STRATEGIC PLAN FOR ECOSYSTEM RESTORATION

Preliminary Draft
August 31, 1998

Prepared for the CALFED Bay-Delta Program,
Ecosystem Restoration Program
by the Core Team

D-027781

To: Reviewers and readers of the Draft Programmatic EIS/EIR

From: The Core Team
Strategic Plan for Ecosystem Restoration

Date: August 31, 1998

We are pleased to submit this Draft Strategic Plan.

Following publication of the Draft ERPP, CALFED was urged by the Scientific Review Panel, stakeholders, and others to convene a team of outside experts to develop a strategic plan to guide and strengthen the ERP. This is the task that we undertook, beginning in late May, 1998. Over the past three months of our work, however, it has become clear that a strategic plan would be of value not only as it pertains directly to the ERP, but as it might serve as a more general guide for other CALFED program elements, and for related programs.

This Strategic Plan has been written as a guide to the restoration of species, habitats, and ecological processes in the Bay-Delta Estuary and its watershed. It is designed to provide a realistic framework for the restoration process using adaptive management in an ecosystem-based approach to problem solving.

This document is different from others that make up the DRAFT PEIS/EIR, in that it is authored by an independent team. We have been able to make recommendations as we saw fit, without policy review.

Because of program deadlines, the time we had to prepare this Strategic Plan has been extremely short, and there has been little time for outside review and input. While we consider this draft to be adequate for present purposes, it will benefit greatly from a thorough external review, and a period of reflection and revision by the Core Team.

We wish to thank those who participated in our work sessions or otherwise made comments and suggestions; but of course any errors or omissions are our responsibility. We would look forward to continued participation in this effort should that prove feasible.

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D-027782

Draft Strategic Plan Table of Contents

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Chapter 2. Introduction

A. Purpose of the Strategic Plan for Ecosystem Restoration

The purpose of the Strategic Plan is to guide restoration of the Bay-Delta ecosystem by providing a framework for refining, implementing, and coordinating the Ecosystem Restoration Program (ERP), early ecosystem restoration implementation (Category III), the Conservation Strategy for threatened and endangered species, and the Regulatory Compliance Strategy. The Strategic Plan embodies an ecosystem-based, adaptive management framework for implementation that is comprehensive, flexible, and iterative so that it can be responsive to changes in a complex, variable system like the Bay-Delta. The Strategic Plan accomplishes this by:

- outlining ERP goals, objectives, restoration measures and information gathering to be achieved during the CALFED Program, with an emphasis on Stage 1, so that decisions in future stages (e.g., decisions related to large scale water conveyance and storage) can be based on a more thorough and practical understanding of their ecological implications;
- developing a learning-based system to facilitate selection of actions and decisions for large scale ecosystem restoration in all stages of the CALFED Program;
- establishing "adaptive management" as the primary tool for achieving ERP objectives and explaining the relationship of adaptive management to the success of the overall CALFED Program; and
- defining a coordinated and comprehensive regulatory compliance and permitting strategy that facilitates ecosystem restoration and, in certain situations, allows the ERP to exceed state and federal regulatory and environmental documentation requirements.

1) Relationship of the Strategic Plan to the Ecosystem Restoration Program, Early Ecosystem Restoration Implementation, the Conservation Strategy, and the Regulatory Compliance Strategy

A) Ecosystem Restoration Program (ERP)

The ERP represents the most ambitious and comprehensive ecosystem restoration ever undertaken in the United States because it encompasses a wide range of aquatic, riparian, and upland habitats located within the Bay-Delta watershed and near-shore ocean environment (see Figures 2-1 and 2-2). The goal of the ERP is to increase and improve aquatic and terrestrial habitat in the Bay-Delta to support healthy, self-sustaining populations of diverse plant, fish, and wildlife species. The Plan for the ERP describes CALFED's vision of a restored, healthy, and functioning Bay-Delta ecosystem (Volume I) and defines restoration objectives and targets

(Volume II) for the 14 ecological zones within the Bay-Delta watershed. Because of the complexity of the Bay-Delta and the large scope of the ERP, the ERP will be implemented in phases over the course of several decades.

The primary purpose of the Strategic Plan is to establish a framework for refining ERP objectives and targets and guiding the phased implementation of ERP actions.

[Insert Figure 1-1 (ERP solution scope) and Figure 1-2 (Delta)]

B) Early Implementation Ecosystem Restoration Projects

State agency, federal agency and stakeholder signatories to the historic Bay-Delta Accord of 1994 recognized that the Bay-Delta ecosystem was in critical condition. Declines in the populations of species already designated as endangered and threatened had necessitated restrictions on harmful human activities, which aggravated long-standing conflicts among Bay-Delta resource users. Accordingly, the signatories agreed to fund high priority, non-flow related ecosystem restoration projects in the interim between the Accord and the implementation of the ERP. This Program, referred to as Category III, has financed hundreds of projects consistent with the priorities and scope of the ERP.

The Strategic Plan will help guide the selection of upcoming Category III projects as the transition to the long-term ERP, as well as the collection and analysis of data that will be produced from projects already selected in earlier rounds of Category III funding.

C) Conservation Strategy

Numerous species who rely upon the Bay-Delta for all or part of their life cycle have experienced population declines as the health of the ecosystem has deteriorated. Several Bay-Delta species have been designated as threatened or endangered by state or federal statutes. CALFED is developing a Conservation Strategy to protect species and habitats in order to ensure Program compliance with the Federal Endangered Species Act, the California Endangered Species Act, and the Natural Communities Conservation Planning Act. The Conservation Strategy relies principally upon the implementation of the ERP to achieve its primary conservation goals.

The Strategic Plan describes an ecosystem-based adaptive management framework for achieving conservation goals.

D) Regulatory Compliance Strategy

Implementation of many ERP actions will require prior approval from both state and federal agencies with regulatory responsibilities in the Bay-Delta. For instance, to ensure that ERP actions comply with the Clean Water Act, CALFED will need to obtain permits from the U.S. Army Corps of Engineers, the U.S. Environmental Protection Agency and the State

Water Resources Control Board. Anticipating the need for regulatory permits and environmental documentation, and estimating the time involved for obtaining them, will expedite the implementation of ERP actions.

The Strategic Plan provides a strategy for obtaining these regulatory approvals in a timely and coordinated manner to avoid unnecessary delays and to maximize the efficient implementation of the ERP.

B. The Problem: The Decline of the Bay-Delta Ecosystem

The Bay-Delta system no longer provides the quantity, quality, or diversity of habitats necessary to support healthy, self-sustaining populations and communities of plants and animals. Several factors have contributed to the steady decline of the Bay-Delta ecosystem. The first major human disturbance of the Bay-Delta watershed occurred 150 years ago when hydraulic mining in the Sierra Nevada foothills sent vast quantities of sediment into Bay-Delta tributaries. Excessive sedimentation destroyed or degraded aquatic habitats as river channels and shallow areas filled with sediment. The reduced capacity of the sediment-filled channels increased the frequency and extent of periodic flooding, which stimulated flood control measures such as levee construction. Levees disconnected river channels from their floodplains, which further altered natural patterns of sediment transport, reduced the amount of (seasonal) wetland habitat, and eliminated fish access to shallow overflow areas that were important for spawning or rearing. The conversion of floodplains to agricultural and urban uses also eliminated the amount of habitat available for plants and wildlife. Dredging operations connected with levee construction and navigation improvements drastically reduced tule bed habitat along the river channels.

As the State's population grew, new dams, diversion structures, and export facilities were constructed to store and transport water. Large dams designed to provide water supply and flood control prevent fish from accessing large amounts of their historical spawning habitat. Dams also disrupt natural patterns of flow and sediment, which degrades downstream aquatic habitat. Dams, diversions and export facilities change seasonal patterns of inflow, reduce annual outflow and reduce the natural variability of flows into and through the Delta, further altering the forces that help to create and maintain habitat. Facilities constructed to support water diversions also cause straying or direct losses of fish (e.g. unscreened diversions) and increased predation (e.g. Delta Cross Channel and Clifton Court Forebay). Entrainment and export of substantial quantities of food web organisms (eggs, larvae and young fish) further contribute to habitat decline.

Water quality degradation caused by pollutants and increased concentrations of substances such as pesticides and herbicides have also contributed to the overall decline in the health and productivity of the Delta. In addition, undesirable introduced species compete for available space and food supplies, often to the detriment of native or economically important introduced species.

C. An Ecosystem Approach Using Adaptive Management

Both the ERP and the Strategic Plan have adopted ecosystem-based management and adaptive management, relatively new concepts in resource management. Within the past few years, all major resource agencies of the US federal government, the California Deptartment of Fish and Game, and many other state agencies have adopted ecosystem-based management as the guiding philosophy of resource management. Despite its emergence, ecosystem-based management and adaptive management are still being integrated into agency policy and operations. The thrust of the Strategic Plan is to describe an implementation and management framework that clarifies how CALFED agencies can use ecosystem-based management, with its attendant emphasis upon adaptive management, to manage Bay-Delta resources.

By incorporating ecosystem-based management and adaptive management, the ERP and the Strategic Plan signal a fundamental shift in the way the ecological resources of the Bay-Delta will be managed. In the past, efforts to combat population declines of threatened and endangered species focused on specific factors in the species' environment believed to affect birth or death rates. Such an approach resulted in piecemeal attempts that usually failed to recover stable, healthy populations of threatened and endangered species. In addition, this approach did not address the needs of unlisted species experiencing population declines that might necessitate their future listing.

The Bay-Delta ecosystem is not simply a list of species. Rather, it is a complex, living system sustained by innumerable climatic, physical, chemical and biological interactions, both within and outside of the Bay-Delta. The ERP and Strategic Plan go beyond traditional efforts at individual species regulation and management with an integrated systems approach that attempts to protect and recover multiple species by restoring or mimicking the natural processes that create and maintain diverse and healthy habitats. This ecosystem-based approach provides several advantages 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, which can enhance the quality of restored habitat.

- restoration of physical processes can benefit not only threatened and endangered species, but also unlisted species, thereby reducing the need for future species listings.

- restoration of physical processes requires less human intervention to sustain remnant or restored habitats.

- restoration of physical processes can produce a more resilient ecosystem capable of withstanding future disturbances.

Replacing the traditional species-based approach with an ecosystem-based approach does not mean that CALFED is relinquishing its responsibility to recover threatened and endangered species. Ecosystem-based management encompasses species management by sustaining and enhancing the fundamental ecological structures and processes that contribute to the well being of the species. Under CALFED's ERP, threatened and endangered species will be rehabilitated not only through the restoration of habitats, but also through the restoration of ecological processes and functions that help create and sustain those habitats.

The difference between process-based ecosystem restoration and conventional species-based management can be illustrated by three alternative approaches to recovering threatened or endangered populations of salmon.

A traditional, species-based approach includes the use of hatcheries to artificially augment salmon populations. While this conventional, engineering-oriented approach can produce a short-term increase in fish populations, hatcheries can also pose a threat to the long-term viability of a species. Because hatcheries confine unnaturally large concentrations of fish, they are vulnerable to disease. Hatchery fish are also produced from relatively limited genetic stock, so they share similar, if not identical, genetic traits. When hatchery-produced fish are released into the wild, not only do they compete with wild fish for food, but they can also spread diseases into wild populations. Because hatchery-produced fish can interbreed with wild fish, they can also homogenize the gene pool and reduce the species' ability to adapt.

An alternative, ecosystem-based approach to recovering salmon populations is to stimulate the production of wild salmon by restoring the freshwater habitats they need for spawning and rearing. Under this approach, river channels that have been deliberately modified (for flood control, navigation, or water supply purposes) or indirectly altered (because of changes in flow or sediment load) are modified physically to resemble natural spawning and rearing areas. Sample restoration actions include adding spawning-sized gravels to potential spawning beds, installing logs in river banks to provide cover and create scour pools, and planting riparian trees along river banks to provide shading, cover, and food for salmon. Although this approach is an improvement over artificial propagation, the physical channel modifications can require continued human intervention because flow and sediment loads in the rivers may have changed (e.g., because of dams or land-use changes upstream) such that the imported gravels and installed logs may wash out or the planted trees may not reproduce.

This suggests a third alternative, process-based ecosystem restoration, which attempts 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. By restoring the ecological processes that create and maintain habitat, we can meet the habitat needs of threatened or endangered species, create conditions that also benefit a range of other species, and reduce the need for continued human intervention.

Further discussion of ecosystem-based management is found in Chapter 5.

1) Adaptive Management

A great deal is known about the Bay-Delta ecosystem and the species that depend on it; however, a large and diverse ecosystem like the Bay-Delta is extremely complex, and we do not understand all of the ecological processes and interactions that animate the Bay-Delta. Research can greatly improve our understanding of the Bay-Delta ecosystem, but research alone cannot account for all of the uncertainties inherent in such a large and complex natural system. Bay-Delta processes, habitats, and species are continually modified by changing environmental conditions and human activities, so it is impossible to know exactly how the Bay-Delta will respond to implementation of the ERP and other CALFED Program components. Restoring and managing the Bay-Delta ecosystem requires a management framework that is flexible so that it can incorporate and respond to new information as it becomes available. Adaptive management uses the process of managing natural systems to simultaneously improve our understanding of those natural systems so that future management actions can be more effective. **This approach to management, in which information and knowledge about the system being managed is both a stimulus for management action and a product of management action, is termed adaptive management.** Because adaptive management is so important to the strategy for ecosystem restoration, we describe the process in some detail here. Further description of the theoretical underpinnings and application of adaptive management to specific issues are presented in Chapter 6.

Because the Bay-Delta is complex and in constant flux, there is no way to guarantee the success of a given restoration or management action. In an adaptive management framework, ecosystem restoration and management actions are provisional, subject to revision as new information becomes available. In this respect, adaptive management treats all management interventions as experiments. This does not mean that management interventions are conducted as a trial-and-error process, because the management actions are guided by the best understanding of the ecosystem available at the time of implementation. **Rather, in treating the interventions as experiments, managers are simply employing the power of the scientific method to ensure that management is as efficient and successful as possible in achieving its objectives.** In adaptive management, treating interventions as experiments means:

1. making management decisions based upon analyses and modeling of the system that is logically rigorous and transparent;

2. being clear about what the management intervention is expected to achieve in terms of restoring ecological structure and function and the implications for species conservation;

3. designing the management intervention to help distinguish among alternative hypotheses about ecosystem behavior, where practical and compatible with the long-term goals of the program;

4. monitoring the effects of the management intervention and communicating the results widely so that progress relative to expectations can be evaluated, adjustments made and learning achieved.

A useful analogy to adaptive management of ecosystem restoration is the clinical trial in medicine. In clinical trials, new therapies are tested on large numbers of patients, the trial is carefully monitored and, at regular intervals the progress of the trial is evaluated 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. However, since success cannot be guaranteed in medicine or in ecological restoration, it is only prudent to approach large-scale interventions as experiments. In this way we can guarantee that unsuccessful interventions will not be perpetuated and multiplied and that successful interventions can be modified to be as efficient of resources (e.g. land, water, tax dollars) as possible.

The key to successful adaptive management is learning from management actions, whether they are research projects or large-scale restoration projects. Learning allows resource managers and members of 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 so that they are more effective or more 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 unforseen 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 help facilitate learning from management actions, an adaptive management framework requires the identification of indicators of ecosystem health, comprehensive monitoring of those indicators, focused research, and phased implementation of actions.

Indicators are features or attributes of the ecosystem that are expected to change over time in response to implementation of restoration actions. Indicators provide measurable evaluations of important ecological processes, habitats, and species whose status individually and cumulatively provide an assessment of ecological health. Indicators of ecosystem health are the gauges used to measure progress toward restoration goals. Indicators can be both general and specific. For example, a broad or landscape-level indicator of ecosystem health might be a comparison of the total area of riparian forest to historic coverage. A more specific indicator might be the concentration of toxic substances in the flesh of adult striped bass.

Comprehensive monitoring is the process of measuring the abundance, distribution, change or status of indicators. For example, contaminant concentrations in fish tissues can be measured at various locations and times in the system to determine if contaminant levels are changing. Continuous monitoring provides the information necessary to evaluate and update restoration actions, and it allows progress toward restoration objectives to be gauged.

Focused research is necessary to improve our understanding of the Bay-Delta processes and interactions that we do not yet fully understand. For example, scientists have not yet determined the needs of certain fish species throughout their life cycle. By focusing research on significant information gaps, we can improve our ability to define the problems affecting the Bay-Delta and the restoration actions necessary to address those problems.

Phased implementation of restoration actions allows resource managers to monitor and evaluate actions implemented early so that future restoration will benefit from the knowledge gained.

Adaptive management requires effective and continuous monitoring of restoration projects so that progress toward restoration objectives can be measured and so that there is a continuous flow of information to enable the evaluation and revision of management interventions. Because of the Bay-Delta's size and complexity and the scope of the ERP, monitoring Bay-Delta restoration effectively and comprehensively will produce huge volumes of data, which requires an efficient information management system so that decision makers and the public can remain aware of changing Bay-Delta conditions. Adaptive management also requires institutional arrangements that are sufficiently flexible to accommodate and respond to new information produced by ecosystem monitoring and new ideas about how to manage natural resources. In an adaptive management framework, it is important that decisions about the effectiveness of a management intervention not be the sole responsibility of the agency or individuals responsible for the project. Scientific oversight is necessary to ensure the credibility of the restoration program, and public involvement in decision making is necessary to build public support for a long-term restoration program. In Chapter 6, we describe essential elements necessary to adaptively manage Bay-Delta resources: efficient information management, flexible institutional design, and scientific oversight.

D. Illustrating Adaptive Management

Figure 2-3 illustrates the process of adaptive management. The first step in adaptive management is to clearly define and bound the problem or set of problems to be addressed. Bounding a problem requires evaluating it along various dimensions (Figure 2-3). Two critical dimensions to consider in restoring and managing natural resources are the geographic scope of the problem and the resources and problems to be addressed. For example, at a programmatic level, CALFED has defined the geographic boundaries of the problem to include the legally defined Delta plus Suisun Bay and Suisun Marsh. Solutions can involve actions outside this geographic region, but they must be related to species, habitats or ecological functions within the Bay-Delta region as defined. Similarly, CALFED has defined the species parameters of the problem to include those species dependent upon the Delta, as defined, for all or part of their life history. Thus, ERP actions will focus primarily upon Delta-dependent species, though CALFED will also maintain species outside of the Delta as part of its Conservation Strategy.

A third dimension of restoration is time. CALFED has defined Bay-Delta problems using several time scales. For instance, CALFED is planning for an initial period of 7-10 years (Stage 1) after which a critical review of certain decisions about water conveyance will be made. But the ecosystem restoration program has a planning horizon of 25-30 years. Species and ecological processes have their own time scales that dictate how quickly one can expect to observe changes after restoration actions. At the species level, for example, Delta smelt with a one year life cycle should respond to ecological restoration quickly. Chinook salmon, with a 3-4 year life cycle, will take much longer to respond. Floodplain meander belts may not establish a long-term rhythm for decades although evidence of channel migration should soon be apparent. Planning for restoration needs to be sensitive to these natural time constraints.

Once a problem is bounded, clear restoration goals and objectives must be stated (Figure 2-3). Goals and objectives for ecosystem restoration are discussed in detail in Chapter 4. Objectives must be tangible and measurable so that progress toward achieving them can be gauged clearly. 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 that can be measured and evaluated would be: "Restore flows and accessability of Battle Creek to winter- run chinook salmon spawning in 7 years." Although objectives may sometimes be stated more broadly than this (as we have done in our draft objectives in Chapter 4), they must ultimately be made specific through models and hypotheses that translate the objective into restoration actions. Limited information is often seen as a constraint to establishing specific goals. Under adaptive management, however, goals are linked to hypotheses about ecosystem function and are subject to revision as new information comes available. In this approach, all objectives are preliminary and are a statement of our best understanding at the time. Part of the design for adaptive management is deciding how best to proceed with management while increasing the information base for decision making. In some cases the best solution will be to maintain the status quo while gaining more information through targeted research. In other cases the best solution will be a bold restoration project that offers the promise of significant ecological benefits and can be designed to generate information about the unknown.

Goals and objectives define what one wishes to achieve in terms of ecosystem or species restoration. Typically, there are many actions or collections of actions that have the potential to accomplish an objective or set of objectives. Individual experts may have very strong beliefs about which actions will be most beneficial. It is rare, however, that there is a clear consensus among experts about what to do. Even when there is a consensus about important actions, it is seldom possible to specify exactly how much of an action will be necessary, where the action should be carried out or how actions should be distributed in space and time to achieve maximum benefits. That is to say, there is considerable uncertainty as to what should be done and conflicting or alternative hypotheses about the effects of particular actions. The relationships that link actions through ecological processes to consequences or outcomes for species or ecosystems constitute a set of models about the behavior of the species or ecological system being managed. In adaptive management it is crucial that these models be written down as a set of conceptual models or hypotheses about the effects of restoration measures (Figure 2-3). These models provide the basis for informed management actions from which a better understanding of the ecological system can be derived.

Defining the problem, setting goals and objectives and articulating conceptual models are all activities rooted in what is known about the species and ecosystems to be managed. These three aspects of adaptive management involve careful evaluation and analysis of existing information. The collation, analysis and interpretation of existing information is a critical preliminary activity in adaptive management. However, the definition of what constitutes "information" is quite broad under adaptive management. The perceptions of experienced individuals, qualitative observation and historical anecdote can be part of the information base as well as systematically collected scientific observations. **What is important is that the information base be open and subject to scrutiny by all interests and that hypotheses about the system and management actions follow logically from the information base.**

The knowledge and hypotheses about ecosystem structure and function summarized in conceptual models lead directly to potential restoration actions. Each model, however, is likely to suggest many possible courses of action. In evaluating alternative actions it is usually very helpful to conduct exploratory simulation modeling based on the conceptual models (Fig. 3). It is important to recognize, however, that these simulations are not intended to capture the complexity and richness of ecological processes. **Rather, they are intended to capture the essential elements of ecological structure and function that underlie management decision making.** They are greatly simplified, clear caricatures of the system in the same way 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 numerous ways. For example:

- they can identify logical inconsistencies in the conceptual models;
- they can clarify where are the nodes of greatest uncertainty in the conceptual models and where new information would be most useful to decision making;
- they allow comparison of the benefits and costs of alternative models of the system and alternative management actions;
- they 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;
- they provide a basis for determining the value of new information on the ecosystem that might be obtained through adaptive experimentation; and
- they help communicate to a broader audience the current understanding of the problem, and the explicit rationale for particular restoration measures or

targeted research.

Based on the analysis of information, the conceptual models and simulations, management actions can be selected for implementation. These actions may be of three types:

1. targeted research to gain knowledge essential for decisions about particular restoration options;

2. pilot or demonstration projects to determine the practicality of restoration actions; and/or

3. large scale adaptive implementation of restoration (Figure 2-3).

These types of actions are not mutually exclusive and, in relation to any particular problem, all three might be undertaken. Consider the following hypothetical example:

Two models for creation of shallow, shaded nearshore habitat in river and Delta channels might be either to set back levees to widen the channel and encourage shallow vegetated habitat along the margins of the newly widened channel or to infill portions of the existing channel and encourage vegetation so that new shallow water shaded habitat is created within the existing channel. Each model involves rather different assumptions about ecological process and function and has different implications for cost and maintenance, long term benefits to a range of species, etc. Simulation modeling of these alternatives might suggest that, although both types of restoration have the potential to be effective, levee set back has a much higher potential benefit but also much higher cost. Uncertainty in the parameters of the models is also sufficiently high that the models cannot be easily distinguished on the basis of present information. However, creating new habitat in existing channels will not preclude future levee setbacks if this proves worth the cost. In this example the best approach might be to proceed with fairly large scale creation of shallow habitat in existing channels but also to undertake pilot projects to test the benefits of levee set back and targeted research to obtain knowledge about specific points of uncertainty in ecological function under the different models. For other problems and models, other kinds of decisions are possible. For example, if uncertainty is high enough, it might be considered prudent to conduct research on major sources of uncertainty before proceeding with either pilot projects or large scale restoration.

Adaptive management involves many crucial decision nodes shown by diamonds in Figure 1-3. The decisions about management actions, whether they involve targeted research, pilot projects or ecological restoration measures, involve permitting and regulatory compliance. There are no established protocols for satisfying the requirements of permitting and compliance in an adaptive management framework. Given the number of threatened and endangered species that will be affected by ecological restoration under CALFED, permitting and compliance requirements can delay decisions, or even undermine the ability of the restoration program to respond in a timely fashion to opportunities for ecological interventions or targeted research. By integrating the ecosystem approach and adaptive management with the regulatory process, the need for permits establishes important decision points for the recognition of progress toward ecosystem recovery. Furthermore, compliance requirements can help ensure that restoration projects incorporate essential monitoring of the ecological effects of management measures.

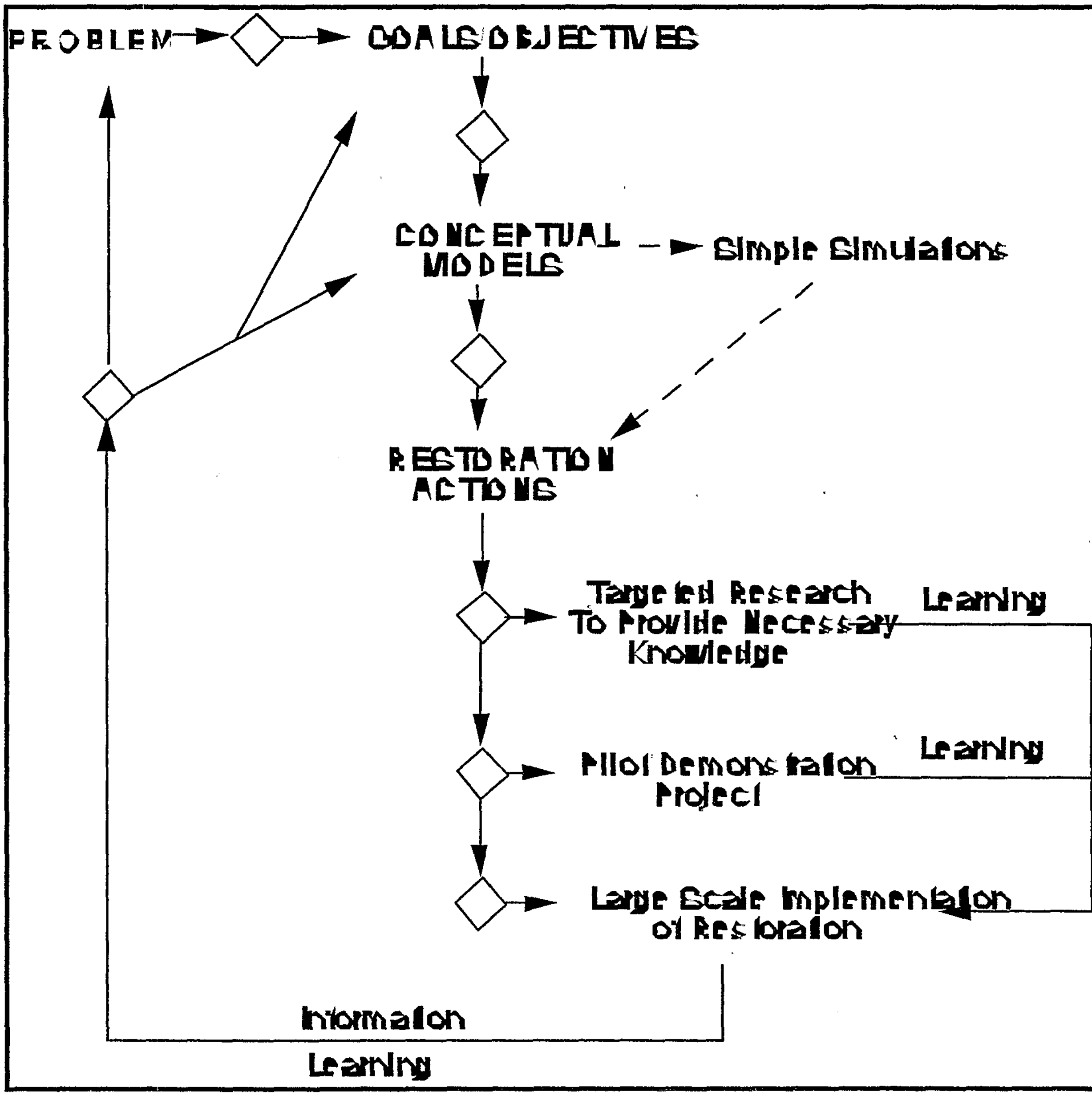
The Strategic Plan identifies opportunities to integrate permitting and compliance into the overall CALFED program in ways that have not been attempted previously. For example, providing for consultation between future project managers of proposed system facilities (such as new levee protection facilities) early in the design/planning stages offers a unique opportunity to avoid creating permitting bottlenecks. **Identifying adaptive management decision points and relating these to decision points in the project design/planning process will help program managers to understand both the potential impacts and the expected benefits of proposed actions and related mitigation measures.**

Decision nodes have the potential to be bottlenecks in the adaptive management system. 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, when to declare the success or failure of a particular intervention are all 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. These issues are addressed in Chapter 6. However, there will always be a significant element of subjectivity in decisions about whether or not to proceed. Open discussion may help to resolve many contentious issues and decisions. Nevertheless, in such a large, complex and contentious public program there will always be a need for a formal dispute resolution process. Dispute resolution is discussed in Chapter 6.

The bottleneck character of decision nodes also is important in terms of regulatory compliance. Chapter 8 discusses the strategy for demonstrating compliance of the ERP with state and federal laws, regulations, and programs. Many of the decision points in the adaptive management system will involve the need to obtain state/federal agency approvals for action recommendations generated by the adaptive management process. Early identification of the "decision points" that required public agency approvals is important. Identifying these decisions would reduce the potential for delays or the creation of adaptive management "cul de sacs" 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.

Ecological restoration of the Bay-Delta presents managers, decision makers, stakeholders and the public with a significant challenge. Much that needs to be done has never been attempted before. The scale of the project is unprecedented. The Strategic Plan gives direction to this bold program. However, its ultimate success will depend on the commitment of all participants and their willingness to keep a clear focus on the ultimate goal of a healthy and sustaining ecosystem within the Bay-Delta.

Figure 2-3. **Diagram of the adaptive management process.** Diamonds indicate important decision nodes in the process. See text for description of the various stages.



Chapter 3. Defining the Opportunities and Constraints

A. The Importance of an Historical Perspective

The Strategic Plan for ecosystem restoration will be a road map to success only if markers from the past are used a guideposts. We need to understand the nature and extent to which humans have altered the original conditions in order to figure out both the goals for restoration and the factors that limit our ability to achieve these goals. If we understand, even sketchily, how the natural hydrological and ecological systems once worked, we gain a better feeling for our ability to return the systems to their historic state, and for the desirability of doing so. Thus, historic studies indicate that massive flooding was an important ecological process in the creation of instream habitat for salmon and other fish but we clearly are not going remove our cities and farms to allow this process to restore itself on a large scale. On the other hand, it is possible to restore flooding as a hydrologic process on a much smaller scale, provided we understand how high flows are likely to affect the stream channels available for restoration. Creation of idealized meandering channels in streams where such channels never existed, for example, is ultimately going to lead to failure, as the water creates its own channels, perhaps winding up where it is not wanted.

An historical perspective can be important for putting restoration projects in proper context: a wetland may have little value for native plants and animals if it isolated from other wetlands, is too small to support viable population of species of interest, or is maintained mainly by artificial means. On a broader scale, we should know if our restoration efforts are going to recreate 10, 1, 0.1 or 0.01 percent of a lost habitat and what that means if the goal is partly to restore species that require lots of space for feeding or breeding or occupy habitats maintained by ecological processes that require lots of room to operate. This in turn can help us to set priorities for habitat restoration and acquisition. Endangered clapper rails, for example, require large expanses of tidal marsh that also contain some high ground for roosting when high tide floods the habitat. Thus clapper rail restoration funds may be best spent acquiring and restoring tidal marsh lands that are contiguous and contain some upland habitat, rather than restoring more isolated pieces of habitat, if the total area of the pieces is larger than the contiguous marshlands.

An historical perspective is also needed to understand how much human activity has changed natural systems and how irreversible that change is likely to be, especially over large areas. By taking a combined historical and watershed level perspective, we can understand the synergistic and cumulative effects of human actions which will constrain restoration objectives. For example, reservoirs halt the natural process of gravel and sediment movement to downstream areas, resulting in streambeds armored by large rocks. Such streambeds are poor habitat for insects and cannot be dug up by spawning salmon trying to bury their eggs. This change is largely irreversible and is only temporarily alleviated by the dumping of gravel into the river. In other cases, the changes may be reversible. For example, setting back, breaching, or removing levees can restore frequent inundation of floodplains. This approach to restoration of riparian habitat is much more likely to be sustainable than the construction of new riparian habitats without regular flooding.

B. Conditions Prior to 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. 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. Prior to 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 over 25,000 and 14,000 mi^2 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*) and steelhead trout (*O. mykiss*). 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 assured 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 Sierras 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 snow and rain fall, 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 south 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 inflowing streams and in the shallows now called Suisun Marsh. 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 savannahs and then bunch grass prairies, supporting herds of pronghorn, elk, and blacktail deer.

1) Hydrology and Landforms and How they Interact to Form Habitat

A) Runoff Processes and Riverine Forms

The largest rivers of the Sacramento-San Joaquin system head 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 river flows) from year to year, but snowmelt reliably produced moderately high flows 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, somewhat less in rivers with snowmelt contributions, and substantially less in rivers draining volcanic formations such as the regions of Mount Shasta and Mount 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 3-1). 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.

2) 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 the summer, to spawn in the 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 also sought out smaller streams not used by salmon. The annual influx of millions of salmon weighing 8-20 kg 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 the 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 large enough sizes 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 (1-2 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 a long time (5+ years) to be around when favorable conditions were present and then flood the environment with large numbers of young. Middens near Indian village sites indicate that these fishes - thicktail chub, Sacramento perch, splittail, hitch, Sacramento blackfish, and others - 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 fish, including salmon. The abundance of fish was presumably one of the reasons these people could exist in relatively high densities (compared to other areas of North America), yet there is no evidence that they depleted the resources they used and 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.

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.

3) 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.

A) Habitat Area and Diversity

There are minimum habitat areas 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, the area of tidal marsh and active floodplain habitat has been reduced to probably less than 5 percent of its pre-1850 extent. Such massive reductions in habitat implies a substantial change in the ability of the species dependent on those habitats to sustain their population levels.

B) 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. To be sustainable in the long-term, restoration of processes will be more effective than physical creation of forms that are no longer maintained by processes. Floodplain inundation and forest succession are two such processes along alluvial rivers.

Floodplain forests depended upon 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.

C) Temporal Variability

The rivers of the Sacramento-San Joaquin system were dynamic environments, with temporal variations from seasonal and inter-annual 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 maintenance of 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 inter-annual variability, especially high flows, are important for restoration of the ecosystem.

D) 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, shallowing towards 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 river banks were typically irregular in outline, and often 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 and/or deposition.

E) Continuity

The longitudinal continuity of water flow, sediment transport, nutrient transport, transport and migration of biota, etc. 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, the continuity of channels allowed for upstream migration of spawning salmon, water-borne 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 be prioritized, in part, to maximize continuity of habitat, such that sites whose restoration would connect other habitats might have priority over other, similar sites.

F) 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. 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 translated 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, finer fractions would be mobile 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 within the channel and because fish can seek refuge in the inundated flood plain.

There were other important ecological interactions between the floodplain and channel, such as shading, food, and large woody debris provided by floodplain vegetation (citation). 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 flashy 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 (citation). Inundation of floodplains and maintenance of high alluvial water tables contributed to maintenance of floodplain aquatic habitats, such as side channels, ox bow lakes, phreatic channels (Ward and Stanford 1995).

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

C. Ecological Transformations Following Colonization

1) Threshold Events Leading to Present Conditions

A) Grazing

Cattle were introduced in 1770 and rapidly expanded under Spanish rule. Along with the introduction of exotic 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.

B) Gold Mining

Beginning about 1850, 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 ridge tops), produced over 1.67 billion cubic yd 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 over 40 mi^2. The bed of the Yuba River near Marysville aggraded about 90 ft, 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 mud flats 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, and with the bed of the Yuba River at Marysville peaking in 1905 and returning 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 tailings piles.

C) Channelization for Navigation

The Sacramento, Feather, and San Joaquin Rivers were important navigation routes, with ocean-going vessels reaching Marysville and Stockton in the 1850's. The influx of hydraulic-mining sediment caused the rivers to shallow, interfering with navigation. In response, river beds were dredged and levees were constructed along river banks (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.

D) 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 rip-rap (and other artificial protection) along many reaches, including most of the Sacramento River downstream of Chico Landing. Rip-rapped banks effectively lock the channel in place, eliminate the contribution of gravels and woody debris from actively eroding river banks, 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).

E) Levee Construction

To protect floodplains against flooding, over 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), which also served to concentrate flow for navigation. By preventing overbank flows, levees reduce the connectivity between channel and floodplain, and thus reduce important ecological interactions. In addition, by eliminating overbank flows and natural floodplain storage, instead concentrating flow in the main channel, levees result in greater depths, faster flow, and higher flood peaks downstream (Figure 3-2) (IFMRC 1994).

F) 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 were the well-drained, broad, linear ridges (natural levees) developed along the current and former channels from overbank deposits, followed by conversion of lower flood basin areas 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 dry land wheat farming, which occupied 3.75 million acres in 1880s (Kelley 1989). In the Sacramento Valley, rice growing developed since 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 ac. Only about

38,000 exist today, about 10% of the historical value. However, it is unlikely that the forest ever occupied the full 364,000 ac at one time (Bay Institute 1998). Along the San Joaquin River, soils and historical accounts suggest a potential pre-1850 riparian zone of 329,000 ac, contrasting with a current 55,000 ac of wetlands and 16,000 ac of riparian forest (Bay Institute 1998). The area currently mapped as riparian forest includes areas of poor quality, heavily impacted by human action. An illustration of a relatively recent conversion of floodplain habitats in the San Joaquin River basin is shown in Figure 3-3. On the floodplain of the Merced River, a complex of side channel habitats were eliminated for agriculture between 195- and 1976.

G) Tidal Marsh Conversion

In the Delta, 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 ac of intertidal wetlands, 145,000 ac of nontidal wetland, and 42,000 ac of riparian vegetation on higher ground (Bay Institute 1998). Today, about 21,000 ac of wetland remain, of which about 8,200 ac are tidal (SFEP 1992). Because tidal wetlands are important habitats for feeding and reproduction of many aquatic species, adequate area of these habitats is probably an important component of ecosystem restoration.

H) Reservoirs and Diversions

Dams constitute important discontinuities in rivers, eliminating the continuity of aquatic and riparian habitat, blocking migration of fish and other organisms. Dams have cut off upper reaches of rivers, hydrologically isolating them (Figure 3-4). Dams have had an especially hard impact on spring run chinook salmon and steelhead trout, which formerly migrated to upstream reaches to spawn. The extent of river channel inhabited by spring-run salmon has decreased dramatically since the early 19th century, as shown in Figure 3-5. Overall, reservoirs were found to be the most important gaps in riparian habitat in rivers draining the Sierra Nevada (Kondolf et al. 1996).

While dams large enough to block fish passage, reduce flows during critical baseflow periods, and reduce frequent floods existed on most rivers in the system by 1940, 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 3-6) (SFEP 1992, Bay Institute 1998). Reservoir storage in the Sacramento River system is now equivalent to 80% of annual average runoff, in the San Joaquin 135% of runoff. As a result, the total runoff to the San Francisco Bay is only about 40 percent of its historical value (Nichols et al. 1986). The seasonal distribution of flows has fundamentally changed, and flood magnitude and frequency profoundly decreased. The 2-year flood now ranges from 5 to 50% of the pre-dam 2-year flood, and the post-dam 10-year floods range from 12-95% of pre-dam values (depending on reservoir capacity in relation to runoff) (Table 3-1).

The reduction in flood flows has transformed river channels of the Sacramento-San Joaquin system. Rates of bank erosion and channel migration in the Sacramento River have declined due to dam construction and due to the 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 are 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 (State Lands Commission 1993). The reduction in active channel dynamics is compounded by the physical effects of rip-rap bank protection structures, which typically eliminate shaded bank habitat and associated deep pools, as well as halting the natural processes of channel migration.

Reduced flood flows 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 flood flows below dams may permit fine sediment to accumulate in gravel 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.

I) Extraction of Sand and Gravel for Construction Aggregate

The rapid urbanization of California has required massive amounts of sand and gravel for construction aggregate (road fill, drain rock, concrete for highways, bridges, foundations, etc.), with annual production of over 100 million tons, 30 percent of the national production (Tepordei 1992). Nearly all of 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 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 predate on salmon smolts, such that the California Department of Fish and Game estimates that 70 percent of the smolts in the Tuolumne River are lost to predation annually (EA 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.

J) 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 m3 to the Sacramento and San Joaquin Valleys. (This is the estimated sediment yield to the large foothills 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 m3, 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 ten 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 to 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 flood flows, 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, 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).

K) 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 sprung 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 1900's 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. However, the fish continued to be affected by other stressors, such as introductions of exotic aquatic species, construction of dams, diversions, and levees, the latter for flood control.

L) Effects of Water Diversions from the Delta on Native Fishes

With construction of the Central Valley Project, Shasta Dam completely changed the hydraulic regime of the Sacramento River by storing winter flows and increasing summer flows. The construction of massive pumps in the South Delta to deliver Sacramento River water to the San Joaquin Valley essentially turned the Delta into a freshwater system, because brackish water was kept at bay (usually) by the inflows. 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. To make up for the loss of salmon and steelhead, large hatcheries were constructed.

In 1960's, 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. Native resident and anadromous fishes continued to decline, as did the native flora and fauna of riparian areas and wetlands. In dry years, migratory waterfowl were largely confined to artificial wetlands and showed marked downward trends as well. Not only was the water available for natural ecosystem processes increasingly diminished in amount but it was increasingly polluted as well, the result of the ever-increasing urbanization of the region and more intensive agriculture. The SWP also created a dependence of San Joaquin Valley agriculture and the metropolitan areas of the southern California on Sacramento River water. Native species continued to decline as water diversions increased and as wetland and riparian habitats continued to be diminished.

M) 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 constituents such as organic carbon, nitrates, phosphates, and herbicides, as well as pesticides toxic to phytoplankton, invertebrates, and larval fish (Bailey et al. 1995).

N) Introduction of Exotic Species

As the native fishes became depleted in the late 19th century, exotic species were brought in (especially following the completion of the transcontinental railroad in 1872): American shad, striped bass, common carp, white catfish. As their populations boomed, those of native fishes declined further. Introduction of exotic 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 exotic species was probably facilitated by altered hydrologic regimes and reduction in -habitats suitable for native species.

Under the federal Endangered Species Act of 1973, there are presently 21 species of plants, 7 invertebrates, 4 fish, 1 amphibian, 1 reptile, 6 birds, and 1 mammal present in the Bay-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 re-allocation of water for environmental purposes, as well as significant improvements in their remaining habitats.

D. Present Conditions and Trends (TO BE COMPLETED FOR FINAL STRATEGIC PLAN)

1) Land Use Patterns and Trends

2) Water Use Patterns and Trends

3) Population Distribution and Growth Patterns

4) Environmental Quality

E. Developing a Strategy that Addresses Existing and Future Regulatory, Economic and Political Conditions and Trends

The ERP needs to be implemented in a flexible manner that allows it to respond to a number of external, non-biological factors, including political, regulatory and economic events/trends. In terms of ERP implementation, over time these external factors could offer opportunities or they could constrain future actions. The ERP Strategic Plan focuses on designing and implementing a flexible and interactive approach to ecosystem protection, management and restoration that would maximize the opportunities presented by future trends/events while, to the extent feasible, minimizing the constraints. In the Strategic Plan, this flexible ecosystem management approach is called adaptive management and it is designed to be integrated into the overall CALFED implementation program. Adaptive management was outlined in Chapter 1 and Chapter 6 provides a detailed description and discussion of adaptive management. Three key non-biological opportunity/constraint factors are discussed briefly in this section: 1) time – the length of time required to implement the ERP; 2) the political factor –

its potential influence on state/federal environmental policies and regulatory programs, and 3) the volatile nature of global economics.

The first consideration involves time. The non-ERP components of the CALFED program will be implemented in stages that now are expected to take up to 30 years to complete. The ERP also will be implemented in stages during this 30-year timeframe as an integrated component of the CALFED program. However, adaptive management is, by definition, a learning process and cannot be defined at the outset of the CALFED program by a specific set of identifiable actions set to occur according to a pre-determined schedule. Adaptive management measures and decisions will continue to be modified and be implemented after other non-ERP components of the CALFED program are completed. Adaptive management within the Bay-Delta ecosystem and other bio-zones will continue, for an unspecified length of time, responding to changing biological conditions and increased understanding of ecosystem processes and needs.

In addition to time, other critical external variables with the potential to impact the ERP involve changes in the state and national political and regulatory environments. As an example, based on the projected CALFED 30-year schedule, there will be 8 presidential and gubernatorial elections before the CALFED Program is completed. These state and national elections will inevitably affect the way existing public policies and programs are interpreted and implemented. Changes in administrations also could lead to new state/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 and legal challenges relating to federal measures such as Habitat Conservation Plans, "No Surprise" Rule and "Safe Harbor" provisions, and the state's Natural Community Conservation Planning (NCCP) process reflect the potential for changes in law, regulation and policy that could impact implementation of both the ERP and the overall CALFED Program.

Beyond the local, state and national political and regulatory realms, global economic influences must be recognized and accommodated. Recent events in Asia and elsewhere demonstrate that other national economies and global economic events can quickly become factors capable of influencing policy decisions at all levels of our government, including decisions affecting the protection and management of critical biological resources. These external events cannot be accurately predicted and the resulting impacts cannot be quantified in advance; however, it is clear that such changes are inevitable, that they could influence the manner in which the ERP is carried out, and that they demand a Strategic Plan approach that is flexible and based on a systematically acquired understanding of the Bay-Delta ecosystem.

The Strategic Plan's application of the adaptive management framework to the ERP decision making process provides the basis for a more efficient and inclusive evaluation of restoration impacts, benefits and alternatives. As an added benefit, it also could help to minimize unnecessary and harmful programmatic changes during implementation of the ERP that could result from the adverse effects of some of the external non-biological events and trends cited above by strengthening and making explicit the rationale for proceeding with each recommended ERP action. Thus, it is likely that decisions made within a science-based, adaptive management framework will be less vulnerable to adverse effects generated by external events than would be the case if a more typical restoration strategy was applied (e.g. decisions cannot be demonstrated to be science-based, fail to consider identifiable alternatives, or appear to be politically influenced/motivated). The buffering effect of the adaptive management approach is strengthened by the decision to apply the adaptive management framework throughout the CALFED Program.

F. Implications for Restoration of Ecosystem-Level Differences in Functions

In developing objectives, indicators, and specific restoration actions for the Bay/Delta system, it is important to bear in mind certain fundamental differences between estuarine and riverine systems, which will influence the likely response of biota to restoration activities and thus help to select the most suitable strategies for different parts of the Bay-Delta system.

In riverine systems, most flows are unidirectional: water, sediment, nutrients and other dissolved constituents, organic material, debris, and biota such as small fish. The habitat in a given reach of river is strongly influenced by the flows it receives from upstream, which in turn are influenced by watershed factors such as basin geomorphology and vegetation, upstream floodplain storage, etc. Seasonal and inter-annual variations in flow are important aspects of the flows. Most significantly, the magnitude, composition, and timing of various fluxes from upstream (e.g., runoff, sediment load, nutrients, large woody debris) have been altered by human actions such as land-use changes, dam construction, levee construction, and clearing of riparian vegetation.

In an estuarine ecosystem, flows are not unidirectional, and differences in salinity give rise to important ecological effects directly and by affecting flow patterns. In a macrotidal estuary such as San Francisco Bay, tidal flows are by far the most significant source of physical forcing at shorter time scales (two weeks or less). Tides produce mixing, break down stratification, cause periodic changes in flow direction and inundation of intertidal areas, and daily and spring-neap variations in estuarine volume and depth. Tidal flux can be influenced by changes in tidal prism, the volume of water exchanged during a tidal cycle. In some small tidal inlets along southern California, filling or diking of tidal marshes so reduced the tidal prism that the remaining tidal flows were inadequate to keep the inlets open. In the Bay-Delta system, filling and diking of tidal marshes has reduced the tidal prism somewhat, but the effect is small relative to the overall patterns of tidal exchange.

The unidirectional flow in riverine systems can be measured, although flood flows (in many respects the most important flows in the riverine system) remain essentially impossible to measure directly due to logistical problems. In the bidirectional flow of tidal systems, flux estimates are notoriously difficult. Estuarine circulations are further complicated by salinity, which in addition to obvious constraints on aquatic ecology related to salt tolerance, also provides the density gradients that allow for strong stratification and gravitational circulation, features absent from rivers. These circulation features influence the residence time and movement patterns of living and other particles in the estuary.

While migrating fish may sometimes reverse direction in rivers, their overall movements are either upstream or downstream. Estimating the flux of fish in rivers is complicated by difficulties in sampling at the locations and times of important migrations, but in some cases fish are funneled through constrictions where they can be counted. In estuaries, however, it is more difficult to estimate fluxes of migrating fish, because fish almost certainly change migration rate or direction on a tidal time scale. Because the ultimate success of our restoration efforts will probably be judged on future populations of important fish species (many of which are migratory), estimates of fluxes of fish will be important, and the limitations imposed on these numbers by physical conditions should be borne in mind.

Much of ecological theory is based on terrestrial habitats in which space can be a limiting factor. Habitat area is often limiting in upstream riverine environments and in nearshore environments of estuaries, where physical space for the organisms constrains the carrying capacity for organisms. (Whether physical habitat is actually limiting depends on the status of other potential limiting factors.) In upstream river environments, the area (and volume) of aquatic habitat are limited by the size of the channel, extent of potentially suitable habitat within the channel (e.g., overhanging bank cover, clean gravel beds), and extent to which the channel is filled with water. Nearshore estuarine systems are limited by the extent of area of attached algae and macroinvertebrates, and available territory for fish. Thus similar principles (e.g., competition for space) probably apply in those areas as they do in terrestrial habitats.

In open-water oceanic and estuarine habitats, however, physical space is unlikely to be a limiting factor for any given species, although it indirectly limits the total abundance of organisms in an area. Two consequences, both relevant to restoration, arise from the non-limiting nature of space. First, density-dependent effects on a population must occur either through food supply or predator response (including cannibalism). These effects can be more difficult to detect than those involving space limitation, and they can occur at any life stage, making modeling of these effects difficult. Second, because space may not be a limiting factor, adding more of it may not increase the abundance of open-water species. For example, when fish-aggregation devices are placed offshore to attract pelagic fish such as tuna, there may not be an increase in abundance but merely an increase in vulnerability to fishing. Because of strong tidal forcing, few if any habitats in the open-water regions of an estuary can be truly considered isolated from each other.

Food supply can be an important limitation in riverine systems as well. In upstream reaches, the fall of leaves, insects, etc. into streams (and even the decay of spawned out salmon carcasses) are important sources, while with distance downstream and increasing river size, these (allochthanous) sources become less important than (autochthanous) primary productivity (Vannote et al. 1980). The upstream reaches important for salmonid reproduction are clearwater water streams with little primary productivity, and are dependent upon allochthanous sources of carbon. Adult spawners generally do not feed (relying on stored food reserves in their bodies). However, rearing juveniles require food, so the health of the riparian corridor is important for the food it provides, and thus projects that improve the riparian vegetation along channels should increase food supply and thus lift a potential constraint on rearing.

In estuarine reaches of the Bay-Delta system, the invasion of exotic species is probably the single most important limitation on ecological restoration, because exotic species have fundamentally altered ecological interactions and even some physical characteristics, such as water clarity. In riverine reaches, however, human-induced alterations to physical processes are probably the most important limitation on restoration. While exotic species have established, and may even be dominant, in riverine reaches, they tend to thrive in environments where physical processes and/or habitat have been altered, such as the higher proportion of exotic species encountered in reaches downstream of dams (Baltz and Moyle 1993).

The fundamental differences (physical and ecological) between riverine and estuarine systems should be borne in mind when contemplating potential restoration actions. For example, restoration of processes such as flooding, sediment transport, large organic debris transport may be more effective in riverine reaches (where these processes have been fundamentally altered by dams and levees) than in estuarine reaches where the most important physical processes are tidal and salinity-driven circulations.

F. Twelve Key Issues and Opportunities

Here we list twelve important issues to consider in developing an adaptive management framework. A successful restoration program will be demonstrated by our ability to resolve or gain a higher level of understanding of how these factors affect the ecosystem early in the program. A blueprint for restoration can only be created and expanded as we become more confident that restoration measures are likely to result in a desired effect. Therefore, resolving substantial uncertainties should be an integral part of the priority Stage 1 actions and monitoring programs. These issues are not merely academic but cut to the heart of both the kinds and sequence of restoration actions, and the degree to which adaptive management must become the basis for the ERP. Where possible, actions should focus on restoring ecosystem processes which create and maintain habitats, providing greater system durability and more sustainable conditions for target species.

The issues are listed below, in approximately increasing order of specificity but unordered with regard to importance. We do not assert that they are the only ones to consider. However, a successful program will have to take these issues into account. Many of them deal with uncertainty resulting from incomplete information and unverified conceptual models, sampling variability, and highly variable system dynamics. Much of this uncertainty is unavoidable and must be taken into account in the adaptive management approach to ecosystem restoration. Thus, we do not claim to know the answers to the questions implied by these issues, but suggest instead the need for adaptive management and probing early in the implementation of Stage 1.

1. *Introduced species*: The ERP is designed to shift the ecosystem from its present state to a new, more desirable state. The single most likely impediment to our ability to make that

shift in the Bay and Delta is introductions of alien species to the system. In the last 3 decades, introduced species have had a greater impact on the species composition and function of this region than any other single human activity. Upstream, establishment of exotic species, facilitated by changes in habitat, has altered the ecosystem with unknown consequences to our ability to restore it. It is imperative that the ERP quickly put into action a robust, thorough program to reduce the flow of invasive species to the lowest possible level, as stated in Goal 5, and to establish habitat conditions that favor native over exotic species.

2. *Natural flow regimes*: Restoration of natural flow regimes in regulated rivers has become the new paradigm in stream restoration. It is based on the assumption that desired species of fish (usually salmonids), high aquatic biodiversity, and preferred riparian conditions depend on variable flow regimes that maintain active channels and floodplains, and keep exotic species at bay. However, a completely natural flow regime for a river reach below a dam is not possible (because of human water demand) and may not even be particularly desirable because the pre-dam sediment supply has been cut off. If upstream cold-water habitat is inaccessible, higher summer flows may be needed. Nevertheless, native species are usually favored by flow regimes that at least resemble the historical flow regime in the pattern of natural, seasonal variability, if not in magnitude. The desired conditions below every major dam are likely to be different, suggesting a need for experimental manipulations of flows, including moderate annual flood flows, and habitat to find the right combination of factors that will maximize ecosystem benefits or assist endangered species in ways that are compatible with other uses of water and river corridors.

3. ***Channel dynamics, sediment transport, and riparian vegetation***: There is growing recognition that dynamic river channels, free to overflow onto floodplains and migrate within a meander zone, provide the best riverine habitats. The dynamic processes of flow, sediment transport, channel erosion and deposition, periodic inundation of floodplains, establishment of riparian vegetation after floods, and ecological succession create and maintain the natural channel and bank conditions favorable to salmon and other important species. These processes also provide important inputs of food and submerged woody substrates to the channel, among their many ecological benefits. The most sustainable approach to restoring freshwater aquatic and riparian habitats is by restoring dynamic channel processes; however, restoration of natural channel processes is now hampered by the presence of levees and bank protection along many miles of rivers. Below reservoirs, the reductions in high flows, natural seasonal flow variability, and supply of sand and gravel have further exacerbated the constraining effect on rivers with levees and rock banks. Thus, it is a priority to identify which parts of the system still have (or can have) adequate flows to inundate floodplains, sufficient energy to erode and deposit, and to identify floodplain and meander zone areas for acquisition or easements to permit natural flooding and channel migration. Sediment deficits from in-channel gravel mining should also be identified, and the feasibility or efficacy of augmenting the supply of sand and gravel in reaches below dams should be evaluated.

4. ***Flood management as ecosystem tool:*** Our present approach is to control floods using dams, levees, bypass channels, and channel clearing. This approach is maintenance-intensive, and the underlying cause of much of the habitat decline in the Bay-Delta system since 1850. Not only has flood control directly affected ecological resources, but confining flows between closely spaced levees concentrates flow and increases flood problems downstream. With continued deterioration of flood control infrastructure, further levee failures are likely. Emergency flood repairs are stressful to local communities and resources, and often result in degraded habitat conditions. An alternative approach is to manage floods, recognizing that they will occur, they cannot be controlled entirely, and that floods have many ecological benefits. Allowing rivers access to more of their floodplains actually reduces the danger of levee failure because it provides more flood storage and relieves pressure on remaining levees. Valley-wide solutions for comprehensive flood management are essential to ensure public safety and restore natural, ecological functioning of river channels and floodplains. The USACE comprehensive study now underway provides CALFED with an opportunity to integrate an ecosystem perspective and adaptive management into the new approach to flood management, and help to redesign the flood control infrastructure to accommodate more capacity for habitat while reducing the risks of flood damage.

5. ***Bypasses as habitat***: The Yolo and Sutter bypasses along the Sacramento River are remarkably successful in reducing flooding in urban areas. They are also important areas for farming. 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. There is also a growing realization that bypasses can be important habitat for waterfowl, for fish spawning and rearing, and possibly as a sources of food and nutrients for estuarine food webs. When the Yolo bypass is flooded, for example, it effectively doubles the wetted surface area of the Delta, mostly in shallow water habitat. Managing the bypasses for the benefit of fish and wildlife, however, may conflict with their use for flood control and farming. There is thus a major need for an evaluation of existing bypasses as habitat in order to reduce management conflicts. New or expanded bypasses and managed flood basins should also be designed with the needs of fish and wildlife in mind.

6. ***Shallow-water habitat***: Restoration of shallow-water tidal and freshwater marsh habitat has received substantial support as a method for achieving species restoration goals. The underlying assumption is that physical habitat of the kind and at the locations proposed is limiting to the populations of interest, and therefore that additional such habitat will increase these populations. This assumption is fundamental to a lot of ecosystem restoration projects, but it has not been tested for many species in this estuary. Furthermore, it is possible that restored habitat will be used by other than the target species, with unknown consequences for natives. The high degree of uncertainty regarding this key topic makes a strong case for an adaptive approach in which options for design and location, and the species-specific benefits of such restoration, are assessed. Large scale pilot projects, accompanied by intensive monitoring of the successional

changes in physical conditions, vegetation cover, and species utilization, are likely needed to resolve these uncertainties.

7. *Contaminants in the Central Valley*: Researchers frequently discover that waters and sediments in various parts of the system are toxic to fish and invertebrates in bioassays. Although there is only limited evidence connecting these conditions to reductions in abundance, this chronic condition does not seem conducive to long-term restoration. Furthermore, there is an ongoing debate over the long-term consequences to human health of chronic exposure to low concentrations of many organic contaminants. Concern over this general topic has prompted us to elevate this to the status of a specific goal for the ERP.

8. *Limiting factors:* For few aquatic species do we have a good idea what limits abundance and production. Difficulties are that density-dependent limits on abundance can be very subtle and episodic, and that data are typically available for only portions of the life cycle. Without knowing the limiting factors, we can only guess at the likelihood that particular actions will benefit a species. Actions directed at individual species may be ineffective because of other, possibly unknown, limits. This suggests the need for action at the ecosystem level, by which we can achieve multiple restoration objectives without understanding mechanisms. The X2 standards are a good example of ecosystem-based actions without a clear understanding of mechanisms. Under the ecosystem approach, restoration actions must be partially based on empirical models, which may have limited predictive capability, or on a general understanding of ecosystem-level processes.

9. *X2 relationships*: Current management of the Bay-Delta ecosystem 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.

10. *Decline in productivity:* Productivity at the base of the food web has declined throughout the Delta and northern San Francisco Bay. Although some of this decline can be attributed to the introduced clam *Potamocorbula amurensis*, not all of the decline is explained. The decline at the base of the food web has been accompanied by declines in several (but not all) species and trophic groups, including mysids and longfin smelt. The long-term implications of this seem to be a reduction in the capacity of the system to support higher trophic levels. This implies a limit on the extent to which Bay-Delta fish populations can be restored unless creative solutions can be found to increase food web productivity.

11. *Entrainment of fish at pumps*: A major impetus behind the CALFED Bay-Delta

Program is concern over the effects of entrainment of fish and other biota in the pumps of the major water projects and, to a lesser extent, the numerous smaller agricultural water diversions in the Delta and along rivers. However, for no species of fish or invertebrate do we have a clear idea of the extent to which entrainment affects population size (DEFT 1998). The answer to this question will determine to what extent an "isolated facility" can be expected to alleviate any problems; thus it is pivotal for choosing facilities for water conveyance. Reducing this uncertainty is also essential to the most efficient allocation of resources for ecological restoration, because proposed solutions to this problem include potentially tens of millions of dollars spent constructing fish screens and new intake facilities over the entire solution area, not all of which may be as effective as intended at reducing population declines.

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. Yet if substantial numbers of salmon fry rear in the Delta and these fish contribute substantial recruitment to the adult population, then actions to enhance Delta rearing of fry would be warranted. Current actions to protect migrating smolts (e.g., pulse flows) might be supplanted by actions designed to protect resident fry (e.g., extended high flows to flood shallow areas). This topic requires research, including adaptive probing and pilot projects.

Other related issues: Two issues do not fit into this list but warrant discussion. One issue that transcends all of the ERP has to do with the institutional structure for Adaptive Management. The culture of most government agencies is contrary to the full integration of Adaptive Management. Establishing an entity capable of implementing real Adaptive Management will be one of the biggest challenges of the ERP, and is discussed further in section 6.B.2.

The second issue concerns the geographic extent of the CALFED-defined problem area. We believe that there are compelling reasons to extend the downstream boundary of the problem area to the mouth of the estuary. Our reasons are many, but include the following key points:

Ecosystem-based restoration must consider where the boundaries of the ecosystem are; in the case of the Bay-Delta the seaward boundary is clearly the mouth of the estuary, not Carquinez Strait.

- Numerous species significantly affected by CALFED actions and frequently residing in the Delta enter the bay as juveniles, including starry flounder, Bay shrimp, and Pacific herring.

- Several species of concern spend much of their time in San Pablo Bay and seaward, including longfin smelt and striped bass.

- Young chinook salmon spend considerable amounts of time in the lower bays on their seaward migration.

- Reduction in productivity of the lower bays probably has significant effects on Delta species such as Delta smelt, and has apparently caused a reduction in productivity in the Delta through tidal mixing.

- Restoration of habitat in the lower bays might therefore be part of an effective strategy for restoring species of interest, when combined with restoration in the Delta itself and on major upstream tributaries of the Delta.

Figure 3-2. **Effect of levees on flood flows and channel geomorphology.** With natural floodplain functioning, much of the flood waters are accommodated on the floodplain, where high hydraulic roughness leads to slower flows, and thus slower downstream transmission of floodwaters (a). Levees concentrate flood waters within 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 on the channel bed (c), which may lead to bed incision (b).

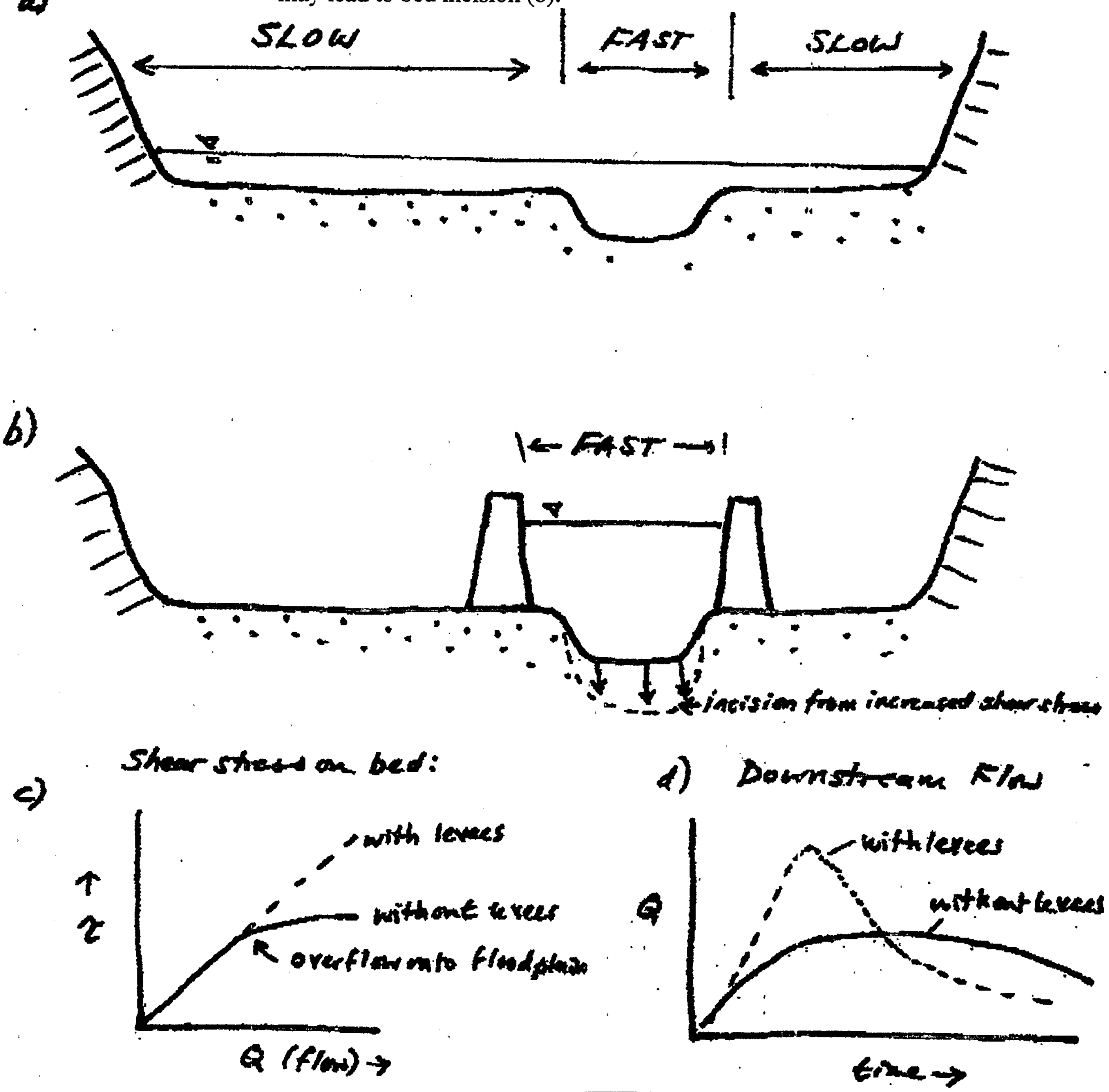


Figure 3-4. Areas cut off by dams.

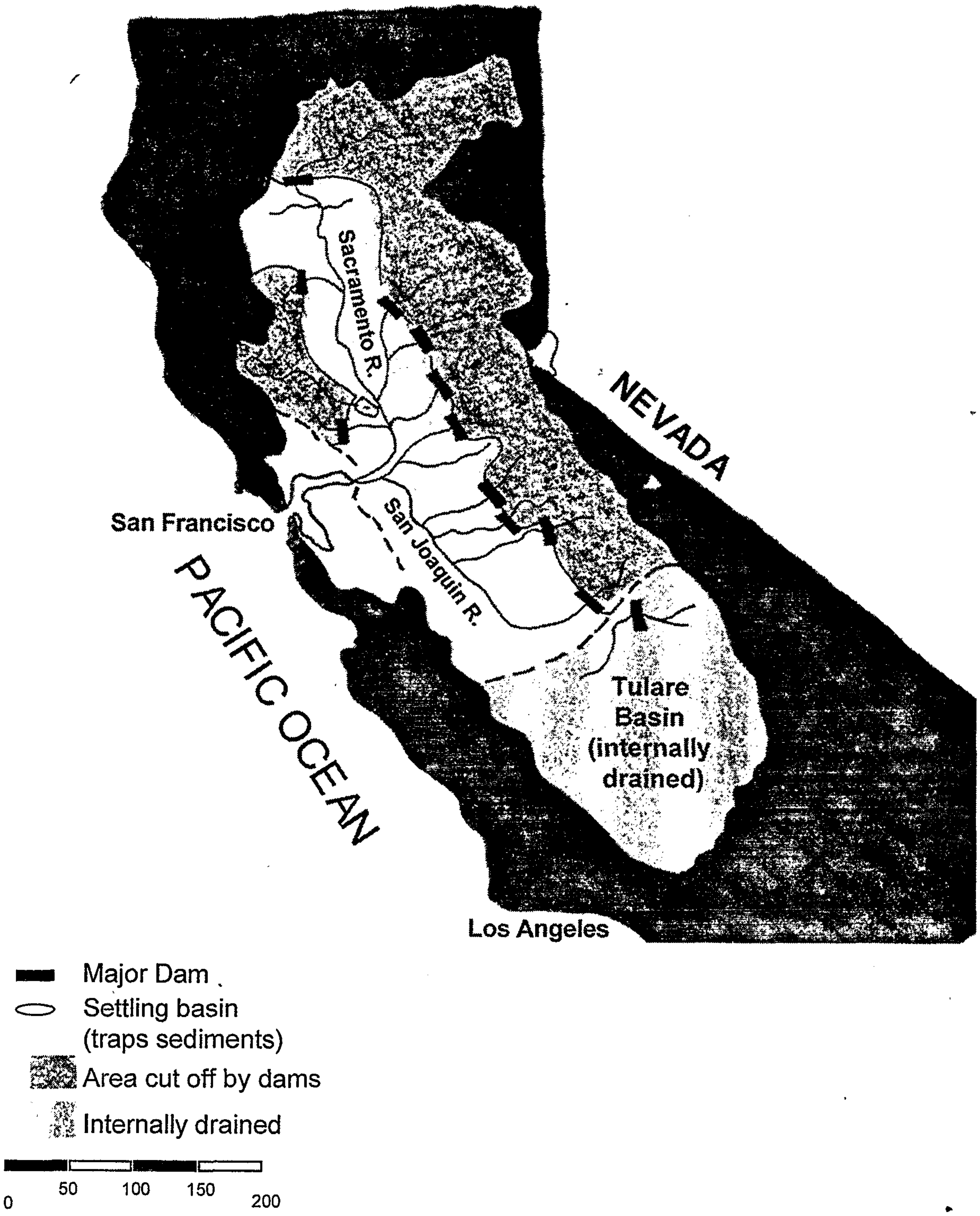
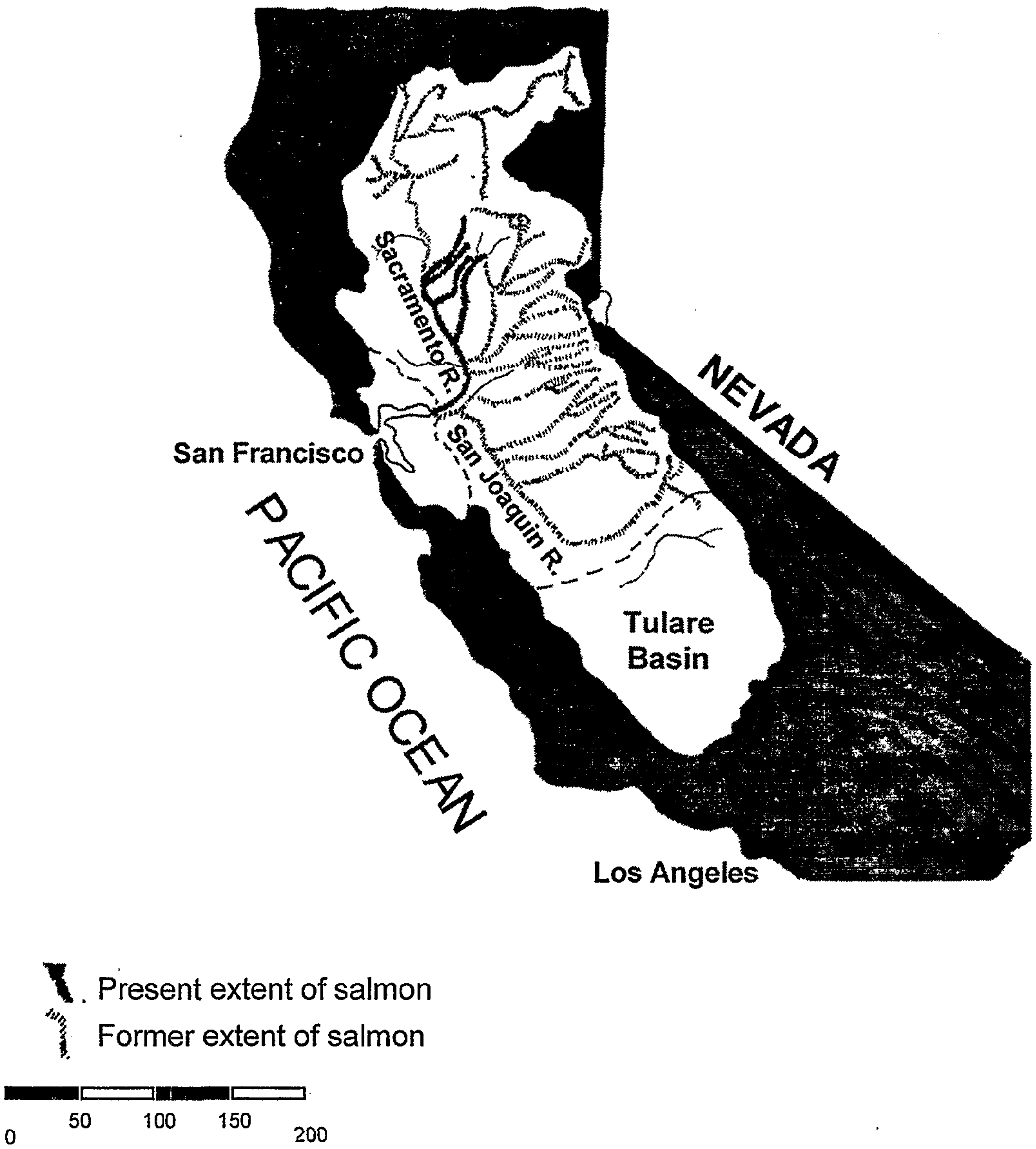


Figure 3-5. Present versus historic extent of spring-run salmon.



Chapter 4. Goals and Objectives

A. Ecosystem Restoration Goals

1) General CALFED Goals.

The mission of the CALFED Bay-Delta Program 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. The Program addresses problems in four resource areas: ecosystem quality, water quality, levee system integrity, and water supply reliability.

The goal for ecosystem quality is to improve and increase aquatic and terrestrial habitats and improve ecological functions in the Bay-Delta to support sustainable populations of diverse and valuable plant and animal species. The CALFED Ecosystem Restoration Program addresses this goal.

2) CALFED Ecosystem Restoration Program Goals.

The Ecosystem Restoration Strategic Plan of CALFED is to be a guide for achieving a reasonable level of "ecosystem quality" for the Sacramento-San Joaquin estuary and its watershed in a way that still allows sufficient water to be available to drive the diverse California economy. The key term ecosystem quality is not well defined and is presumably the same as the similar terms "ecosystem health" and "ecosystem integrity"(e.g., Woodley et al. 1993). All these terms imply the desirability of ecosystems that not only will maintain themselves through natural processes with minimal human interference (i.e., at low cost) but will be aesthetically attractive and produce goods and services in abundance for humans.

While many specific actions and goals to achieve a high level of ecosystem quality for the parts of the estuary and watershed within the purview of CALFED are given in the Ecosystem Restoration Program Plan, the broader, overall goals are less clear. The CALFED goals for ecosystem restoration are as follows:

1. Achieve, first, recovery and then large, self-sustaining populations of at-risk native species dependent on the Delta and Suisun Bay, support similar re-establishment 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 non-listed native species.

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

3. Maintain and enhance populations of selected species for sustainable commercial

and recreational harvest, consistent with goals 1 and 2.

4. Protect or restore functional habitat types throughout the watershed for public values such as recreation, scientific research, and aesthetics.

5. Prevent establishment of additional non-native species and reduce the negative biological and economic impacts of established non-native species.

6. Improve and maintain water and sediment quality to eliminate, to the extent possible, toxic impacts on organisms in the system, including humans.

A) GOAL #1 ENDANGERED SPECIES

Achieve, first, recovery and then large, self-sustaining populations of at-risk native species dependent on the Delta and Suisun Bay, support similar re-establishment in abundance 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 non-listed native species.

This goal is listed first because 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 the CALFED Bay-Delta Program. "At-risk species" are those native species that are either formally listed as threatened or endangered under state and federal laws or that have been proposed for listing. It 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 rainbow trout, and Sacramento splittail. The goal gives highest priority to the legal recovery of species formally listed under the Federal and State Endangered Species Acts because of the high degree of legal protection given the species, especially under federal law. The Strategic Plan, however, also supports actions that will lead to the restoration of large, self-sustaining populations of these endangered species and encourages/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 along 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 Strategic Plan 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 towards endangerment and extinction are halted.

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

1. The state and federal ESAs largely mandate species recovery as the way to achieve ecosystem recovery.

2. 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).

3. Species can be good indicators of ecosystem recovery and their distribution and abundance is comparatively easy to measure.

B) GOAL #2 ECOSYSTEM PROCESSES AND BIOTIC COMMUNITIES

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

Biotic communities are dynamic assemblages of species that typically occur together, in part because of common physiological tolerances, and interact with one another. This goal recognizes that an ecosystem restoration plan must include restoration and maintenance of ecosystem processes, such as seasonal fluctuations in flow and salinity, cycling of nutrients, predator-prey dynamics, and food web structure. While these processes will exist no matter what organisms make up the biotic communities, they may not function within the constraints identified with 'healthy' ecosystem functioning. Particular assemblages of organisms within defined set of conditions (the biotic communities) therefore become indicators of the ecosystem 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 stresses rehabilitation rather than restoration because so many of the physical and chemical processes in the watershed have been fundamentally altered by human activity. Thus 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.

C) GOAL #3 HARVESTABLE SPECIES

Maintain and enhance populations of selected species for sustainable commercial and recreational harvest, consistent with Goals 1 and 2.

This goal recognizes that maintaining some species in numbers large enough to sustain

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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 biotic communities. Note that 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 estuary and watershed are likely to have negative effects on other species. The goal states "selected" species because some species that may be harvested (e.g. *Corbicula* clams, mitten crabs) are also nuisance species for which it is highly desirable to reduce populations. The species selected for harvest management must be chosen in ways that recognize that species regarded as harvestable varies considerably among ethnic groups and can change with time. Thus most native cyprinids (e.g., splittail, blackfish, hitch) are held in high regard by people of Chinese heritage, even though they are disdained by fishers of European heritage.

D) GOAL #4 HABITATS

Protect or restore functional habitat types throughout the watershed for public values such as 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, riparian forest). Because of this they 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 can cycle through the entire system). The ERP Plan (Vol. 1, 1998) identifies major habitat types within the estuary and watershed, while Moyle and Ellis (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 Ecosystem. 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 Ellis (1991) and others. There are many direct benefits that 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, 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 creation of clean water, removal of toxic materials from air, and delivery of nutrients to systems producing fish and other economically important aquatic organisms (Daily 1997).

E) GOAL #5 INTRODUCED SPECIES

Prevent establishment of additional non-native species and reduce the negative biological and economic impacts of established non-native species.

This goal is arguably part of the first four goals because protection and enhancement of species, communities, and habitats in estuary and its watershed implicitly includes reducing the impact of invasive non-native 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 Bay-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 is a problem that 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 exotic species such as water hyacinth and the Asiatic clam (*Potamocorbula*) continue to have major negative impacts on more desirable species in the system and methods of control have to be devised. It is important that the control methods not be as harmful as the invading species they are designed to control.

F) GOAL #6 TOXICS

Improve and maintain water and sediment quality to eliminate, to the extent possible, toxic impacts on organisms in the system, including humans.

Like solving the problems with introduced species, solving the problems of toxic materials in the ecosystem could be considered part of the first four goals. Once again, this problem is so pervasive and poorly understood that it deserves recognition as a distinct goal. Major potential problems associated with toxics include the following:

1. Persistent toxics, such as heavy metals, accumulate through food chains, creating health problems not only for carnivorous fish but for the animals that eat them, such as birds and humans.

2. New, highly toxic biocides are aperiodically flushed into the ecosystem through agricultural and urban drains, creating water that is temporarily toxic to small invertebrates and fish; such toxic events may go unnoticed because of the brevity of each event and the small size of the organisms immediately affected.

3. Pesticide use in the Central Valley is increasing, with increased potential for negative effects on aquatic ecosystems.

4. There is considerable potential 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 Cantera spill on the upper Sacramento River).

5. Toxic materials accumulate in sediments where they can affect benthic organisms directly (and the food webs they support) or sit as 'time bombs' waiting to go off when the sediment is disturbed.

6. Substances once thought to be harmless can turn to have harmful effects in subtle ways, e.g., as carcinogens or hormone disruptors. The impact of toxic substances is also an area in which there is high public awareness and considerable concern over the risks of consuming harvested organisms or of drinking water from the system.

3) What Are the Goals Designed to Achieve?

The goal statements provide the basis for a vision of a desired future condition of the Bay-Delta estuary and associated ecosystems. Basically, they lead to a definition of what is meant by "ecosystem quality" as applied to the CALFED region.

First, the goals reflect a desire for ecosystems which are not continually being disrupted by unpredictable events, such as the invasion of exotic species capable of altering ecosystem processes, massive levee failures, or new endangered 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 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. This means the ecosystems under the purview of CALFED are not 'natural' ecosystems in which humans are primarily observers but are systems that (1) continue to be altered by human activity, but in a directed fashion, (2) allow people to both live and make a living in them, and (3) produce products that benefit the larger society, such as water, power, and food.

Third, the goals reflect a desire for ecosystems which maintain substantial self-sustaining populations of the remaining native species and some high-value exotic 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 exotic 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.

C. Ecosystem Restoration Objectives

Each of the six strategic goals for the ERP has a series of objectives associated with it. The objectives, presented below, are meant to be used to determine whether or not progress towards achieving the goal is being made. They are mostly stated in terms of management actions designed to have a favorable impact on the Bay-Delta ecosystem and watershed. However, some are also stated in terms of studies that will teach us how the ecosystem behaves, so 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).

Objectives can be both short term and long term. *Short term objectives* (e.g., recovery of an endangered species) should be clearly feasible, relatively easy to measure, and achievable in reasonable lengths of time (usually <25 years). The time period is not the same as Stage 1 of the CALFED process. *Long term objectives* (e.g., achieving a large self-sustaining population of a species) may be more difficult to determine and require additional resources and knowledge to achieve. They usually will take longer than 25 years to attain.

Stage 1 expectations are meant to be measures of the progress towards meeting short-term objectives made in the first 7-10 years of implementation of the ERP. These expectations have two basic components: improvements in information to allow better management of the ecosystem and improvements in physical and biological properties of the Bay-Delta ecosystem and watershed. Frankly, it is unlikely that the expectations under every objective will be met, yet failure to meet a significant proportion of the expectations will be regarded as a major reason to re-evaluate and redirect the CALFED ERP process.

Individual objectives in the Strategic Plan 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 processes. For example, several long-term objectives are designed to achieve numbers or densities of spawning salmon equivalent to those of a fixed time in the past. Basically, we will not really know if such numerical objectives are realistic until some manipulations of one or more regulated rivers have been made 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 Workgroup "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 below, but most will have to be developed.

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 that is 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.

The catalog of objectives that follows was generated by looking at goals in the ERP Plan, reviewing existing species recovery plans, discussions among the Core Team and CALFED staff, and examination of drafts of various documents produced by stakeholders. However, it is not complete. Therefore, the objectives presented should be considered to be models for objectives that are not presented here. It is not unreasonable to expect that as we learn more about the system some established objectives will change in focus and additional new objectives will be established.

Goal# 1.Achieve, first, recovery and then large self-sustaining populations of at-risk native species dependent on the Delta and Suisun Bay, support similar recovery 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 non-listed native species.

Because there are so many species covered under this goal, they have been divided into four groups in terms of priority for CALFED attention. Many are "at-risk" species, which are in danger of extinction if present trends continue.

First priority species are at-risk fishes, most of them listed under the ESA or proposed for listing, whose management for restoration is likely to have large-scale effects on ecosystem functioning (e.g., requiring large amounts of freshwater at certain times of year). First priority species are species for which CALFED takes major responsibility for their recovery ('R' species of the CALFED Conservation Strategy Team),removing them from the threat of extinction, *at a minimum.*

Second priority species are those in danger of extinction but for which conservation measures are less likely to have large-scale impacts on estuarine processes because of their limited habitat requirements within the estuary (e.g., brackish water plants). Second priority species are a mixture of species that CALFED will take direct responsibility for recovery ("R" species) and species to which CALFED will "contribute to recovery" to remove them from the threat of extinction (i.e., assist recovery where possible but not make the recovery a major focus of CALFED). This latter group of species are the 'r' species of Conservation Strategy Team.

Third priority species are at-risk species that primarily live upstream of the estuary or in San Francisco Bay for which CALFED will contribute to recovery (also 'r' species).

Fourth priority species are native species in the estuary and watershed not yet at risk of extinction that have the potential to achieve that status if steps are not taken to reverse their declines or keep populations at present levels. These species are those that CALFED will try to "maintain" at present levels or higher('m' species of the Conservation Strategy Team).

The objectives and expectations for this goal are narrowly aimed, for the most part, on actions that benefit individual at-risk species. In the short run, this is appropriate because ecosystem restoration requires that we keep all the pieces around for the rebuilding process. However, simultaneously with species recovery actions, it is essential to be working on actions that restore habitats (Goal 4) and ecosystem processes (Goal 2). In fact, for species not in immediate danger of extinction, the preferred method of working towards the goal of self-sustaining populations should be to improve or increase the habitats that support them, in part by making restoring natural ecosystem processes.

PRIORITY GROUP I. AT RISK NATIVE SPECIES DEPENDENT ON THE DELTA AND SUISUN BAY WHOSE RESTORATION IS LIKELY TO HAVE LARGE-SCALE EFFECTS ON ECOSYSTEM FUNCTIONING.

Objective #1 Restoration of delta smelt to the Delta and Suisun Bay.

A. Long-term objective: To restore delta smelt abundance to levels that existed in the 1960s and 1970s, as measured over a period of at least 10 years.

B. Short-term objective: Achieve the recovery goals for delta smelt that are given in the Delta Native Fishes Recovery Plan

Rationale: Delta smelt were extremely abundant in the system when the "standard" trawling program in the Delta began in the 1960s. This period is used as a standard simply because that is when the data available for comparative purposes begins. Conditions in the estuary were clearly favorable for the species in that period. Achieving the long-term objective may be impeded by the presence of several introduced species, notably the clam *Potamocorbula amurensis*, inland silversides, and wakasagi. If future investigations determine that substantial reductions in delta smelt are due to the introduced species currently established, this objective may need to be scaled back.

Stage 1 expectations. In 7-10 years, the delta smelt population indices should be within the same range that they have been in the period 1990-1998. The basic factors limiting delta smelt distribution and abundance should be determined (e.g., reduced food supply, interactions with exotic species, negative effects of diversions) and, where feasible, overcome through habitat and ecosystem process restoration.

Linkages: [note: these should be developed at the end of the writing process because many of the objectives are overlapping or synergistic]. Goal 2 (1,2,3), Goal 3 (1), Goal 5 (1,5), Goal 6 (1,6)

Objective #2. Restoration of winter-run chinook salmon to the Sacramento River and the Bay-Delta estuary.

A. Long-term objective: Create self-sustaining populations of winter-run chinook salmon in both the main stem Sacramento River and in Battle Creek at abundance levels equal to or greater than those in the Winter Run Chinook Recovery Plan.

B. Short-term objective: Achieve recovery as defined in the NMFS Winter Run Chinook Recovery Plan.

Rationale: Winter-run chinook salmon are unique to the Sacramento River and are adapted to spawn in the cold, spring-fed rivers now located above Shasta Dam. They are currently maintained through extraordinary effort in artificial cold-water habitat below Keswick Dam in the Sacramento River and in a special hatchery program. Because they are so vulnerable to disasters (e.g., a toxic spill from Iron Mountain mine, just upstream), at least one other naturally reproducing population needs to be established to reduce the probability of extinction. Battle Creek, a cold-water stream to which Winter Run Chinook have been deliberately denied access in the past, is the best and probably only site available for such restoration. It is quite unlikely that winter-run chinook salmon will ever be much more abundant than specified in the Recovery Plan goals because available habitat is so limited.

Stage 1 Expectation. The cohort replacement rate in 7-10 years should exceed 1.0 and average abundance should increase. Battle Creek restoration (a CVPIA project) should have proceeded to a point where winter run chinook will have spawned in the creek 2-3 times.

Objective #3. Restoration of spring-run chinook salmon to Central Valley streams and the Bay-Delta estuary.

A. Long-term objective: restore wild naturally-reproducing populations of spring-run chinook salmon to numbers and/or spawning densities in the Sacramento river system equivalent to those that existed in the 1930's, as measured over a period of at least 25 years.

B. Short-term objective: achieve recovery, as defined by the Delta Native Fishes Recovery Plan (or in a federal recovery plan developed after they are formally listed as a threatened species).

Rationale: Spring-run chinook salmon were historically the most abundant run of salmon in central California. Unfortunately, they spawned primarily in stream reaches that are now above major dams. The biggest blows to their abundance came when Shasta and Friant dams were built. A run of 50,000 spring-run chinook salmon was stranded when Friant Dam shut off San Joaquin River flows alone. Attempts to rear spring-run chinook salmon in hatcheries have largely failed and both hatchery and wild populations in the Sacramento River proper are hybridized with fall run chinook. The only streams maintaining small runs of wild, unhybridized spring -run chinook salmon are Deer, Mill, Butte and Big Chico creeks. This salmon stock was proposed for listing in 1997 and will almost certainly be declared a threatened species by NMFS. It is not certain if additional subpopulations can be re-established in other Sacramento basin streams or in the San Joaquin basin but the possibilities need to be investigated.

Stage 1 expectations. Better methods for estimating population sizes should be developed. Populations in Deer, Mill, and Butte Creeks should remain within numbers found in the streams in 1990-98, with a cohort replacement rate greater than one. Factors limiting survival of out migrating smolts should be determined. The ability of Big Chico Creek to sustain spring-run a chinook population should be evaluated and measures taken to improve its capacity to support salmon. The potential for other streams, including Battle Creek, to support runs of spring-run chinook salmon should be evaluated.

Objective #4. Restoration of late fall-run chinook salmon to Central Valley streams and the Bay-Delta estuary.

A. Long-term objective: restore wild naturally-reproducing populations of late fall-run chinook salmon to numbers and/or spawning densities in both the Sacramento river equivalent to those that existed in 1967-1976, as measured over a period of at least 25 years, and re-establish a self-sustaining population in the San Joaquin drainage.

B. Short-term objective: achieve recovery, as defined by the Delta Native Fishes Recovery Plan, or in a federal recovery plan developed if they are formally listed as a threatened species.

Rationale: Late-fall run chinook salmon have long been recognized as a distinct run in the Sacramento River and, formerly, in the San Joaquin River, although their numbers were not quantified until Red Bluff Diversion dam was completed in 1967. The dam was a major factor contributing to their most recent decline. NMFS does not separate late fall-run from fall-run chinook salmon in their listing proposal but there is ample evidence that the two forms represent a distinct life history patterns in the Sacramento River and need to be managed separately. Late-fall run chinook were a main-stem spawner and were probably separated from their principal spawning grounds by Shasta and Friant dams. Restoration may be possible in a number of rivers (e.g., the Tuolumne) that have had their flow regimes adjusted so that over-summering of juveniles is possible.

Stage 1 Expectations. Late-fall run chinook salmon numbers should not fall any lower than they have been in the 1990s. Factors limiting their abundance should be determined and methods to determine their actual abundance should be developed.

Objective #5. Restoration of self-sustaining fall-run chinook salmon to Central Valley streams and the Bay-Delta estuary.

A. Long-term objective: Restore self-sustaining populations of fall-run chinook salmon to all their native streams, except those above Shasta Reservoir, with numbers of fish of wild origin equal to or exceeding the average numbers of fish of both hatchery and wild origin from 1980-1998.

B. Short-term objective: Recover San Joaquin fall-run chinook salmon to criteria in the

Delta Native Fishes Recovery plan and, assuming that salmon of wild origin make up 50% of the fall run in the Sacramento River, have wild salmon spawners number 75,000-100,000 fish each year.

Rationale: When Shasta and Friant dams were built, to inaugurate the modern era of the hydraulic society, implicit promises were made that fisheries for salmon would not decline. It was assumed that hatcheries and habitat improvements would make up for any losses caused by the dams. The hatchery system has been, at best, a partial success even though it has focused heavily on fall-run chinook salmon. Because of the hatcheries, the status of wild populations in the Central Valley is ambiguous.

Much of the habitat previously available for wild-spawning fish is permanently disconnected from the migration corridors. However, the remaining habitat or, the 'new' habitat in the tail waters of large dams, should be usable for spawning at densities (fish per unit of habitat, either area or distance) as great as those that existed before the construction of Shasta, Friant, and other dams. The objective, therefore, is to restore the numbers and spawning densities to pre-Shasta/Friant values of fall run chinook salmon. The assumption that pre-dam numbers and densities of salmon can be restored in presently available habitat depends upon a number of assumptions about habitat quality and the biology of the fish that need to be tested.

Stage 1 Expectations. Wild fall-run chinook salmon numbers should not fall any lower than they have been in the 1990s. Factors limiting their abundance in each major river should be determined, including the impact of hatchery fish. Programs (e.g., mass marking of hatchery juveniles) should be instituted to easily distinguish hatchery from wild fish and surveys made to determine the contribution of hatchery fish to natural spawning.

Objective #6. Restoration of self-sustaining Central Valley steelhead to Central Valley streams and the Bay-Delta estuary.

A. Long-term objective: Restore self-sustaining populations of steelhead to all streams still likely to support populations, with numbers of fish of wild origin equal to or exceeding the average numbers of fish of both hatchery and wild origin from 1980-1998.

B. Short-term objective: Determine the abundance and genetic identity of existing steelhead populations and develop population enhancing measures for remaining wild populations.

Rationale: When dams were built on all Central Valley rivers, steelhead were denied access to their historic spawning grounds in upstream areas. It was generally assumed that hatchery production would make up for any losses caused by the dams. Hatchery production of steelhead has encountered numerous problems, which have limited its success. For example, one major hatchery (Nimbus) raises steelhead that are derived from fish imported from the Eel River because native steelhead were in short supply (perhaps depleted by removal of wild individuals for use in the hatchery). Because of the hatcheries and changes to the rivers, the exact status of wild populations in the Central Valley is not clear but they are certainly at low levels. The biggest remaining populations of wild steelhead appear to be in the Yuba River and in Deer and Mill creeks (Tehama Co.)but the status of these runs is uncertain. For these reasons, NMFS has listed Central Valley steelhead as threatened. The objective, therefore, is designed to restore the numbers and spawning densities of wild steelhead to a point where the species can sustain a substantial sport fishery. The assumption that reasonably high numbers and densities of steelhead can be restored in presently available habitat depends upon a number of assumptions about habitat quality and the biology of the fish that need to be tested. It is likely that restoration of this fish will require providing it with access to upstream areas now blocked by dams (e.g., Yuba River upstream of Englebright Dam).

Stage 1 Expectations. Central Valley steelhead numbers should not fall any lower than they have been in the 1990s. The status of steelhead in the Yuba River and in Deer and Mill creeks should be determined. A research program on factors limiting their abundance should be initiated, including a study of the impact of hatchery fish. Available spawning and rearing habitat should be identified. Programs (e.g., mass marking of hatchery juveniles) should be instituted to easily distinguish hatchery from wild fish.

Objective #6. Restoration of longfin smelt to the Delta and Suisun Bay.

A. Long-term objective: To restore longfin smelt abundance to levels that existed in the 1960s and 1970s, as measured over a period of at least 10 years.

B. Short-term objective: Achieve the recovery goals for longfin smelt that are given in the Delta Native Fishes Recovery Plan.

Rationale: Longfin smelt are arguably one of the most endangered fishes in the estuary although the petition for listing as an endangered species was declined (largely for genetic reasons). Longfin smelt were extremely abundant in the estuary when the fall midwater trawling program began in the 1960s. This period is used as a standard simply because that is when the data available for comparative purposes begin and it covers a series of wet and extremely dry years. There is evidence that longfin smelt were abundant enough in the 19th century to support a fishery. Because longfin smelt abundance has a strong relationship to X2 position, future abundance may be tied closely to available fresh water and the ability to manipulate outflows to favor the species. Achieving the long-term objective may be impeded by the presence of several introduced species, notably the clam *Potamocorbula amurensis*. If future investigations determine that substantial reductions in longfin smelt is due to the introduced species currently established, then this objective may need to be scaled back.

Stage 1 expectations. In 7-10 years, the longfin smelt population indices should stay within the same range that they have been in the period 1990-1998, unless there is an exceptionally long period of drought. The basic factors limiting their distribution and abundance should be determined.

Objective #7. Restoration of green sturgeon to the Delta and Suisun Bay.

A. Long-term objective. Maintain large enough populations of green sturgeon so that commercial, subsistence, and sport fisheries can be maintained for them, both inside and outside the estuary.

B. Short-term Objective. Learn as much as possible about the life history requirements and population dynamics of green sturgeon in the Sacramento River and estuary, including its relationship to other green sturgeon populations, to see if the recovery goals in the Delta native fishes recovery plan are realistic. If so, the goals should be implemented.

Rationale: The green sturgeon is relatively uncommon in the Bay-Delta system compared to the white sturgeon and probably always has been. However, the population appears to be one of only three still in existence in North America, so needs special consideration. Very little is known about the requirements of this species in the system and the recovery goals in the Delta Native Fishes Recovery Plan are based on knowledge gained from their incidental catch in white sturgeon studies and fisheries. Thus restoration/management of this species depends on much better knowledge than currently exists. Because it is so long lived (50+ years) and seems to have relatively low levels of exploitation in the system at the present time, there is time to conduct systematic research on its biology to determine the best ways to increase its populations.

Stage 1 expectations. Basic facts about the population structure, distribution, and life history of green sturgeon should be determined and a management plan developed to insure its survival.

Objective #8. Restoration of Sacramento splittail to the Delta, Suisun Bay, and the Central Valley.

A. Long-term objective: Restore the Sacramento splittail to being one of the most abundant fish species in the Delta, Suisun Bay and Marsh, the lower Sacramento River and the lower San Joaquin River.

B. Short term objective: Achieve the recovery goals for splittail that are listed in the Delta Native Fishes Recovery Plan.

Rationale: The Sacramento splittail was once widespread in lowland waters of the Central Valley but is today largely confined to the estuary, except during wet years. The Sacramento splittail population dropped to a low point in the estuary during the drought of the 1980s but rebounded to high levels in the estuary during wet years of the 1990s. It is likely that reproductive success of this species is tied to the timing and duration of flooding of the Yolo and Sutter By-passes and to flooding of riparian zones along the major rivers of the Central Valley, so a return to its former abundance and distribution will require special management of these areas.

Stage 1 expectations. At least one additional strong year class should have developed to maintain splittail populations, while factors limiting splittail spawning and recruitment success are determined and accounted for in a management plan.

PRIORITY GROUP II. AT RISK NATIVE SPECIES DEPENDENT ON THE DELTA AND SUISUN BAY WHOSE RESTORATION IS NOT LIKELY TO HAVE LARGE-SCALE EFFECTS ON ECOSYSTEM FUNCTIONING.

Objective #1. Restoration of anadromous lampreys dependent on the Delta and Suisun Bay.

A. Long-term objective: restore wild self-sustaining populations of anadromous lampreys to all accessible rivers in which they historically occurred.

B. Short-term objective: evaluate the status and life history requirements of Pacific lamprey and river lamprey in the Central Valley and determine their use of the Delta and Suisun Bay for migration, breeding, and rearing.

Rationale: Lampreys are anadromous species that clearly have declined in the Central Valley but the extent of the decline has not been documented, except that they are much less abundant than formerly. Pacific lamprey probably exist in much of the accessible habitat available today but this is not in fact known. The cause of the decline of lampreys is presumably due both to the decline of salmonids (major prey species), to deterioration of their spawning and rearing habitat, to entrainment in diversions, and to other factors affecting fish health in the system. As for salmonids, much of the habitat previously available for wild-spawning lampreys is permanently disconnected from the migration corridors. However, the remaining habitat or, the 'new' habitat in the tail waters of large dams, should be useable for spawning. Presumably, restoration of salmonid populations will also benefit lampreys, although this assumption should be regarded as a hypothesis, not a fact. If the assumption is not true, lampreys may have to be treated as Priority I species.

Stage 1 expectations. Surveys should be conducted to determine the status of lampreys in the Central Valley and a status report should be in place that recommends restoration actions.

Objective #2. Restoration of at-risk endemic brackish water tidal marsh plants.

Long-term objective: Have self-sustaining populations of Mason's lilaeopsis, Suisun Marsh aster, Suisun thistle, soft birds-beak, alkali milk vetch, Delta mudwort, and Delta tule pea and similar declining endemic species located throughout their original native range in marshes associated with the Bay-Delta estuary.

Short-term objective: Protect existing populations of the species and restore habitat to provide sites for expansion of all rare native species that require tidal or brackish-water marshes.

Rationale: The seven species listed here are examples of plants that are largely endemic to brackish water marshes of Suisun Bay and elsewhere in the estuary. Only two of the species (Suisun thistle and soft bird's beak) are formally listed as endangered, but all seven are at high risk of extinction because of habitat alteration. Restoration of these species to the point where they were no longer in danger of extinction would indicate that major marsh restoration projects in the region had succeeded.

Stage 1 expectations. The status of the seven species listed here should have improved. Surveys of present ranges of the species (and other rare marsh plants), studies of their ecological requirements, and identification of key restoration sites should be completed. On-going marsh restoration projects in the Bay-Delta should be evaluated according to their success at restoring rare native plant species and lessons learned applied to new projects.

Objective #3. Restoration of California clapper rail

A. Long-term objective: Have self-sustaining populations of California clapper rail located throughout their original native range in tidal marshes of the Bay-Delta estuary.

B. Short-term objective: Protect existing populations of the species and restore habitat to provide sites for expansion of present populations.

Rationale: The California clapper rail requires tidal salt marshes for all phases of its life cycle. Its populations have declined as these marshes have been eliminated and fragmented, permitting easier access of exotic predators (e.g., house cats, red fox), people, and other intruders to their nesting and high-tide roosting areas. These birds should recover as tidal salt marshes are allowed to re-expand and as marsh restoration efforts proceed.

Stage 1 expectations. Habitat for all existing populations should be protected and management plans should be in place to further improve existing habitats for clapper rails. Potential additional restoration sites should be identified.

Objective #4. Restoration of Swainson's hawk

A. Long-term objective: Have self-sustaining breeding and wintering populations of Swainson's hawk located throughout their original native range in the Delta and the Central Valley.

B. Short-term objective: Determine the status of all California populations of Swainson's hawk and institute protection plans for key breeding areas. Determine the importance to the species of the small numbers that overwinter in the Delta should be determined and develop plans to expand the number of overwintering birds, if desirable and possible.

Rationale: Swainson's hawk is listed as a threatened species by the state of California because its numbers have declined to a small (<2%) percentage of its original population. It is a species that nests in riparian areas and forages in upland grasslands and crop lands. The decline has been caused by the combined loss of riparian nesting habitat and foraging habitat and by large mortalities to its overwintering habitat in Argentina. A small number of these hawks overwinter in the Delta rather than migrating, for unknown reasons. If restoration of breeding habitat does not significantly reverse the decline of these birds because of mortality during their long migrations, then there may be a need to find ways to encourage more overwintering in the Delta.

Stage 1 expectations. A recovery plan for Swainson's hawk in the Central Valley and Delta should be instituted, with key habitats identified and initial protective steps taken.

Other species in this group

Calif. black rail
Suisun Song sparrow [treat with Alameda song sparrow?]
Salt marsh harvest mouse
Ornate shrew
San Pablo California vole
Valley elderberry beetle

PRIORITY GROUP III. AT-RISK SPECIES IN THE WATERSHED AND SAN FRANCISCO BAY NOT DEPENDENT ON THE DELTA AND SUISUN BAY

Objective # 1. Restoration of California red legged frog to representative habitats throughout its former range

A. Long-term objective: Develop refuges in habitats throughout its former range that will each maintain 100+ breeding pairs of red-legged frogs, established from reintroductions.

B. Short-term objective: Locate and protect any remaining populations of red legged frogs in the CALFED region.

Rationale: Red legged frogs are virtually extinct in the region, with just a handful of tenuous populations remaining in the Central Valley (none near the estuary) [SF Bay?]. Their inability to recover from a presumed major population crash in the 19th century (due to over exploitation) has been the result of a combination of factors (in approximate order of importance): (1) predation and competition from introduced bullfrogs and fishes; (2) habitat loss, (3)pesticides and other toxins, (4) disease, and (5) other factors. Because of the poor condition of the few remaining frog populations and the continued existence of major causes of their decline, accomplishing this objective, in either the short or long term, may not be possible. Any refuge developed for this species will necessarily require continuous intensive management and development of experimental exclosures from non-native species. The long-term goal will be achievable only if the refuge experiments work and are cost-effective (e.g., it might be better to put dollars into restoring areas outside the region where red legged frogs still maintain populations naturally). Refuges for red legged frogs will benefit other at-risk species as well, such as giant garter snakes, Pacific pond turtles, and tiger salamanders.

Stage 1 expectations. All red-legged frogs populations in the region should be located and protective measures taken where possible. At least one experimental population should be established.

Objective #2. Restoration of California tiger salamander to representative habitats throughout its range.

A. Long-term objective: Establish refuges for California tiger salamander throughout its range that will maintain its present genetic and ecological diversity.

B. Short-term objective: Identify and protect remaining California tiger salamander populations in the CALFED region.

Rationale: California tiger salamander populations are disappearing rapidly in the CALFED region because of habitat alteration, especially urban development, and introductions of exotic fishes into their breeding ponds. They require fish-free breeding ponds next to upland habitat containing rodent burrows in which they can over-summer. Patches of suitable habitats are naturally somewhat isolated from one another, promoting genetic diversity within the species which presumably reflects adaptations to local conditions. Long-term survival of these diverse populations depends on numerous protected areas containing both breeding ponds and upland habitats.

Stage 1 expectations. A thorough survey of tiger salamander populations in the CALFED region should be completed and actions taken to protect remaining populations in counties bordering the Bay-Delta.

Objective #3. Restoration of Sacramento perch within its native range.

A. Long-term objective: establishment of multiple, self-sustaining populations of Sacramento perch within the Central Valley region.

B. Short-term objective: Evaluate the status and biology of Sacramento perch to see if restoration of wild populations within its native range is possible.

Rationale: The Sacramento perch was once one of the most abundant fish in lowland habitats of the Central Valley. With the exception of a small population in Clear Lake, it has been extirpated from natural habitats within its native range, apparently because of competition and predation from introduced centrarchid fishes. It would be certainly be formally listed as an endangered species except for the fact that it has been widely introduced into reservoirs, lakes, and ponds outside its native habitats in California and in the other western states. While some of these introduced populations are probably secure, most are in artificial waters subject to dewatering and other perturbations and a number have disappeared in recent years. There is thus a need to establish populations in places within their native range that can be closely monitored to be sure this species persists in the future. It is quite likely that many, if not all, of these places will be artificial habitats (ponds, reservoirs, etc.).

Stage 1 expectations. A thorough status review of the Sacramento perch should be completed and a plan for its long-term preservation in the Central Valley developed. At least one experimental population should be established in the Delta.

Objective #4. Restore populations of native anuran amphibians throughout the CALFED region.

A. Long-term objective: Have self-sustaining populations of all native anuran amphibians (frogs, toads) present throughout their native ranges, in all major watersheds in the CALFED area.

B. Short-term objective: Determine the causes of anuran amphibian declines in the CALFED area, develop restoration strategies, and implement them where feasible.

Rationale: The frogs and toads of California are in a general state of decline, but especially in the Central Valley watershed. The ranid frogs (red-legged frog, foothill yellow-legged frog, mountain yellow-legged frog, cascades frog) are in steep decline. Foothill yellow-legged frogs, for example, have virtually disappeared from the San Joaquin drainage since the 1970's (when they were still common). Red-legged frogs have become so rare they are federally listed as endangered (and are treated separately as a consequence). While the decline of these amphibians can be tied to global amphibian declines, the principal proposed causes to a large extent originate in the region: introduced species and air-borne pesticides. Implication of pesticides has considerable implications for human health as well, and may reflect a need to change certain farming practices.

Stage 1 expectations. Complete status surveys of all anuran amphibians should be made and the major causes of declines should be determined. Long-term plans should be developed and instituted to create conditions that will allow populations to recover throughout their ranges.

Objective #5. Restore self-sustaining populations of western pond turtles to habitats throughout the CALFED region.

A. Long-term objective: Restore self-sustaining populations of western pond turtles to habitats throughout the CALFED region, including the Delta.

B. Short-term objective: Determine the status and habitat requirements of pond turtles throughout the region and develop a conservation strategy in concert with habitat protection measures.

Rationale: The western pond turtle is the only turtle native to the Central Valley region and to much of the western United States. Although considered to be just one widely distributed species, it is likely that the pond turtle is a complex of closely related species, each adapted for a different region. The Pacific pond turtle is still common enough in the CALFED region so that it is not difficult to find them in habitats ranging from sloughs of the Delta and Suisun Marsh to pools in small streams. The problem is that most individuals seen are large, old individuals; hatchlings and small turtles are increasingly rare. The causes of the poor reproductive success are not well understood but factors that need to be considered include elimination of suitable breeding sites, predation on hatchlings by exotic predators (e.g., largemouth bass, bullfrogs), predation on eggs by non-native wild pigs, diseases introduced by non-native turtles, and shortage of safe upland over-wintering refuges. If present trends continue, the western pond turtle will deserve listing as a threatened species (it may already).

Stage 1 expectations. Populations of turtles that appear to still have successful reproduction should be located and protected, in conjunction with other habitat protection measures. Causes of the decline should be determined and a recovery plan developed based on the findings.

Other species in this group

Giant garter snake
Greater sandhill crane
Yellow-billed cuckoo
Least Bell's vireo
Bank swallow
Calif. yellow warbler
Western least bittern
Riparian brush rabbit
Delta green ground beetle
Lange's metalmark butterfly

PRIORITY GROUP IV. DECLINING NATIVE SPECIES THAT ARE REGARDED AS HAVING A RELATIVELY LOW RISK OF EXTINCTION AND/OR WHOSE REHABILITATION DOES NOT NECESSARILY DEPEND ON CONDITIONS IN THE DELTA OR SUISUN BAY.

Objective #1. Reverse the decline of native resident fishes.

A. Long-term objective: within 25 years, all resident native fishes will have stable or increasing populations, in multiple localities, with, as much as possible, interconnections among localities.

B. Short-term objective: Determine the distribution, status, and habitat requirements of all native resident fishes in the CALFED region to see if species-specific strategies are needed to reverse declines or if habitat-oriented restoration strategies will be adequate.

Rationale: The Central Valley has a native resident fish fauna that is largely endemic to the region. Some species are extinct (thicktail chub) or nearly extinct (Sacramento perch) in the wild. While some native species (e.g., Sacramento pikeminnow [squawfish], Sacramento sucker) are clearly thriving under altered conditions, others have more problematic status(e.g., hitch, Sacramento blackfish, hardhead). While it is likely that most of these species will benefit actions listed under Goal #2, there is a need to determine if some have unique problems or requirements that will prevent them from responding to general habitat improvements.

Stage 1 expectations. A distribution and status survey of native stream fishes should be completed. Sites with high species richness or containing rare species should be identified for special management. A recovery strategy for native fish assemblages should be developed.

Objective #2. Restoration of spadefoot toad populations to representative habitats throughout its range.

A. Long-term objective: Establish refuges for California spadefoot toad throughout its range.

B. Short-term objective: Identify and protect remaining spadefoot toad populations in the CALFED region.

Rationale: Spadefoot toad populations are disappearing rapidly in the CALFED region because of habitat alteration, especially urban development, and introductions of exotic fishes into their breeding ponds. They require fish-free breeding ponds next to upland habitat in which they can burrow for over summering. These habitats are naturally somewhat isolated from one another, promoting genetic diversity within the species which presumably reflects adaptations to local habitat conditions. Long-term survival of these diverse populations depends on protected areas containing both breeding ponds and upland habitats.

Stage 1 expectations. A thorough survey of spadefoot toad populations in the CALFED region should be completed and actions taken to protect remaining populations in counties bordering the Bay-Delta.

Objective #3. Restore assemblages of planktonic organisms in the Delta and Suisun Bay to states of increased abundance and greater predictability in composition.

A. Long-term objective: Increase abundance of zooplankton to the levels that existed prior to the introduction of the Asiatic clam, *Potamocorbula amurensis*, with zooplankton communities containing native species as significant components.

B. Short-term objective: Maintain the planktonic assemblages at roughly the range of variability of abundance and composition that they have been since the Asiatic clam became established by preventing new introductions and determining conditions that favor native organisms such as *Neomysis mercedis* and *Eurytemora affinis.*

Rationale: The long-term objective is quite likely impossible to achieve because recent invading species, from the Asiatic clam to various crustacean zooplankters, will continue to play major ecological roles in the system, to the detriment of fish and other native organisms. However, at the very least it is possible to stop further introductions of exotic species which have the potential to change the system yet once again, in an unpredictable fashion. This objective is also a call to develop a thorough understanding of the planktonic portion of the Bay-Delta ecosystem in order to predict the impacts of large scale ecosystem alteration projects on the plankton.

Stage 1 expectations. Major steps should be taken to halt activities (e.g., dumping of contaminated ballast water) that result in the establishment of new species of invertebrates and fish in the estuary. Further development of our understanding of the how the Bay-Delta ecosystem functions should allow recommendations on how to maintain native zooplankton species, in the context of broader ecosystem management goals.

Objective #4. Prevent further human-caused irreversible changes to the benthic invertebrate assemblages in the Bay-Delta ecosystem.

A. Long-term objectives: Have diverse benthic assemblages throughout the estuary that contain ONLY the same species that are present today, including the remaining native species, and that are not dominated by one or two exotic species.

B. Short-term objectives: Halt furtner introductions of exotic species, determine conditions that favor remaining desirable species, and find methods (if any) to reduce dominance by single exotic species, especially the Asiatic clam in Suisun Bay.

Rationale: The benthic assemblages of invertebrates in the Bay-Delta region are made up largely of exotic species, although a few native crustaceans still are present in numbers. Many of these exotic invertebrates are thoroughly integrated into the food webs of the region and are major prey of native birds, mammals, and fishes. New benthic invasions, largely from ballast water introductions, are constantly occurring, however, and some, such as the invasion of the Asiatic clam, have causes major alterations to the benthic (and planktonic) assemblages. If present trends continue, further invasions can be expected with the potential to once again generate major changes in the benthos, most likely with unfavorable effects on at-risk or harvested species. In order to stabilize benthic assemblages to conditions of reasonable and desirable diversity and abundance, it is necessary to (1) halt further invasions, (2) create water quality and hydraulic conditions that favor desired assemblages (e.g., those containing abundant native *Corophium* spp.), and (3) reduce the dominance of single exotic species, especially the Asiatic clam. None of these actions is easy to do and the latter two will require considerable research to institute.

Stage 1 expectations. All introductions of exotic invertebrates into the estuary should be halted. Investigations into the biology of benthic assemblages should continue, in order to find ways to create more desirable assemblages in an ecosystem context.

Other species
Resident waterfowl
Migratory waterfowl
Shorebird 'guild'
Wading bird 'guild'
Neotropical migrants (birds)

Plants

Goal 2. Rehabilitate natural processes in the Bay-Delta estuary and its watershed to support, with minimal ongoing human intervention, natural aquatic and associated terrestrial biotic communities, in ways that favor native members of those communities.

Arguably, the objectives to restore species in Goal 1 are just subsets of the objectives below. Ultimately, recovery to abundance of at-risk species requires restoration of their habitats, which in turn requires the rehabilitation of the ecosystem processes discussed here, over broad areas. These objectives are not in order of priority.

Objective #1. Manage the hydrologic regime for the Bay-Delta estuary in ways that favor native species, desirable non-native species, and natural habitats.

A. Long-term objective: Have a hydrologic regime in the Delta, Suisun Bay, San Pablo Bay, and San Francisco Bay that is favorable to maintenance of large, self-sustaining populations of species and habitats treated separately under Goals 1, 3 and 4.

B. Short-term objective: Continue to adjust and evaluate the X2 position as a standard to measure success of establishing a favorable hydrologic regime in the Bay-Delta system. Evaluate other measures and actions designed to create favorable conditions for depleted species and implement them where feasible.

Rationale: The restoration to abundance of most, if not all, of the native species and habitats in the Sacramento-San Joaquin estuary depends on having a dynamic hydrologic regime (and associated hydraulic processes) that creates conditions favorable for all portions of the life cycles of the "key" species (those listed in Goals 1 and 3). The principal measure in place today of the suitability of the hydrologic regime for key species is the X2 relationship [the number of kilometers the 2 ppt salinity isohaline is from the Golden Gate], which indicates the position of the salinity gradient in the estuary. The suitability of X2 as measure is still being tested and studies are underway to determine why it seems to be a reasonably good predictor of the annual success of many species. As more is learned about the hydrodynamics of the estuary, especially about the importance of the low-salinity zone, direct and indirect modifications of estuarine processes (in an adaptive management context) should continue.

Stage 1 expectations. Studies on the factors affecting the relationship between X2 and the abundance of key organisms should be on-going but a basic understanding for the at-risk species should be developed and used to implement strategies for their recovery.

Objective #2. Increase estuarine productivity.

A. Long-term objective: Using knowledge gained in the shorter term, raise the level of ecosystem productivity to lift limits on production of desirable species of fish and invertebrates.

B. Short-term objectives: Determine the limits on productivity and the major sources of organic carbon contributing to the estuarine ecosystem. Generate hypotheses as to the actions that might be effective at increasing productivity, and conduct pilot studies based on those findings.

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 or seasonally flooded 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.

Stage 1 expectations. Studies on organic carbon sources and cycling should be encouraged in order to generate hypotheses as to factors limiting their availability. These hypothesis (and findings generated from testing them) should be applied to help set priorities for restoration actions.

Objective #3. Manage channels in the Delta and Suisun Marsh in ways that allow natural processes to create and maintain in-channel islands and shallow water habitat.

A. Long-term objective: Have large expanses of shallow water habitat, both on the edges of channels and on small channel islands, that will be maintained by natural processes.

B. Short-term objective: Set priorities for channels in terms their importance for shallow water habitat; develop and implement protection strategies for existing and restored shallow water habitat in those channels; investigate the value of shallow-water habitat in supporting and increasing abundances of desirable species.

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. Ultimately much of this shallow water habitat will be along Delta and Suisun Marsh channels (recreating some of the original channel-marsh system) or on small islands in the channels. The desirable physical and biotic characteristics of these habitats may be created artificially initially but the expectation is that they will be maintained by natural processes (tidal flux, sediment inputs from upstream, etc.). This means that human activities in these channels that have negative impacts on the habitats will have to be restricted such as boating at speeds that generate erosive wakes or channel dredging.

Stage 1 expectations. Channels or channel reaches most suited for restoration and protection of shallow water habitats should be identified and given priorities for restoration activities. Detrimental human activities in these channels should be eliminated through a phased program associated with restoration activities. Major studies of the use of shallow water habitats by native and non-native species should be undertaken to test the assumption that shallow water habitat is indeed the key to restoring many of the native species.

Objective #4. Create flow and temperature regimes in regulated rivers that favor native aquatic species.

A. Long-term objective: Native fish and invertebrate assemblages will be restored to regulated streams wherever possible, using methods developed during the short-term objective phase.

B. Short-term objective: Provide adequate flows, temperatures, and other conditions to double number of miles (as of 1998) of regulated streams that are dominated (>75% by numbers and biomass) by assemblages with 4+ native fish species.

Rationale: Virtually all streams in the region are regulated to a greater or lesser degree and the regulated 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 and increasing flows during summer months. Native invertebrates and riparian plants may also respond positively to these flow regimes. Achievement of this objective will require additional systematic manipulations of flows below dams (or the re-regulation of existing flow regimes) to determine the optimal flow/habitat conditions for native organisms, as part of the short term goal. Part of the studies should be to determine if the objective can be achieved without 'new' water, by just altering the timing of releases or by developing conjunctive use agreements that allow more water to flow down the stream channel. These findings can then be applied opportunistically to achieve the long-term goal.

Stage 1 expectations. Surveys should be completed to determine the status of native fishes in all regulated streams of the Central Valley and flow recommendations made to restore native fishes where feasible. Where negotiations are underway for relicensing of dams, agency personnel should request flow regimes favorable for native fishes.

Objective 5. Provide flow releases in regulated streams to mobilize gravel beds, drive channel migration, and inundate floodplains in order to maintain channel and sediment conditions favorable to native aquatic and riparian organisms.

A. Long-term objective: For regulated rivers in the region, establish scientifically-based high flow events necessary to maintain dynamic channel processes, channel complexity, bed sediment quality, and natural riparian habitats where feasible.

B. Short-term objective: Through management of the reservoir pool and/or deliberate reservoir releases, provide a series of experimental high flow events in regulated rivers in order to observe flow effects on bed mobility, bed sediment quality, channel migration, invertebrate assemblages, fish abundance, and riparian habitats over a period of years. Use the findings of these studies to re-establish natural stream processes where feasible, including restoration of periodic inundation of remaining undeveloped flood plains.

Rationale: Native aquatic and riparian organisms in the Central Valley evolved under a flow regime with pronounced seasonal and year to year variability. Frequent (annual or biannual) 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. By deliberately releasing such flows from reservoirs, at least some of these physical and ecological functions can probably be recreated. A program of such high flow releases (commonly termed 'flushing flows') lends itself well to adaptive management, because the flows can easily be adjusted to determine the level needed to achieve specific objectives. However, it should be recognized that channel adjustments may lag behind hydrologic changes by years or decades, which requires that monitoring be long-term. 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 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 high flow events that are likely to be higher than those needed to maintain most native fish species but important for maintaining in-channel and riparian habitats for other species (invertebrates, birds, mammals, etc.).

Stage 1 expectations. Studies should be conducted on 5-10 regulated rivers in the Central Valley to determine the effects of high flow releases. Natural flood plains should be identified that can be inundated with minimal disruption of human activity. Where positive benefits are shown, flow recommendations should be developed and, where feasible, instituted.

Objective 6. Re-establish frequent inundation of floodplains by removing, breaching, or setting back levees and, in regulated rivers, by providing flow releases capable of inundating floodplains.

A. Long-term objective: Re-establish active inundation of floodplains with area targets and inundation frequencies(one to five years)to be set for each major alluvial river based on probable pre-1850 floodplain inundation regimes and on existing opportunities to modify existing land uses.

B. Short-term objective: Re-establish active inundation of at least half of all remaining unurbanized floodplains in the Central Valley, where feasible.

Rationale: Frequent (usually annual or biannual) 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) limits shear stress exerted on the bed, reducing channel incision, (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. The actions necessary to re-establish active inundation will probably require major land purchases or easements, and financial incentives to move existing floodplain uses elsewhere, as has been done in the Midwest since 1993.

Stage 1 expectations. All existing unurbanized floodplains in the Central Valley should be identified and a priority list for flood plain restoration projects developed. Strategies for the restoration of natural channel-flood plain dynamics should be developed and implemented in at least two large demonstration projects. Use initial floodplain reactivation projects to increase understanding of channel-floodplain interactions and potential restoration of processes.

Objective 7. Restore coarse sediment supplies to sediment-starved rivers downstream of reservoirs.

A. Long-term objective: Implement a comprehensive sediment management plan for Bay-Delta system that will minimize problems of reservoir sedimentation and sediment starvation, shift aggregate extraction from rivers to alternate sources, and restore continuity of sediment transport through the system to the extent feasible.

B. Short-term objective: Develop methods and procedures to end gravel deficits below dams and mining operations; prioritize for correction existing streams with major deficit problems and initiate action on at least 10 streams.

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. Accomplishing this objective can be done by a wide variety of means, but most obviously through artificial importation of gravel and sand. Other possible actions include: (1) explore the feasibility of passing sediment through small reservoirs; (2) remove nonessential or low-value dams; (3) eliminate instream gravel mining on channels downstream of reservoirs, and limit extraction on unregulated channels to 50 percent of estimated bedload supply or less(or levels determined not to negatively impact fish and other ecological resources); (4) develop incentives to discourage mining of gravel from river channels and adjacent floodplain sites; and (5) develop programs for comprehensive sediment management in each watershed, accounting for sediment trapped by reservoirs, availability of sediment from tributaries down stream of reservoirs, loss of reservoir capacity, release of sediment-starved water downstream, channel incision and related effects, and the need for sources of construction aggregate.

Stage 1 expectations. Identify sediment-starved channels in the Bay-Delta watershed, develop strategies to, mitigate sediment starvation such as shifting mining of gravel from river channels to alternate sources, adding gravel below dams, removal of non-essential dams, etc., and implement (and monitor) demonstration projects to mitigate sediment starvation in at least six rivers.

Objective # 8. Increase the extent of freely meandering reaches and other pre-1850 river channel forms.

A. Long-term objective. Re-establish active meander belts on all formerly meandering alluvial reaches in the Central Valley except those densely urbanized or with infrastructure whose relocation would be prohibitively costly.

B. Short-term objectives. Inventory (at 1:1200 scale or better) along all major river reaches bank conditions and land uses on adjacent floodplains. Prioritize for acquisition land or easements in rural areas with high potential for urbanization, especially around meander bends. Begin an acquisition program.

Rationale: Freely migrating 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 maintain. Flood plain 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). This objective is compatible with and parallel to Objective #2.

Stage 1 expectations. Plans for meander belts should be developed for all major river corridors and priorities for land acquisition and easements established. Development of a meander belt should begin on at least one river.

Goal 3. Maintain and enhance populations of selected species for sustainable commercial and recreational harvest, consistent with goals 1 and 2.

Somewhere between 40 and 50 species of fish and invertebrates are harvested in significant numbers in the CALFED region, as are a number of species of birds (waterfowl, mourning doves, ring-necked pheasants). he Ecosystem Restoration Program has the potential to affect the harvest of many of these species, improving most of them in the long run. For the purposes of the ERP, the harvested species are divided into three groups according to their priority for attention by the CALFED program. *High priority* species are those whose abundance is likely to be strongly affected by CALFED actions and/or whose enhancement is likely to generate conflicts with the restoration of native species. *Second priority* species are species that support important fisheries or harvests but whose populations are not likely to be affected strongly by CALFED actions in the short run or whose enhancement is not likely to generate major conflicts with the restoration of native species. *Low priority* species, not treated here, are species that support relatively small or incidental fisheries or harvests and whose enhancement (if any) is not likely to generate major conflicts with the restoration of native species. Note: within each category, objectives are not listed in order of priority.

I. High priority species

Objective #1: Maintain fisheries for striped bass

A. Long-term objective: Allow striped bass numbers (and harvest) to increase gradually as conditions in the restored estuary favor its reproduction and survival. Use harvest and other management measures to ensure that increases in striped bass populations do not jeopardize programs to sustain native species.

B. Short-term objective: Maintain the fishery for striped bass at its present levels but without special intervention (e.g., hatcheries).

Rationale: The striped bass is a non-native species that is a favorite sport fish in the estuary. It is also the most abundant and voracious piscivorous fish in the system and it has the potential to limit the recovery of native species, such as chinook salmon and steelhead. Therefore, the management for striped bass must juggle the objectives of providing opportunities for harvest while not jeopardizing recovery of native species. An appropriate policy may be to allow striped bass to increase in numbers as estuarine conditions permit but not to take any extraordinary measures to enhance its populations, especially artifical propagation. Artificially reared bass have the potential to not only depress native fish populations but also populations of wild striped bass, because larger juveniles (of hatchery origin) may prey on smaller juveniles (of wild origin). If increases in bass numbers appear to adversely affect recovery of native species, additional management measures may be required to keep bass numbers below the level that pose a threat to native species.

Stage 1 expectations. Investigations into competing (or interacting) hypotheses about the causes of striped bass decline should continue. If rearing programs for juvenile striped bass are continued then investigations should be conducted on the impact of artificially reared fish on both other fishes of concern and on wild-spawned striped bass.

Objective #2: Maintain fisheries for American shad.

A. Long-term objective: Allow American shad numbers (and harvest) to increase gradually as conditions in the restored estuary and streams favor its reproduction and survival. Use harvest and other management measures to ensure that increases in American shad populations do not jeopardize programs to sustain native species.

B. Short-term objective: Maintain the fishery for American shad at its present levels but without special intervention (e.g. special flow releases).

Rationale: The American shad is a non-native species that is an important sport fish in the estuary and its spawning streams, although less seems to be known about its life history in the estuary than any other major game fish. It is a common planktivore and occasional piscivore in the system and it may have the potential to limit the recovery of native species, such as chinook salmon. Therefore, the management for American shad must juggle the objectives of providing opportunities for harvest while not jeopardizing recovery of native species. An appropriate policy may be to allow American shad to increase in numbers as estuarine conditions permit but not to take any extraordinary measures to enhance its populations, especially flow releases specifically to favor shad reproduction. If increases in shad numbers appear to adversely affect recovery of native species, additional management measures may be required to keep bass numbers below the level that pose a threat to native species.

Stage 1 expectations. No special efforts to increase American shad numbers should be made. Their impact on juvenile salmon (predation) in the Sacramento River should be investigated.

Objective #3. Enhance fisheries for white sturgeon.

A. Long-term objective: Increase white sturgeon numbers (and harvest) by improving habitat conditions for spawning and rearing.

B. Short-term objective: Continue to manage white sturgeon for the sustainable sport fishery, without artificial propagation.

Rationale: 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, 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.

Stage 1 expectations. White sturgeon will continue to support a significant sport fishery in the estuary and will not experience a significant decline in abundance.

Objective #4. Maintain fisheries for non-native warmwater gamefishes.

A. Long-term objective: Non-native warmwater game fishes will continue to be abundant enough in many parts of the estuary and river systems to support a substantial sport fishery.

B. Short-term objective: Increase our knowledge about warmwater sport fishes in the Delta, Suisun Marsh, riverine backwaters, and elsewhere to find out their interactions with native fishes, limiting factors, and their contaminant loads (for both fish and human health).

Rationale: White catfish, channel catfish, brown and black bullhead, largemouth bass, and various sunfishes are among the most common fishes caught in the sport fishery in the Delta, Suisun Marsh, riverine backwaters, reservoirs, and other lowland waters. Although this fishery is poorly documented, it is probably the largest sport fishery in central California in terms of people engaged in it and in terms of numbers of fish caught. There is no sign of overexploitation of the fishes, although some (e.g., white catfish) have remarkably slow growth rates. The fishes and the fishers are always going to be part of the lowland environment and deserve support of the management agencies. However, habitat improvements that favor native fishes may or may not favor these game fishes as well, especially improvements that increase flows or decrease summer temperatures. The effects of the various CALFED actions on these fish and fisheries need to be understood, as do the interactions among the non-native fishes and the native fish CALFED is trying to protect.

Stage 1 action. Studies should be conducted to find out how major CALFED actions are likely to affect the warmwater fish and fisheries and how the fishes affect the recovery of native at-risk species. In particular, the potential of the non-native fishes to use and dominate newly created warmwater habitat should be investigated.

Objective #5. Alter practices to augment chinook salmon and steelhead populations by the entire state, federal, and private hatchery system in light of CALFED goals.

A. Long-term objective: Develop a hatchery system and hatchery practices that truely augment salmon and steelhead populations without having detrimental effects on wild populations of salmon.

B. Short-term objective: Evaluate closely all salmon and steelhead hatcheries and hatchery practices in the CALFED region to determine their effects on wild populations of salmon and steelhead. Take the first steps to change these practices if needed.

Rationale: The hatchery system in the Central Valley for salmon and steelhead was developed with the best of intentions, to maintain the fishery for these species that would be otherwise be lost as the result of dams and diversions blocking access to spawning habitat. To a certain extent, it has succeeded by maintaining the commercial and sport fishery for chinook salmon. Unfortunately, the focus on hatcheries, which have been successful mainly for fall-run chinook salmon, has been associated with the continued decline of other runs of salmon, of wild runs of fall chinook, and of native steelhead stocks. Salmon and steelhead originating from hatcheries may actually have aggravated this problem by interacting with wild fish and by encouraging high harvest levels in fisheries. A major emphasis of the CALFED 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 hatcheries, whether state, federal, or private (non-profit) can play in this recovery is uncertain. For severely depleted stocks (e.g., winter run chinook)hatchery rearing can provide a temporary insurance policy 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 artifical propagation of some stocks should be halted completely.

Stage 1 expectations. The role of every hatchery in the Central Valley in restoring salmon populations should be evaluated by an independent panel of experts. Where information is lacking, research programs should be conducted. No new hatcheries or hatchery programs should be started until the evaluation for the entire system is completed.

Objective #6. Enhance populations of waterfowl for harvest by hunting and for non-consumptive recreation.

A. Long-term objectives: Substantially increase the numbers of resident and migratory ducks and geese that use the CALFED region by increasing habitat available to them.

B. Short-term objective: Continue restoration of wetlands suitable for waterfowl production and over-wintering, while developing strategies for management of waterfowl areas that are compatible with other species, habitat, and ecosystem process restoration goals in CALFED.

Rationale: For decades, the principal motivation for the protection and enhancement of wetlands in the Central Valley, Delta, Suisun Marsh, and the rest of the estuary has been to provide habitat for migratory and resident waterfowl, especially for hunting. Many of these wetlands are on private land developed specifically for hunting. In recent years, the impressive flocks of ducks and geese from the Pacific Flyway that use the Central Valley and the estuary have become major attractions for large numbers of wildlife viewers, helping to make wetland restoration a much more publically-supported activity. Many of the wetlands, both permanent and seasonal, are intensely managed specifically for waterfowl and such management may at times conflict with broader ecosystem restoration goals or with goals to recover endangered species. Some examples: Flooding of rice paddies for waterfowl in winter may require water needed by migratory salmon. Management of waterfowl areas along the estuary for plants favored as food by ducks and geese may discriminate against native plants or animals that require marshlands less favorable to waterfowl (e.g., saltmarsh harvest mouse). Emergency levee repairs to protect waterfowl habitat may disturb clapper rails seeking high ground during the flood. Such conflicts need to be resolved for the benefit of all species, mainly by greatly increasing the amount and variety of wetland habitat and by developing management strategies for existing waterfowl areas that provide benefits to at-risk species.

Stage 1 expectations. Acquisition and development of wetlands favorable for waterfowl (e.g., Yolo Basin Wildlife Area) should be continued. For existing public wildlife areas, plans to reduce conflicts between waterfowl management and management for other native species, including provisions for emergency situations (e.g., levee repairs), should be developed. For private waterfowl areas, incentives for implementing broader, ecosystem-based management goals should be improved.

II. Second priority species

Objective #1. Enhance fisheries for Pacific herring.

A. Long-term objective: Maintain a high level of harvest management that will allow for sustainable fisheries for Pacific herring and their roe.

B. Short-term objective: Continue, with caution, the present limited-entry fishery and determine the major factors that limit both the fishery and herring spawning in San Francisco Bay.

Rationale: Pacific herring support the most valuable commercial fishery in San Francisco Bay. The fishery is highly seasonal and focuses on spawning fish, for the fish themselves, their roe, and *Kazunoko kombu* (herring eggs on eel grass). The fishery is presently a limited entry fishery. It seems to be an example of successful fisheries management because the fishery has been able to sustain itself through a series of years with highly variable ocean and bay conditions. An important connection to the ERP process 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 in order to make sure it can continue indefinitely.

Stage 1 expectations. In the next 7-10 years the fishery should continue at roughly present levels and investigations should continue to determine factors limiting herring abundance and spawning success, especially as tied to Bay-Delta physical processes.

Objective #2. Maintain fisheries for signal crayfish in the Delta.

A. Long-term objective: Allow signal crayfish numbers (and harvest) to increase gradually as conditions in the restored estuary favor its reproduction and survival. Use harvest and other management measures to ensure that increases in crayfish populations do not jeopardize programs to sustain native species.

B. Short term objective: Maintain signal crayfish populations at present levels, in order to support the existing sport and commercial fisheries.

Rationale: The signal crayfish is an introduced species that supports a small commercial fishery, as well as a sport fishery, in the Delta. It has been established in the Delta for nearly a century and appears to be integrated into the Delta ecosystem, appearing as a major food item for otters and some fish. The signal crayfish has fairly high water quality requirements so its populations will presumably increase as water quality in the freshwater portions of the Delta improves. Its role in the ecosystem and the effects of the fishery on that role need to be investigated.

Stage 1 expectations: An investigation of the ecological requirements of the crayfish and the effects of the fishery should be conducted, to find out if any special management for either is needed.

Objective #3. Maintain fisheries for grass shrimp in the San Francisco Bay.

A. Long-term objective: Allow grass shrimp (*Crangon spp., Paleomon*) numbers (and harvest) to increase as conditions in the restored estuary favor their reproduction and survival.

B. Short term objectives: Maintain grass shrimp populations at present levels as a minimum, in order to support the existing commercial fisheries. Determine factors regulating their populations in order to discover if the fisheries conflict with other ecosystem restoration objectives.

Rationale: Grass shrimp are a mixture of native and introduced species that support a small commercial fishery in San Francisco Bay, largely for bait. The relative abundance of the various species as well as their total abundance appears to be tied in part to outflow patterns. It is likely that these abundant shrimp are important in Bay-Delta food webs leading to many other species of interest. The role of these shrimp in the Bay-Delta ecosystem and the effects of the fishery on that role need to be investigated.

Stage 1 expectations: An investigation of the ecological role and requirements of the shrimp species and the effects of the fishery should be conducted, to find out if any special management for either is needed.

Objective #4. Develop fisheries for abundant under-utilized non-native species in the Bay-Delta system.

A. Long-term objective: The development of fisheries that harvest non-native species that have become abundant in the region, in part to reduce the abundance of nuisance species.

B. Short-term objective: Investigate the abundance and biology of potentially harvestable exotic species and encourage the development of fisheries that do not have negative effects on ecosystem restoration programs.

Rationale: Exotic species, some actually or potentially harmful to native species, are extremely abundant in some parts of the Bay-Delta system yet are at best only lightly harvested. Examples include various species of clams, mitten crab, several species of gobies, and common carp. Harvest of these species could potentially have positive effects on native or more desirable species, although it is possible that some of the species are so deeply imbedded in the ecosystem their removal could cause significant, perhaps undesirable, changes. A first step in developing a harvest of abundant exotics is to discover their fisheries potential (areas of concentration, contaminant loads, market, etc.) and how a fishery might interact with ecosystem recovery efforts.

Stage 1 expectations. A list of un-harvested or lightly harvested species that have commercial potential should be developed and their potential for supporting fisheries established. If high potential can be demonstrated, then experimental fisheries should be encouraged.

Objective #5. Change the role of trout hatchery and planting programs to make them more compatible with CALFED goals.

A. Long-term objective: Make sure that trout hatcheries and their associated planting programs do not interfere with or negate CALFED ERP actions.

B. Short-term objective: Evaluate the trout hatchery and stocking program in California to determine its impact on populations of wild trout and other fish.

Rationale: Trout hatcheries, state, federal, and private, have long attempted to satisfy angler demands for catchable trout by rearing domesticated fish for planting in streams, reservoirs, and lakes. There is little question that these planting programs are successful in providing angling for many people, especially in reservoirs and tailwaters of reservoirs. However, in some streams angling for domestic trout may put artifically high pressure on wild stocks of trout and steelhead or planting of domestic trout may introduce diseases to which other trout (and other organisms, including native frogs) are not immune. In some alpine lakes, regular plantings of trout are endangering native frog populations. There is thus a need to closely evaluate all trout stocking programs that take place in the CALFED area to make sure they are compatible with the CALFED goals.

Stage 1 expectations. A team of experts should be appointed to formally evaluate all aspects of the state and federal trout hatchery programs and issue recommendations in 1-2 years.

Objective #6. Maintain or enhance fisheries for marine fishes and shellfishes in San Francisco and San Pablo bays.

A. Long-term objective: Keep sport fisheries for diverse fish species in San Francisco and San Pablo bays at levels at least comparable to those of 1985-1995, or higher.

B. Short-term objective: Evaluate the status and trends of the major fish and fisheries in the bays to determine management strategies.

Rationale: San Francisco and San Pablo bays support a rich fauna of native marine fishes, from sharks to surfperches to flounders, as well as of invertebrates such as dungeness crab and rock crab. These fishes in turn support sport fisheries within the bay and commercial fisheries outside the bay, because of the movement of fish and crabs between the bays and the ocean. The abundances of some species, especially several species of surfperch, have apparently declined in recent years for reasons which are uncertain. The California Department of Fish and Game has a long-term Bay Study program that is addressing questions of the distribution and abundance of bay species. It needs to be continued and the data analyzed in depth to determine cause of fish declines, if any.

Stage 1 expectations: The CDFG Bay study program should continue and in-depth analysis of existing data should be performed, to develop management strategies for the fisheries of the bays.

Objective #7. Enhance fisheries for native cyprinid fishes.

A. Long-term objective: Increase populations of native cyprinds so they can support special fisheries for them.

B. Short-term objective: Maintain fisheries at their present levels while evaluating factors that limit the abundance of the target species.

Rationale: Sacramento blackfish, hitch, and splittail support small commercial and/or sport fisheries, as do non-native common carp and goldfish. Other large native minnows also have the potential to support fisheries (e.g., pikeminnow, tui chub). The commercial fisheries, aimed at supplying fish to Asian markets in the big cities of California, are largely unstudied and lightly regulated. Likewise, there is little information on the recreational fishery for splittail in the Delta. Because the CALFED ERP seeks to increase populations of native fishes, finding ways to make sure the native cyprinids can support fisheries for speciality markets seems very compatible with the other objectives. The fisheries may also have to be regulated more closely to prevent over fishing or impacts on non-target species.

Stage 1 expectations. The fisheries for native cyprinids should be evaluated and management strategies devised to maintain both the fish and the fisheries.

Goal 4. Protect or restore functional habitat types throughout the watershed for public values such as recreation, scientific research, and aesthetics.

The objectives listed here strongly overlap with those for individual species, which need appropriate habitats to thrive. This section recognizes that habitats have many values to human beyond the "important" species they support and need to be restored, in abundance, for to satisfy those values. Most of the objectives here are general rather than specific and in fact call for more specific restoration objectives to be developed for each type of habitat.

Objective #1. Restore large expanses of all major habitat types in the Delta.

Long-term objective: Restore major habitat types in the Delta to at least 20% of the acreage that existed in 1906 or to a point where all at-risk species that depend on the habitats are no longer at risk.

Short-term objective: Develop and begin implementation of action plans for restoring large and significant examples of major habitat types in the Delta.

Rationale: All major natural habitat types in the Delta 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 in increased susceptibility of the remaining areas to irreversible degradation (e.g., invasion by exotic 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 continue exist in the future. This reversal will require a large number of diverse and localized actions, from levee setbacks to land acquisition to better management of existing sites. The major habitat types to be restored include tidal shallow water habitat, freshwater emergent wetland, channel islands and associated habitats, tidal sloughs, nontidal freshwater emergent wetlands, seasonal upland wetlands, vernal pools and surrounding uplands, riparian forests and associated upland areas, perennial grassland, and inland dune scrub. In order to make restoration actions systematic and cost-effective, specific objectives need to be established for each of the habitat types, as well as subsets of them that have distinctive biological characteristics, and then priorities set within each objective for protection and restoration activities.

Stage 1 expectations. Objectives should be formulated for each habitat type, with restoration objectives based on clearly stated conceptual models. Within and between habitat types, conservation and restoration activities should be prioritized. Work should begin on those projects given highest priority within a year of adoption of the Strategic Plan.

Objective #2. Restore large expanses of all major habitat types in Suisun Bay, Suisun Marsh, and San Pablo Bay.

Long-term objective: Restore major tidal or upland habitat types in Suisun Bay, Suisun Marsh, and San Pablo Bay to at least 20% of the acreage that existed in 1906 or to a point where all at-risk species that depend on the habitats are no longer at risk.

Short-term objective: Develop and begin implementation of action plans for restoring large and significant examples of major habitat types in the Delta.

Rationale: All major habitat types in Suisun Bay, Suisun Marsh, and San Pablo 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 in increased susceptibility of the remaining areas to irreversible degradation (e.g., invasion by exotic 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 continue exist in the future. This reversal will require a large number of diverse and localized actions, from levee setbacks to land acquisition to better management of existing sites. The major habitat types to be restored include: tidal shallow water habitat (including tide flats), tidal saline emergent wetland, tidal sloughs, nontidal perennial aquatic habitat (adjacent to wetlands), seasonal upland wetlands, vernal pools and surrounding uplands, riparian habitats and associated upland areas, and perennial grassland. 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 outflows and tides. Many are being invaded by exotic 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 objectives need to be established for each of the habitat types, as well as subsets of them that have distinctive biological characteristics, and then priorities set within each objective for protection and restoration activities.

Stage 1 expectations. Objectives should be formulated for each habitat type, with restoration objectives based on clearly stated conceptual models. Within and between habitat types, conservation and restoration activities should be prioritized. Work should begin on those projects given highest priority within a year of adoption of the Strategic Plan.

Objective #3. Restore and maintain substantial examples of all aquatic, wetland, and riparian habitats in the Central Valley and its rivers.

A. Long-term objective: To have multiple examples of all aquatic habitat types in Moyle and Ellison (1991) and Moyle (1996) protected and managed on a self-sustaining basis, throughout the watershed, to a point where all at-risk species that depend on the habitats are no longer at risk.

B. Short-term objectives: Systematically identify and locate the best examples of the aquatic habitat types identified by Moyle and Ellison (1991) and Moyle (1996) and/or similar schemes and prioritize them for conservation. Develop and begin implementation of action plans for restoring significant examples of each habitat type.

Rationale: Moyle and Ellison (1991)and Moyle (1996) developed a scheme for classifying the aquatic habitats of California for the purposes of conservation. Other classification schemes of aquatic habitats also exist. Whatever the system, it is obvious that the diversity of aquatic habitats is 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 protection of examples of the entire array of habitats in the region provides some assurances that rare and unusual aquatic organisms will also be protected, preventing contentious endangered species listings.

Stage 1 expectations: Inventory of habitat types should be completed and areas prioritized for conservation actions. Restoration actions should be evaluated and initiated where feasible.

Objective 4. Increase the area of tidal marsh (freshwater, brackish, salt) by removing or breaching levees (opening them to tidal action) and by increasing the elevation of subsided, leveed former marsh.

A. Long-term objective. Restore the amount and diversity of tidal wetlands to the level that existed in 1906 or similar reference date.

B. Short-term objectives. Inventory and prioritize for restoration diked former marsh sites and develop techniques for restoration through large-scale manipulations of high-priority areas, especially on Delta islands.

Rationale: Tidal wetlands are a diverse group of habitats included under Objectives 1 and 2 in this series. However, they merit additional attention beyond those objectives because their restoration is urgently needed for the benefit of many species. They also represent, by acreage, some of the largest restoration projects that are likely to be attempted in the system. Restoration of tidal marshes in the Delta in particular will require major effort and innovation, because so many of the islands that could be restored to tidal marsh now have elevations considerably below sea level. If flooded, they will be too deep for marsh restoration at the present time. Therefore restoration will require large-scale pilot projects to find ways to restore marsh lands to such islands.

Stage 1 expectations: Ongoing efforts to restore large expanses of tidal marsh should continue and experimental pilot projects to restore tidal marshes to Delta islands should be undertaken.

Objective # 5. Maintain large expanses of agricultural land adjacent to restored aquatic, riparian, and wetland habitats and manage these lands in ways that are favorable to birds and other wildlife.

A. Long-term objective: Keep as much land as possible near restored habitats in agriculture while encouraging agricultural practices that favor birds and other wildlife and that mimimize run-off of contaminants into nearby waterways.

B. Short-term objectives: Identify and prioritize for management agricultural lands in the region that are likely to have strong interactions with nearby wetlands, riparian areas, or aquatic habitats or that are important as habitat for waterfowl and other birds. Acquire conservation easements on high priority lands and provide incentives to farmers to use farming methods and crops that are favorable to wildlife.

Rationale: The CALFED region is one of the most productive agricultural areas in the world, so agricultural lands and practices will always have a big influence on natural habitats in the area. The 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, 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 use every scrap of available land. Thus, ideally, there should be a buffer zone of agricultural land that is farmed in environmentally friendly ways between the natural habitats and more industrial agriculture lands or urban areas.

Stage 1 expectations: High priority agricultural lands should be identified and the process begun to acquire easements from willing sellers; incentive programs should be develop to encourage the planting of crops favored by wildlife and to farm in ways that minimize environmental damage to adjacent areas.

Objective #6. Manage the Yolo and Sutter by-passes as major areas of seasonal shallow water habitat.

Long-term objective: Make the Yolo and Sutter by-passes into regions that are intensely managed to favor native fish and wildlife on a seasonal basis.

Short-term objectives: Develop strategies for keeping water in the by-passes or in portions of them during periods critical for the life cycles of at-risk fish and wildlife. Conduct experimental manipulations of relatively small regions to test potential restoration methods. Use the information learned to develop strategies for managing new by-passes in the San Joaquin Valley.

Rationale: The Yolo and Sutter by-passes are artificial flood plains that were constructed in the 1920s as means to reduce or eliminate flooding of Sacramento and other towns. They are immense in size and devoted largely to agriculture when not flooded. When flooded (mostly during the winter months of wet years) the Yolo By-pass alone doubles the wetted surface area of the Delta. Recent studies indicate that the by-passes are potentially important spawning areas for splittail and rearing areas for juvenile chinook salmon, as well as for other species. Their potential as seasonal flood plain habitat that essentially replaces habitat lost from diking and urbanization is just beginning to be appreciated. A major wildlife area has just been established in the Yolo By-pass. Managing the by-passes 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 by-passes are being planned, the lessons learned in managing the Yolo and Sutter by-passes may have broad implications.

Stage 1 expectations. Studies of the by-passes and how they are used by fish and wildlife should be continued and expanded. Experimental flooding of small portions of the Yolo By-pass should be attempted, in order to test ideas of the use of artificially flooded areas in dry years by at-risk species, such as splittail and salmon. CALFED or its member agencies should work with farmers in the by-passes to find ways to make agriculture as compatible as possible with fish and wildlife conservation.

Goal 5. Prevent establishment of additional non-native species and reduce the negative biological and economic impacts of established non-native species.

The 10 objectives below, when taken together, are a call to limit as much as possible a major and continuing environmental problem: invasions by exotic species. If the problem is not addressed, then many of the CALFED ecosystem restoration efforts may not succeed. The objectives show that new invaders have many sources and that even reducing the problem substantially is likely to impact many businesses that involve exotic species in one way or another. Solving the problem will also necessarily involve a high degree of public involvement and some sacrifices.

Objective #1: Eliminate further introductions of new species in ballast water of ships.

A. Long-term objective: Eliminate the dumping of all organism-contaminated ballast water and ballast sediment into the estuary.

B. Short-term objective: Eliminate the dumping of all ballast sediment into the estuary. Reduce the amount of ship ballast water contaminated with estuarine organisms from other ports that is dumped into the estuary to 5% of 1998 levels by the year 2005, and to 1% of 1998 levels by the year 2008.

Rationale: The introduction of exotic 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 once every 14 weeks. The new species greatly increase the expense and difficulty of restoring the estuary. A new invader can effectively destroy the value of a restoration project if it favors the habitat created. Aquatic invasions also can and have harmed public health, decimated fisheries, and impeded or blocked water deliveries. Substantial reductions in the number of organisms released via ballast water can be 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 exotic species by this means. Current standards include regulations requiring the exchange or treatment of ballast water at a level that is 95% effective at removing ballast water organisms. Strict controls on ballast water exchange should be enacted and enforced on shipping into San Francisco Bay at the earliest possible time. If prevention cannot work, the shipping industry must be made responsible for the damage caused by ballast water organisms because such introductions must be regarded as deliberate and unauthorized, rather than "accidental".

Stage 1 expectations. Same as short-term objectives. In addition, Better mechanisms to treat ballast water to eliminate unwanted organisms should be developed. Baseline monitoring of the organisms released in ballast water should be immediately initiated so we can assess progress and monitor compliance. Studies should be completed to investigate the ecological and economic impacts of introductions into the Bay-Delta system to demonstrate that strong action is warranted.

Objective #2. Eliminate the use of imported marine baits.

A. Short-term and long-term objective: Eliminate the use of imported, non-native marine species for bait in San Francisco Bay and elsewhere in California.

Rationale: At the present time, live polychaete worms are shipped 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). It should be banned by the Fish and Game Commission and the baits replaced by local organisms or by artificial bait.

Stage 1 expectation. The importation of live marine baits and their associated shipping materials should be banned, unless the industry can demonstrate that all the organisms imported cannot become established in California.

Objective #3. Halt the introduction of freshwater bait organisms into the waters of Central California.

A. Long-term objective: Halt the introduction of additional species of bait organisms in the CALFED area and the further spread of species already established.

B. Short-term objective: Develop and institute strategies, working with the bait industry, the fishing community, and interests representing the environment and other sectors that may be affected by such introductions, to halt the introduction and spread of organisms used as bait in fresh and brackish water.

Rationale: Many kinds of aquatic organisms are used for bait. 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. Other new organisms may be brought in as "hitch-hikers" in shipments of bait fishes. There is also a need to better educate the fishing public on the adverse impacts of invasive species (see objective 4).

Stage 1 expectations. Working with the bait industry and other interested parties, a plan should be developed and instituted to greatly reduce, and eventually eliminate, the introduction of unwanted bait organisms into natural waters.

Objective #4. Halt the deliberate introduction and spread of potentially harmful species of fish or other aquatic organisms in the Bay-Delta and Central Valley.

A. Long-term objective: Prevent the establishment through deliberate introductions of any additional fish species from outside the state or from other watersheds within the state, into Central California.

B. Short-term objective: Develop a program to educate the public (especially anglers) about the dangers of moving fish and other organisms around.

Rationale: The California Department of Fish and Game (DFG) 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 Davis Reservoir. If the highly predatory pike had become established in 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 Davis Reservoir demonstrates the need for the development of 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 yellowlegged frog that lives there, pushing the species further towards endangered species listing.

Stage 1 expectations. An aggressive public information program should be developed in regard to species introductions

Objective #5. Halt the release of fish and other organisms from aquaculture operations into Central California waters, especially those imported from other regions

A. Long-term objective: Halt the non-deliberate introduction into natural waters of aquatic organisms from aquaculture facilities that is often a by-product of aquaculture operations. Prevent the importation from other regions of organisms from other regions into aquaculture facilities in the Bay/Delta watershed unless major quarantine regulations and/or facilities are in place.

B. Short-term objective: Institute an independent, scientific assessment of the pathways and risks of the introduction into the environment of organisms imported from other regions by aquaculture and of any changes needed in California's current management of the industry to prevent such introductions. Develop and institute strategies, working with the aquaculture industry and interests representing the environment and other sectors that may be affected by such introductions, to halt the introduction and spread of invasive or harmful non-native species via aquaculture.

Rationale: Stocks of fishes and invertebrates are imported from other regions for rearing in aquaculture facilities in the Bay/Delta watershed, 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, and on sport and commercial fish in Central California waters. Of greater concern is the potential for the introduction of parasites and diseases of commercial, recreational and native fish and shellfish. There are also many examples of such diseases introduced by aquaculture into various parts of the world, sometimes with devastating impact on commercially important species.

Stage 1 expectation. An independent assessment of the pathways, risks and needed management of aquaculture introductions should be completed; management measures to eliminate by-product introductions should be adopted and implemented.

Objective #6. Halt the introduction of invasive aquatic and terrestrial plants into Central California.

A. Long-term objective: Halt the importation, sale, and use of aquatic and terrestrial plants that can have potentially harmful impacts on ecosystems in the CALFED region.

B. Short-term objective: Develop and institute strategies, working with the horticulture industry and interests representing the environment and other sectors that may be affected by such introductions, to halt the introduction and spread of invasive plant species.

Rationale: Many areas of the Central California landscape are dominated by exotic 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! There clearly is a need to evaluate the plants imported into California from other regions and to better regulate the horticultural industry to make sure potentially invasive plants are not available for spreading by gardeners, landscapers, and people engaged in restoration/reclamation activities. There is also a need to better educate the public on the adverse impacts of invasive species and the need to not to allow garden plants to escape into natural environments.

Stage 1 expectation. Plants sold in California by the horticulture industry that pose a threat to ecosystems in the CALFED region should be identified and evaluated for invasive potential. Special attention should be paid to plants imported into the region from other areas. Working with the horticulture industry and affected interests, a plan should be developed and instituted to greatly reduce, and eventually eliminate, the introduction of additional invasive plant species into natural environments.

Objective #7. Halt the release and spread of aquatic organisms from the aquarium/pet trade into the waters of Central California.

A. Long-term objective: Halt the release and spread of aquarium organisms and aquatic pets in the CALFED area.

B. Short-term objective: Develop and institute strategies, working with the aquarium industry and interests representing the environment and other sectors that may be affected by such introductions, to halt the introduction and spread of non-native species from the aquarium/pet trade.

Rationale: 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. Non-native turtles 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 (although there have been some surprising exceptions), the industry is constantly searching for and bringing in new species from all types 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. There clearly is a need to make sure that potentially harmful organisms are not available to aquarists and that new organisms are not brought in as "hitch-hikers" in shipments of aquarium fishes. There is also a need to better educate the public on the adverse impacts of invasive species and the need to not release aquatic pets into natural environments. A good model for this could be the program now in place in Hawaii, which (among other things) has a big public education component and requires all aquarium stores to have a special tank into which people can release unwanted aquatic pets.

Stage 1 expectations. Organisms in the aquarium/pet trade should be identified and evaluated for invasability. Working with the aquarium/pet industry and affected interests, a plan should be developed and instituted to greatly reduce, and eventually eliminate, the introduction of unwanted aquatic organisms from these sources into natural waters.

Objective #8. Reduce the impact of exotic mammals on native birds and mammals.

A. Long-term objective. Have in place mechanisms which can minimize the negative effects of house cats, red fox, domestic dogs, roof rats, house mice and other non-native predators and competitors on populations of native birds and mammals, especially at-risk species.

B. Short-term objective. Develop both the means and the public support for limiting the invasion and impacts of non-native mammals into natural areas.

Rationale: Probably few issues are as potentially contentious to the public than 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 region), 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 trade-offs in protecting abundant and conspicuous predators that prey on native species, as well as programs to rid areas of other exotic mammals. Economical but lethal means of control (poisons, traps) are often controversial for many of these species. There is thus a need to focus on prevention (e.g., containment and neutering of pets), on non-lethal means of removal (e.g., live-trapping) where possible, and on developing support for lethal control where necessary. Prevention and non-lethal methods are typically labor intensive, continuous, and more costly than limited agency budgets can endure. Therefore there is a need to develop either better methods or bigger budgets for control if self-sustaining populations of many native birds and mammals are to be maintained.

Stage 1 expectations. An aggressive public information program on the impacts of such exotic mammals in wildlife areas should be conducted. Plans for long-term control of invasive mammals should be developed, with alternatives clearly spelling out the impact of no or low control.

Objective #9. Develop focused control efforts on those introduced species where control is most feasible and of greatest benefit.

A. Long-term objective. Eliminate, or control to a level of little significance, all undesirable non-native species, where feasible.

B. Short-term objective. Eradicate or contain those species for which this can readily be done, gaining thereby the largest benefit for the least economic and environmental cost; and to monitor for the arrival of new invasive species and, where feasible, respond quickly to eradicate them.

Rationale: Non-native species are now part of most aquatic, riparian, and terrestrial ecosystems in California. In most instances, control is either not possible or not desirable. However, in some instances control of invasive species is needed to protect the remaining native elements. 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 waterbodies are in general more controllable than organisms free to roam throughout large, hydrologically-connected systems. Third, while biological control is conceptually a very appealing technique, 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, when physical or chemical methods control methods are used in a program of maintenance control rather than eradication, this means committing to ongoing environmental disturbance, and expense, and possibly public health risks indefinitely. 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 a species needing eradication that is currently not being dealt with is English cordgrass in the bay that has been described by some scientists as the most aggressive and invasive salt marsh plant in the world. It has been in the Bay for 20 years, which is its only known California location, without spreading so has not generated concern. However, in other parts of the world it has also sometimes sat around for a few decades without doing much of anything, then suddenly taken off and taken over entire estuaries in a few years. In San Francisco Bay it is known from one site only, where it was planted, and where it exists in a single patch. It could easily be eradicated.

Stage 1 expectations. Assess existing introductions to identify those with the greatest potential for containment or eradication, and consider this in prioritizing control efforts. Monitor for, and respond quickly to contain and eradicate new invasions, where this is possible. Develop a mechanism where by new invasions can be dealt with quickly and effectively.

Objective #10. Prevent the invasion of the zebra mussel into California.

A. Long-term and short-term objectives: Develop an emergency response strategy to quickly contain and eradicate zebra mussels should they arrive in 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.

Stage 1 expectation. A determination should be made as to which waters which are most likely to serve as an initial site of invasion for zebra mussels (taking into account both water quality and other environmental factors and the mechanisms likely to transport zebra mussels); a zebra mussel monitoring program for these waters should be developed; and a rapid response strategy should be developed to contain and eradicate an incipient zebra mussel invasion.

Goal # 6. Improve and maintain water and sediment quality to eliminate, to the extent possible, toxic impacts on organisms in the system, including humans.

The objectives within this goal are very broad, in part because they should overlap with more specific objectives developed in the Water Quality Program (WQP) of CALFED. The WQP, however, is focused on improving water quality for human health, so the reason for this section of the ERP is to make sure that water quality goals developed for human health are compatible with those needed for improving ecosystem health.

Objective #1. Reduce the concentrations and loadings of contaminants in all aquatic environments in the CALFED region.

A. Long-term objective: Reduce concentrations and loadings of contaminants that affect the health of organisms and ecosystems in water and sediments by 90% as measured against current average levels.

B. Short-term objective: Reduce concentrations and loadings of contaminants that affect the health of organisms and ecosystems in water and sediments by 25-50% as measured against current average levels.

Rationale: A wide variety of herbicides, pesticides, fumigants, and other toxic materials enter the aquatic environment of the CALFED region from many sources. The number and variety of contaminants entering the rivers and estuary is poorly known, as are their toxic effects, in part because the amounts and kinds are constantly changing. However, there is good reason to think that toxic compounds are having many negative effects on aquatic organisms, both acute and chronic. These same compounds can have effects on human health, so reduction in their entry into the aquatic systems should have positive health benefits as well. Reducing concentrations of toxic contaminants is not easy because it will require broad changes in land management practices and in the chemical dependency of agricultural and urban areas for pest control. It will require reductions in the amounts and kinds of pesticides applied for many purposes and changes in the way they are applied to reduce their ability to contaminate aquatic ecosystems. Changes in industrial practices that result in contaminants being released (e.g., hydrocarbons from oil refineries) will also be required,

Stage 1 expectations. Strategies and financial incentives should be developed and implemented that reduce the use of herbicides, pesticides, fumigants, and other toxic materials in urban and agricultural areas. The monitoring of contaminants should be substantially increased, both as applied and in the environment in order to get better handle on what is going where and on the association of contaminants with declines of aquatic species. Annual goals should be established for the reduction of selected contaminants (e.g., carbofuran, chlorpyifos, diazinon, hydrocarbons, selenium) and monitoring programs set up to determine success of reduction programs.

Objective #2. Develop regional plans to reduce the effects of non-point source

contaminants.

A. Long-term objective: Implement for all watersheds in the Central Valley, as well as in the Delta, watershed management plans to reduce or eliminate contaminant loads flowing into aquatic ecosystems.

B. Short-term: Develop watershed management plans to reduce or eliminate contaminant loads flowing into aquatic ecosystems.

Rationale: Contaminants from agricultural, industrial, and urban run-off are potentially major sources of mortality to aquatic organisms and can cause damage to aquatic ecosystems that is often hard to detect and regulate on an individual basis. Therefore, the best approach to the regulation of non-point source contaminants seems to be cooperative watershed plans with built-in incentives for reducing contaminant loadings of waterways.

Stage 1 expectations. Using existing data and analyses, major watersheds in the Central Valley should be rated or ranked according to the amount they are impaired by contaminants. Plans to reduce contaminant loads in at least 10 watersheds for which such plans do not exist at the present time should be developed an implemented.

Objective #3. Reduce contaminant loads in harvested organisms.

A. Long-term: Eliminate the need for health warnings as the result of contaminants in fish and invertebrates from the Bay-Delta estuary and watershed.

B. Short-term: Identify major sources of contaminants (e.g., heavy metals) in the flesh of harvested fish and invertebrates to see if reduction in sources of contaminants is likely to reduce contaminant loads in fish and invertebrates.

Rationale: Many resident fish and invertebrates contain high levels of heavy metals and other contaminants, resulting in warnings that their consumption may be hazardous to human health. Elimination of this contamination in the short run is unlikely, but systematic reduction of sources may eventually make all harvested organisms in the estuary and watershed safe to eat. In some cases, such as mercury, reduction of loads to safe levels may be extremely difficult because of deposits in sediments but strategies to reduce loads are still needed.

Stage 1 expectations. Major sources of contaminants in fish should be identified and drainage-specific plans developed to reduce their entry into the ecosystems.

Objective #4. Reduce to acceptable levels the release of oxygen-depleting substances into aquatic systems throughout the CALFED region.

A. Long-term goal: Eliminate run-off and discharges that contain undesirable concentrations of animal wastes, sewage, and other substances that can deplete oxygen levels in streams and sloughs.

B. Short-term goal: Identify major sources of oxygen-depleting substances throughout the CALFED region and develop strategies for their reduction; reduce the aquatic areas regarded as degraded by animal waste, sewage, and other organic substance by at least 50%.

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 cause rapid eutrophication, resulting in fish kills and dominance by undesirable organisms. Such contamination, although diminished, is still common and needs to be reduced further, especially from agricultural sources. For example, low oxygen levels in the lower San Joaquin river are often a barrier to the movement of 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.

Stage 1 expectations. Sources or areas of problem releases of oxygen-depleting substances should be identified and incentive programs developed to reduce the amount of organic contamination coming from agricultural areas.

Chapter 5. The Strategic Plan

A. Ecosystem Restoration Program Overview

The mission of the CALFED Bay-Delta Program 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. In terms of ecosystem restoration, this mission is given tangible focus through the goals and objectives outlined in Chapter 4. Central to the Ecosystem Restoration Program (ERP) is the acknowledgment that ecological processes throughout the Central Valley, its rivers and the Bay-Delta will have to be restored and enhanced if endangered species are to be restored and the Bay-Delta ecosystem is to support abundant and resilient populations of plants, fish and wildlife.

Ecosystem restoration and the rehabilitation of threatened and endangered species is, however, only one of a number of major problems facing the region; water quality, water supply and levee integrity are also at issue. As population has grown and human activities have intensified in the region, water quality problems have begun to emerge. Although water quality throughout the region remains relatively good, there have been instances of poor water quality in the rivers and parts of the delta and the frequency of "events"of poor water quality appears to be increasing. For example, bromide concentrations are a significant concern in water exported from the delta. Furthermore, there is increasing concern over the potential ecological and human health effects of long-term chronic exposure to low levels of multiple contaminants.

Issues of water supply and water allocation, always contentious, have intensified in recent years as demands on the existing distribution and allocation system have grown and concerns over the ecological consequences of redistributing water in time and space have moved up in priority. Redesigning operating systems and retrofitting existing conveyance systems to reduce or eliminate their adverse environmental consequences, ensuring efficient use of existing water and designing new, ecologically acceptable conveyance systems are all problems of immediate and growing importance.

Levees protect adjacent lands from flood and help channel and direct water, particularly through the delta. Many of the levees are old and at risk of failure particularly under high flows or in the event of an earthquake. Any significant breaching of the levee system would cause billions of dollars in property damage and could both endanger human life and damage critical wildlife habitats. Critical levees need to be upgraded while others could be removed once human activities have been relocated.

Ecosystem restoration is, therefore, part of a larger program of activities to address this broad range of problems. The Ecosystem Restoration Plan needs to be consonant with this broad range of activities and objectives.

The range of issues and problems described above are most strongly expressed in the legally defined Delta of the Sacramento and San Joaquin Rivers, Suisun Bay and Suisun Marsh.

The focus of restoration and management is, therefore, the Bay-Delta area. However, the causes of the problems and their solutions cover a much broader area, including the drainage basin of the Central Valley, the southern California water service area, San Pablo and San Francisco Bays and the coastal marine environment from Oregon to Pt. Conception. Ecosystem restoration may, therefore, involve activities that occur well outside the Bay-Delta. Nevertheless, the intent of ecosystem restoration within the CALFED program is still to improve the well being of species dependent on the Bay-Delta. For the purposes of restoration planning it is useful to think of the large problem area as consisting of 3 nested and interconnected zones. At the center is the Bay-Delta ecosystem which is the geographic focus of restoration. Surrounding this is a geographical zone of primary interest comprised of North San Francisco Bay and the Sacramento and San Joaquin Rivers and their tributaries below major dams. Most restoration activities will take place within the Bay-Delta and the zone of primary interest. The outermost zone, including the coastal ocean and Central Valley tributaries above major dams, will be addressed secondarily in the event that actions in this zone are essential to the success of actions within the primary zone.

The Bay-Delta and the zone of primary interest can be divided into 14 ecological zones each representing a predominant physical habitat type and species assemblage. These zones are described in detail in Volume II of the ERP. Within each zone, ecosystem restoration activities can be tailored to the particular biophysical characteristics of the zone and priorities for the zone. Having multiple and definable ecological zones each containing a variety of habitat types allows for the nesting of adaptive management actions within zones or their distribution among zones in ways that both maximize the learning opportunity while minimizing the overall risk to sensitive species. The Bay-Delta and zone of primary interest, thus provide a rich array of opportunities for ecological restoration. The strategic plan provides a blueprint for capitalizing on these opportunities.

B. Elements of the Strategic Plan

The Strategic Plan provides a framework and guidance for achieving ecosystem restoration in the Bay-Delta. There are eight elements to this strategy:

1. **Clear, measurable goals and objectives.** A clear and measurable set of goals and objectives for ecosystem restoration. The goals establish the broad expectations of the ecosystem restoration program while the objectives provide a set of criteria by which success or failure of the ecosystem restoration may be judged. ERP goals and preliminary objectives are presented in chapter 4.

2. **Ecosystem-based approach.** Both the ERP and the Strategic Plan embody an ecosystem-based approach to restoring and managing natural resources. The ecosystem approach dictates that certain elements of the program will be present (e.g. integration of environmental, economic and social issues, an adaptive approach to management/restoration) and suggests ways that other elements should be organized (e.g. a nested, hierarchical approach to compliance). The ecosystem approach is described in more detail later in this chapter.

3. **Adaptive management**. Adaptive management will be the means by which habitat and species restoration objectives are achieved. The ecosystem approach acknowledges that because of uncertainty in the behavior of ecological processes, best management practices cannot be predetermined. By treating management initiatives as experiments the act of managing will itself provide the information necessary to achieve restoration objectives. Comprehensive monitoring and evaluation of programs and an efficient system of information management and dissemination will provide a positive environment for learning and adaptation. Adaptive management, monitoring and evaluation and information management are described in more detail in chapters 1 and 6.

4. **Conceptual Models**. Conceptual models will provide an heuristic basis for designing adaptive management initiatives. Such models will assist in describing and explaining ecosystem structure and function, define explicit hypotheses about the linkages between management interventions and restoration outcomes and provide a framework for quantitative simulation and evaluation of alternative hypotheses in adaptive management. The design and use of conceptual models is described later in this chapter.

5. **Staged Implementation** Staged implementation will allow early implementation of actions that are relatively uncontroversial or offer substantial restoration benefits. More uncertain and controversial activities may be delayed until focused research, modeling and/or demonstration experiments reveal the likelihood that benefits will outweigh costs. Also, because CALFED actions related to water quality, water supply and levee integrity may impact ecological restoration, the ERP must be linked to and coordinated with the other components of CALFED. Thus, there will be staging of ERP projects as part of coordination with other activities within CALFED. Some aspects of staging are discussed later in this chapter and in Chapter 6.

6. **Compliance Strategy**. The strategy for compliance with regulations and legislative mandates will allow for smooth and timely approval of management actions by providing solid scientific and legally defensible bases for proposed actions. Compliance with the regulatory framework is crucial as formal challenges to management actions can create costly and destructive delays in meeting program objectives. Compliance in the context of ecosystem management and adaptive management is discussed in detail in chapter 8.

7. **Scientific and Public Involvement**. The strategy for communication will be open, responsive and technically rigorous. Routine external scientific and professional review of programs and monitoring results coupled with peer reviewed publication of major findings will ensure the scientific credibility of the program. Open and efficient consultation with the public and stakeholders will ensure that the program meets public and stakeholder expectations as well as regulatory requirements. Information management and communication are discussed in Chapter 6.

8. **Dispute Resolution**. The program will include an effective dispute resolution system to address issues where consensus cannot be reached. The management of water and

resources involve management actions that generate a lot of conflict. Invariably there will be issues where competing interests cannot agree. In such instances the options are to set the issue aside or invoke some form of dispute resolution. Where uncertainty is high and restoration is at stake, setting aside the issue may not be an option. The means of resolving disputes should be credible and agreed to in advance of substantive management action. Dispute resolution is discussed in Chapter 6.

To illustrate how these eight elements will work together in ecosystem restoration we provide an example of ecological restoration to benefit spring-run chinook salmon in Deer Creek (Chapter 7) and outline an action plan for Stage 1 of the program (Chapter 9). Finally, we provide comment and guidance on the long term development of the program (Chapter 10). We sketch the long term development of the program in very broad terms as what can or should be done in the future is entirely dependent on the outcome of stage 1 activities.

C. Defining Ecosystem Restoration

The ERP is about ecosystem restoration yet ecosystem restoration is not defined in either Volume I or II of the ERPP. Ecosystem restoration is a contentious issue in resource management and a significant amount of confusion surrounds the concept (Richardson and Healey 1996). The term itself seems to imply that the ecosystem will be put back into a structural and functional configuration defined by some historic baseline. Historic analysis of ecosystem transformation is important in defining how the system has changed over time and in helping to identify patterns of structure and function that may be useful in restoration. However, we do not regard ecosystem restoration as the process of recreating any particular historic configuration. Rather, ecosystem restoration is the process by which we ensure that the capacity of the system to provide valued ecological goods and services to society is maintained or enhanced.

Historically, water and land use has emphasized certain kinds of economic and social benefits without sufficient consideration for the concomitant loss of other benefits when ecological systems were altered and transformed (Healey 1998). As a consequence, the Bay/Delta is home to an increasing number of introduced nuisance species, many native species have been reduced to the status of threatened or endangered under the ESA/CESA, economic values associated with many native species and habitats have been lost or severely degraded, and biodiversity and natural amenity values have been lost. In this context, ecosystem restoration means reestablishing a balance in ecosystem structure and function so that the lost ecological goods and services may be regained in some reasonable measure while still maintaining the kind of diverse and vibrant socioeconomic climate for which the region is famous.

This is not to say that change and adjustment will not be required. Ecosystem restoration is not about having your cake and eating it. However, there is no benefit to ecosystem restoration if it destroys the fabric of the society it is intended to serve. 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.

D. The Ecosystem Approach

Since 1992, each of the primary land management agencies in the US (The National Park Service, The Bureau of Land Management, The Fish and Wildlife Service, The Forest Service) has independently announced that it is implementing an ecosystem approach to managing the resources under its stewardship (Hennessey 1997). While ecosystem management has, thus, become the underlying management philosophy of these agencies, there is still considerable controversy as to what, exactly, constitutes ecosystem management (Healey 1998, Hennessey 1997). In its monograph on the scientific basis of ecosystem management, the Ecological Society of America (ESA 1995) identified 8 elements of ecosystem based management that illustrate well the character of this emerging paradigm:

1. **Long term sustainability is a fundamental value.** This element highlights the importance of inter-generational equity. Resources should be managed today to ensure that the needs of future generations will not be compromised (WCED 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). Ecosystem restoration under CALFED addresses this element in its emphasis on recovering native species and biodiversity and in its emphasis on naturally sustaining ecosystem processes.

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 and unattainable "pristine" condition but provides considerable latitude for negotiating and defining desirable future conditions. Furthermore, since goals are to be stated in terms of measurable criteria, progress can be explicitly evaluated. The ERP and the Strategic Plan have developed tangible and measurable goals and 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, since 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 units within the solution zone is a further acknowledgment of the interconnectedness among elements of structure and function in the solution area.

5. **Ecosystems are dynamic.** This element highlights the fact that 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. Adaptive management is one powerful tool for embracing uncertainty that is integral to CALFED. And there is implicit recognition of the importance of dynamic processes in the concern over effects of the seasonal hydrograph on particular species and in the 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 define the necessary degree of dynamic change to maintain ecosystem function.

6. **Context and scale are important.** This element highlights the fact that 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 made congruent with those of critical ecological processes in the system to be managed. This element of ecosystem management is still relatively weak in the CALFED ERP. 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.** This elements highlights the fact that 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 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.** This element highlights the fact that our understanding of ecosystems is incomplete and subject to change so that management planning and programs cannot be categorical. Every program of management is an experiment and should be treated as such. Again, we emphasize that in calling management programs "experiments" we are simply recognizing the opportunity to integrate the problem solving power of the scientific method into resource

management. Management actions will still be taken because they are believed to be the best solutions to perceived problems. Treating the actions as experiments, however, means that we deliberately plan to take advantage of the opportunity to learn from each management action so as to improve the process of management over time. This is adaptive management and it is at the core of ecosystem management.

E. Program Components

Within the ERP, program components are described as implementation objectives, targets and programmatic activities. The targets and programmatic activities provide a very broad set of activities related to restoration and management of habitats and target species. Targets are both quantitative and qualitative and programmatic actions specify how each target is to be achieved. Targets and their associated programmatic activities can be further divided into 3 classes:

1) those that have sufficient certainty of success to justify full implementation in accordance with adaptive management, program priority setting and phased implementation;

2) those that will be implemented in stages with appropriate monitoring to judge benefit and success; and

3) those for which additional research demonstration and evaluation is needed to determine feasibility or ecosystem response.

Each of the 14 ecological zones has its own set of implementation objectives and targets based on the particular problems and opportunities inherent in each zone.

The ecosystem restoration activities described in the ERP fall broadly into four categories: making more habitat, improving existing habitat, restoring ecological processes, and reducing anthropogenic stresses. Although all categories are probably important to the range of species, restoring ecological processes and reducing anthropogenic stresses are more commonly identified in the rehabilitation of fish species whereas increasing and improving habitat are more commonly noted for insects, amphibians, reptiles, birds and mammals.

Although the ERP provides an important description and rationale for a wide range of activities to benefit target species and rehabilitate ecosystem functions, several critical elements of a strategy are missing. The listed activities have not been subject to the process c. .tlined in the Strategic Plan. They need to be revisited and re-prioritized in terms of the objectives outlined in the Strategic Plan. In this way they can be developed within the context of conceptual models of ecosystem function and explored as alternative policies in simulation models. This process, which is central to adaptive management, provides an objective basis for prioritizing the various activities in terms of perceived benefits and costs, for determining appropriate quantities of restoration to achieve stated objectives, and for determining whether to proceed with large-scale restoration, pilot projects or targeted research. Viewed in this way, the ERP provides a list of opportunities while the Strategic Plan provides a means to analyze and implement those opportunities in the most effective way.

F. Staged Implementation

The Strategic Plan envisions three levels of staging to accomplish ecosystem restoration in an efficient manner. At the highest level, the ERP must be integrated with other CALFED activities so that restoration activities will not be compromised by activities aimed at water quality, water supply or levee integrity. Furthermore, activities related to water quality, water supply and levee integrity may open up opportunities by which ecosystem restoration could benefit. It is our view that the other components of CALFED would benefit from an adaptive approach in the same way that ecological restoration will benefit. An adaptive management framework could provide an effective means for linking, integrating and staging projects in all aspects of CALFED. In addition, ecosystem restoration may be linked to and benefit from activities outside CALFED such as the CVPIA and the Core of Engineers' plans for flood management in the Central Valley. For example, making Battle Creek accessible to chinook salmon is being undertaken under the CVPIA and this action is important to ecosystem restoration under CALFED. The Corps' plans for flood management will have significant implications for projects such as levee set-back, ecosystem restoration in flood channels and Deer Creek restoration under CALFED.

At the second level is the staging of projects within the ERP. Although we have not attempted to analyze this in any formal way in preparing the Strategic Plan, it seems obvious that there is an optimal sequencing of projects to achieve species and ecosystem goals within ecosystem restoration. For example, floodplain restoration on the San Joaquin may not be very effective until, or unless, sufficient water is available to inundate floodplains and restore channel activity. Similarly, restoring channel migration as a means of augmenting bedload supply may not be effective if downstream gravel mining removes much of what is added. These are simply obvious examples. Simulation modeling of alternative conceptual models may reveal more subtle connections that would require appropriate staging of projects.

At the lowest level is staging within projects. This refers to the relationships among research, pilot projects and large scale restoration as well as rules for moving among these levels of activity. The information flow within adaptive management provides a partial but not a complete basis for such decisions. For example, it can always be argued that information is insufficient to justify large-scale implementation. The uncertainty associated with this decision can be partially mitigated by designing the large scale intervention as an adaptive experiment so that additional information is derived from the large scale implementation. Often more difficult, however, are decisions about when to scale back or stop certain restoration activities. The individuals and agencies involved in such projects naturally develop ownership and personal investment in the projects and often find it difficult to judge them in a fully objective way. Decisions at this level and, indeed, at the other levels will be greatly assisted by having an independent scientific review committee to help keep the program on track and proceeding.

toward a successful conclusion.

G. Use of Conceptual Models in Decision-Making and Directing Investigations

Restoration or rehabilitation programs for complex ecosystems must be based on clear concepts about how the system is believed to function, how it has been altered or degraded, and how various actions might improve conditions in the system. This section discusses the uses (and abuses) of conceptual models in this context, and presents examples in which conceptual models of various aspects of the Bay-Delta-River ecosystem are used to explore management alternatives and identify needs for research and monitoring.

Conceptual models are simplified illustrations of what we think are the most critical cause and effect pathways (i.e., how ecosystems function). There is no unique set of conceptual models that provides a basis for ecosystem restoration and that can be determined *a priori*. Rather, conceptual models for ecosystem restoration are utilitarian representations of critical relationships that should emerge from discussions among scientists, managers, and stakeholders about perceived problems with the Bay-Delta.

We sound a note of caution about the enthusiasm over conceptual modeling that has swept the CALFED community. The first rule of conceptual or quantitative modeling is that the model should be designed for a particular purpose. Conversely, a model designed for one purpose will be less effective when used for another purpose, and a model designed to be generally useful may have no uses at all. Developing a comprehensive suite of conceptual models would be a dry and uninformative exercise, and would not advance our ability to understand or manage the ecosystem. Our use of conceptual models should be directly aimed at solving particular problems, and the models should contain only those elements relevant to solving those problems, including alternative explanations that might yield alternative solutions.

1) Development of conceptual models

There is no recipe for developing conceptual models, nor is there a template for what they should look like. A conceptual model is simply an explicit representation of a set of concepts held by its author(s). Everybody has implicit conceptual models about all aspects of the world, and most people working in Bay/Delta science or management have implicit models of how the ecosystem works and how it might respond to manipulations. Making implicit models explicit requires abilities in teaching and presentation.

Conceptual models can be constructed using flow diagrams, matrices, or other diagrams, or without diagrams. When flow diagrams are used, it is important to be clear about what is flowing: i.e., whether the arrows represent flows of material, individual organisms, information, or influence.

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 alterations of management or analytical actions. This will not happen by itself but must be accomplished through a systematic, periodic reevaluation of the conceptual models. We suggest that this should happen at least once every three years, or more often if developments in a particular field are rapid.

2) Uses of conceptual models

Conceptual models can be used as heuristic tools, to explain theories, as a basis for quantitative models, to identify critical points for research or monitoring, or, in ecosystem restoration, to link human activities or possible human interventions to outcomes that are important to society. For adaptive resource management the most important uses of conceptual models are for linking human activities to valued outputs, highlighting key uncertainties for research and adaptive probing, and identifying monitoring needs. However, it is useful to develop these models with the intent of further elaboration into quantitative models. These can be used as a basis for predicting, and thereby testing, the amount of intervention required to produce a desired result in a program of adaptive management.

Conceptual models can be used to explore how human actions affect aspects of ecosystems (species, habitats, communities, landscapes) that society values, and to provide justification for particular management interventions to repair or enhance valued ecosystem attributes or products. In developing such models, it is critical to identify reasonable alternative hypotheses about how key pathways in the system might work. This can foster acceptance by interested parties whose alternative views of the scientific basis for management have been included. In addition, it identifies areas where uncertainties preclude a single, possibly irreversible, management action. It also provides a framework for preliminary evaluation of the costs and benefits of conducting adaptive exploration to distinguish between the competing hypotheses.

Conceptual models of the links between management actions and valued ecosystem products also provide a basis for designing monitoring and evaluation programs to assess the benefits of management interventions. For any program of adaptive management, whether passive or active, it is essential that the conceptual models underlying management actions and their predictions (whether qualitative or quantitative) be made explicit and that the monitoring and evaluation program be tied to these models.

3) Some examples

Here we provide several examples of conceptual models to illustrate ways they could be used. The models presented here are more or less hierarchical: first we present an extremely simple landscape-level model, followed by an ecosystem-level model, and several models of specific processes. The models are used to explore issues such as salmon restoration and effects of entrainment in state and federal pumping facilities.

We do not assert that these models are the best possible representations of the processes being considered. Rather, we present them to illustrate how they can be used. At the end of this section we present steps required to carry out the activities suggested here.

A) Landscape-level model

This model applies to chinook salmon, but its principles could also 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, either between the rivers and the estuary, or between the estuary and the ocean. They do so by migrating, and in doing so they expose themselves to human interventions and other environmental conditions in each region. 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 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.

Specific issues concerning production of chinook salmon are discussed in Chapter 7.

B) Ecosystem-level model

For this example we examine the effects of freshwater flow and exports on various species of fish and invertebrates. In particular we focus on the "Fish-X2" relationships (Jassby et al. 1995), by which abundance or survival of several estuarine and anadromous species is related to X2, the distance up the axis of the estuary to where daily average near-bottom salinity is 2 practical salinity units (psu). This index is useful in encapsulating the physical response of the estuary to freshwater flow.

Since X2 is controlled by freshwater outflow from the Delta, it varies with both inflow and export flows. The principal issue addressed here is what alternative management tools are available besides X2 for maintaining or enhancing populations of estuarine species.

Figure 5-1 illustrates the diverse mechanisms that could operate 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, there is good evidence from this estuary (Kimmerer 1998) that direct physical effects on fish are more likely. These effects occur through two general classes of mechanisms. First, flow conditions in the estuary set up by tides and freshwater input, and in some cases by export flows, may alter the degree of retention within the estuary, thereby affecting population size. Second, the extent of physical habitat may change with freshwater flow through such effects as inundation of flood plains or expansion of low-salinity shallow habitat.

Now consider how alternatives to X2 might be developed under these three scenarios. If the mechanism is believed to be stimulation at the base of the food chain, then appropriate management actions might include some effort to enhance the input of nutrients or organic matter to the estuary. If retention is the issue, this would suggest a research program to narrow the time period over which retention is critical to each population of interest, and possibly for some species an alteration of flow or export schedules. If habitat is the issue, then physical restoration of habitat or judicious use of flow to maintain some appropriate salinity-depth relationship might be in order.

Thus, a very simple model can be used to illustrate how divergent the management options might be, and how critically they depend on the assumed mechanism. To provide further detail on the ecosystem-level model we use part of the Estuarine Ecology Team's report on the "Fish-X2" relationships (EET 1997). That report included a matrix (Figure 2) that summarized knowledge on each of the potential mechanisms underlying the observed relationships. For each mechanism and each species, a symbol was used to denote the importance of that mechanism to that species, and the degree of certainty/uncertainty associated with that mechanism and species. Although the intent of this matrix was to develop research proposals, it can also be used for examining various alternative causes for variation in abundance with flow.

The symbols used (Figure 5-2) are large and dark for mechanisms that are believed to be important but for which there is little information. Large, open circles denote important mechanisms for which at least some, possibly qualitative, information exists. A distinction was made between mechanisms that operate in the estuary and those that operate entirely upstream, such as variation in spawning habitat for salmon. These upstream mechanisms were included for completeness but were not discussed in any detail.

Each of the mechanisms has a precise definition (EET 1997), but we consider here only a few of them. First, examine the row labeled "Reduced entrainment (CVP-SWP)." There are 5 large open symbols and a number of smaller symbols. Large symbols are given for all of the anadromous species included in the matrix except for splittail. Thus, the EET believed that for these 5 species, entrainment could explain at least part of the observed X2 relationships, and this relationship was reasonably well-understood.

Now examine the row labeled "gravitational circulation strength". There are 6 large filled circles, including species that recruit from the ocean as well as several that move down-estuary during development and then reside mainly in Suisun or San Pablo Bays and the Delta. Similarly, several issues relate to habitat, of which "rearing habitat space" was considered an important probable mechanism for the largest number of species, although knowledge of this topic is limited.

The matrix and discussion above are useful for an overview of the likely mechanisms underlying the fish-X2 relationships. In terms of CALFED activities, it is probably most helpful for illustrating the extent of uncertainty and the multiple mechanisms likely to be operating. It is also useful for focusing attention on differences among the mechanisms that may require further research or adaptive probing. In the next two sections we present more detailed models of the mechanisms discussed in the previous two paragraphs and show how these details can be very important in choosing appropriate restoration actions in the bay and Delta.

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 5-3). 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 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 river flow 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 3 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, 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 the confluence (i.e., the Low-Salinity Zone, which under low-flow conditions in late spring is at about the confluence). Behavior of the larvae is non-negligible in this model, particularly when they reach brackish water and begin to migrate vertically.

Salmon smolts are mostly governed by their own behavior, particularly that aspect of it that determines whether they migrate along the shore or across the river. If the former, they are more vulnerable to diversions such as at the Delta Cross-Channel than if they are distributed across the channel. In addition, at the more landward nodes tidal flow, rather than net flow, has the most influence on their movement patterns. This is because we assume that, like all other organisms living in tidal environments, they are exquisitely sensitive to the tidal movements and phasing, and are capable of moving downstream rapidly using the tidal currents. Thus, their movement is governed by an interaction between their behavior and the tide.

These alternative models make radically different predictions about the effect of entrainment on these species and the most effective measures to minimize the effects of entrainment (Table 5-1). According to Model A, losses can be minimized by reducing exports and maximizing flow, and moving the intake up into the Sacramento River would have a clear benefit. Model B, on the other hand, suggest that export flows are not very important in killing salmon, and that 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 support an important role of variation in export flow in explaining variation in salmon smolt survival (Newman and Rice in prep.).

For young striped bass, the predictions of Model A are again that net flows are important and that increasing flow and reducing exports would increase early survival. Model B, on the other hand, posits 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 fish is at first, 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 predictions of the two models of effects of moving the intake site.

For Delta smelt, the picture is a bit less clear. Under model A, minimizing exports is very important, and moving the intake facility would be very helpful for Delta smelt. The export-inflow ratio can be used to scale exports to the available water; minimizing that ratio is believed to reduce the proportion of the smelt population that is entrained. Model B works similarly to the model for striped bass, in that 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 landward. Thus moving the intake facility would have little effect except under very low-flow conditions.

These results suggest a need for an adaptive-management approach to determining the effects of entrainment. Although this is being attempted in the Vernalis Adaptive Management Program, and has been suggested for flow conditions during seaward migration of spring run salmon, adaptive probing could be greatly expanded to attempt to resolve this key issue.

These results, along with the findings of the Diversion Effects on Fish Team (DEFT 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.

D) Model of Contrasting Mechanisms Underlying X2 Relationships

Here we contrast two mechanisms that are 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 mechanisms are gravitational circulation and extent of physical habitat for rearing. These contrasting mechanisms suggest completely different strategies for increasing abundance of these populations other than through the use of the X2 relationships.

Recent developments in understanding of the physical characteristics of the estuary have altered our perception of how the biota use their environment (e.g., Burau 1998). Figure 5-4 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 within 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 makes water want to go 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 opposite forcings determine the length of the salinity gradient and therefore the density gradient. High 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 5-5) can occur throughout the estuary if stratification occurs. This happens primarily in deep regions such as the Golden Gate, the main channel through Central and San Pablo Bays, and in Carquinez Strait. It is rare in the main channel of Suisun Bay (Bureau 1998). We assume (because 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 5-4). Under low-flow conditions (Figure 5-5 top) stratification is slight. Near-bottom currents are smaller than near-surface currents and slightly stronger on the ebb than on the flood near surface, and on the flood than the ebb near-bottom.

When freshwater flow is high, the density gradient is compressed and stratification is stronger, causing an intensification of gravitational circulation: the ebb-flood asymmetry in near-bottom currents in particular is greater.

Certain species of bay residents 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 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 these populations, and if it does indeed increase with flow (at least over some range), then this too could explain the observed relationships.

Actions to protect and enhance the abundance of these species (and the predatory species that depend on them) differ depending on which mechanism is most important. If the major mechanism is gravitational circulation, there is little that can be done to enhance these populations other than to increase freshwater flow (note that dredging channels may also 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 considerably less flow.

E) Conceptual Model of Meander Migration in a Regulated River

This conceptual model (Figure 5-6) 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 3-1). 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), it 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 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, to undergo gradual succession to species adapted to finer grained soils and less frequent inundation as the surface builds up through overbank sedimentation, as the channel migrates away from the site allowing it to undergo succession without disturbance. 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 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 diluted 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 partly compensates for the sediment deficit through erosion of 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 (or flood pool managed creatively to increase the frequency of high flows) to re-activate dynamic channel processes. However, if the high flows are not accompanied by an augmented supply of sand and gravel, the result may be an enlargement of the channel and a paucity of gravel deposits. Tributaries downstream of the reservoir deliver flow and sediment, which are affected by land-uses and other influences in the tributary watersheds.

The rate of meander migration may also be influenced by bank cohesion (a property of the floodplain sediments), root strength (which depends on the extent and type of riparian vegetation, which in turn can be affected by riparian management policies and restoration actions), and the presence of artificial bank protection. By stopping or slowing meander migration, artificial bank protection (including bio-technical protection techniques) can reduce river dynamism and habitat complexity.

The favorable habitats created by meander migration can also be lost or degraded by grazing (reducing riparian vegetation and causing collapse of overhanging banks), channel clearing and dredging for flood control or gravel mining (eliminating the complex habitats created by meander migration), and removal of large organic debris for flood control or navigation (eliminating the habitat complexity associated with the organic debris).

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. Such an ecosystem restoration approach would be expected to benefit multiple species and life stages, so may need to be justified on broader grounds than benefits to a single species.

H. Next steps

A substantial number of issues need to be explored so that appropriate restoration actions can be selected. We suggest the following method to characterize key issues and to develop actions that can resolve them.

1. *Identify the major issues surrounding potential restoration actions.* These issues should

not be hard to identify, most of them having been contentious for a long time. Many are listed in Section xx.

2. *Identify and brief a team of several key people involved with each issue.* These people should be experts in their field, with perhaps 1-2 from other estuary/river systems. The team members would meet for an initial briefing with a broader group including stakeholder and agency representatives, and with alternative viewpoints presented.

3. *Conduct workshops on the key issues.* The team would then meet privately once or more, with some opportunity for analysis between meetings. Brief reports would be prepared after workshops to apprise stakeholders and agencies of progress.

4. *Hold public workshop(s) to present findings.* These workshops would be used to disseminate findings and recommendations, and to provide review and feedback.

5. *Develop report and conduct peer review.* The team would then prepare a report which would be sent to two or more anonymous reviewers.

Figure 5-1. **Schematic diagram showing potential causative pathways underlying the "Fish-X2" relationships.** The labels "trophic" and "physical" indicate that causative pathways to the left of the diagram are more biological, based on feeding relationships, while those on the right 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 within 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 within their habitat, or an increase in the quantity or availability of physical habitat.

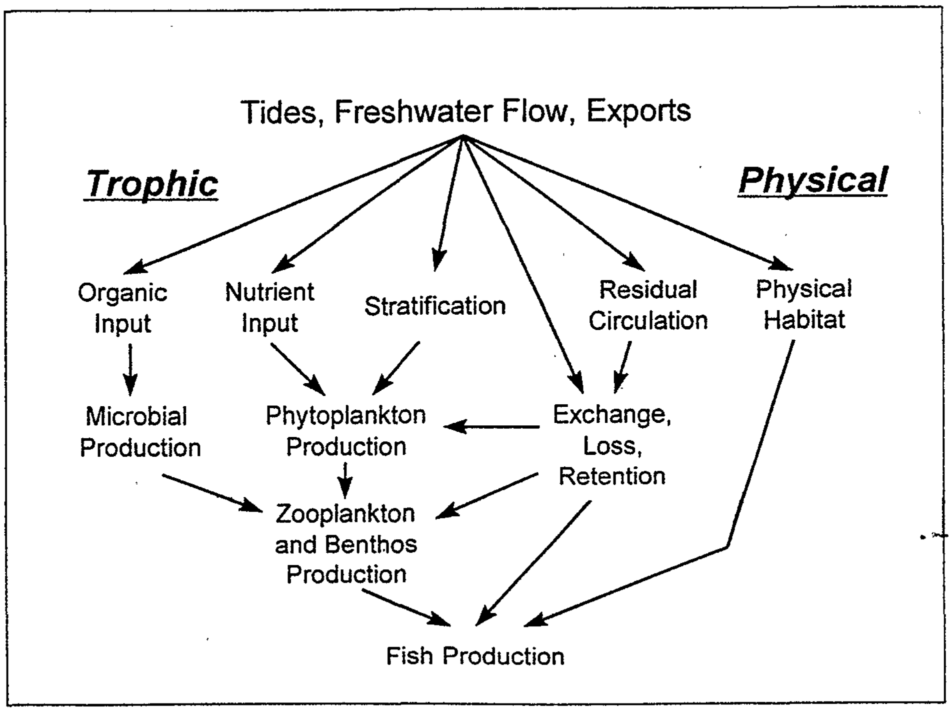

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Figure 5-2. **Estuarine Ecology Team's summary of potential causes underlying "fish-X2" relationships**, with symbols indicating a potential mechanism according to the key at right. Several minor mechanisms have been eliminated to simplify the diagram. "Upstream" effects refer to flow effects that occur entirely upstream of the Delta. Species are:

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 effect are in the delta)
NM	*Neomysis* and other mysids

Species

X_2 Mechanisms	CF	PH	SF	WS	AS	SB	LF	DS	ST	CS	NM
Spawning Habitat Space		◯		◍	◉	◯	•	●	◯	◯	
Spawning Habitat Access				◍	○	○			◯	◯	
Co-occurrence of Food		●		•	•	●	●	●	●	•	•
Rearing Habitat Space	◯	●	●	●	●	◯	◯	●	●	•	•
Predation Avoidance: Turbidity		•			•	○	•	•	•	○	●
Predation Avoidance: Shallow	•	•	•						•	○	
Predation Avoidance: Encounter	•						•	●	•	•	
Reduced Entrainment (CVP-SWP)			•	○	◯	◯	◯	◯	•	◯	○
Reduced Entrainment (PG&E)	•		•		○	○	●	●	•	○	•
Reduced Entrainment (Agricultural)			•		•	◯	•	●	•	•	•
Toxic Dilution	•	•	•	•	•	○	•	•	●	•	•
Transport	•			◯	◯	◯	◯	•	•		
Gravitational Circulation Strength	●	○	●			●	●	●			●
Entrapment Zone Residence Time						●	●	●			●
Temperature (As affected by flow)					•	•				◯	•
Strong Migratory Cues	•	•	•	◉	◯	•			•	◯	
Higher Production of Food	•	•			●	●	●	●	•		●

Relative Uncertainty
• Higher
○ Lower

Importance
● High
• Low

◉ Upstream Effect

Figure 5-3. **Alternative conceptual models of flow and fish movement in the Delta under low-flow, high-export conditions.** 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.

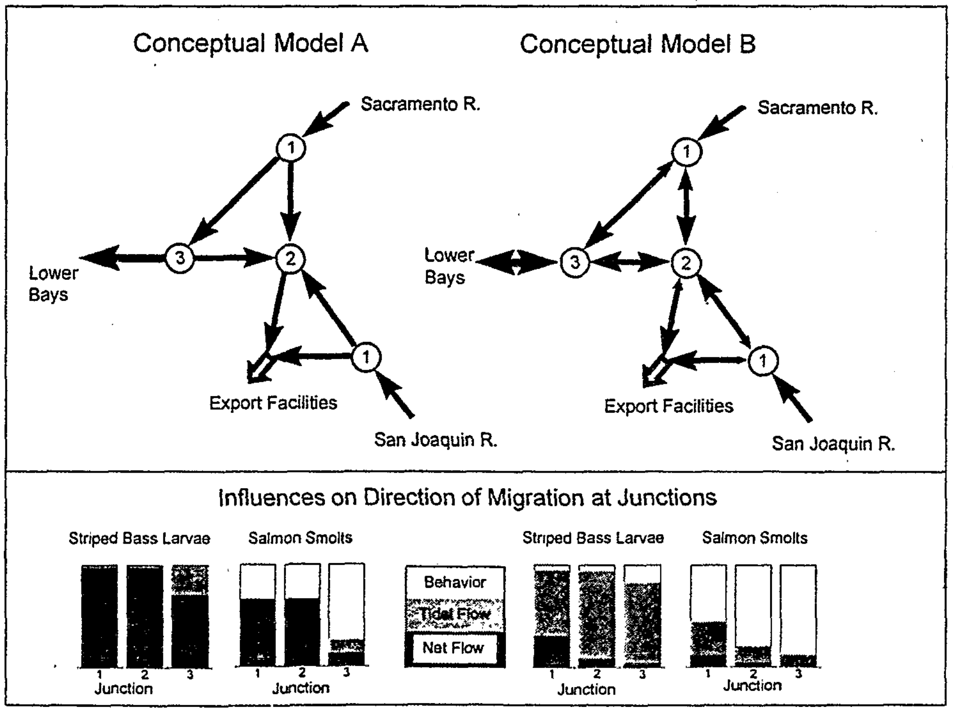

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Figure 5-4. **Conceptual model of flow effects with emphasis on the brackish parts of the estuary.** Freshwater inflow and tides are the major forcing functions. The principal role of freshwater input is in setting up a pressure (level) gradient along 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 due to tidal mixing between fresh and salt water sets up a density gradient. This interacts with tidal mixing and bathymetry to produce various degrees of stratification and gravitational circulation.

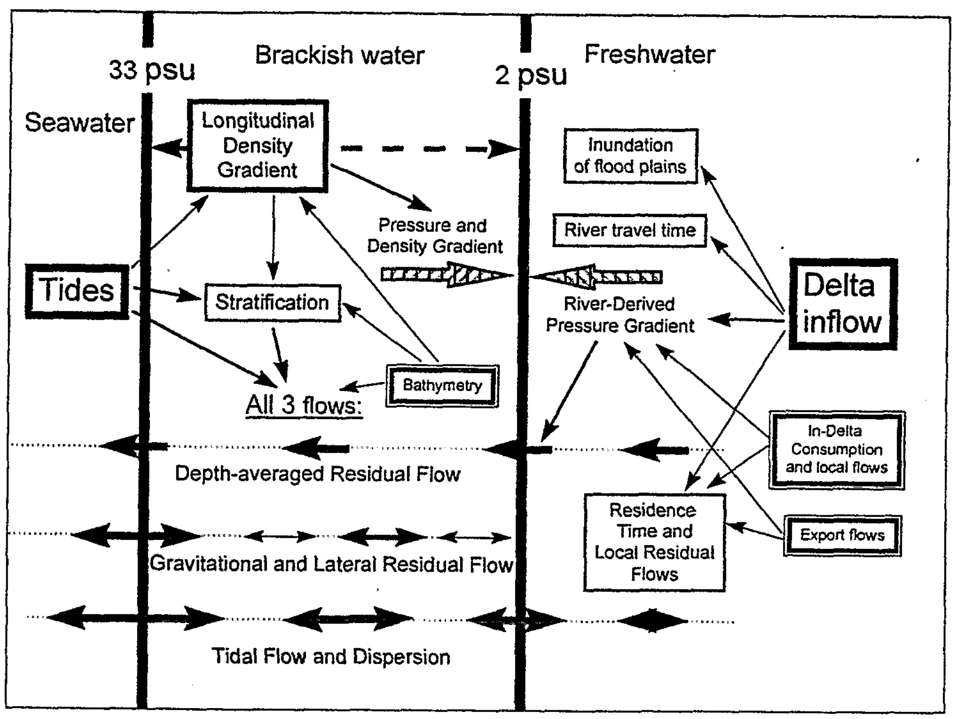

Figure 5-5. Conceptual model of the mechanism for the X2 effect based on gravitational circulation. Several species recruit from outside the estuary and must enter the bay to reach nursery areas; some other species reproduce within the bay but then move up the estuary for rearing. Tidal flows in the 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.

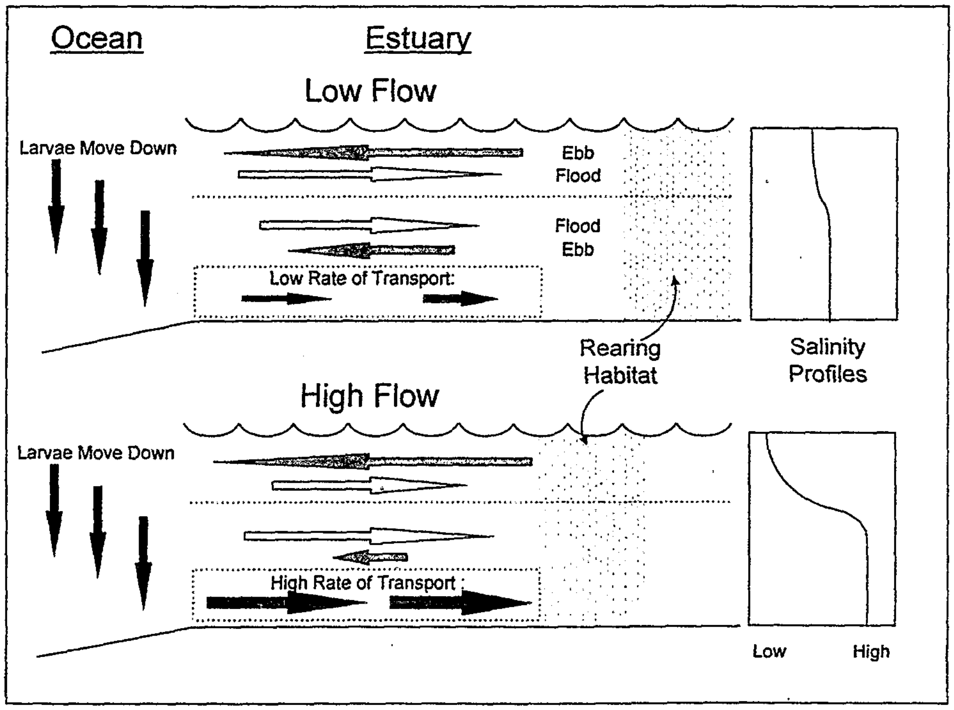

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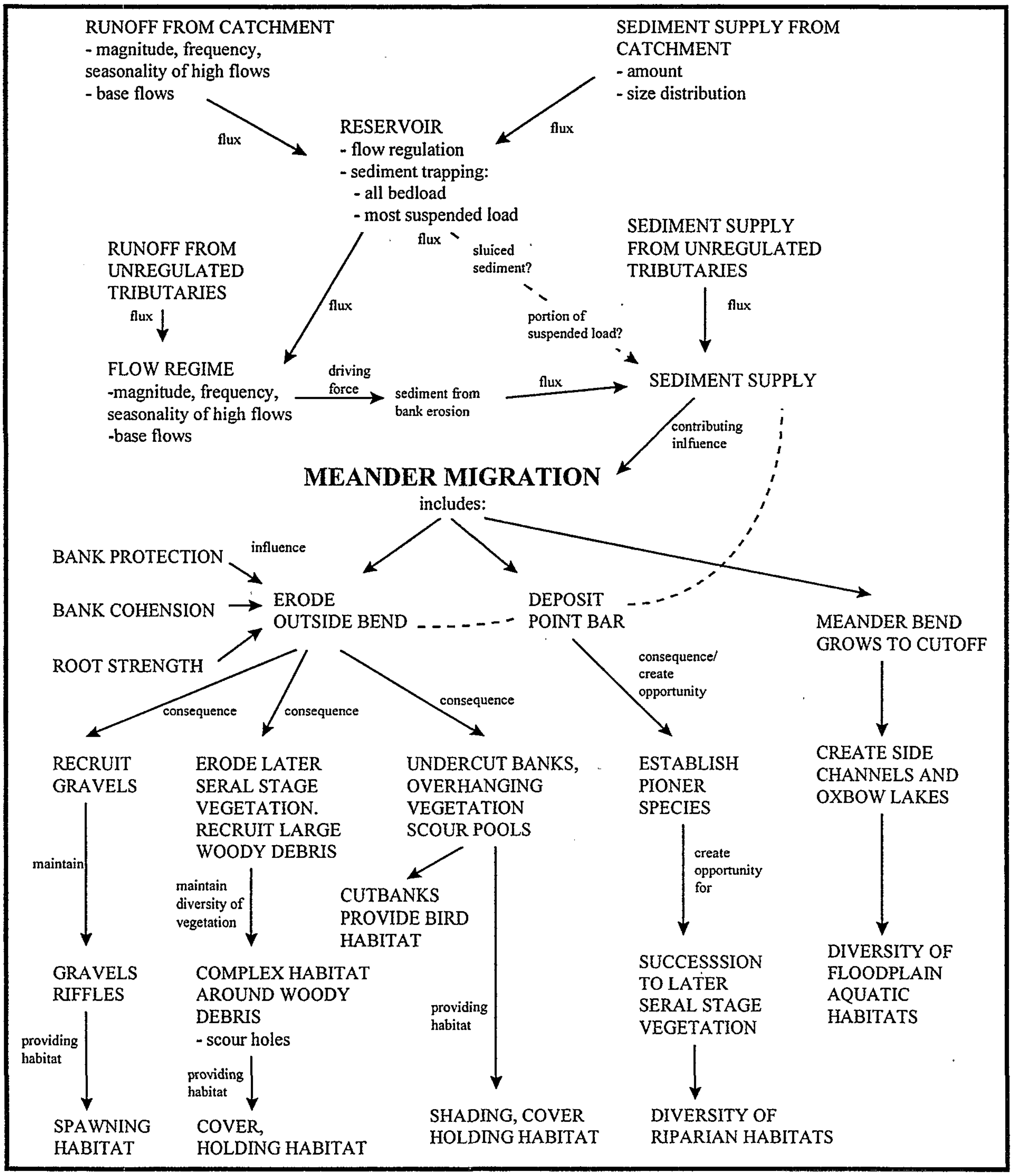
Figure 5-6. Meander migration model.



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Chapter 6. Adaptive Management

A. Ecosystem Management in an Experimental Mode

1) Building Adaptive Management Into the Program

The problem of restoring ecosystem quality in the Bay-Delta area is challenging to say the least. First, the problem is not that well defined. What does "restoring ecosystem quality" mean in the practical sense and how will we know if we have achieved it? Who decides what constitutes acceptable ecosystem quality? What kinds of intervention and how much intervention will restore ecosystem quality? We have attempted to address this uncertainty by specifying clear goals and objectives, but this is only one important step toward defining the problem.

Second, whatever the real problem is, it is manifest at various time and space scales. Human intervention at any "scale" will propagate inward and outward to have consequences at all scales. It is not at all clear at what scale it is most advantageous to intervene to achieve any particular objective. Nor are the most advantageous kinds of interventions well known and tested.

Third, any intervention will be costly in resources spent and/or opportunities foregone. Without some effective and objective means of prejudging interventions and evaluating the consequences of those that are implemented, scarce resources may be wasted in ineffectual management actions.

These characteristics, a diffuse problem that is manifest in various ways and for which remedial actions are highly uncertain, are typical of issues in natural resources management. 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 standardized 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. A suite of techniques, collectively termed Adaptive Environmental Assessment and Management or simply Adaptive Management (Holling 1978, Walters 1986) is gaining popularity as a practical approach to management under uncertainty. Although by no means universally accepted, adaptive management has been employed in the design of large scale environmental restoration projects (Lee 1993). Since the present depleted state of many valued species and habitats in the Bay-Delta region is largely a consequence of the application of the traditional form of analysis and remediation in resource management, it seems doubtful if more of the same will suffice to restore the ecosystem. Adaptive management is the most promising available alternative approach.

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 our existing understanding of the system(s) to be managed in terms of explicit models of dynamic behavior that spell out both assumptions and predictions clearly enough 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 account of 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.

The critical variable in adaptive management is uncertainty, uncertainty in the dynamics of complex systems and uncertainty in the consequences of various potential management interventions. In a program like CALFED, the uncertainty is compounded by the need to effect change at large time and space scales. The only way to learn about such systems and their dynamics is through large scale manipulations of the system. CALFED is such a large scale manipulation of the environment and it is impractical, indeed impossible, to gather the information necessary to predict the consequences of CALFED without undertaking CALFED. The program to solve the problem, therefore, becomes the means by which we can learn about the problem. The trick in adaptive management is to design the management program to ensure that beneficial actions are taken in a timely manner but also to structure projects so that alternative concepts are probed and learning is an active consequence of management. As Lee (1993) argued, information has value both as a stimulus for action and as a product of action. The information value of action is the component of value routinely ignored in traditional approaches to management (Healey and Hennessey 1994).

If we are to realize the full information value of management actions they should be designed as experiments and evaluated as experiments in the same way that new medical therapies are first implemented as clinical trials (experiments) to ensure their effectiveness. Unfortunately, strict adherence to experimental protocols is not possible in a restoration project like CALFED.

There is, after all, only one Sacramento/San Joaquin Delta and its various component parts are all strongly interconnected. Independent replication of control and treatment measures is not possible in either space or time. Nevertheless, designing management interventions as experiments still has 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, 1989, Walters and Holling 1990).

Walters (1986) recognized three approaches to management: 1) trial and error in which early management options are chosen at random whereas later choices are made from a subset of the early options that performed best; 2) 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 3) active adaptive in which two or more alternative hypotheses about system dynamics are explored through management actions. The first approach is illustrated by early approaches to stream habitat rehabilitation in which supposedly beneficial alterations were made to streams and those that proved successful (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 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. It fits well with the incremental remedial approach to policy evolution that is common to public agencies (Lindblom 1959). It is administratively simple since all "units" are treated alike and information needs and information management is relatively simple. In passive adaptive management, however, learning about the system is confined to a very narrow window and there is virtually no possibility of determining whether the underlying hypothesis about the system is right or wrong. Thus, although passive adaptive management takes account of uncertainty, it has only limited capacity to reduce uncertainty.

Passive adaptive management will be an important component of the CALFED adaptive management strategy. The notion of CALFED itself, complex as it is, can only be implemented in a passive adaptive way. There is no alternative "policy" to CALFED that can be implemented as a contrasting experiment. As well, many elements of CALFED 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.

Active adaptive management is the most powerful approach for learning about the system under management but also often the most contentious. Active adaptive management programs tend to create the 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 CALFED, notwithstanding the critical status of many of the species CALFED 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. 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 two kinds of adaptive manipulation. For many situations, it may be clear what kind of intervention is needed (increased spring and summer flows into the Delta for salmonid conservation for example) but there is uncertainty about how much intervention is needed. The concern is not with the form of the model relating flow to conservation but with the parameters of the model. An active adaptive experiment could be designed to improve the estimation of parameters by manipulating spring and summer flow in appropriate ways. For our purposes, let's call this kind of adaptive experiment "adaptive probing." In some instances, this kind of experiment can be designed around natural fluctuations in environmental variables. A good example of this kind of experiment was undertaken to improve estimates of optimal sockeye salmon escapement to the Fraser River. In the 1970's, historic data were consistent with the hypothesis that escapement over the past decade was near that for maximum sustained yield. However, an alternative hypothesis that two-tin... the present escapement would provide much greater sustained yields could not be ruled out. 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 1980's with very positive results in terms of yields in the late 1980's and early 1990's.

In other instances, the greatest uncertainty may be about the best kind of intervention (increased spawning escapement or reduced cross channel transport as conservation measures for spring-run chinook, for example). In this case, for illustration, the concern is with the form of the model (although obviously the size of the intervention is also important). Again, an active adaptive manipulation could be designed to determine which model (escapement or Delta transport) was the more important in chinook conservation. For our purposes, let us call experiments designed to distinguish among fundamentally different models (hypotheses) "adaptive exploration." The Bay-Delta ecosystem problem is replete with such unresolved alternatives. Where opportunities exist to distinguish among such alternatives through active adaptive experimentation, CALFED should seriously explore the possibility. Tools for assigning probabilities to models, updating probabilities in the light of new information and rules for efficient design of adaptive experiments are provided in Walters (1986) and Hilborn and Mangel (1996).

CALFED is not a single project but many projects that must be interlinked into a coherent whole. The size and complexity of CALFED introduces additional dimensions into the problem of adaptive design. Since it is quite possible that the success of some projects may depend on the outcomes of others and that some interventions may be synergistic whereas others are antagonistic, the sequencing of projects and their arrangement in space and time are all potentially important to the success of CALFED. A hierarchical set of rules for deciding among projects needs to be developed to guide decision making. These rules might be incorporated into formal models of decision making. As a preliminary list, the decision rules might look something like the following:

1. Emphasize projects that will have the greatest absolute benefits and the greatest benefit-cost ratio for native species.
2. Emphasize projects that will provide the most useful information about system dynamics.
3. Emphasize projects that will provide results in a short time frame.
4. Emphasize projects that will be the most self-sustaining in the long term.
5. Emphasize projects that are complementary in their effects unless the conflict provides important information about system dynamics.
6. Emphasize projects t' . have high public support and visibility.

Given the opportunities for ecosystem restoration under CALFED, it is likely that many individual projects will not have measurable consequences for the species of concern. It may be helpful, therefore, to classify projects into three types: 1) Small projects that individually will have small impacts on the system or species recovery but which, collectively may have important overall impacts or serve complementary functions (e.g. small scale riparian restoration, screening of irrigation intakes); 2) large scale projects that individually should have measurable impact on the system or target species and can be implemented as passive adaptive experiments; and 3) adaptive probing or adaptive exploration projects designed to distinguish among competing hypotheses.

For smaller projects the criteria of success may have to be more modest than species recovery. Suitable criteria for small projects might be that the desired habitat attributes (ecological structure and function) were created, the desired habitat attributes were maintained over time with limited human intervention and species of concern made use of the habitat in the ways hypothesized. At this level of evaluation it should be possible to build some important learning opportunities into management with little overall risk to any sensitive species. For example, experiments designed to test competing hypotheses about the most efficient and effective kinds of habitat design could be done at this scale with the proviso that there is an important limitation on interpretation; population level effects cannot be inferred from local responses (Riley and Fausch 1995).

Large projects provide the opportunity for evaluating overall population responses as well as creation and maintenance of structural and functional aspects of habitat. Because of the diversity of activities contemplated under CALFED and its relatively short time horizon, incorporating efficient experimental design of even large projects may be difficult as confounding among the effects of different projects is likely. Opening up of the floodplain, changing hydrographs, removing dams to provide access to significant amounts of habitat would all constitute large scale projects with potential dramatic effects. However, collections of smaller projects might constitute a significant intervention with measurable population level effects. Whether or not large scale projects should be staged to ensure that their independent effects can be distinguished is not obvious. Such decisions could be assisted by modeling outcomes based on expected value of perfect information (e.g. Walters 1986).

As noted earlier, adaptive probing or adaptive exploration experiments are likely to be contentious. In some instances, however, they may be the only way to determine the practical benefits of certain kinds of management interventions. For example, if it is hypothesized that increasing spring and summer flows through the delta will benefit anadromous salmon an adaptive probing experiment seems to be the only feasible way to determine how large a flow will be required to achieve a particular benefit. Since any manipulation or reallocation of water is likely to be costly, experiments with flow may have a very high information value. As noted earlier, smaller scale experiments may be relatively easy to implement and can provide significant learning opportunities.

A) Experimental opportunities at the landscape level

The Scientific Review Panel (October 1997) recommended that every opportunity be taken to experiment at the landscape scale. If we define the landscape as the CALFED solution area, then CALFED is a landscape scale experiment. However, it can only be pursued as a passive adaptive experiment. Within the CALFED design there will be many levels of manipulation so that defining expected outcomes at each stage will be an important part of the passive adaptive experiment.

B) Experimental opportunities at the ecosystem level

The collection of ecosystems within the Bay-Delta and the solution area that will be subject to manipulation as part of CALFED is reasonably large. Most of the large scale ecosystem restoration interventions anticipated under CALFED are manipulations at the ecosystem level (e.g. removal or set back of levees, changes in hydrology, reduction in toxic or nutrient inputs, etc.). There will be opportunities for both passive and active adaptive experimentation at the ecosystem level. The problem will be to ensure experimental designs that are not so confounded as to be uninterpretable. Once again, this demands careful definition of the problem boundaries and modeling to explore alternative designs prior to implementation.

C) Experimental opportunities at the habitat level

Habitat manipulations are likely to be among the most numerous activities under CALFED. Individually they may not have large impacts on critical aquatic species but may be significant for less wide ranging species (amphibians, reptiles, insects, plants, etc.). These kinds of small scale manipulations provide many obvious opportunities for experimentation and active learning. They may also provide the easiest ways to get communities and interest groups directly involved with CALFED activities.

D) Experimental opportunities at the species level

Species level projects might include both attempts to reduce adverse impacts of certain introduced species (harvesting of *Potamocorbula*, for example) and attempts to increase abundance and/or distribution of desirable native species (through introductions or short term culture to get local populations above critical levels, for example). The information value of such management actions can also be considerable if they are designed as proper experiments.

E) Experimental Protocols

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 effects outcomes, efficiency of various experimental designs, the value of information about alternative dynamics, etc. As we noted in the introduction (Chapter 2), models of the system may suggest that more research prior to pilot testing or large scale intervention is the most efficient approach, or that pilot testing or large scale intervention can be implemented at the outset.

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 key variables.**

4. **Update probabilities of alternative hypotheses** based on monitoring results and, if necessary, adjust management policy.

5. **Design new interventions based on improved understanding.**

At the heart of adaptive management is the intimate and hierarchical connection between hypotheses about system dynamics, critical variables that will permit evaluation of hypotheses, and monitoring. Although certain kinds of information will be generally useful and will form a part of monitoring and evaluation regardless of the management program, many kinds of information will be specific to particular hypotheses and experiments. As a consequence, there will be no universally applicable set of indicators or monitoring program. Both will be specific to the particular models and management interventions that come to form CALFED. Any monitoring and evaluation program, therefore, needs to be an integral and flexible component of the management program.

B. Monitoring, Research, and Scientific Oversight

1) Monitoring and Research Program

Monitoring and research are essential components of the Strategic Plan and of CALFED's operational philosophy of adaptive management. Monitoring is essential for evaluating progress toward CALFED objectives, and provides the empirical basis for learning under adaptive management. However, monitoring alone is insufficient. Adaptive management includes targeted research to address fundamental questions relevant to CALFED programs and adaptive probing to distinguish among alternative hypotheses about the best management solutions. Furthermore, even routine restoration actions where there is broad agreement about their projected benefits need to be carefully designed if they are to provide a good opportunity for learning. Such actions need to incorporate careful experimental design with monitoring as an integral component of the design to ensure that changes are detectable and attributable to the action.

A) Ecological Indicators.

Ecological indicators are measures of ecological attributes, populations, or processes, which can be used to measure aspects of ecosystem health and the success of restoration efforts. The choice of ecosystem indicators will be based on (and tied to) the goals and objectives. Ecological indicators can play a very useful role in adaptive management, to track conceptual models and effects of adaptive probing. The CALFED Indicators Group has put a substantial effort into developing ecological indicators for the Bay-Delta system, which has helped to focus attention on ecosystem-scale processes and problems. Indicators developed by the group will be among the most useful measures of ecosystem function, and provide important information for decision making.

B) Comprehensive Monitoring, Research and Assessment Program

The United States Geological Survey (USGS), San Francisco Estuary Institute (SFEI), and Interagency Ecological Program (IEP) are developing a Comprehensive Monitoring, Assessment and Research Program (CMARP). This program is described in the Stage I report and proposal for Stage II, developed by the CMARP steering committee (April 24, 1998). CMARP is intended to address needs for monitoring and research of the CALFED Program and CALFED agencies. In addition, it will incorporate elements of existing monitoring and special studies programs such as the SFEI Regional Monitoring Program, the Department of Interior Comprehensive Assessment and Monitoring Program, the CALFED Operations Group Real-time Monitoring, the Vernalis Adaptive Management Program, and the IEP environmental monitoring activities. Thus, CMARP is intended to meet many of the monitoring needs in the estuary.

Below are several additional aspects of a successful program that we suggest should be integrated with CMARP.

Science oversight committee. Our main concern is to ensure that the principles and practices of adaptive management be incorporated in CMARP administration, since CMARP itself has no control over system design or operations. The adaptive management program will require an organizational framework that has sufficient scope, depth and breadth of understanding, and authority to recommend changes in CALFED operations as well as in the CMARP program itself. This implies a standing oversight committee that is independent but sufficiently familiar with CALFED operations to offer insightful review. This committee is described further below under 'Institutional Framework'.

Peer review This is always an issue in using science to guide management. The Bay-Delta-River arena has seen decades of management based on studies that have not passed peer review. Although these studies may have considerable scientific merit, they have not been subject to the process of quality control concerning the relevance of the findings and the accuracy of the interpretation that characterize main-stream science. This kind of legitimacy is provided in science through peer review.

Science used to justify CALFED management decisions should 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 (Because it often takes more than 1 year from date of submission to final acceptance in peer reviewed journals, and another year or longer for the article to appear, "timely" review of management decisions or rationale may require parallel time frames). It also provides important contact with the broader scientific community that will be very useful in establishing review teams (see 'Institutional Framework' below).

This approach has been suggested at several annual meetings of the Interagency Ecological Program with only spotty success. Staff scientists need the time to write and publish their findings in more than just internal technical reports and their career progress should be judged, in part, on such publication. They also need more opportunities for collaboration with university and other scientists to help them get their findings out into the broader arena. Both of these requirements demand commitment by the overseeing institution to provide the necessary time and opportunities.

2) Scientific Review of the Adaptive Management Process

There will be three levels of review in the adaptive management process: review of progress toward the goals of the ERP, review of proposed and ongoing adaptive management actions, and review of individual research and monitoring projects within CMARP.

Review of the entire program to ensure that it is making progress toward goals of the ERP should happen on an annual basis, possibly in conjunction with an annual meeting of the science oversight group. The reviewers would comprise a body of scientists similar in makeup (and perhaps identical) to the CALFED Scientific Review Panel convened in October 1997. This review should produce a report summarizing the "State of the CALFED region," or "Status of the Scientific Basis for CALFED actions."

The review of individual actions will occur annually as well, but with a rotation schedule so that not all actions are thoroughly reviewed every year; but each action would be reviewed periodically. The interval between reviews will depend on the nature of the action, but should be based on the time scale of expected system response determined through preliminary modeling. In addition, actions would be reviewed in the event that new information became available that impinges on their outcome.

Review of individual research and monitoring programs under CMARP should occur on a rotating basis as for the CALFED actions. In addition, these programs should be peer-reviewed at the proposal stage. CMARP targeted research projects should additionally be held to some minimum standard of publication of findings; for example, specific questions should be answered in the scientific literature within two years of completion of the project, or two years of completion of the stage of the project investigating the questions. These reviews should be separate, and performed by different people, from the reviews of ERP actions.

Many pilot projects and large scale interventions may be difficult to approach as subjects of independent scientific peer review. The projects should be reviewed at the proposal stage, but it may be unrealistic for a "peer scientist" in Michigan, for example, to comment on a proposal to flood Delta islands or set back levees on the San Joaquin River? To judge these projects (except for certain design aspects) requires considerable local knowledge. For many projects, the ERP will have to depend on internal review with oversight by the scientific oversight committee or locally constituted committees comprised of individuals with both technical background and local experience or familiarity with the affected resources and the geographic context.

Reviews of actions and CMARP programs should address several key questions about the progress and direction of the program, and the need to occasionally correct course:

1. Is this program doing what it was intended to do (i.e., was the action taken, was the monitoring or research conducted more or less as proposed)?

2. Is the program accomplishing its objectives (i.e., is the action having the desired effect,

are the questions being answered, are the results being published)?

3. Does this continue to have the priority it had when first proposed and authorized (i.e., if CALFED priorities change should resources continue to flow to this program)?

4. Should the action or program be expanded to encompass larger scale projects, or designed to affect a larger geographic area, or be implemented on more tributaries?

5. Should the action or program be continued, but modified and refined in particular ways, based on lessons from the initial implementation results and on evaluation by the oversight group and others?

B. Institutional Considerations

Below are some of the considerations for the institutional framework for the ERP. For two reasons we defer further development of these ideas: 1) CALFED must develop an institutional structure for implementing all of its programs, into which the ERP implementation must fit; and 2) CMARP is developing institutional structures for monitoring and research, which must fit with the ERP framework. This document will provide both with suggestions for developing their programs.

1) Ensuring Learning and Adaptive Flexibility

Adaptive management imposes some requirements on the ERP governing body that differ substantially from the needs of most resource agencies. It must be able to learn and adapt based on the new information and understanding obtained. Limitations to active adaptive management will include institutional culture and inertia, availability of resources (water, money, people) to carry out the experiments, and restrictions based on endangered species and other regulations. Inertia can be overcome only with a sincere commitment on the part of the ERP governing body to take active steps to improve knowledge about the system, and close contact between scientists responsible for understanding and overseeing the scientific activities and managers responsible for integration with other CALFED programs and with overseeing system operations.

A good model for the conduct of an adaptive management program is the clinical trial in medicine. A committee oversees these large experiments with new treatments and decides whether to terminate early when the evidence shows that the new treatments are better or worse than the existing methods or to justify further testing on the basis of results to date. Furthermore, Bayesian statistical techniques can be used to judge progress and update probabilities among competing hypotheses. These techniques can be built into the program along with decision rules that may be more socially and ecologically relevant than the 0.05 criterion commonly used in natural science. The clinical trial procedures may help with developing such decision rules.

Since we are far from certain about the outcomes of various interventions (because of uncertainty in the science but also inherent unpredictability of an ecological system), we cannot avoid actions that have either no effect or are actually harmful. adaptive management requires that the ERP governing body learn from what could be seen in hindsight as mistakes, and that it be prepared to alter course once the evidence suggests it. This will require an almost heroic insistence on flexibility and an ability to defend individual actions as part of the overall program even when they turn out badly.

Endangered-species regulations limit or prohibit actions believed to reduce protection of listed species, regardless of the value of these actions for increasing knowledge or the certainty that protection will actually be reduced. These limitations can be replaced by substantial ecosystem-based programs that can demonstrate a strong likelihood of maintaining or increasing protection over the long term. The analogy with clinical trials is useful here too: if standard treatments are ineffective, a trial of new treatments can be justified but must be closely monitored and either abandoned if it is harmful, or used in place of the standard treatment if it improves protection.

A) Duties of the ERP Governing Body

The ERP governing body will need to fit into the entity designed to manage all CALFED programs. Its principal duty will be to ensure that the principles and practices of adaptive management are followed in taking actions, evaluating their effects, conducting research on key issues, and revising actions to respond to changing conceptual models or system responses.

Specific duties may include:

1. Oversee the adaptive management design of the ERP and CALFED as a whole and the essential contribution of CMARP to this design. This is envisaged as an active, ongoing activity requiring familiarity with all of the major CMARP and CALFED activities.

2. Conduct workshops annually, or more frequently if necessary, with CMARP scientists and CALFED staff to disseminate findings, assimilate new understanding, and discuss changes to the program. In addition, conceptual models will be revised or updated during or after these workshops on topics for which new information becomes available.

3. Conduct or direct analyses to evaluate effectiveness of CALFED actions.

4. Based on the above, develop proposals for active adaptive management manipulations, and submit them to the CALFED management entity for approval and implementation.

5. Make key decisions depicted in Figure 2-3 regarding the kinds of actions to be initiated and how those actions evolve over time; when to start new projects and abandon old ones. It must also oversee CMARP, working with its top scientists to

review programs, evaluate the development of knowledge, and ensure adequate peer review.

6. Coordinate with other CALFED programs. Since it is not clear whether the other programs will incorporate adaptive management, there may be friction between the ERP and the other programs over the need for flexibility and changing practices based on new knowledge. In addition, the ERP must be consulted by other programs proposing actions that may affect the ecosystem, and must be allowed to develop an adaptive management alternative to an action proposed by another program.

7. Ensure scientific quality in the ERP; this will include (at a minimum) setting up a process whereby all scientific personnel are expected to publish scientific findings in peer-reviewed journals, and holding periodic outside reviews of the adaptive management program (see below).

8. Ensure accessibility of results of adaptive management actions, and of CMARP data and findings to all interested individuals and institutions both inside and outside CALFED.

9. Provide public outreach about ERP activities including workshops, an up-to-date web page, and newsletters.

10. Determine permitting requirements for anticipated future activities including CMARP sampling, and establishes schedules for early application to prevent delays of actions.

11. Have resource and budgetary control. The ERP governing body must have the capability to establish contracts, set up and administer budgets for projects, receive funds, acquire or purchase property, acquire permits, issue grants, and all of the other administrative activities associated with managing a diverse suite of projects.

12. Establishment and management of the information database needed system to support implementation of the adaptive management framework and overall ERP operations

13. Authority to apply for, process applications and serve as the "permittee" for necessary regulatory permits/approvals, including the ability to prepare or supervise preparation of the environmental documentation (CEQA/NEPA documents) necessary to obtain such permits/approvals

14. Budget authority, including control of operating funds and investment control over any endowment Funds

15. Authority to receive lands, easements, funding in support of ERP implementation

16. Authority to initiate purchase of lands and easements recommended under the adaptive management approach.

17. Authority to convene and conduct public hearings as appropriate to support implementation of ERP activities.

18. Authority to employ personnel, both professional and administrative, that it determines to be necessary to conduct restoration, research, monitoring and other adaptive management activities.

B) Attributes of the ERP Governing Body

There is an inherent tension between several pairs of attributes that the body must have:

Assurances vs. adaptive management: The body must be structured to provide assurances about actions it will take and demands it will make for resources. This is in fundamental conflict with the need for flexibility that is an essential attribute of an adaptive management program.

Independence vs. connection: The body must be independent to prevent political and other concerns from interfering with the scientific aspects of the program. Yet, it must retain connections with stakeholders, agencies, and the other CALFED programs to ensure coordination.

Science vs. other activities: The practice of adaptive management requires scientific expertise in a number of fields. Many of the other activities (e.g., public outreach, project management, coordination) will have little if any scientific content. Although these disparate needs can be accommodated in a standard organizational structure (e.g. any of the resource agencies), this structure may fail to elevate scientific decision-making to the level required by the ERP.

Based on the duties and the tensions described above, we believe the ERP governing body should have the following attributes:

1. It should be non-regulatory. This will eliminate the inherent conflict of interest that occurs when regulatory organizations also incorporate scientific investigations of the subjects of their regulation.

2. The structure should provide for an independent scientific oversight group responsible for reviewing and advising on the scientific duties above. The purpose of the scientific oversight group is to help ensure ERP actions are not taken if they do not have suitable scientific backing. This can occur through a

process of both informal advice and formal recommendations from the group to ERP management staff and other CALFED program managers.

3. The ERP governing body, on advice from the scientific oversight group would be empowered to establish, on short notice, one or more teams whose purpose would be to respond rapidly to new findings or new developments (e.g., levee failures) that may affect the success of ERP actions, or to take advantage of opportunities for improving management of increasing knowledge (e.g., through unusual flow events).

4. The scientific oversight committee should comprise about 8-12 accomplished individuals not directly connected with CALFED activities (at least 2 should be from outside California) capable of understanding, analyzing, and deciding on key technical issues. These individuals should serve on this committee for periods of 2 years or more to allow for an adequate level of commitment and familiarity with the program.

2) Information Storage, Collation, and Dissemination in a Timely Manner

A) Information system requirements.

CALFED is committed to a decision process and to outcomes that are placing extraordinary demands upon its information system.

Under phased decision making, important actions (including conveyance and storage) are being predicated upon certain pre-set conditions being met. In some cases the degree of compliance will be obvious, but more commonly the decision to proceed will be in large part a matter of judgement on the part of stakeholders and their technical, scientific, and legal advisors. Judgements will commonly have to be made using information that is incomplete and imperfect. Deficiencies at key turning points can lead to conflict and delay. To the extent that new information may be needed to refute a pre-stated conclusion, deficiencies will lead to acquiescence.

Stakeholder involvement places special demands upon the system. A large number of organizations and individuals must review important CALFED actions, and these participants expect full, quick access to all of the information being used to evaluate or justify a proposed action. This means ready access to not only results and conclusions, but to baseline information, monitoring data, modeling parameters, and assumptions.

CALFED's administrative environment is an issue in itself. Not only does the organization span a number of State and federal agencies (which need constant day-to-day participation), but experts from disparate disciplines must review and comment across geographic and institutional barriers.

Adaptive management, by its very nature, requires information. Virtually every environmental intervention offers an opportunity (and obligation) to document the ecosystem's prior condition and response to impact, and offers an opportunity to validate or revise hypotheses. Adaptive management involves continuing inventory, analysis, and interpretation. Such rational, comprehensive, science-based decision making requires an extremely robust information system, especially in comparison to the more traditional form of incremental decision making.

B) System parameters

To meet the needs itemized above, CALFED's information system capabilities should be enhanced along the following lines.

Continued use of traditional means of communication (paper documents and graphics, land mail, fax, telephone) will be needed, of course for communication with the public, for technical use during a transition to more widespread use of advanced technology. There should be more aggressive deployment of advanced technologies (such as: email, digital document management and library services, web-based publishing, relational databases and geographic information systems), to overcome current obstacles to more rapid and efficient communication. The task is mainly one of taking existing, off-the-shelf technologies and injecting them into day-to-day use. CALFED itself can take leadership in this, but the system needs to permeate the workspace of the constituent agencies and stakeholders.

The information system should provide for rapid production, dissemination, review of, and comment on reports and publications. The Web can be used more fully. Large or complex materials could be published on CD as well as on the web and on paper. The inevitable mountain of paperwork, needs to be available in digital form so that it can be subject to information management, indexing, copying, and telecommunication. Publication in any one of several standard digital formats would greatly facilitate the use of CALFED documents. Several companies offer free "helper applications" (downloadable over the web at no cost) that would be of great value if only CALFED materials were presented in an appropriate format.

Except in unusual circumstances, information should be considered as open to public scrutiny. Any information used to support or challenge a CALFED action must be freely available to all. Information should be free of charge (or at the minimal cost of preparation). Proprietary information purchased by CALFED or cooperating agencies (e.g. satellite imagery) should be paid for once, with the provision that subsequent distribution should be free over the web.

A digital library should be developed, not only to help manage day-to-day information, but to build the archive to support Records of Decision. This library should be based upon a multi-organization, distributed, information network, as opposed to attempting to build a centralized information facility.

C) System Components

To meet the needs and objectives above, the CALFED information system should have the following, interrelated components: Email services, which would include address lists, and email reflectors for work groups and stakeholders.

Internet services need to include a web page much like the present one (at http://calfed.ca.gov) with notices of meetings, hearings, and technical workshops. Reports could be put on line with text, graphics and maps, with links to data, tables, models, and GIS layers. The web server could also provide protected virtual work space for teams and advisory panels, in which a number of participants might engage in simultaneous, remote authoring and review. The web page could provide links to sources of information on CALFED activities and on the regional environment. This aspect could be as simple as a link to the California Resources Agency's CERES Information Catalogue (http://ceres.ca.gov/catalog/), or preferably would offer strengthened coverage of CALFED issues and sources of scientific and planning information. Digital Library services should provide web-based access to reports in common use within the CALFED community. These could include digital copies of traditional reports.

In the future, CALFED documents should be prepared in both standard and HTML format so as to exploit web capabilities for presentation of complex material (color tables and maps) over low-band-width web connections to the general public. The Bureau of Land Management has developed an on-line EIR/EIS that serves as a good example (The Golden Queen/Soledad Mountain Mine: http://www.ca.blm.gov/GoldenQueen/).

D) Geographic Information Systems

Given the breadth and depth of CALFED issues, GIS is an absolute essential for a number of critical functions, including simple project tracking, database management, monitoring, analysis of the interconnectedness of actions, and visualization of complex scientific and planning information. The system should link and integrate the map libraries of all CALFED agencies and collaborators, rather than create a new central repository. Traditional stand-alone GIS operations should be linked via Web-based GIS capabilities, as described at: (http://www.regis.berkeley.edu/deltapub/GIScore5.html), GIS data layers should not be thought of as separate maps in an atlas, but as graphic objects that can be integrated with text and databases (e.g. monitoring locations, or restoration site lists).

C. Dispute Resolution

1) Dispute Management

This Strategic Plan recommends that certain amplified procedures be adopted for dispute management and resolution. This is necessary for a number of reasons:

- There will be substantial, continuing, uncertainty in managing dynamic ecosystems;

- The breadth of the CALFED mission is such that widely disparate values are at stake, and there is a long history of conflict which no amount of planning and coordination can completely overcome.

2) Dispute Management as part of the internal CALFED structure.

The CALFED administrative structure in itself is designed for conflict resolution. Policy makers and stakeholders representing disparate interests are given early identification of problems before they become fully developed and difficult to modify. Many aspects of current and planned CALFED operations also help to diffuse conflicts:

- A robust information system (which helps level the playing field for participating agencies and interest groups)

- Stakeholder involvement at the earliest stages of planning.

- Participatory design (as in Category III projects), can help make projects non-controversial. [Projects that are designed deep in-house and then "sold", can be expected to generate more controversy].

- Care in preparation of Records of Decision, coupled with sunshine information policies.

- Third-party evaluation of information (e.g. Independent Scientific Review, peer review of publications, ...)

- The need for extraordinary dispute resolution measures may still arise due to:

  - A logjam in the decision process, coupled with the need for prompt action (natural disaster, or impending actions which are outside the CALFED purview)

  - external impacts requiring that new stakeholders be involved

3) Additional measures.

A special structure for dispute resolution may be needed to provide for a level of review that is somewhere in-between normal procedures on the one hand, and having the dispute taken outside of CALFED to the courts or legislative bodies, on the other.

It is recommended that CALFED create a formal process for dispute resolution; and that this framework should be established prior to its need. While the specific approaches to dispute resolution will be dictated by the dispute at hand, the process would in each case likely include the following:

- Formal announcement that an issue is being subjected to an extraordinary dispute resolution process.

- Each dispute resolution process is to be run by neutral facilitator.

- The scope of the issue would be made clear, with specification of the "decision space" consistent with legislative mandates and limits on delegation of authority.

- There would be a clear pre-statement of the means by which the final recommendation or decision is to be rendered (administrative decision, arbitration, consensus, majority vote).
- Stakeholder denomination and analysis.

  - Parties to be "at the table" would be named, and procedures set up for involving those on the perimeter (for example, the opportunity to observe or to make comments at specified intervals, or not, as the case may be).

  - Each stakeholder's position would undergo formal description and analysis, to ensure that concerns and priorities are clear to all parties.

- Intensive decision support. Litigation commonly forces each side in the dispute to take an extreme position. DR is expressly designed to provide all parties with lower-risk ways of exploring more central positions. The process should thus be less that of a formal hearing, and more that of an informal but professional workshop, with briefings, discussion, and interpretation of the "facts" at issue. Special attention should be give to data visualization, as it is the varying interpretations of the significance of information that may be important. CALFED could consider the development of a "Situation room" for interactive visualization, using GIS, high-resolution graphic displays, photography, and video. Digital library services should be employed to speed document provision and management.

- Resolution Processes. There are at least two alternative approaches:

  - Expert, Blue Ribbon Panel. In this approach, CALFED's Scientific Review Panel could be buttressed by further expert opinion, for example, a panel formed by the National Academy of Sciences. This has the advantage of added credibility, but may not move the process very far ahead of what the CALFED panel would have already accomplished.

  - Joint Fact Finding. The so-called "Advocacy Science" used in litigation is also found in the administrative and political realms. Knowledgeable stakeholders know (or at least believe) that the adoption of a particular index, or the use of a particular model may harm their interests. Differing viewpoints in science are inevitable, but a structure can be provided to try to move beyond a battle of experts, and to define common ground and points on which progress can be built. The key to this process is to bring experts into face-to-face communication (that is, without intervening translation of their methods and findings by lawyers and administrators). This helps the experts to explore disputed scientific questions, and to recommend means for clarification and resolution. Any one of a number of techniques can be used to help overcome barriers to neutral scientific dialog (e.g. Delphi to deal with power and personality factors).

- Dispute resolution conclusion and dissemination of results. The dispute resolution process normally would conclude with a report covering points of agreement, and an agenda for resolution of remaining issues. Conclusions might be in the form of a written agreement, with a White Paper giving the details. It is also common to hold a public forum.

Chapter 7. An Example of Adaptive Management Using Conceptual Models: Chinook Salmon and Deer Creek

A. Overview

This chapter provides an example of how ERP actions should be formulated and selected. The example we give is for spring and fall-run chinook salmon in the Deer Creek ecosystem. 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 they integrate across the entire landscape of the CALFED solution area. 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 have also been proposed for listing but their overall abundance is much higher than that of spring-run chinook. 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 a number of specific restoration measures have been proposed for Deer Creek in recent years. In this chapter, we show how simple conceptual models can be used to evaluate various possibilities for rehabilitation of salmon populations and habitat and how these might fit within the larger context of spring-run life history and factors limiting its population.

B. Background

1) Species vs Ecosystem-Based Restoration

This example also illustrates the different assumptions underlying species-based vs. 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 which move between major ecosystems like chinook salmon because removal of 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 within which individual species thrive and attempts to restore that ecological context (structure and function) under the assumption that 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 can also be difficult to justify as a method for restoring individual species. As illustrated in this chapter, 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.

2) Deer Creek Chinook Salmon Life Histories

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

Spring-run salmon enter the rivers from the ocean from March through May. While migrating and holding in the river, spring 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 visual and 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 chinook migrate up Deer Creek from April through June (Vogel 1987a,b), 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 chinook are immature; their gonads mature during summer holding period (Marcotte 1984). Eggs are laid in large depressions (redds) hollowed out in gravel beds. The embryos hatch following a 5-6 month incubation period and the alevins (sac-fry) remain in the gravel for another 2-3 weeks. Once their yolk sac is absorbed, the juveniles emerge and begin feeding.

Historically, spring-run adults were a mixture of age classes ranging from two to five years old. Possibly because of fishing in the ocean, the majority of the fish now are probably three-year olds. During the summer holding period in freshwater pools many large adult salmon may be caught by anglers (who snag them accidentally with spinning lures), 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, but scarce in pools close to roads.

Fall-run chinook salmon ascend Deer Creek in October-November (sexually mature), spawn immediately (October - early December), utilizing gravels in lower elevation reaches, mostly in Lower Deer Creek. Fall run spend less time in freshwater 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-April, others may hold in the streams until fall, and still others may wait for over a year and move downstream the following fall as yearlings (C. Harvey, CDFG, pers. comm.). The outmigrants may spend some 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.

3) Status of Chinook Salmon Populations

Spring-run chinook salmon are in a state of decline and will probably soon be listed as a threatened species (see Objective 3 under Goal 1, Priority I). Thus, actions likely to protect and enhance this stock should receive high priority. At the same time, actions to protect and improve habitat should not only help spring run salmon, but other fish such as fall-run chinook, steelhead, Pacific lamprey eel, and a complete assemblage of native foothills fishes and native amphibians. Similarly, actions to benefit spring-run habitat would probably achieve other objectives at the ecosystem level. The principal assumption from the perspective of this important stock 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 drainage and in the Salmon River in the Klamath-Trinity drainage (Campbell and Moyle 1991).

Within Deer Creek, spring-run abundance has been low since the early 1980's (Figure 7-1). The Mill and Big Chico Creek populations have suffered similar declines, but the Butte Creek population has not, for reasons which are uncertain. These declines are the reason for concern over the status of spring run and the proposed listing.

Fall-run populations have also declined, but not nearly so precipitously. In large part, this is because access to their (lower elevation) spawning grounds has not been cut off as has the spring-run habitat.

4) Habitat Restoration Proposed for Deer Creek

With declining salmon returns throughout the Bay-Delta system and the extinction of spring-run salmon in most of the rivers they formerly inhabited, Deer Creek and the other remaining spring-run 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 dewatered below irrigation diversions. While there may be argument about the amounts of water needed, minimum flows in the reach are clearly needed.

Other proposed measures have addressed the apparent armoring of the bed of Deer Creek, through mechanical ripping of the gravel bed, artificial addition of smaller gravel, and installation of log structures to hold the imported gravel in place (CDFG 1993, USFWS 1995, CALFED 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. While measures such as adding smaller gravel to the channel may provide some short-term benefit, the shear stresses in the channel are so high that the gravels will be likely to wash downstream during the next flood. Similarly, in-channel structures and even riparian bank plantings may be washed out in high flows under present channel conditions. Thus, many of the measures proposed may not be sustainable, but, under present channel conditions, would likely require maintenance after high flows.

C. Overall Conceptual Model for Spring-Run Chinook Salmon

Figure 7-2 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 Deer Creek must be placed in the context of the 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 7-2 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.

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, then density-independent factors, mainly downstream, will predominate. In that case habitat restoration upstream will have little if any effect on population size.

The currently 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 Objectives 5 and 6; Goal 4 Objective 3).

A conceptual model of fall-run chinook salmon would be similar to that for 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.

1) 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 7-1). For its first two miles, Lower Deer Creek (the alluvial reach on the Sacramento valley floor) migrates across an active channel 1,000 - 2,000 ft wide, bounded by bluffs (typically 5 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 7-2). 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 baseflows are maintained in Deer Creek by springs in the volcanic rocks. The average flow at the US Geological Survey gauge (located at the transition from the bedrock canyon to the valley floor) is 317 cfs (Mullen et al. 1991). Despite the baseflows 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 4000 ft), 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 US Geological Survey). It is during such large floods that Deer Creek would historically shift channels. About ten miles of levees were built by the US 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 two miles down to Hwy 99, following another of the many distributary channels of the alluvial fan.

2) 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 cutbanks 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 US Army Corps of Engineers flood control project, which built over ten 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 US 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 1980's cost about $1 million dollars, 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' (CDFG 1993, USFWS 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 (point bars, riffles, etc) 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.

D) 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 devegetated 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.

1) 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 7-3). 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 7-4.

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%/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.

3) 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.

A) 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 7-5). These models are briefly summarized in Table 7-1. 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.

Table 7-1. Summary of differences between alternative conceptual models A and B in Figure 7-5 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 Delta	No	Moderate	Moderate
Ocean Harvest	No?	Low	High

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 the CALFED program, 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 7-6). 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.

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 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.

C) 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 7-7 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, 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 undulation in the streambed are important 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 re-established.

E. 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, gravel adding gravel to the specific sites in the channel may provide localized, short-term benefits to spawning habitat, but a more sustainable approach to increasing 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. Moreover, a successful restoration approach must look beyond the site to account of watershed-level influences. if high suspended sediment concentrations occur while eggs are incubating, incubation success may be reduced. While such problems have not been documented on Deer Creek to date, the interaction suggested by the model implies that attention be paid to potential sources of suspended sediment from upstream, particularly during incubation periods.

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.

F. 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. Meantime, 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 (if it ain't broke, don't fix it), 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.

Figure 7-1. Location map, Deer Creek.

Figure 7-2. **Distributary channels of the Deer Creek alluvial fan**, as shown by contour lines on the US Geological Survey 1:12,000-scale topographic maps.

Figure 7-3. Time course of spring run chinook salmon escapement. Data from Candidate Species Status Report 98-01 to the Fish and Game Commission.

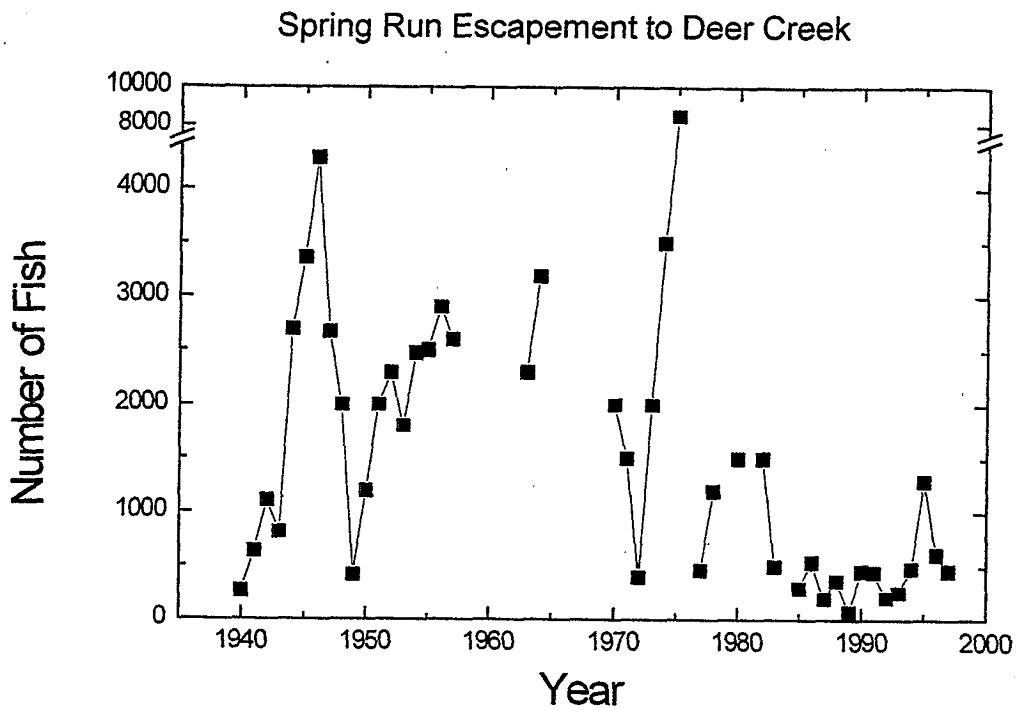

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Figure 7-4. Summary of the life cycle of Deer Creek chinook salmon. The four oval areas represent the four major geographic regions. Arrows indicate a change of state of surviving salmon, with only ocean harvest mortality displayed explicitly. Terms in italics indicate the major transformations occurring in each phase.

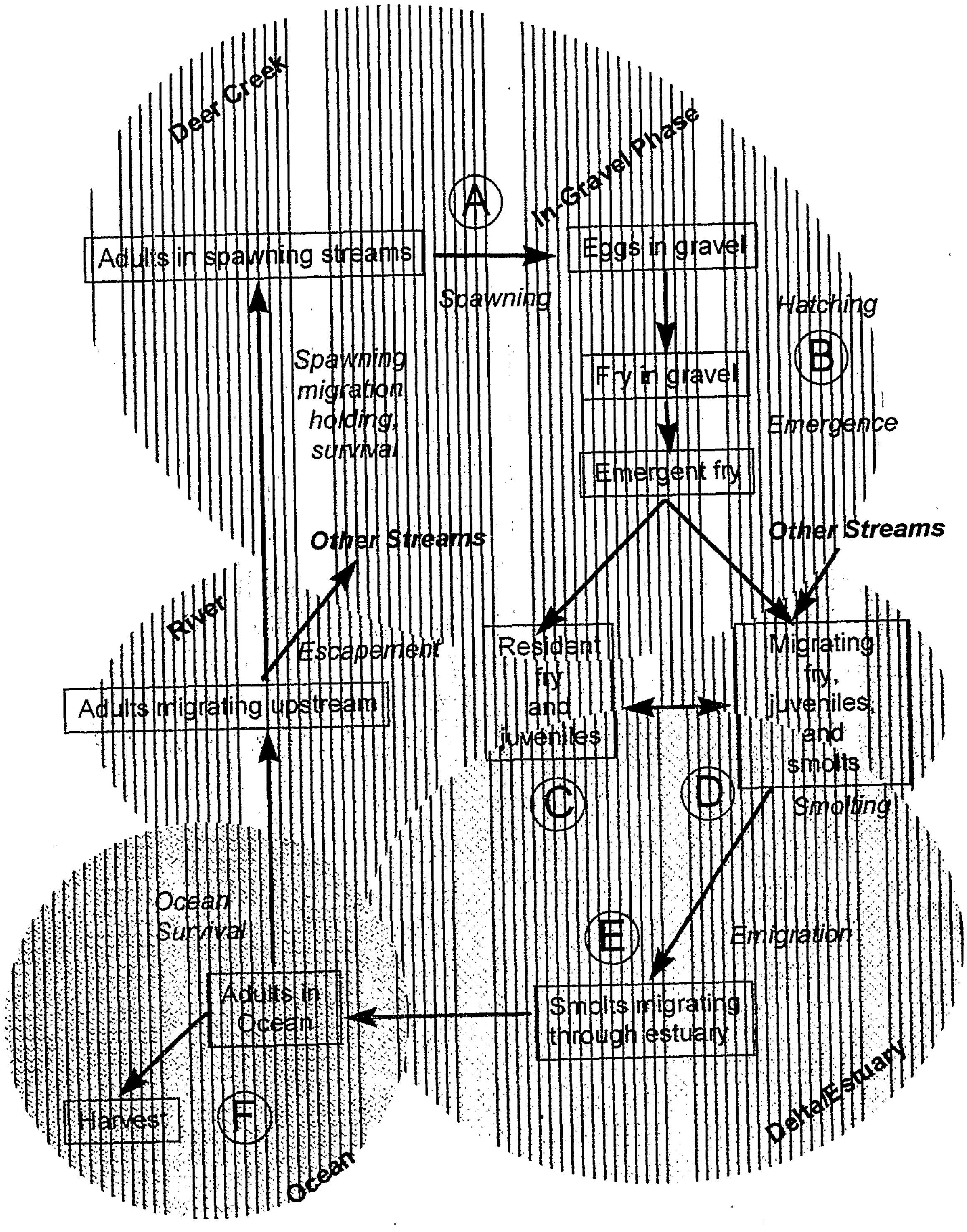

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Figure 7-5. Alternative conceptual models of salmon smolt production for Deer Creek spring-run chinook. Arrows represent transformations of fish from one life stage to the next, and thickness of arrows indicates relative magnitude of population undergoing transformation. Conceptual Models A and B differ in the importance of effects at several stages of the life cycle (Table 7-1).

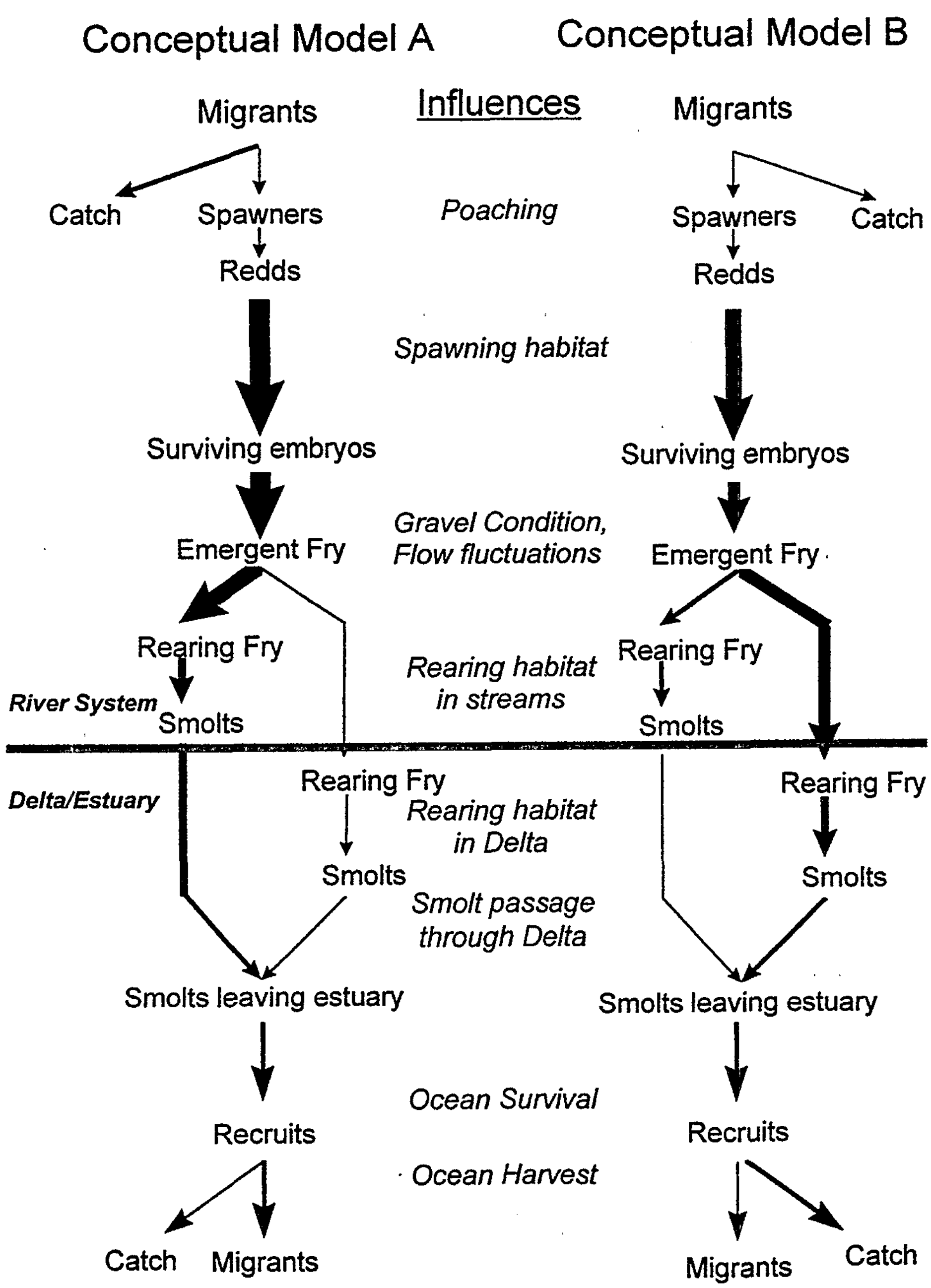

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Figure 7-6. Alternative conceptual models of flow and salmon movement in the Delta under low-flow, high-export conditions. Arrows and circles comprise a schematic of the Delta, with the circles representing key nodes where flow and fish diverge. Single 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.

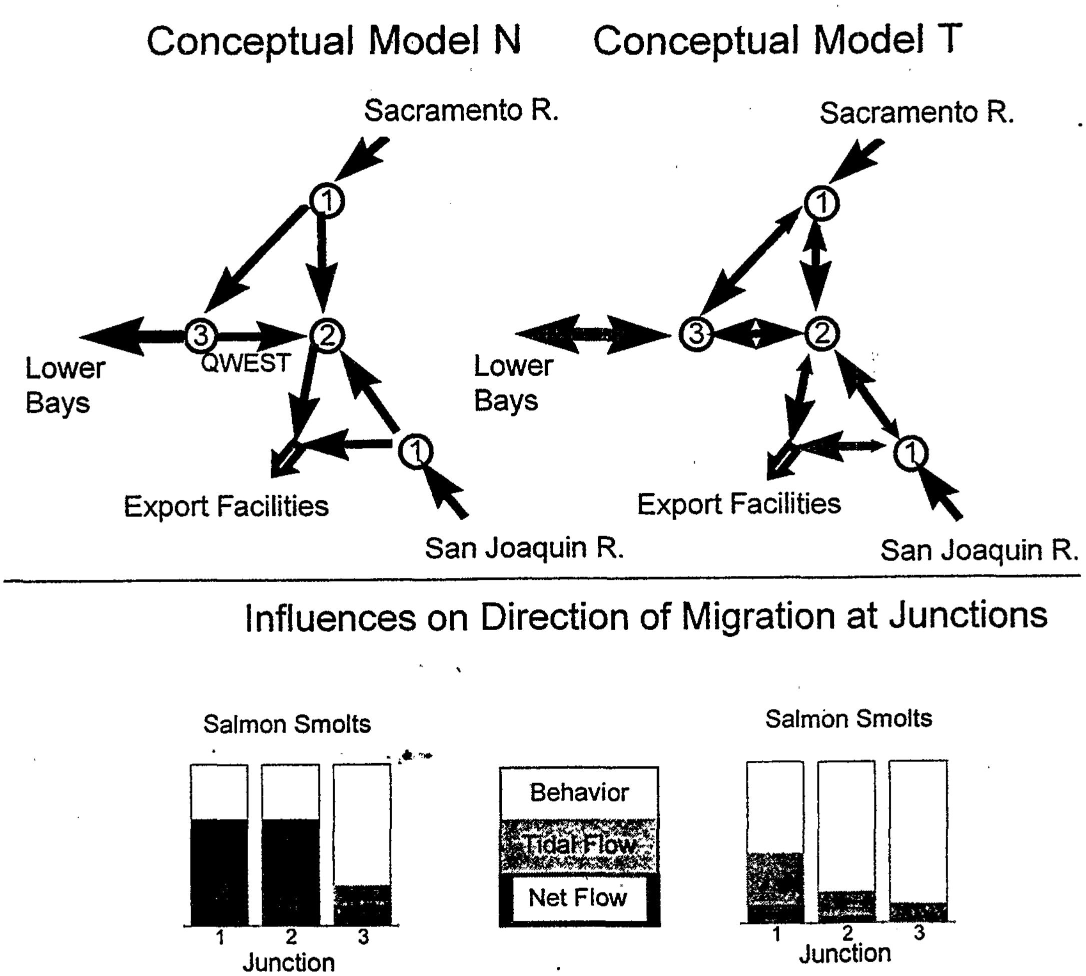

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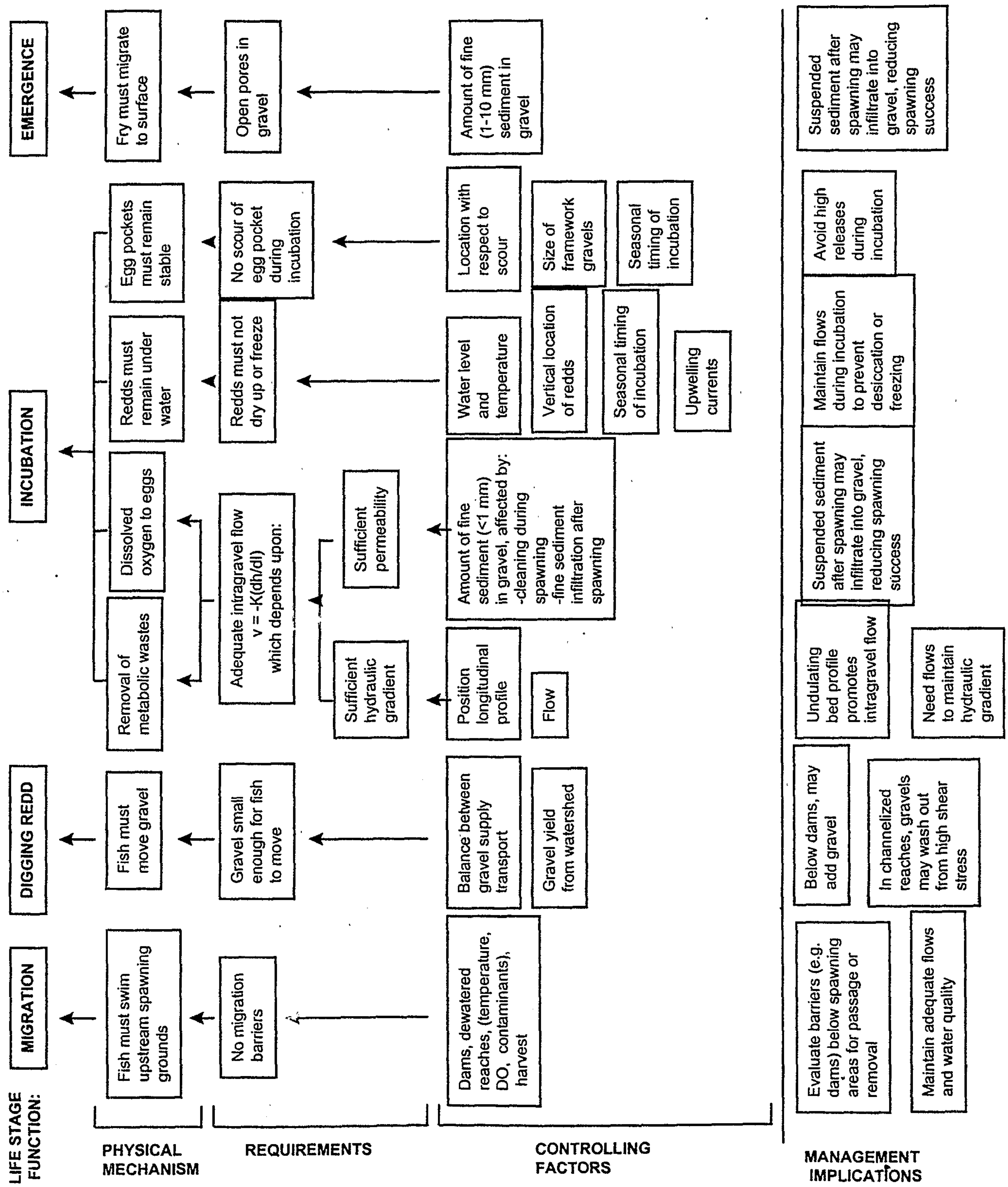
Figure 7-7. Conceptual model of salmon spawning, showing factors affecting success at various life stages.



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Chapter 8. Recommended Regulatory Compliance Strategy Demonstrating that the Ecosystem Restoration Program Complies with Applicable State and Federal Laws, Regulations and Programs

A. Overview of the ERP Compliance Discussion

CALFED is developing a comprehensive regulatory compliance strategy to ensure that implementation of the preferred alternative will comply with existing laws and regulatory requirements. This chapter describes compliance issues specific to the Ecosystem Restoration Program (ERP) that CALFED will consider in developing the comprehensive compliance strategy.

The ERP identifies over 700 potential restoration actions for the Bay-Delta. Implementation of many ERP actions will require prior approval from both state and federal agencies with regulatory responsibilities in the Bay-Delta. To obtain these approvals, CALFED will need to demonstrate that the ERP actions satisfy the requirements and standards established by applicable state and federal laws and regulations. Typically, compliance with laws and regulations is demonstrated by obtaining: (1) necessary permits from agencies responsible for regulating specified activities (e.g. impacts to endangered species or regulated habitats such as wetlands) and (2) environmental clearances (e.g. certification of California Environmental Quality Act (CEQA) or National Environmental Policy Act (NEPA) documents).

Several ERP actions that require permits or environmental clearances may be covered adequately by the Programmatic Environmental Impact Statement/Report (PEIS/EIR) and related approvals that will be obtained prior to the beginning of Stage 1. The benefits and impacts of these actions are understood at a level of detail that justifies their implementation during Stage 1. However, the majority of proposed ERP actions, including potential Stage 1 actions, have not been described or analyzed in sufficient detail. Consequently, they will need to be reviewed within the adaptive management framework, and CALFED will need to obtain additional permits and environmental clearances before they can be implemented.

B. Need for a Compliance Strategy

Because of the linkages among many CALFED Program components, many ERP actions will have a bearing upon, or will be dependent upon, the implementation of other ERP actions, as well as the implementation of other CALFED actions contained in the Water Quality Program, the Levee System Integrity Program, and the Storage and Conveyance Programs. Some actions may need to be staged simultaneously, while others will need to be staged in succession. Therefore, any delay in the implementation of an ERP action has the potential to disrupt the schedule of several other actions.

Since many ERP actions will require the acquisition of additional regulatory permits and the preparation of additional environmental documentation, it is important that ERP managers anticipate the permit and environmental documentation requirements of ERP actions to prevent unnecessary delays in implementation. CALFED is developing a comprehensive, coordinated, long-term compliance strategy to ensure that permit and environmental documentation requirements are integrated within the adaptive management decision process so that they can be obtained in a timely manner.

C. Purposes of the Compliance Strategy

The ERP Compliance Strategy will be designed to accomplish the following purposes:

- Identify all state and federal agencies with CEQA/NEPA or permitting authority over proposed ERP actions that affect biological resources, including, but not limited to: US Fish and Wildlife Service, National Marine Fisheries Service, California Department of Fish and Game, US Environmental Protection Agency, US Army Corps of Engineers, and State Water Resources Control Board.

- Identify specific permitting requirements and standards established by laws and regulations administered by applicable regulatory agencies, including, but not limited to: state and federal Endangered Species Acts, the Natural Communities Conservation Planning Act, federal Clean Water Act, and related regulations and codes.

- Provide a framework that will facilitate effective compliance with the CEQA and NEPA, recognizing the need to implement the ERP and CALFED Program in stages over 30 years.

- Identify proposed ERP actions in sufficient detail so that each action can be evaluated to determine: 1) needed regulatory and environmental clearances (many projects will require multiple approvals and permits; 2) the specific location and character of the action so that potential impacts and benefits can be identified; 3) environmental impacts and feasible alternative actions and/or mitigation measures; and 4) linkages between specific ERP actions and other ERP actions, as well as non-ERP actions within the overall CALFED program (e.g. levee protection, water supply, water quality, etc.). A linkage refers to functional connections between proposed actions that could serve to enhance or be essential to the success of one or both actions. For instance, an action proposed to restore a wetland could depend on water availability or water quality. Or, a proposed action could be contingent upon the completion of a particular research or monitoring program.

- Define and implement an adaptive management framework for ERP and linked non-ERP actions to: 1) evaluate and select actions to be undertaken during Stage 1 and subsequent stages; and 2) guide implementation of selected actions consistent with the adaptive management decision framework described in Chapter 6 and illustrated in Exhibit _

(Framework for Adaptive Management).

- Identify ERP actions that should occur in Stage 1 based on the application of adaptive management principles and other relevant criteria, and, as necessary, determine whether actions proposed to occur in Stage 1 are adequately covered by the PEIS/EIR and related certifications. If necessary, develop a phasing plan for Stage 1 activities and decisions to assure that applicable permitting and environmental approvals are obtained and Stage 1 actions are implemented in a timely manner.

- Integrate the ERP adaptive management approach with implementation of non-ERP CALFED actions by assuring consultation between ERP managers and other program managers early in the decision making process for non-ERP actions that would impact significant biological resources or that are determined to be essential actions precedent to other proposed ERP or non-ERP actions (i.e. consultation should begin at the conceptual and early facility design/decision stages so that alternative solutions and assessments of the potential impacts and benefits associated with a proposed action can be addressed prior to committing to specific solutions).

- Provide the basis for "assurances" to program participants and others affected by or interested in the ERP and CALFED, that ERP and other program elements are progressing in a reasonably balanced, timely and equitable manner capable of achieving CALFED restoration and other programmatic goals.

D. Regulatory Programs and Reviewing Public Agencies

The ERP Compliance Strategy will enable program managers to obtain necessary state and federal permits and approvals in a manner that is both timely and efficient of resources. Because the ERP focuses upon The ERP Compliance Strategy

Because of the scope of state and federal regulatory programs, it is important to begin by understanding that some regulatory agencies/programs are critical to the success of the ERP. The ERP compliance strategy focuses on species, habitat and ecosystem issues, including water quality. The strategy identifies the state and federal agencies/programs that directly address these issues. Other regulatory programs are broadly related to ecosystem health (e.g. the Clean Air Act); however, the mitigation and management solutions for these programs do not directly complement or contribute to ERP restoration solutions and impacts. Therefore, permits and approvals involving agencies other than those discussed below are addressed as part of a strategy separate from the ERP Strategic Plan, recognizing that some of these approvals ould delay ERP actions if they are not obtained in a timely manner (e.g. approvals involving potential impacts to cultural resources or air quality).

The most relevant state and federal agencies and program requirements include: State of California regulatory permits and approvals - California Endangered Species Act, Natural

Community Conservation Planning Act, Streambed Alteration Agreements, assorted Fish and Game Codes, and San Francisco Bay Conservation and Development Commission (BCDC); Federal Laws/Programs - Federal Endangered Species Act, Federal Clean Water Act, and Rivers and Harbors Act.

E. Environmental Documentation Approach

The CALFED Bay-Delta Program is a joint state and federal program. Therefore, evaluation of potential environmental impacts associated with ERP actions and other CALFED components will be conducted jointly in accordance with both CEQA and NEPA requirements. Under CEQA these documents are referred to as impact "reports" (EIR) while under NEPA they are called impact "statements"(EIS). To address this need, CALFED Program has prepared a Draft Programmatic Environmental Impact Statement/Environmental Impact Report (PEIS/EIR).

1) Program Implementation Under a Programmatic EIS/EIR

Staged implementation of the ERP is necessary because of the complexity of the Bay-Delta system, limits on available scientific data, and an inability to predict future events and how the ecosystem will respond to specific ERP actions. For these reasons, and because most program actions being considered are not yet precisely defined, CALFED elected to prepare a "programmatic" environmental document. The Draft PEIS/EIR (p. 1-9) explains that it describes and evaluates the potential environmental consequences of actions at a programmatic level of detail rather than at a site-specific level of detail. The Draft PEIS/EIR goes on to state (p. 1-10) that it is intended to ". . . support the selection of a preferred program alternative rather than the selection of a specific action." As a result, the scope of environmental documentation covered by the Draft PEIS/EIR limits the number of specific ERP actions that can be implemented without completing additional environmental documentation.

Consistent with the language in the CEQA Guidelines (section 15168), the Draft PEIS/EIR proposes that "second tier" or "site specific environmental documents"be prepared for individual projects after the Final PEIS/EIR is certified. Thus, the programmatic EIS/EIR could expedite the preparation of future environmental documents. For instance, policy-level decisions and impacts addressed by the PEIS/EIR generally need not be re-examined, but specific ERP actions that were not addressed in the programmatic document will require an "Initial Study" or "Environmental Assessment" to determine whether the proposed action could have significant environmental effects not previously considered, and therefore requiring a subsequent document. At this time, proposed actions are not sufficiently defined and potential consequences of future actions are not adequately understood for the Strategic Plan to recommend a specific documentation strategy. More information is needed.

A) First Priority: Identification of Precise Actions and Environmental Documentation Needs

Preparation of environmental documents under CEQA/NEPA involves considerable time, generally ranging from a few months for a "negative declaration" and "finding of no significant impact" to more than a year for a relatively simple EIR/EIS and longer for more complicated projects. Therefore, from an implementation perspective, one of the most important tasks for the ERP is to develop a systematic approach for identifying permit and environmental documentation requirements of proposed actions in time to allow for appropriate review and approval. Anticipating environmental documentation requirements will help prevent unnecessary delays in obtaining necessary permits and in implementing ERP actions.

The adaptive management decision framework is an important tool for enabling ERP program managers and others to identify information needs with increasing precision and in a timely manner. Under the adaptive management framework, program managers can periodically scope out information needs for specific projects at several stages of the decision making process (see Figure 3, Framework for Adaptive Management Planning). The first review may occur when an action is precisely defined and considered for selection as a recommended ERP action. Subsequent opportunities occur prior to or concurrent with the modeling and research steps in the adaptive management process.

B) A Case Study: Integrating Adaptive Management with the Compliance Strategy for the Deer Creek Study Area (TO BE COMPLETED FOR FINAL STRATEGIC PLAN)

F. Staged ERP Implementation and Provision for "Assurances"

One of the most challenging aspects of the CALFED process for the ERP involves the need to maintain a reasonable balance in terms of progress in completing ERP actions and progress in completing actions in other components of the CALFED Program. After the PEIS/EIR is certified and the Record of Decisions (RODs) are prepared, program participants will be monitoring program implementation to determine whether it is being implemented and operated as agreed. Water users have made it clear that it would not be acceptable for CALFED to spend one billion dollars on restoration without defining water operating rules or resolving water conveyance and storage alternatives. Other interests have been equally adamant in declaring that decisions must not be made on the same issues without sufficient progress on the ERP and adaptive management.

1) The Need to Define "Adequate Progress" Among Program Elements

Virtually all parties agree that for CALFED to succeed, there must be some degree of symmetry or balance in terms of progress among Program elements. Therefore, during staged implementation of CALFED and ERP actions, there is a critical need to:

- identify measurable levels of progress (i.e. thresholds) toward restoration and other program goals for each stage of implementation;

- identify tools capable of facilitating attainment of identified performance thresholds; and

- link ERP progress to attaining measurable progress (threshold decisions or performance levels) for other program components such as financing, governance, water project operating rules, water storage and conveyance, water quality, and levee protection.

Facilitating attainment thresholds could involve developing specific tools, in the form of incentives, or alternative solution pathways (e.g. funding for water purchases) that would contribute to meeting performance standards and maintaining incentives for all parties to stay involved at each stage of the implementation process.

These tools are not available now; therefore, a primary compliance objective during Stage 1 should be to formulate such incentive and solution options. Preferably, these tools would be developed before any decisions on major program features, such as conveyance or surface storage alternatives. At a minimum, they should be developed concurrent with a final decisions on the preferred program alternative.

G. Conclusion

Chapter 8 has provided a wide ranging description of a long-term regulatory compliance strategy for the ERP. In doing so, it has attempted to capture the scope and variety of issues that must be addressed as the ERP and CALFED are implemented in stages over 30 years. Hopefully, the discussion of linkages and assurances that bind the ERP to other elements of the Program is useful. It is difficult, if not impossible, to draw hard lines separating the ERP from other elements of CALFED. It is nearly as difficult to separate the issue of assurances from the compliance strategy. The interrelatedness of CALFED program problems and solutions across program boundaries is pervasive and, ultimately, commands attention.

The following Chapter steps away from the long-term focus and addresses a strategy for Stage 1 of the ERP. Stage 1 begins to implement adaptively managed restoration and should provide a sound foundation for, and effective transition to, subsequent stages of the ERP.

Chapter 9. Recommended Strategy for Implementing Stage 1 of the Ecosystem Restoration Program

A. Introduction: Relation of the ERP to Stage 1 of CALFED

In its recent document "Developing a Draft Preferred Program Alternative" (August 5, 1998), CALFED described Stage 1 as the beginning of a series of actions that would form the basis for the long-term CALFED solution. The same document also stated that Stage 1 does not lead to a set of specific, pre-defined outcomes. Stage 1 is the beginning of an adaptive management implementation process where future outcomes in all Program components are dependent on the results of yet to be defined decisions and outcomes. The adaptive management approach is described in some detail in Chapter 6. Under the adaptive management approach, each of the actions proposed for inclusion in the ERP, starting with Stage 1 and including later stages of ERP implementation, will be evaluated in accordance with the principles and process outlined in Chapter 6.

A review of the Stage 1 "indicators" for success identified by CALFED in the August 5 document indicates that the ERP should be either the primary or significant contributor responsible for achieving three of the CALFED Stage 1 objectives cited. The ERP will be the primary mechanism responsible for "improving conditions in the Bay-Delta for listed and proposed species and beginning the process of recovery for these species" and for "building an information base for transition to Stage 2 and future decisions." In addition, the ERP will play a key role in "addressing the conditions and linkages necessary before proceeding with storage and conveyance decisions . . .." The term "linkages" has two meanings in this context: (1)"assuring" that the CALFED program will be implemented as promised; and (2) identifiable relationships between ERP actions, such as the need to complete research or monitoring tasks, or a need to make a decision on one action before a subsequent decision can be made on another action.

The Strategic Plan has been prepared with these objectives in mind. However, a more focused view of the ERP objectives for Stage 1, a view that is based on an adaptive management approach, is outlined in the following sections.

B. ERP Stage 1: Character and Objectives

The overriding characteristic of Stage 1 from the Strategic Plan perspective is that it marks the beginning of a decision and implementation process where actions and alternatives begin to be evaluated within an adaptive management framework. In this context, it needs to be clear that the Strategic Plan recommendations for the ERP are not based on or influenced by, any presumptions that would limit future ERP alternative actions/solutions considered during the adaptively managed decision making process (e.g. presumptions regarding future conveyance or surface storage solutions). With these comments in mind, the Strategic Plan strategy for Stage 1 of the ERP is aimed at carrying out the following tasks as part of an adaptively managed decision process:

1. **provide the ecological and procedural foundation** (i.e. adaptive management approach) for future stages of ERP implementation;

2. **identify critical CALFED decisions** in the ERP and other Program components that will be linked to or dependent on ERP information and actions;

3. **identify and refine our understanding of linkages between ERP actions;**

4. **identify linkages between ERP and other Program actions** where either functional/technical linkages are identified or the need for assurances is present;

5. **select criteria for identifying and prioritizing actions** considered for Stage 1 and subsequent stages of implementation;

6. **identify a comprehensive list of specific ERP actions** and decisions to be included in Stage 1;

7. **identify sub-stages or phases within Stage 1** that reflect the time required to complete necessary environmental documentation and/or obtain permits for recommended actions, thereby enabling Stage 1 to progress in a balanced, defensible manner and provide an effective foundation for Stage 2 decisions and actions; and

8. **identify "transition" tools and procedures**, including measures of "progress" that relate to decisions on major program elements and can assist program managers in completing Stage 1 and beginning Stage 2 of the ERP and overall CALFED implementation efforts.

Based on the above work program elements, the following discussion addresses actions and decisions that should begin and, in some cases, be completed, in Stage 1.

C. Developing a List of ERP Actions and Decisions for Inclusion in Stage 1

In order to compile a list of actions for inclusion in Stage 1 of the ERP a number of factors and actions must be considered and/or completed. These include: (a) identifying what is already covered adequately by the PEIS/EIR and ROD; (b) understanding the status of the prior list of Stage 1 ERP actions compiled by staff; (c) developing criteria to guide the selection of proposed Stage 1 actions that carry out the adaptive management "decision rules" set forth in Chapter 6; and (d) providing a process whereby CALFED and stakeholders can work collaboratively to agree on a list of actions.

1) Identifying Actions Covered by the Final PEIS/PEIR and ROD

A review of the actions included within the latest CALFED documents indicates that, even if the suggested program-level actions were precisely defined and reviewed within an adaptively managed decision framework, most of these actions could not proceed in Stage 1 without additional environmental approvals and agency review and permitting. Therefore, one of the first tasks for program managers between now and the publication of the "Revised" Draft PEIS/PEIR would be to systematically review the suggested ERP actions to determine whether, and to what extent, additional documentation or permits would be required.

2) Status of the Existing CALFED Stage 1 List of ERP Actions

The Stage 1 ERP action list compiled by CALFED staff addresses the need to identify programmatic actions for inclusion in the CALFED Program Project Description (see Exhibit _, Preliminary Stage 1 ERP Programmatic Actions). This list of Stage 1 ERP actions will be reviewed with stakeholders, Core Team or others as part of the adaptive management decision framework for Stage 1. It is intended to be the first step in preparing a final list of Stage 1 actions that would be finalized during Stage 1. The final list will be based on a review of all potential ERP actions within an adaptive management framework as described in Chapter 6 (including the 700-plus actions in Volumes I and II of the ERP and other proposals). The 16 actions proposed by CALFED staff were described at a "program level" so that CALFED could prepare the "Project Description" for the "Revised" Draft PEIS/EIR scheduled to be completed later this year. Proposed actions on the staff list do not provide specific project locations or contain precise descriptions of expected benefits, potential impacts, or details explaining how the action would be implemented. These purposes and characteristics will be addressed as part of the process for finalizing Stage 1 actions.

3) Developing a Process for Finalizing Stage 1 Actions

For Stage 1 to be successful, a formal process will be established as soon as possible to review previously-proposed actions (including the more than 700 actions in Volumes I and II of the ERP), and to set the ground rules for identifying all potential new actions. Project proponents should be invited to elaborate on the action's purposes, and on underlying (probably heretofore implicit) conceptual models. A number of proposed Stage 1 projects have already been geo-located and entered into a GIS, and this effort will be expanded to include Category III projects and others. A simple project tracking database will be established to provide basic access to project descriptions, permit requirements, status, responsibilities, and so on.

Once the this material has been organized, a step-by-step review will be undertaken to define each action in terms of its goals, objectives, monitoring and research, and relation to other projects. Projects will be evaluated to identify ways to increase the information gained from that project during Stage 1. This might take the form of a recommendation to expand the monitoring and research component of the action itself, or to initiate focused research on a related ecosystem process, or landscape-level issue. Finally, using the selection criteria outlined in the following section, projects will be ranked and prioritized, probably by categories of activity. This process could use any one of a number of ranking techniques (lexicographic, simple value analysis) to avoid making decisions by rote and to help clarify each action's role in ecosystem restoration.

The review process would conclude with specific recommendations on: (a) actions to be initiated during Stage 1; and (b) on the longer-term process for CALFED's consideration of new proposals. Because of the complexity and variety of potential ERP actions, it is likely that refinement of the Stage 1 list of actions will need to continue into at least the first year of Stage 1. After Year 1, the list of recommended actions will continue to be refined on an ongoing basis in accordance with evolving adaptive management findings/recommendations and the Stage 1 "selection criteria" for actions discussed below.

D. Selection Criteria for Stage 1 ERP Actions and Category III Restoration Measures

Under an ecosystem-based, adaptive management approach, it will be important to re-evaluate previously-proposed actions and to set procedures for evaluating and prioritizing actions yet to be designed. Proposals have evolved over a number of years and flow from a large number of goals and intentions. In only a few cases are the proposals supported by explicitly stated goals, objectives, and criteria for evaluation of their success. None of the previously proposed actions contained in Volumes I and II of the ERP was evaluated within the context of the adaptive management approach recommended for the ERP. Thus, it is important for this Strategic Plan to: (1) introduce new criteria designed to help make Stage I ecosystem-based and adaptive; and (2) suggest a process for further evaluating both previously-proposed actions and new actions yet to be proposed.

The selection criteria below will be applied throughout the process of nominating, evaluating and selecting ERP actions for Stage 1 implementation. The recommended criteria include amplified versions of the six "decision rules" set forth in Chapter 6 and four additional criteria that could be of special relevance to the adaptive management process during Stage 1. The criteria include:

1. Emphasize projects that will have the greatest absolute benefits and the greatest benefit-cost ratio for native species.

2. Emphasize projects that will provide the most useful information about system dynamics.

    Is the project replicable? Can the results be generalized? Will it contribute to a better understanding of the ecosystem and the effects of stressors? Will implementation of this action restore and help understand an important ecosystem process (e.g. nutrient cycling, fluvial dynamics)? Will it help future decisions about large scale ecological restoration and species conservation.

3. Emphasize projects that are complementary in their effect unless the conflict provides important information about system dynamics.

4. Emphasize projects that will provide results in a short time frame, thus providing

key information during Stage 1 that may be needed during the time of transition to Stage 2.

5. Emphasize projects that will be the most self-sustaining.

6. Emphasize projects that provide information richness.

   Does the action include some control over detailed design and location for research purposes? Does the proposed site of the action have good background information and historical data?

7. Emphasize projects that are based on ecosystem modeling.

   Did its need arise from conceptual modeling or science-based inquiry? Is the action supported by conceptual and simulation modeling of underlying ecological processes?

8. Emphasize projects that address causes, rather than symptoms.

   Does it address the causes of ecosystem degradation, or just the symptoms? Can the environment and outside forces be controlled or manipulated so that the target cause-and-effect relationships can be illuminated?

9. Emphasize projects that are designed to achieve explicit, tangible and measurable objectives.

10. Emphasize projects that have high public support and visibility.

The above criteria should be used, and in some cases, may take precedence over more traditional criteria. For example, under some circumstances it might make sense to undertake a fairly costly and uncertain pilot project, even one with only minor benefits to the ecosystem, if the action is needed to shed light on a key ecosystem process. The decision to undertake such a project would depend on such things as a benefit-cost analysis that weighed the value of the information gained and the benefits to the ecosystem against the potential costs (environmental costs if things go wrong and financial cost of the action). This is not to say that adaptive management inevitably leads to risky projects, only that it does not rule them out.

It also may be advisable to consider criteria which, although not related specifically to adaptive management, nonetheless would aid in the Stage I selection process. For instance project consideration could favor projects that provide for: (1) Geographic Coverage–filling out coverage of Ecological Zones within the Delta, tributary streams or watersheds that enable a broader understanding of the regional environment; or (2) Fungibility–selecting an action because it creates an asset (such as new water rights or land ownership) that would retain value and could be sold or traded at a later date if the actual result of the proposed action does not live up to expectations or is not needed.

E. Recognizing the Probable Need for Phasing Stage 1 ERP Actions and Decisions

A review of actions already identified for possible inclusion in Stage 1 by CALFED or stakeholders reveals that more information would be needed for many projects before Final Stage 1 decisions could be made. For many actions, the detail available in the project description and the level of understanding of project benefits and impacts is limited. In addition, there are other candidate actions that have not been discussed and may need to be considered prior to finalizing the Stage 1 action list.

Therefore, potential Stage 1 actions being compiled in accordance with the earlier selection criteria also should be concurrently identified and categorized based on the following factors:

- amount of new documentation and permitting required to obtain final agency approvals;
- time required to complete documentation and permitting;
- timing considerations of linkages to other ERP or non-ERP CALFED actions; and
- potential to "bundle" ERP and non-ERP Stage 1 actions for environmental documentation and permitting.

In this way, program managers could estimate when an action would be ready to commence. This information will be useful in screening actions in three ways. First, screening almost certainly will demonstrate that a phasing plan will be needed to organize and implement Stage 1 ERP actions. Different action characteristics and environmental/permitting requirements will result in actions coming on line in a sequential manner, not all at once. Second, screening would identify actions that should not be considered for Stage 1 because of timing limitations (i.e. if it would take too long to get approvals or other actions necessary, it would not occur until Stage 2). Third, screening would enable program managers to identify and organize actions included within Stage 1 based on timing considerations. For instance, screening could provide the initial forecast of actions that could be initiated in year 1 of Stage 1, and other actions that would have to occur later in Stage 1.

This evaluation process should be initiated immediately and continue concurrent with the compilation and finalization of the list of recommended actions for Stage 1.

F. Stage 1 ERP Phasing Plan (Years 1 through 7, or longer if needed)

Restoration actions for Stage 1 will be reviewed and screened using the selection criteria discussed earlier in this Chapter. The factors and process outlined in the discussions immediately preceding this section suggest that a phasing plan should be prepared to guide restoration actions during designated sub-stages of Stage 1. Although the following discussion of phasing is conceptual, it is helpful to walk through a sequence of actions that would be involved in formulating and implementing a specific Stage 1 phasing program.

As a starting point, a phasing plan will recognize several factors:

- under the current CALFED schedule, Stage 1 does not commence until the year 2000, roughly 16 months following release of the Draft Strategic Plan;
- it would not be desirable to delay implementation of ERP restoration activities such that a significant "time gap" occurred following certification of the programmatic PEIS/EIR/ issuance of the ROD, and initiation of adaptively managed restoration activities;
- some restoration actions will be adequately covered under the PEIS/EIR and ROD, and could begin in Year 1 of Stage 1;
- some actions would require additional documentation and/or permitting, but might be ready for implementation prior to completion and public distribution of the Final Programmatic EIS/EIR for public review, and prior to certification of the PEIS/EIR and issuance of the ROD;
- other actions would require considerable documentation and permitting, resulting in a 1, 2, or even 3 year approval process for individual actions, or sets of actions; and
- many restoration actions could not begin prior to completion of Stage 1.

With the above factors in mind, an illustrative phasing approach is outlined below identifying some of the actions and decisions that need to be considered by CALFED, stakeholders and the public as the programmatic documentation is being readied for completion and agency approval and certification by the end of next year. The illustrative approach establishes three sub-stages (stages 1A, 1B and 1C) within the seven-year Stage 1 timeframe. Stage 1C also serves to provide a transition between Stage 1 and Stage 2 ERP implementation.

1) Stage 1A -- Actions and Decisions Targeted for Year 1 (2000)

A) Purpose

Following certification of the programmatic environmental document and issuance of the programmatic ROD, either CALFED or a new successor entity will begin implementing the ERP. The purpose of the first phase of Stage 1 is to assure that the essential first steps necessary to enable the ERP to be implemented occur as soon as possible to avoid a "gap" in ecosystem management and restoration activities.

B) Actions During Stage 1A

Category III restoration projects initiated prior to certification of the programmatic CALFED documents will continue up to and into Stage 1A. Between now and the beginning of Stage 1A, steps should be taken to assure that, upon obtaining programmatic approvals, either CALFED as a transition entity or the successor entity (staffed to manage program activities) must be in place to commence Stage 1 ERP restoration. To the extent feasible, "start up" tasks necessary to initiate monitoring, research, conceptual modeling and information system management under the adaptive management approach should be completed.

CALFED's Information System should be quickly strengthened, especially in the areas of Web-based communication, GIS, Region-wide inventory, project tracking, digital document management, and digital library services. These steps will take time to develop, and should be instigated as soon as possible so as to be in full form during Stage 1.

- Products of the Indicators Work Group will be integrated with efforts in conceptual modeling and monitoring.
- CMARP should have the architecture for monitoring and research in place by the end of Stage 1 a.
- Depending on CMARP's actions, CALFED may need to give further support to the development of conceptual models during this phase. Models should be prepared showing the management direction for each Ecological Zone. Conceptual models underlying proposed Stage 1 actions should be nested within higher-level modeling to help determine how restoration efforts are expected to contribute to goals and objectives.

Restoration actions initiated in Year 1 would be limited. Such actions probably would be restricted to 3 types of activities:

1. actions that would not involve significant documentation or require regulatory approvals from other state and federal agencies
    - creation of partnerships with universities
    - research not requiring species "take" permits
    - adaptive management actions involving short-term changes in flow releases below dams, within safety parameters and operating rules
2. actions that are adequately covered by CALFED's programmatic documentation and approvals; and
3. actions requiring very limited additional documentation and permitting (e.g. requiring

between 90 days to 6-8 months to complete).

The last category of actions could be implemented in Stage 1A only if: (1) Stage 1 actions could be selected before the end of this year; and (2) documentation and permitting requirements would be completed in time to be addressed in the final programmatic CALFED documentation sent out for public review and comment next year. Given these restrictions, the number of restoration actions that can start in Year 1 will be limited.

C) Decisions/Products Necessary Prior to or During Stage 1A

In 1999, prior to the beginning of Stage 1:

- Finalize a "preliminary" list of Stage 1 actions and assign preliminary phasing designation (e.g. Stages 1A, 1B or 1C)
- Agree on strategy (with USACOE, USEPA, SWRCB, CDFG) for processing/obtaining CWA 404 permits and 401 certifications on other than a project by project basis
- begin preparing supporting environmental documentation for actions identified for implementation during the Years 2 and 3

During Stage 1A:

- Submit documentation and permit applications to appropriate reviewing agencies and begin preparing of support documentation for actions intended to commence in Year 4.
- Refine, if necessary, the Stage 1 list of ERP actions
- Complete the Section 7 Consultation(s) for federal actions scheduled for Years 2 and 3
- Identify opportunities to "batch" actions for programmatic approvals or "bundle" individual actions for coverage under consolidated environmental documents and permit applications

2) Stage 1B Actions/Decisions targeted for years 2 through 4 (2001-2003)

A) Purpose

The ERP begins to be implemented in earnest in Stage 1B. The focus during Stage 1B would be to commence the substantive restoration, monitoring/modeling and research actions identified for Stage 1 implementation. Based on potential refinements to the "List of Actions" completed during Year 1, this stage should manage implementation activities to focus on the critical questions/issues identified to be addressed during Stage 1.

B) Actions

All elements of the ERP restoration program should be functioning by the middle of the second year. By this time some of the "second tier" supplemental environmental approvals and permits should be obtained and significant restoration actions should begin within the adaptive management framework. Actions would include:

- continuation of actions that do not require permits (e.g. implementing an outreach program, building university or private/public partnerships, coordination of activities and outreach to water districts/authorities and farm bureaus, completing the information management system etc.);
- beginning acquisition of easements and progress on developing a water market and acquiring water for critical ecosystem activities;
- initiation of pilot projects designed to test major restoration and management hypotheses (such as those relating to stream geomorphology and Delta hydrology) in order to address critical questions and issues relating to future ERP and CALFED actions;
- actions recently receiving environmental approvals and permits during years 2 and 3 that are not dependent on or linked to other ERP or Program actions scheduled to occur later in the implementation process;
- completion of project level documentation/permitting for actions scheduled under Stage 1C; and
- complete Section 7 Consultation(s) for Stage 1C actions.

C) Decisions/Products During Stage 1B

By year 2 the long-term managing entity for the ERP also should be operational. By Year 4, the last year in Stage 1B, the restoration program should be staffed and fully operational.

3) Stage 1C Actions/Decisions targeted for years 5 through ? (2004 2006+)

A) Purpose and Decisions

Stage 1C should fulfill at least two important purposes. First, it should provide for completion of those "critical" actions (e.g. restoration, research and monitoring/modeling activities) identified in the programmatic documentation and refined during Stage 1 that function almost as conditions precedent to making decisions on major Stage 2 actions. Other actions included in Stage 1 should be completed to the extent feasible. Second, it should provide for a smooth operational transition between Stage 1 and future stages of CALFED implementation by, to the extent feasible, completion of Stage 1 actions, preparation of reports/analyses that document findings and recommendations relating to the major guidance and decisions expected to occur during Stage 1 (e.g. relating to decisions on surface storage and conveyance facility alternatives).

B) Actions

To the extent feasible, completion of the set of actions included on the Stage 1 action list. As noted, particular attention and focus should be given to actions identified as being critical to decisions on major facilities or programs scheduled to occur at some future time following Stage 1.

Specific actions initiated during this phase would include those where environmental document approvals and permits were obtained either during Stage 1B or the beginning of Stage 1C.

Finally, Stage 1C will require actions (e.g. program administrative, regulatory compliance and restoration management) necessary to provide for a smooth transition from the "short-term" Stage 1 ERP purposes/objectives to the long-term ecosystem restoration program. Included among these actions should be a formal workshop/hearing consisting of:

- a week-long set of proceedings dedicated to evaluating all aspects of adaptive management during Stage 1 addressing questions such as

  What did we learn? What worked and what didn't?
  What critical uncertainties remain? What efforts should be abandoned?
  What did we get for what was spent? How are listed species doing?

- preparation and presentation of a "State of the Ecosystem Report" by the managing entity

- assessment by independent scientists/professionals of the status of and progress made under Stage 1, including: (1) progress on key adaptive management and "linkage" issues identified for resolution (or significant progress) during Stage 1; and (2) other issues/questions (see above) recognized during adaptive management activities that should be considered during Stage 2 implementation.

The independent science assessment would be reviewed by ERP program managers and others as part of a formal review of the effectiveness of the Stage 1 ERP program and consideration of possible refinements in the adaptive management approach. The assessment also would be considered by decision makers involved in planning, designing and implementing solutions to major project level and program-level decisions included in Stage 2.

Although Stage 1 is normally discussed in terms of a 7-year stage, it may take longer than 7 years to complete this stage. The length of Stage 1 should be determined by the time needed to complete "critical" actions identified above and prepare the findings and recommendation capable of guiding decisions on major facilities/decisions identified as a part of Stage 2. Therefore, the timing of Stage 1C should relate to the need to complete critical tasks, not an arbitrary pre-set number years.

Chapter 10. The Long-Term Strategy (The 20-30 Year Horizon)

(TO BE COMPLETED FOR FINAL STRATEGIC PLAN)

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