.

1. Working with CMARP, determine how existing monitoring programs can be adjusted to detect the appearance of any new species susceptible to their sampling methods. Also determine a process of notification should a new species be detected.

2. Working with CMARP, develop species specific monitoring programs as needed to detect the appearance of a specific NIS in the CALFED area of concern. Also determine the process of notification should that species be detected.

ACTION 5B: Develop and recommend materials suitable to educate and train monitoring groups and field scientists in the detection and recognition of new NIS introductions.

1. Develop a list of experts for each taxonomic group.

2. Support development of appropriate keys to facilitate identifications of established and invading organisms.

ACTION 5C: Evaluate NIS data to develop information for CALFED Programs and managers to assist with directing CALFED actions.

ACTION 5D: Develop a comprehensive relational database with georeferenced data documenting habitat and landscape features as well as vector information for use with GIS to assess the distribution of likely sites for new invasions.

1. GIS system would be used in conjunction with GIS showing jurisdictional boundaries to establish authorities and permitting requirements.

2. GIS will be used to project the rate of future spread based on changing distribution patterns, habitat and landscape variables.

ACTION 5E: Participate with the Science Coordinating Committee of the California Biodiversity Council in cooperating on developing the links to other organizational resource databases.

OBJECTIVE 6: RESEARCH

SUPPORT AND COORDINATE SCIENTIFIC INVESTIGATION BY RESEARCHERS FROM STATE AND FEDERAL AGENCIES, ACADEMIC INSTITUTIONS, NONPROFITS AND OTHER ORGANIZATIONS THAT ADDRESS POTENTIAL MANAGEMENT STRATEGIES TO PREVENT THE INTRODUCTIONS, LIMIT SPREAD AND REDUCE THE HARMFUL IMPACTS OF NIS INTO THE SAN FRANCISCO BAY-DELTA, SACRAMENTO-SAN JOAQUIN RIVERS AND THEIR WATERSHEDS.

ACTION 6A: In partnership with other states and federal agencies, academic institutions and environmental groups develop specific and regional listings of NIS, that have the potential to infest or spread and negatively impact the ecosystems of the CALFED solution area.

1. Utilize existing knowledge base to develop lists of NIS that represent a potential threat to invade CALFED areas of concern.
2. Utilize the above list to develop a decision-making matrix which includes the pathways, vectors, impacts, control feasibility and options of specific organisms.
3. Evaluate the matrix to determine the species most likely to arrive, least likely to be managed or controlled successfully and very likely to create a high level of negative impacts.
4. Develop a process to prioritize research needs encompassing CALFED objectives and program elements that would provide information necessary to make informed judgements about targeting species.

ACTION 6B: Promote support of appropriate biosystematic infrastructure, including alpha-taxonomy, genetics, maintaining collections and enhancing expertise through the combined efforts of public agencies, universities, NGOs and other groups. Define alpha-taxonomy: species determination based on existing published morphology and anatomical characteristic and taxonomic keys.

ACTION 6C: Conduct or promote research on selected species that threaten to invade via state or federal research initiatives, academia, or the private sector.

1. Evaluate the potential interaction between NIS, if it were to establish, and native biota of the CALFED area of concern. (found in the CALFED Habitat Conservation Strategy). (examples *Spartina alterniflora* and *S. foliosa*, green crab and *Cancer magister*)
2. Investigate the interactions between NIS, habitat restoration efforts and CALFED activities including conveyance, etc.
3. Support research to develop information that may translate into management actions to prevent, control, limit spread or eradicate NIS. Work cooperatively with industry and stakeholders whenever possible. Such topics may include:
   - Reproductive and dispersal mechanisms
   - Viability
   - Life history
   - Suitable habitats
   - Biocontrol
   - Ecological interactions with native flora and fauna
   - Integrated pest management
   - Genetic diversity
   - Geographic origin
   - Hybridizing ability
   - Early detection technologies
   - Invasibility of Ecosystems
4. For organisms determined to be especially harmful and difficult to control, support early detection efforts and rapid response activities.
5. Whenever possible, support the development and documentation of information about NIS impacts to the food web and how those impacts may relate to efforts to revive specific populations of concern.

ACTION 6D: Coordinate with CMARP to support the conduct of research to investigate the establishment of beneficial, native organisms as part or restoration or rehabilitation actions. Recommend that CALFED policy include the proactive use of native species during restoration activities whenever possible.

ACTION 6E: Incorporate the information obtained through monitoring and research to ensure that CALFED actions do not contribute to the spread of NIS.

ACTION 6F: Develop/implement mitigation/control activities to reduce/eradicate populations of targeted NIS.

1. Assess physical, chemical and biological mechanisms with respect to economy, efficiency, species-specificity, efficacy, timeliness, and all associated risks/impacts.

2. Create work group with expertise on the biology of the species and with knowledge of the habitats and economic systems being impacted.

3. The work group will develop a list of control activities ranging from Rapid Response (in coordination with other Rapid Response efforts) to long term site/facility specific activities to mitigate impacts.

4. Develop list of criteria to be used to evaluate the success of the control activity as well as criteria to evaluate any negative impacts from control efforts.

ACTION 6G: Evaluate the economic significance of the overall impacts for NIS with respect to impacts on industrial facilities, water diversions, transportation and commerce activities, fisheries and agricultural activities, navigational needs and recreational activities, etc.

1. Develop a means of valuation of economic impacts in collaboration with economic professionals.

2. Develop a database that includes measurable economic impacts and estimated values of NIS on above activities and facilities.

3. Include this information in the matrix of Goal II, Action 6A1.

4. Based on these estimates, develop a priority ranking of economic impacts associated with different NIS.

ACTION 6H: Support the evaluation of the public health risks of NIS.

1. Determine the identity of species of public health interest (e.g. Cholera bacteria) likely to be coming into SF Bay or Delta.

2. Identify the vectors associated with NIS species of public health interest.

3. Develop a priority list of the most likely and the most dangerous species of public health interest based on information and recommendations developed by public health agencies.

ACTION 6I: Develop human behavior and activity modification recommendations wherever feasible to reduce the negative impacts of NIS.

OBJECTIVE 7: TECHNOLOGY AND INFORMATION TRANSFER

ENSURE THE AVAILABILITY OF ALL INFORMATION AND TECHNOLOGY DEVELOPED THROUGH THIS PROGRAM TO CALFED PROGRAM MANAGERS FOR MANAGEMENT AND POLICY DECISIONS AND TO OTHER INTERESTED PARTIES.

ACTION 7A: Encourage and support the publication and distribution of NIS information directly relevant to CALFED restoration activities in readily available and user friendly formats to promote informed decisions and actions.

ACTION 7B: Establish NIS LIST SERVE and NIS web pages on the CALFED website to facilitate information transfer with links to CMARP.

ACTION 7C: Encourage and support the publication of information developed through this program in appropriate and accessible media.

ACTION 7D: Provide regular updates of information developed through this program to organizations such as: the ANS Task Force, WRP, industries (i.e., aquaculture, bait), water agencies, irrigation districts, the Western Weed Coordinating committee and other interested parties.

ACTION 7E: In cooperation with CMARP, provide education and training for personnel responsible for monitoring to acquaint them with NIS infestations and spread potential.

ACTION 7F: Utilize existing technology transfer programs (such as IEP, ICE_NRPI) and when necessary, work through CMARP to develop new programs to distribute research findings and technology advances.

OBJECTIVE 8: ENFORCEMENT AND COMPLIANCE

DEVELOP AND SUPPORT EFFECTIVE ENFORCEMENT AND COMPLIANCE MEASURES WHICH ADDRESS PREVENTION, CONTROL/ERADICATION AND REDUCTION OF NEGATIVE IMPACTS.

ACTION 8A: Through NISAC, establish and encourage improved enforcement and compliance with regulations and authorities which will contribute to the prevention, control, or eradication of NIS.

ACTION 8B: NISAC will review existing enforcement programs and recommend improvements, changes or additional programs as needed.

ACTION 8C: Encourage the expansion and enhancement of the operations, responsibilities and funding of such prevention activities as the CDFA border inspection stations.

ACTION 8D: Inform public health agencies of NIS infestations which may have public health implications.

ACTION 8E: Support and enhance the operations and projects of the organizations responsible for ongoing enforcement and compliance programs to limit spread of NIS.

ACTION 9A: Evaluation program will be specified for each Action and/or Task undertaken as part of this plan.

1. The evaluation will address CALFED goals and objectives, as well as the NIS Program goals and objectives.

2. The evaluation will be inclusive, involving those with implementation responsibility, resource user groups and other affected by the program or plan implementation.

ACTION 9B: Convene annual workshop which includes some presentations, facilitated discussion about NIS research, management advances, and problems to evaluate current progress and future needs.

ACTION 9C: An annual report highlighting progress, achievements and revisions will be prepared, distributed and made available on the web site.

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