Starting the Discussion

Foundation Concepts and Some Initial Activities to Restore Ecosystem Functions to the California Delta

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Delta Vision Blue Ribbon Task Force

The overarching ecological vision for the Delta is to conserve, enhance, and restore those ecological functions that result in viable populations of desirable species in a manner resulting in resiliency of those functions and populations.

FIRST DRAFT

Photo: Stuart Siegel 2003 Brown's Island

A Disclaimer about this Document

The Delta needs a *strategy* and a *plan* for restoring its ecosystems and their supporting human and natural processes so as to achieve the Delta Ecological Vision. The process of formulating such a strategy and plan sits ahead. Earlier in 2007, Delta Vision initiated a group it called the Eco Design Team. Though the group had the opportunity to meet once to date to produce the ecological vision statement presented here, it has not begun to work on a Delta Ecosystem Restoration Strategy or Plan.

Delta Vision must produce its Strategic Plan by October 31, 2008. That document may be the vehicle for developing the Delta Ecosystem Restoration Plan. The Bay Delta Conservation Plan, a water contractor-led HCP/NCCP process, expects to have its "conservation strategy" ready in June 2008 and it may be the vehicle. The CALFED Ecosystem Restoration Program's Conservation Strategy is available as a draft and is currently undergoing revisions; it may be the vehicle. The CALFED Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) process, underway since 2002 with a long hiatus in 2005-2006, had as its original mission to prepare a Delta Ecosystem Restoration Implementation Plan; it has not advanced that far but has been developing a comprehensive package of conceptual models that describe the current state of knowledge about the Delta and several of its species as well as a process for applying those models to evaluate the effectiveness of restoration actions.

This document is a **starting point** for the Delta Vision Strategic Plan component related to ecosystem restoration. It is not complete, comprehensive, nor the product of any one of the above efforts. Though the author, Stuart Siegel, has been actively involved in some of these key Delta ecosystem planning efforts, the ultimate product that this document could aims towards – the Delta Ecosystem Restoration Strategy/Plan – requires a fully collaborative effort. This document came into existence in a very short time period; time allowed for considerable discussion, mainly one-on-one, but it did not allow for the collaborative formulation essential for where it needs to go next nor for the completion of all its content. Consequently, this document is a draft that will *change* considerably once it enters into the collaborative formulation context.

The primary challenge to developing a comprehensive Delta Ecosystem Restoration Plan is that the multitude of parallel planning processes largely draws upon and therefore over taxes the same finite pool of human resource expertise. Without a concerted effort to reduce the overlap by bringing together these parallel activities into a collaborative process, it may not be possible to produce a Delta Ecosystem Restoration Plan that has the input and support of all the parties involved in these many processes. Strong vision and leadership is essential now to bring about an effective, collaborative strategy.

I. Introduction

The Delta Vision Blue Ribbon Task force adopted *Our Vision for California's Delta* on November 30, 2007. In that vision, the Task Force stated first and foremost that the Delta ecosystem is a co-equal goal with water supply for sustainable management of the Delta. This document provides a starting point for developing a *Delta Ecosystem Restoration Plan*. Such a restoration plan will describe a vision (a high level romantic view of the Delta of the future), goals (desired outcomes of restoration efforts), and objectives (measureable targets to which specific actions aim) and link these with a discussion of their contribution to resilience and durability.

Contents of this Document

This document begins with statements of the **vision and goals** for restoring the Delta. Objectives are a major task clearly outstanding for next-phase planning efforts as they embody the full breadth of ecosystem needs. Next, this document summarizes the **opportunities and constraints** to restoring Delta ecosystems which informs the boundaries of what may be possible. To facilitate developing a comprehensive restoration strategy, the document next compiles a suite of **principles**; more collaborative discussion on these principles is clearly in order. The need for ongoing, coordinated, and well-funded **science** within an Adaptive Management framework is an essential ingredient to address the complexity and uncertainties of the Delta. This document also recognizes that **failure** is a real possibility, driven by factors like sea level rise, catastrophic levee failures, invasive species, and by the human element itself.

Because the primary declines and conflicts between water supply and ecosystem center around aquatic species, their recovery are the highest priority restoration objectives. We know that the most important restoration efforts to meet these objectives are (1) restoring flows through the Delta, (2) restoring key habitats for aquatic species (tidal marshes, floodplains, and open water), (3) restoring processes especially food web productivity, and (4) reducing stressors. Future efforts to articulate these objectives in detail will then allow for more precise determinations of the range, magnitude, geography, and timing of all needed restoration efforts and stressor reductions. Though many solutions are necessary upstream and downstream of the Delta, this document focuses on in-Delta restoration activities inclusive of Suisun Marsh.

This document concludes with two lists of activities that begin to move the region toward development and implementation of a restoration plan – (1) assuming that about $2.5 billion will become available with pending bonds initial activities for expenditure of those funds and (2) independent of bond funds, activities that should be conducted in parallel by other efforts that are necessary to restore Delta ecosystems. <u>The entries on these lists are a *subset* of what is required</u>; they merely bring focus to some key opportunities and critical actions around which implementation efforts can begin now (and in several instances are already moving forward). What remains to be accomplished is to tie these activities back to the restoration objectives that remain to be articulated and thus consider what refinements may be appropriate to fine-tune their effectiveness.

Vetting of this Document

This document is incomplete and not fully vetted. Many individuals contributed valuable inputs and reviews during its preparation. Ultimately, however, the very short time frame for development of this first draft means it is neither complete nor subjected to adequate scrutiny as a complete package. Consequently, this document should be considered a living document to be frequently updated during development of the Delta Vision Strategic Plan and regularly revisited in the long term.

Integration with Other Delta Efforts

There are several ongoing Delta-wide planning and science-based efforts that the information presented in this document draws from and in the longer term must integrate with:

- CALFED Delta Regional Ecosystem Restoration Implementation Plan (DRERIP)
- CALFED Ecosystem Restoration Program Conservation Strategy: Sacramento-San Joaquin Delta and Suisun Marsh and Bay Planning Area (ERP CS)
- Bay-Delta Conservation Plan (BDCP)
- Suisun Marsh Habitat Restoration and Management Plan (SMP)
- Endangered Species Acts (ESA) recovery plans
- Operating Criteria and Plan for the Central Valley Project and State Water Project (OCAP)
- Central Valley Project Improvement Act implementation plans (CVPIA)
- Basin plans of the State and Regional water quality boards, including TMDLs, and the impaired water body [Clean Water Act 303(d)] list
- Conservation planning efforts of various non-governmental organizations

II. Delta Ecosystem Restoration: Vision, Goals, Objectives and Moving Forward

The Delta Ecological Vision

The overarching ecological vision for the Delta is to conserve, enhance, and restore those ecological functions that result in viable populations of desirable species in a manner resulting in resiliency of those functions and populations.

- Delta Vision Eco Design Team, October 2007

For the purposes of this document, these terms have the following meanings. CONSERVATION means to put in place legally binding measures that protect public and private lands and waters from human activities that degrade their natural resources and processes that support ecological functions. ENHANCEMENT means to improve the ecological functioning of existing landscapes and waterscapes. RESTORATION means to reverse landscape or waterscape degradation by reintroducing habitats, organisms, processes, and functions *within the modern context of the landscape*. Restoration specifically recognizes that the modern landscape is vastly and permanently different from its pre-disturbance setting. VIABLE POPULATIONS of a given species mean adequate abundance and genetic diversity to support its persistence over the long term. RESILIENCY means the capacity of an ecosystem to tolerate disturbance without changing into a qualitatively different state that is controlled by a different set of processes; a resilient ecosystem can withstand perturbations and rebuild itself when necessary.

Perhaps the most vexing problem is establishing measureable definitions of resiliency and viability. But in order to know whether we have made any progress, we will have to establish definitions and formulate metrics that can be applied to specific activities, regions within the Delta, selected time frames, and the system as a whole. Below is a first attempt at such definitions; much work remains.

Population Viability and Resiliency

Though not all tools necessarily exist today nor does a clear understanding yet exist of what levels constitute population viability, we can state the metrics that define viability: population abundance and genetic diversity of that population. Key indicators of population viability are reproduction, spatial and temporal availability of resources that support each life history stage, and the absence of stressors that interfere at any life history stage.

It is implicit that the population is free living. The above could all refer to a captive population. There is also the relatively large literature on population viability analysis that provides insights into how to assess population viability. For most Delta species the data to run such analyses are probably not available but the literature provides a framework for developing the necessary models/data. www.ramas.com/pva.htm provides a general outline and some references.

Ecosystem Resiliency

Though several attributes of resiliency can be described as shown here, the fundamental challenge facing a manager is defining measureable attributes of the ecosystem that will index resiliency. Formulating such concrete measures is a critical task to incorporate into a Delta Ecosystem Restoration Plan. Resilience implies processes of feedback and homeostasis in ecosystems which may exists but at present it is not clear how to measure it except by challenging the system and watching the response.

Properties of resiliency: Resistance to perturbation (inertia), ease of recovery (elasticity), degree of perturbation before change (amplitude or latitude), resistance to shifting to alternate state (malleability or precariousness), likelihood of recovery through reversal or other path (hysteresis), and the influence of multiple scales (panarchy)

Diversity attributes that support resiliency: Diversity acts to absorb change, allow multiple paths of response, and buffer against dependencies on selected attributes. Specific types of diversity that support resiliency are: multiple functional groups (groups of species that perform a similar task), number of species within functional groups, overall diversity of species and populations, plasticity of functional responses, and abundance and connectivity of habitats in space, time, and the ecosystem functions they perform.

Ecological characteristics that influence resiliency: Complexity, historical dependencies, nonlinear dynamics, threshold effects, multiple alternate states, limited predictability, and interactions across multiple scales

Role of stressors: stressors interfere with ecosystem functioning, population dynamics, and ecological interactions. They thereby interfere with our ability to restore the environments and species.

Knowing when we have a resilient ecosystem: while it is probably possible to develop and measure a suite of performance indicators of ecosystem resilience, it is extremely challenging to draw conclusions about the point at which the levels of these indicators collectively translate into "resilience". Recent years have shown that it is much easier to identify an ecosystem that is not displaying resilience. Reversing consistent downward declines in abundance of target species, such as shown in the Pelagic Organism Decline, is then one minimum measure of resilience.

Goals for Ecosystem Restoration

The following six goals for ecosystem recovery in the Delta are modified slightly from the Ecosystem Restoration Program Plan Strategic Plan for Ecosystem Restoration, July 2000:

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

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

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

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

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

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

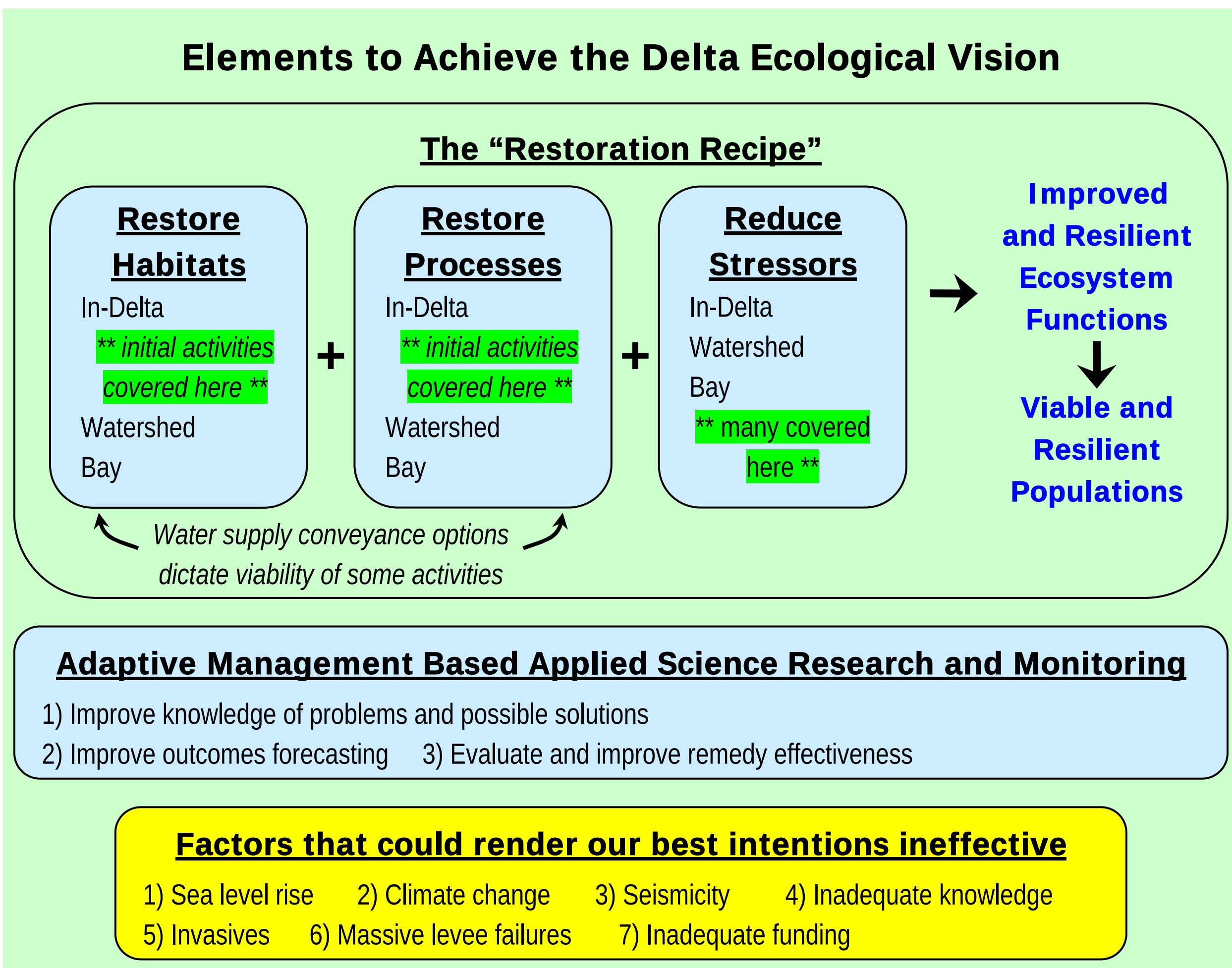
Highest Priority Restoration Objectives: Aquatic Species

Because the primary declines and conflicts between water supply and ecosystem center around aquatic species, their recovery are the highest priority restoration objectives. We know that the most important restoration efforts to meet these objectives are (1) restoring flows through the Delta, (2) restoring key habitats for aquatic species (tidal marshes, floodplains, and open water), (3) restoring processes especially food web productivity, and (4) reducing stressors. Future efforts to articulate these objectives in detail will then allow for more precise determinations of the range, magnitude, geography, and timing of all needed restoration efforts and stressor reductions.

Considering these needs in the long term requires taking projected sea level rise into account. To meet that need, one additional modern landscape must be added to the efforts necessary to fulfill these restoration objectives: conservation of undeveloped lowland grasslands contiguous with lands that could be restored to tidal marsh. Incorporation of these lowlands allows for landward shifting of restored tidal marshes as sea level rises, thereby providing for ongoing persistence of the marshes.

What it Takes to Fulfill the Ecological Vision

Formulating strategies to achieve the Delta Ecological Vision is a complex task that requires the input of numerous governmental and non-governmental organizations and individuals. We describe an overarching approach that combines a "restoration recipe" with the need for science to fulfill our vision. Our limited knowledge, irreversible changes to the system and likely future changes suggest that we may fail but a scientific basis and an adaptive management approach will greatly increase our chance of success. The diagram below illustrates these points.



The "Restoration Recipe"

Taking the *ecological vision* as our goal, the restoration recipe is quite simple – we need to restore natural habitats, we need to restore natural processes, and we need to reduce stressors. The incredible complexity in applying such a recipe is the subject of this document. The diagram above shows the types of topics contained in the lists presented in Section IV below.

Science is Key to Achieving Success

Success in achieving the Delta Ecological Vision is founded upon using and advancing the best science. Success will hinge on our knowledge about the interactions underlying the problems we're trying to fix. That knowledge helps us identify possible solutions. Success also hinges upon our ability to forecast outcomes of actions, both positive and negative, so that we can proceed with as much clarity as possible. Science-based assessments of the results of our actions (monitoring) is our best tool to guide all our future actions. Collectively, these science efforts and their application into the planning, decision making, and implementation processes are the concept known as Adaptive Management.

Fortunately, we have several broad-based scientific efforts in process – the Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) science syntheses, the Pelagic Organism Decline (POD) research, and a host of other directly related research and monitoring activities.

A Word of Caution – We Can Fail

We must understand one extremely important caveat that applies throughout this entire discussion: we can fail. We are trying to "fix" an incredibly large, complex, unpredictable, and severely altered ecosystem. Externalities like sea level rise or invasive species may fundamentally undermine our efforts. We may not know what we need to know in order to succeed. We may not end up providing the Delta the habitats and processes it needs. As a society we may not achieve the level of commitment nor provide the long-term funds needed to meet the demands of the challenge at hand. We can make mistakes.

At risk is not only the Delta's ecosystem but the extinction of some species such as Delta smelt. The precautionary principle thus tells us to move forward carefully, consider the reversibility of actions we take, do our best to project outcomes, and integrate science-based adaptive management throughout. Because extraordinary measures may be necessary given that the future could be very different, precaution may not be the best policy in all instances, although reversibility is always desirable.

Next Planning Steps: Strategic Ecosystem Restoration Planning

The next steps in advancing towards a Delta Ecosystem Restoration Plan are (1) establishing a comprehensive suite of **ecosystem restoration objectives**, and (2) assembling a comprehensive suite of ecosystem restoration actions that have been scrutinized through a rigorous scientific evaluation to be effective in meeting those objectives, fulfilling the goals, and achieving the ecological vision.

CALFED's DRERIP effort provides the rigorous scientific evaluation tools and process and will be ready for use in 2008.

Establishing the objectives and assembling actions is complex from a technical and organizational perspective. Technically, it requires a tremendous *collaborative* effort of scientists and managers that draws upon a broad range of expertise from agencies, universities, water contractors, and other Delta stakeholders; the challenge is simply too large for a small entity to succeed. See the 1999 *San Francisco Bay Habitat Goals Report* for what a comparable effort required. Organizationally, it needs to serve many masters. The large number of concurrent and somewhat parallel planning efforts currently underway, however, does not provide the level of collaborative planning the challenge demands. Instead, it tends to over-tax the available human resources pool, creating a competitive environment. In some instances it also decouples necessary links to the needs and requirements of other efforts that have direct bearing.

An updated approach organizationally is necessary to generate a Delta Ecosystem Restoration Strategy/Plan that can achieve the broad buy-in necessary from a remarkably diverse stakeholder community. What form such a collaborative organization can or should take is beyond the scope of this document but it is clear that Delta Vision, BDCP, ERP, OCAP, and ESA must work together, probably along with CVPIA and the Water Board. DRERIP and IEP along with the CALFED Science Program provide the main science foundation. Existing institutional arrangements do exist within the Ecosystem Restoration Program that could be built upon to address planning, implementation, grants dispersement, public involvement, science oversight, and resource agency coordination in the context needed today.

Moving in Parallel: Implementing the Many Actions Already Being Planned

It is critical to point out that parallel to this system-wide planning effort should be active efforts to implement actions that are already well underway in their own planning and design processes and that we have high confidence at this stage will generate significant benefits cost effectively. The tables in Section IV are intended to help identify these projects.

III. The Complex Delta: Opportunities and Constraints

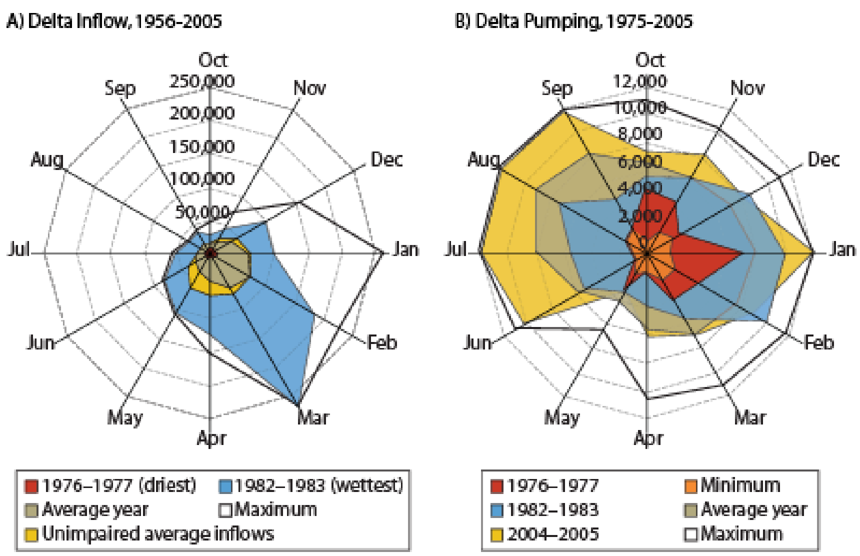
The complexity of the Delta defines the opportunities and constraints within which we must develop the ecological vision: inadequate knowledge, unpredictability, lack of control, uncertainty, and tightly coupled human-natural systems undermine our abilities to develop effective approaches. Ecological improvements will necessitate finding mutual human-ecological interests, accepting some trade offs, and working with complexity.

Ecosystem Restoration Opportunities

Focusing on restoring tidal marshes, floodplains, open water habitats (including flow and geometry changes), and stressor reductions, extensive opportunity exists even in face of the numerous impediments described later.

Flow

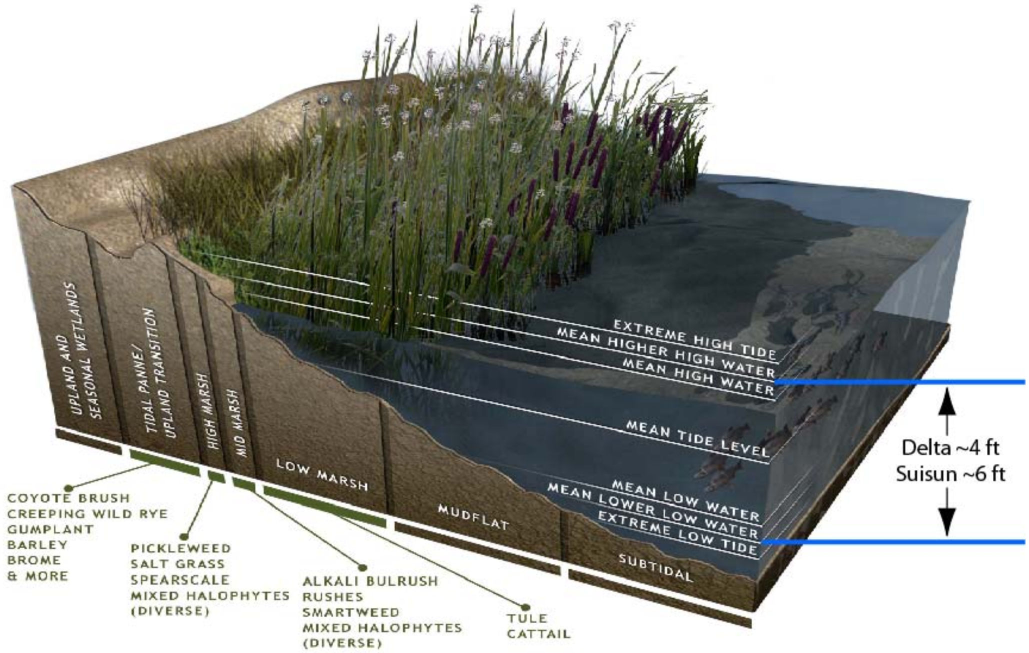
Restoring flows for the Delta ecosystem can be accomplished in numerous ways and developing and evaluating options is an active pursuit of other Delta planning efforts. Critical to defining how to restore flows is to understand the timing of needed flows to accomplish its many purposes. Native species evolved under natural Mediterranean climate conditions – winter wet, summer dry. We regulate inflows via dam operations and upstream diversions (diagram A below). We export throughout the year at varying magnitudes (diagram B below), a setting relatively disconnected from natural conditions. Well beyond the scope of this document is the effort to scrutinize water operations carefully alongside ecological needs to determine what to do when and how to accomplish it.



Seasonal and Annual Variability of (A) Delta Inflows and (B) Delta Pumping, from DWR DAYFLOW DATA. Note scale difference in flow rates between the two diagrams. *From PPIC 2007*

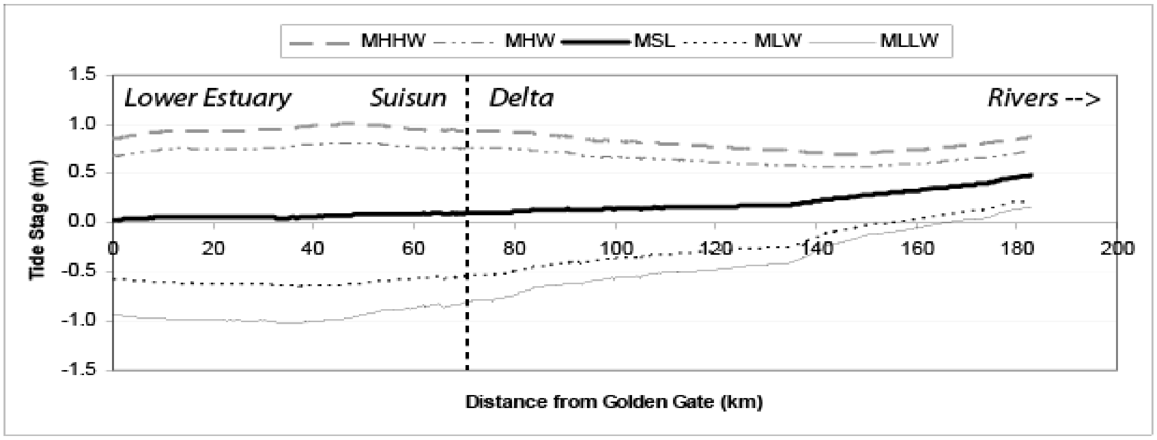
Opportunities and Limits: the Narrow Elevation Band of Intertidal Marshes

Tidal marsh exists within a narrow elevation band associated with the local tidal range. Tidal freshwater marsh vegetation grows at most intertidal elevations; Suisun's tidal brackish marsh vegetation grows across a narrower range of intertidal elevations; and the lower estuary's tidal salt marshes grow in the narrowest upper intertidal elevations.



Perspective view of a tidal brackish marsh profile (e.g., Suisun Marsh) with adjacent uplands and open water. *Moffatt & Nichol and Stuart Siegel, 2007*

The vertical range of the tides is not large – much of the Delta experiences tidal variations of around four feet; Suisun tides are closer to six feet. Not only does tide range decrease moving up the estuary to the rivers, the base height or mean sea level also rises because of the river inflows. Consequently, the actual elevations that are "intertidal" vary around the Delta and establishing the relationship between the land and water requires more than a simple analysis and to date has not been accomplished though DWR has efforts underway to provide these data.



San Francisco Estuary-California Delta Tidal Datum Profile (modeled). *From DWR 2004*

Within the ~500,000-acre Delta, there are about 58,000 acres of undeveloped, diked lands at intertidal elevations of which about 3,000 acres are at moderate to high risk of development (Figure 1). Suisun has about 28,000 acres at suitable intertidal elevations. Where sediment supply is higher such as the North Delta and parts of Suisun Marsh, sedimentation can raise land elevations; thus, lands that have very shallow subtidal elevations may be suitable for tidal marsh restoration as well. Suisun has another ~23,000 acres of shallow subtidal lands and the Delta about 25,000 acres.

Opportunities and Limits: Floodplains and Lowland Grasslands

About 118,000 acres in the Delta are undeveloped lowlands extending above current high tide heights to the +15 ft elevation; Suisun Marsh has about 5,000 acres. These lands could be used for accommodating sea level rise, floodplain restoration (large tracts already are actively managed floodplains: Yolo and Cosumnes), and habitats for wildlife species that utilize landscape mosaics of estuarine and grassland areas. Floodplains can and do extent further upstream than this somewhat arbitrary elevation indicates. About 19,000 acres are at moderate to high risk of development in the Delta. Were a higher sea level rise accommodation elevation used, then there would be more land acreage of this type.

Geometry

Humans have constructed numerous “connecting” waterways throughout the Delta for shipping and water supply conveyance (Figure 2). Connecting what were naturally disconnected waterways that produced significant heterogeneity in the aquatic environment has radically altered flow geometry and homogenized the aquatic environment, changing flow routes and residence time that affects fish, their food resources, and water quality. Native species evolved under natural heterogeneous conditions and likely a cause of their decline is the modern homogeneity of the Delta’s remaining aquatic environments. The current water surface area of the Delta is about 57,000 acres (excluding Liberty Island and Little Holland Tract which add another 6,000 acres), much of which could be enhanced to provide improved open water habitats for aquatic species. Suisun has about 26,000 acres of open water.

Active Impediments to Ecosystem Recovery

Several stressors actively impede ecosystem function in today's Delta, and could obstruct our future success. In approximate order of significance they are:

Habitat loss: reclamation and flood control

Reclamation and flood control have eliminated more than 95% of the Delta's original 450,000 acres of wetlands. Floodplain and riparian losses within and upstream of the Delta have suffered similar fates. These losses eliminate habitats for foraging, breeding, and refuge; eliminate important ecosystem functions that benefit wildlife and humans; and create undue reliance upon and pressure on the remaining areas.

Diversions, conveyance, exports, and flow

Diversions above and within the Delta, conveyance across the Delta, exports, maintaining export water quality are the most significant set of controls on the Delta's aquatic ecosystem. The collective impacts on flow regimes, inundation patterns and water quality create several fundamental conflicts with ecosystem processes. Flow is a fundamental element of habitat and transport for pelagic organisms. Diversions entrain fish and their food resources. Flow direction and magnitudes affect migration and movement of fish and their food supplies, limit access to suitable habitats, and alter water quality. Water supply management controls salinity variability and residence time which affects primary and secondary production and many related ecological processes. Constructed waterways have created artificial links among natural waterways, altering flow direction and volume, salinity and residence time. Collectively, these stressors comprise the single greatest driver on population viability and ecosystem resiliency.

Geometry, variable residence times, and connectivity

Historically, the Delta contained major rivers and sloughs as well as branching, dead-end or dendritic channel networks connected to their adjacent floodplains and marshes. This geometry provided high residence time diversity critical in primary production and other ecological processes. Reclamation eliminated many of the dead-end slough systems and removed marshes and floodplains. Dredging and channeling of waterways for navigation and conveyance connected most remaining waterways (see Figure 2). Today the Delta consists largely of nothing but levee-confined conveyance canals carrying water around and above isolated islands. These changes have greatly homogenized Delta residence times and eliminated ecological connectivity, thereby disrupting many key ecological processes.

Water quality: discharges from agriculture, wastewater, industry, recreation

Selenium, Pyrethroids, ammonium, mercury, heavy metals, persistent organic compounds, oil and grease, and many more classes of contaminants enter the Delta from numerous sources within and outside the Delta. These contaminants can have direct and indirect adverse impacts to wildlife, interfere with ecosystem productivity, alter food web structure, and impact public health.

Invasive species: competition, habitat modifications, predation

The San Francisco Bay Estuary and Delta is one of the most invaded aquatic systems in the world. Future invasions are inevitable. Keystone species – those that play a vital role in shaping the natural environment – present the largest headaches. Several species severely restrict our ability to improve the Delta's natural resources. Brazilian waterweed (*Egeria*), water hyacinth (*Eichhornia*), overbite clam (*Corbula*), and asian clam (*Corbicula*) are the four most significant keystone species currently affecting the Delta's ecosystem. They alter habitat suitability, consume vast quantities of primary and secondary production, and alter species composition and food web structure.

Dams: sediment supply and flow regimes

The capture of sediment by dams reduces sediment supplies into the estuary and deprives the Delta of the material needed for restoring intertidal land elevations. Some species, such as Delta smelt, require sediment-based turbidity for successful feeding or predator avoidance. Dams also regulate river flows, converting natural runoff regimes into ones with reduced winter and spring flows and increased summer and fall flows; native plant and animal species evolved under flow regimes of high inter- and intra-annual variability that differ strongly from our current managed regime.

Looming Impediments to Ecosystem Recovery

Several changes will impede ecosystem function in tomorrow's Delta. Some we may be able to address while others we have no control over and must design our future taking them into account. As with the active impediments above, these looming impediments could obstruct success.

New species invasions

New invasions, particularly quagga mussels, should be expected and considered in restoration planning. It is important to reduce the likelihood of new invasions by improving such things as border inspections and ballast water management. However, in the long term such actions can only reduce the number or delay the arrival of new invaders and give us breathing room to prepare for their impacts. These invasions will be excellent tests of the resilience of our ecosystem and our best tools to minimize their effects will be to focus restoration efforts on those uniquely Californian habitats and processes that native species rely on.

Levee integrity

Ecosystem recovery strategies that rely upon intact levees present high risk of failure. In the shorter term, though, we may be forced to rely on these levees. In the long term, we should anticipate the ecosystem impacts of those levees most likely to fail and integrate such expectations into our efforts.

Subsidence

Subsidence of delta lands has greatly limited our opportunities for restoration. Costly and complex earthworks projects are not likely to be the most effective use of limited ecosystem restoration dollars, making options for subsided lands far more limited. Figure 2 shows Delta lands situated approximately within modern intertidal elevations. Many areas combine high-risk levees with high levels of subsidence making the long-term value of these lands to the ecosystem (or for any other use) questionable.

Sea level rise

Strategies must incorporate landward migration of tidal influence wherever possible, address available sediment supply and plant productivity necessary for building land elevations, and address higher river stages and how floodplains flood, all while keeping our eyes on flood control concerns. Site choice of suitable habitat restoration efforts must consider not only current benefits but benefits into likely futures.

Climate change and variability

Though multifaceted, the most significant effects of climate change concern how much water will be available for the ecosystem, seasonal timing of that water supply, and the quality of that water especially, but not only, its salinity. Continued shifts in California precipitation patterns away from snowfall to rain will put additional stress on levees and subsided lands by increasing the frequency, duration and strength of flood flows.

Population growth

Development on the Delta periphery removes lands suitable for restoration and essential to accommodate sea level rise, exacerbates the many stressors that accompany urbanization, forces levee maintenance, and vastly complicates nearby restoration efforts by creating and exacerbating flood control needs.

Private land ownership

Much of the lands ideally suited for ecological restoration are privately owned. To make real advances in achieving the Delta ecological vision, we must protect extensive lands from development and restore natural ecosystems on a vast scale, collectively representing many tens of thousands of acres of land. Coordinated efforts amongst the land owner community and local, state and federal governments and NGOs will be a corner stone for making real progress with acquiring fee title or conservation easements.

Tidal restoration changes tidal range

Restoring lands to tidal action for marsh restoration causes the rise and fall of the tides themselves to change, resulting in lower high tides and higher low tides or less "tidal range". Tide range could be reduced by up to 2 feet or so. As marsh restoration sites rebuild their elevations, the dampening of tidal range will diminish. The consequence for restoration is that the "band" of suitable intertidal elevations (Figure 1) narrows, leaving us with more and deeper subtidal areas and less restored acreage at upper elevations.

Principles for Formulating Ecosystem Recovery Strategies

From the above descriptions of opportunities and constraints affecting Delta ecosystem restoration, we can articulate a series of principles to guide our ecosystem recovery strategy. These principles include: (1) guide where we want to go, (2) determine how to get there, (3) understand the positive and negative outcomes, (4) address competing hypotheses of how the human-natural system functions and can we can adjust it.

We drew upon several recent documents for these principles: the Bay-Delta Conservation Plan *Draft Science Advisors Report*, October 2007; Michael Healey's *Design Principles for a Sustainable Ecosystem in the Bay-Delta*, October 2007; Michael Healey's *Ecological Context Memo*, July 2007; Stuart Siegel's *Delta Restoration Primer*, July 2007; Stuart Siegel's talk at the State of the Estuary Conference, *Determinism, Randomness, and Chaos: Delta Ecosystem Restoration*, October 2007; and work of the nascent *Delta Vision Eco Design Team*. Readers interested in more depth should refer to these documents.

There are a number of ways to articulate principles and the discussion around these principles will continue. We have drawn primarily upon the Draft BDCP Science Advisors Report with added principles from the other sources. Many of the region's scientists actively engaged in Delta efforts participated in developing the BDCP principles and they in turn drew upon a variety of sources including the two Michael Healey documents.

Ecosystem recovery will only be achieved through addressing the active and looming impediments described above

Stressor reduction is one of the three variables of the "recovery recipe" above. Of all the listed stressors, it is clear that recovery is most dependent upon restoring natural habitats and reducing the impacts of water management on the ecosystem.

Restore habitats around the Delta to spread risk of localized or region-wide disasters

Multiple examples of each restored habitat type around the Delta will provide resilience to localized or region-wide disasters in the Delta. This approach suggests that there will be continuing conflict between the desirability of multiple restoration sites to guard against disaster and to spread benefits more broadly versus fewer larger sites where benefits may be disproportionately valuable.

Keystone species play significant roles in Delta ecology

Keystone species exert broad-ranging effects on ecosystem structure and/or function through alterations in competition and predator-prey dynamics. Keystone species additions (invasive species) and removal (species extinctions) have and will continue to affect Delta Ecology.

The coupled human-natural systems are integral to the Delta's future

Management of human activity and uses of the landscape and water is integral to successful management and conservation of desired species, ecosystem types and biodiversity in the Delta/estuary. The value of a healthy ecosystem to the humans that use it is often hidden in arguments about costs and conflicts.

Connected, diverse habitat mosaics support resiliency

Connectivity across habitats and the diversity of those habitats are essential features of ecosystem functions and support resiliency. No species in the delta uses only one habitat, making it important to identify all the habitats used by different life stages and to understand how animals move among the habitats they require.

Drawn from the Bay-Delta Conservation Plan October 2007 Draft Science Advisors Report

1) Changes in the estuarine ecosystem may be irreversible
2) Future states of the Delta ecosystem depend on both foreseeable changes (e.g., climate change and associated sea-level rise) and unforeseen or rare events (e.g., the consequences of new species invasions
3) The Delta is part of a larger river-estuarine system that is affected by both rivers and tides. The Delta is also influenced by long-distance connections, extending from the headwaters of the Sacramento and San Joaquin rivers into the Pacific Ocean
4) The Delta is characterized by substantial spatial and temporal variability, including disturbances and extreme events that are fundamental characteristics of ecosystem dynamics. The Delta cannot be managed as a homogeneous system
5) Species that use the Delta have evolved life history strategies in response to variable environmental processes. Species have limited ability to adapt to rapid changes caused by human activities

6) Achieving desired ecosystem outcomes will require more than manipulation of Delta flow patterns alone
7) Habitat for fish and wildlife species should be defined from the perspective of the specific suite of environmental needs of each species and not merely as vegetation type, land (water) cover type, or land (water) use type
8) Changes in water quality have important direct and indirect effects throughout the estuarine ecosystem
9) Land use is a key determinant of the spatial distribution of contaminants, and their temporal dynamics, and has other influences on the Delta ecosystem
10) Changes in one part of the Delta may have far-reaching effects in space and time
11) Prevention of undesirable ecological responses is more effective than attempting to reverse undesirable responses after they have occurred
12) Adaptive management is essential to successful conservation
13) Conservation actions to benefit one species may have negative effects on other species
14) Data sources, analyses, and models should be documented and transparent so they can be understood and repeated
15) Predicting ecosystem responses, especially to changes in system configuration, can be informed by the complementary use of statistical and process models. Statistical models can be used to document status and trends, while process-based models are required for understanding system responses and for forecasting responses to new conditions.
16) There are many sources of uncertainty in understanding a complex system and predicting its responses to interventions and change

IV. Initial Activities for Achieving the Ecological Vision

The initial activities for achieving the ecological vision come from applying five criteria to the broad range of possible activities; in applying these criteria, we acknowledge that many important efforts are not included that fully warrant future implementation. These criteria are:

1) Address the most important needs first
2) High potential for positive outcomes
3) Low potential for adverse consequences
4) Reasonable implementation horizon including complexity in working through existing constraints and uncertainties
5) Cost effective use of ecosystem dollars

The activities included here fall into one or more of the following categories:

- Acquire and restore lands for tidal marsh restoration
- Acquire easements or fee title and create new seasonal floodplains which can include ongoing agricultural production
- Enhance existing seasonal floodplains
- Acquire easements or fee title on key adjacent uplands for sea level rise accommodation and to preserve and establish habitat mosaics
- Relocate key diversions to reduce/remove ecosystem interferences
- Alter Delta geometry
- Cost share key activities with other primary purposes that offer clear ecosystem benefits
- Targeted flow increases for aquatic species
- Stressor reductions

Activities are split into two tables: Initial Ecosystem Restoration Activities (Table 1) and Activities Best Pursued in Parallel by Other Delta Efforts (Table 2). As some ecosystem restoration activities are or may be dependent on water conveyance configurations, Table 1 indicates degree of dependence.

The actions come from many source documents and conversations with people working on Delta issues across the spectrum: the Delta Vision Stakeholder Coordination Group, Delta Vision context papers, CALFED Ecosystem Restoration Program Stage 2 Conservation Measures, Pelagic Organism Decline studies, PPIC Report, Suisun Marsh Plan, Delta Regional Ecosystem Restoration Implementation Plan, and Bay-Delta Conservation Plan.

Finally, implementation budgets for actions should designate 10-20% of total funds for two purposes:

1) Conduct post-implementation project assessment (monitoring) with specific questions and methodologies formulated through a science-based adaptive management approach
2) Fund post-implementation corrective measures as needed. Improved scientific knowledge and unpredictable events could require adjustments.

One final note about Tables 1 and 2 – due to running out of time, not all entries are complete. One very notable general omission is that none of these activities are yet linked back up to objectives or goals, which several commentators suggested would be very helpful. A task for the next iteration!

Table 1. Initial Ecosystem Restoration Activities

1. Restore tidal marsh in Cache Slough complex

Description: (1) land acquisition including adjacent lowland grasslands, (2) interior grading as needed to reconstruct natural geomorphic features such as channel networks, (3) levee breaches, (4) relocate North Bay Aqueduct intake on Barker Slough, (5) relocate large local agricultural intakes, (6) active control of Brazilian waterweed, water hyacinth, clam
Purpose: (1) provide fish and wildlife habitats to benefit desirable species, (2) increase available primary production to support food web, (3) accommodate sea level rise to maintain functions over the long term, (4) intake relocation to shift net flow downstream and avoid drinking water dissolved organic carbon issue, (5) invasives: without control, colonization could reduce or preclude achieving target benefits
Expected Outcomes/Performance Indicators: (1) mosaic of evolving habitats supporting numerous species at significant scale; (2) connection to Yolo, Sac River, Suisun Marsh; (3) increased food supply for fish, birds, marine mammals; (4) landward migration of intertidal marsh over time; (5) reduced water treatment needs; (6) improved hydraulics so fish can reach habitats and primary production can reach Sac River and beyond
Rough Costs: acquisition and restoration – $ 75-100 M; intake relocations – $ 200-300 M?; invasives control – $ 10 M?
Implementation readiness: Moderate to high. Extensive land acquisition needed; ongoing efforts by DFG and Solano Land Trust. Intake relocations more complex as several options available; could tie to larger water supply endeavors. On all action lists.
Comments: Highest feasibility tidal marsh restoration in all of Delta due to least subsidence, proximity to highest Delta sediment supply, connection to extensive lowland grasslands, and proximity to Yolo Bypass, Suisun Marsh, and Sac River. Relatively little costly flood control requirements IF implement at large scale. Must address invasives issue and intake relocations. Possible to conduct targeted field studies to evaluate transport effects of intake relocation. Potential risk associated with this action due to the most prevalent population of Delta smelt occurring in this region of the Delta; monitoring of species and system response necessary to manage changes.
Acreage estimates: 8,400 ac intertidal; 13,300 ac lowland grassland; 1,400 ac shallow subtidal; 1,400 ac

medium subtidal; 600 ac deep subtidal
Activity categories: tidal marsh restoration, food web productivity, sea level rise accommodation, habitat mosaics, diversion relocation
South Delta Export Conveyance Dependence: None

2. Restore tidal marsh in Suisun

Description: (1) Implement Suisun Marsh Plan 9,000 acres <u>at a minimum</u>; (2) Land acquisition; (3) Interior flood control; extent highly property specific; (4) Restore tidal action
Purpose: (1) Provide habitats to support at-risk aquatic and terrestrial species; (2) Reduce ongoing adverse effects of diked lands management (especially low dissolved oxygen, subsidence)
Expected Outcomes/Performance Indicators: (1) Increased population abundances of at-risk aquatic and terrestrial species; (2) Reduced frequency and magnitude of low dissolved oxygen events and associated impacts to aquatic organisms.
Rough Costs: (1) acquisition ~$20 M; (2) implementation ~$20-50M
Implementation readiness: High. Suisun Marsh Plan EIR/S expected 2008.
Comments: Long-standing planning effort by federal, state, and local agencies including private land owners has led to development of Suisun Marsh Plan, nearly complete. EIR/S will provide significant step forward in impact analysis to facilitate permitting of restoration projects. Challenges for positive outcomes are limited sediment supply, invasive plants, invasive clams.
Acreage estimates: minimum 9,000 ac; there is about 28,000 acres of intertidal elevation diked lands plus another 23,000 acres that are at shallow subtidal elevations that may be viable for tidal marsh restoration
South Delta Export Conveyance Dependence: None except within broader context of salinity regimes

3. Conserve Cache Slough-Suisun ecological corridor

Description: (1) land or easement acquisition; (2) targeted land management enhancements
Purpose: (1) maintain undeveloped lowland grassland/vernal pool complex corridor that links Cache Slough to Suisun Marsh to support corridor-dependent species, (2) provide contiguous wetland-upland habitats to support multi-habitat dependent species and natural processes
Expected Outcomes/Performance Indicators: (1) mosaic of habitats supporting species dependent upon contiguous wetland and upland habitats, (2) conserve listed species dependent on lowland grasslands/vernal pool complexes, (3) provide avian and mammal migration corridor between freshwater wetlands in Cache Slough and brackish wetlands in Suisun
Rough Costs: $ 60-200 M for maximum land/easement acquisition acreage; lower with more targeted acquisitions. Enhancement and management endowments could add another $ 30-60 M again depending on acreage and properties
Implementation readiness: Moderate to high. Focus on acquisition of significant acreage fairly extensive; ongoing efforts by DFG and Solano Land Trust. Minimum land use changes necessary.
Comments: Proximity to Jepson Prairie and several conservation banks already being managed for wildlife
Acreage estimates: ~32,000 acres
South Delta Export Conveyance Dependence: None

4. Yolo Bypass Enhancements

Description: (1) convert Fremont weir to operable structure to allow lower Sac River flows to flood bypass; raise in spring to limit flooding at higher river stages only; (2) enhance fish passage through Fremont weir for multiple species; (3) enhance Lower Putah Creek local floodplain; (4) enhance connectivity, fish passage and agricultural access along toe drain/Lisbon weir; (5) update fish ladder at Fremont weir; (6) localized floodplain enhancement such as along toe drain.
Purpose: (1) Increase inundation frequency to yearly or biannual; (2) Improve quality and availability of juvenile salmonid rearing habitat; (3) Improve quality and availability of splittail spawning and rearing habitat; (4) Improve primary production exports to lower Sac River/west Delta; (5) provide for improved salmon and splittail access to Putah Creek; (6) Improve fish passage at Fremont weir; (7) Improve migratory and resident bird habitats
Expected Outcomes/Performance Indicators: (1) Improves existing habitats and values provided by one of the most significant flood control structures through diversity of habitats and enhancements of outdated facilities; (2) Increases primary production inputs to Delta during important spring flooding conditions; (3) Keeps landowners engaged and supportive of restoration; (4) Provides additional data on operational impacts at population level of listed salmon and sturgeon.
Rough Costs: $ 250 M
Implementation readiness: High. Extensive past efforts involving multiple stakeholders has identified range of options, concerns of land owners and agricultural interests as well as Yolo Wildlife Area management.
Comments: Contaminants such as methyl mercury may be problematic with additional flooding. The stakeholders of the Bypass have developed a strategy for how to move forward with restoration in the Bypass. Compatibility with flood control and potential conflicts with long term land management needs further evaluation. Viability of existing land uses and economics needs further evaluation as well.
South Delta Export Conveyance Dependence: None

5. Enhance Mokelumne and Cosumnes floodplains linked to tidal restoration

Description: (1) Implement Cosumnes River Preserve Management Plan; (2) Implement McCormick-Williamson tidal restoration from North Delta Flood Control and Ecosystem Restoration Project; (3) Advance floodplain planning, acquisition and enhancement on lower Mokelumne; (4) Establish agricultural leases similar to Yolo Bypass wherever possible
Purpose: (1) Expand floodplain into the Delta's edge through restoration of McCormack and setback levees along the north and south fork Mokelumne rivers; (2) Improve flood control for low-lying communities; (3) Provide spawning and rearing habitats for splittail; (4) Provide rearing habitats for outmigrating salmonids; (5) Provide increased primary production into the aquatic system
Expected Outcomes/Performance Indicators: (1) Provides channel habitat diversity and seasonal floodplain which would improve channel flow capacity in the Delta
Rough Costs: ???
Implementation readiness: High. Planning processes have been ongoing for the Cosumnes River Preserve and for the North Delta Flood Control and Ecosystem Restoration Project.
Comments: Refer to December 2007 Cosumnes River Preserve Draft Management Plan and the soon-to-be released Draft EIR/S for the North Delta Flood Control and Ecosystem Restoration Project for full details.

South Delta Export Conveyance Dependence: Potentially none though in close proximity to isolated facility and through-Delta conveyance routes so could be very affected

6. Restore tidal marsh at Dutch Slough

Description: (1) Select and construct alternative from design options; (2) Conduct science-based monitoring
Purpose: (1) Benefit fish and wildlife; (2) Inform key questions of design and outcomes applicable to other Delta restoration
Expected Outcomes/Performance Indicators: (1) Improved abundances of native fish species; (2) Increased primary and secondary production in local area; (3) evaluation of restoration design strategies applicable to other Delta restoration sites
Rough Costs: $ 50 M
Implementation readiness: Very high. CEQA should be completed in 2008, permits 2009.
Comments: DWR-owned property purchased with CALFED funds for restoration. Design prepared specifically to test key uncertainties in providing ecosystem functions for fish. Primary challenges are invasives (Brazilian waterweed, water hyacinth, clam) and lack of sediment supply to reverse subsidence.
Acreage estimates: 1,200 ac
South Delta Export Conveyance Dependence: None

7. Evaluate and Implement if Effective: reconnect Elk Slough to the Sacramento River and manage Elk, Sutter and Steamboat Sloughs for salmon passage and fish habitats

Description: (1) Conduct studies to determine relative benefits and detriments to salmon and other fish to address uncertainties relative to possible predation by introduced fish species; (2) If studies indicate benefits support moving forward, then remove levee at north end of Elk Slough at Sacramento River, convert rip-rap lined conveyance canals into riparian corridors, and explore whether re-aligning entrances to Sutter and Steamboat sloughs would increase ecological functions and connectivity
Purpose: (1) Validate that intended benefits would be realized before implement restoration action; (2) Improve salmonid passage routes through the Delta
Expected Outcomes/Performance Indicators: (1) Study results with clear recommendations regarding relative benefits, possible detriments, options for addressing detriments if benefits warrant implementation; (2) Increased survival of out-migrating juvenile salmonids; (3) May also benefit adult salmon up-migration
Rough Costs: ???
Implementation readiness: Fairly high. Studies could be implemented readily; implementation elements not as clear about readiness.
Comments: May have regional benefits in reducing Delta Cross Channel impacts. Short term studies of relative predation risk along different routes would enhance certainty of benefits. Design of river channel and entrance could greatly affect percent of population entering new pathway.
South Delta Export Conveyance Dependence: Potentially very high dependence

8. Provide matching funds to improve wildlife-friendly agriculture

Description: (1) Provide matching funds to available federal Farm Bill sources (2) Use funds to implement long-term wildlife-friendly agricultural practices on lands not likely to be converted for habitat restoration
Purpose: (1) Improve habitats for migratory birds on Pacific Flyway; (2) Improve habitats for resident wildlife including Sandhill Crane, reptiles, amphibians; (3) Provide mechanism for reducing conflicts between agriculture and wildlife
Expected Outcomes/Performance Indicators: (1) Increased quantity of lands supporting wildlife; (2) Improved functions of agricultural lands to benefit wildlife; (3) Reduced adverse effects of agricultural lands on wildlife.
Rough Costs: $ 100 M arbitrary amount; should be sufficiently large to have meaningful impact
Implementation readiness: High. Depends on renewal of federal farm bill currently held up in Congress; could be rolled out very quickly as large body of available knowledge on what practices to implement
Comments: Acknowledges important role of agricultural lands supporting wildlife. Incentive programs in the majority of the Delta's agricultural practices would do little to reduce the risk of catastrophic levee failures. Better suited for higher elevation lands not likely to be converted any time in the near future to tidal or floodplain habitats as not so dependent on levee stability to provide ecological benefits.
South Delta Export Conveyance Dependence: Potentially very high dependence to the extent that agricultural water supply quality is affected by conveyance

9. Conduct science-based adaptive management research and assessment (monitoring)

Description: (1) Funds distributed through body governed by scientists from multiple organizations and managers *independent* of any one organization's control. (2) Entity to develop and implement Adaptive Management Research and Monitoring Plan in progressive stages (i.e., regularly update the plan itself); (3) Build upon existing institutions of Science Program and IEP
Purpose: (1) Complexity of system + unpredictability of timing and effects of future events + unpredictability of responses to restoration = need for clear understanding of system and its responses to actions and external drivers; (2) Provide multi-year funding so scientists can spend time doing science not fund raising; (3) Allocate funding based on priorities identified in the Adaptive Management Plan
Expected Outcomes/Performance Indicators: (1) Guide phased implementation based on improved system understanding and on outcomes of prior actions and dynamic external drivers; (2) Identify and correct problems resulting from our actions and external drivers
Costs: Minimum $ 250 M (10% of total funds available) that are additional to activity-specific funds dedicated to post-implementation science-based monitoring
Implementation readiness: High.
Comments: Fundamental element of successful ecosystem restoration

10. Evaluate potential for lower San Joaquin River floodplain and implement if viable

Description: (1) Conduct focused evaluation of existing topographic data and river stage data to determine flood frequency potential of lands from Vernalis to Old River plus one parcel on east side of San Joaquin between Old River and Highway 4 bridge; (2) Evaluate existing infrastructure impediments to flood flow conveyance, such as railroad and highways. IF viable options exist, then (3) Acquire lands or expand or establish new flow easements including Stewart Tract, south of Paradise Cut and further upstream areas; (4) Construct interior features, inflow and outflow structures; (5) Establish agricultural leases similar to Yolo wherever possible; (6) Coordinate and integrate with San Joaquin River flow negotiations
Purpose: (1) Create new floodplain habitat where none currently exists to provide habitats for juvenile salmonid rearing, splittail spawning and rearing, and to increase primary production for food web support; (2) Provide new migratory and resident bird habitats; (3) Provide flood bypass capacity to reduce flood potential along the lower San Joaquin
Expected Outcomes/Performance Indicators: (1) Attenuate flood flows on historic floodplain while enhancing survival and growth of salmonids, splittail and other native fishes; (2) Possible revenue stream from agricultural leases
Rough Costs: ???
Implementation readiness: Medium to high. Topographic and river stage data available. Infrastructure data generally available though level of detail needed may have to be acquired. Nature Conservancy completed opportunity assessment in 2001. Active efforts underway for San Joaquin River restoration that may link directly to opportunities on the lower river
Comments: Great potential exists for flood control and ecological benefits yet a very complicated endeavor. Some elements and outcomes conveyance dependent. Tied in part to upstream changes associated with river restoration and flow changes
South Delta Export Conveyance Dependence: Flood control benefits independent on conveyance. Ecological benefits highly dependent for the lower floodplain areas along south side of Old River; ecological benefits further upstream potentially less dependent on conveyance

11. Create clear passage route for migratory fish (especially salmonids) from Vernalis to Chipps Island: reverse selected constructed waterways connections

Description: (1) Isolate cross connections that connect the three historic forks of the lower San Joaquin River; (2) Manage and eliminate the oxygen sag barrier at Stockton (could be done by isolating the DWSC and routing fish around); (3) Isolate passage route from south Delta export effects; (4) Operate DCC to limit masking of SJR migration cues by Sacramento River water.
Purpose: (1) Allow for salmonid and other fish to migrate southern Delta effectively
Expected Outcomes: (1) Enhanced survival of juvenile salmonids; (2) Enhanced numbers of adult salmonids reaching spawning areas; (3) Connectivity between tidal restoration proposed in Action 5 below
Rough Costs: ???
Implementation readiness: Needs initial planning (including hydrodynamic modeling) to develop such a route

Comments: This action can be accomplished in a variety of ways; see "develop and implement ecologically beneficial through Delta conveyance system in Table 2, Item #6
South Delta Export Conveyance Dependence: High

12. Conserve lowland grasslands

Description: (1) Land/easement acquisition; (2) Establish agricultural leases wherever possible on acquired lands
Purpose: (1) Provide the lands necessary to sustain diverse estuarine habitats under future sea level rise; (2) Provides for ecological landscape mosaic essential to support many wildlife species
Expected Outcomes/Performance Indicators: (1) Persistence of quantity and quality of estuarine habitats around the Delta's perimeter over the long term; (2) Retention of landscape mosaics spanning estuarine and lowland grassland communities
Rough Costs: $ 200 M ??
Implementation readiness: Challenging as involves extensive land or easement acquisitions
Comments: Focus efforts where lands link to current or viable future intertidal restoration areas and where clear landscape mosaics can be established; focus initially on lands planned for development or within urban spheres of influence. Some of these lands may benefit from enhanced land management practices to promote ecological functions while retaining other land uses
Acreage estimates: 111,000 acres in the Delta; 5,000 acres in Suisun
South Delta Export Conveyance Dependence: Varies around the Delta; no dependence in northwest Delta, potentially high dependence along east Delta, and very dependent in south Delta

13. Increase late winter and early spring San Joaquin flows for fish

Description: (1) Extend spring pulse flow period to mimic natural freshets from April 1 through June 1; (2) provide rim dams on reservoirs to release "channel-forming flows" to mobilize spawning gravels and enhance natural river processes
Purpose: (1) Enhance outmigration of juvenile salmonids, splittail, maybe sturgeon; (2) improve spring run adult migration; (3) Inundate and maintain floodplain and riparian habitats in lowlands adjacent to or within the Delta
Expected Outcomes/Performance Indicators: (1) Increased reproduction of salmonids and splittail; (2) increased recruitment of salmonids and splittail
Costs: ???
Implementation readiness: High, as operational modification
Comments: Could also achieve some benefits under current conveyance configuration by coordination with water project operations, as with the currently implemented Vernalis Adaptive Management Program. This action needs to be done in conjunction with Action 2 above or alternative barriers to reduce entrainment at the south Delta Export Pumps

14. Restore tidal marsh in Fabian-Union-Middle Roberts complex

Description: (1) Land acquisition; (2) Interior grading to recreate natural geomorphic features such as tidal channels; (3) Levee breaches
Purpose: (1) Create food web productivity and inputs to Delta; (2) Enhanced rearing for salmonids, splittail and other native fishes
Expected Outcomes/Performance Indicators: (1) Improved food base for pelagic fishes outside of area occupied by overbite clam (*Corbula*); (2) Enhanced survival and growth of salmonids, splittail and other native fishes
Rough Costs: (1) acquisition could be $200 M or more; (2) restoration
Implementation readiness: Moderate. Extensive acquisition necessary. Dependence on conveyance fundamental control for implementation
Comments: Establishment of Brazilian waterweed (Egeria), water hyacinth (*Eichhornia*), and overbite clam (*Corbula*) must be addressed to facilitate realizing benefits. If restore all lands concurrently, eliminate need for flood protection measures as all lands are islands with natural upland edges along the southern boundaries. Critical element is how tides reach south Delta – via Old River, Middle River, perhaps reconnected Whiskey Slough to Middle River, and/or San Joaquin River. Approaches linked to conveyance options.
Acreage estimates: Complex as a whole contains 12,700 acres intertidal elevations, 18,000 acres of adjacent lowland uplands, 10,500 acres of shallow subtidal, and 12,500 acres of deeper subtidal or 53,700 acres total. A very significant size
South Delta Export Conveyance Dependence: High. Under current conveyance, export pumps would draw organisms (fish and prey) whenever operating, limiting benefits to those periods of little or no exports. If implement an ecologically-based through Delta conveyance (see Action 5 in Table 2) then would be very significant contribution.

Table 2. Essential Parallel Activities for Implementation by Other Efforts with Separate Funds

1. Invasives Control

Description: Brazilian waterweed, Water Hyacinth, Asian clam, overbite clam
Purpose: (1) Eliminate competition for primary production; (2) Eliminate habitats that support predatory fish; (3) Promote access by desirable fishes to restored intertidal habitats
Expected Outcomes/Performance Indicators: (1) Significant increase in available primary production to support beneficial aquatic food web dynamics; (2) Reduced predation pressure on native fishes; (3) Increased population abundances of desirable fishes
Implementation readiness: Moderate. Resolving environmental issues around aquatic herbicide application for the invasive plants a major concern. Effective methods not clear for all species requiring control
Comments: High priority to fund existing control efforts, work through environmental concerns of control methods, and fund research to identify control options if any where none currently known.

2. Increase spring Delta outflows

Description: (1) Implement management and operational activities to increase total Delta outflow during the February-June period in "below normal", "dry" and "critically dry" water years to create low-salinity habitat (i.e., 1 to 3 parts per thousand salinity) in Suisun Bay. This might be best achieved by revisiting the conditions required to 'trigger' Port Chicago compliance.
Purpose: (1) Increase amount (i.e., area or volume) of low-salinity open water habitat; (2) facilitate downstream transport of sediment, nutrients, prey, and anadromous and estuarine juvenile fish; and (3) promote improved abundance and survival of multiple fish and aquatic invertebrate species;
Expected Outcomes/Performance Indicators: (1) Increased population abundances of longfin smelt, striped bass, other spring-outflow dependent species; (2) increased area or volume of low-salinity habitat during the spring; and (3) increased intra-annual variability in salinity to produce conditions less favorable for some invasive and stressors species particularly the toxic blue-green algae *Microcystis* and overbite clam.
Implementation readiness: Moderate to high.
Comments:

3. Increase fall Delta outflows to maintain X2 at 80km Sep-Dec

Description: (1) Implement management and operational activities to provide total Delta outflow levels sufficient to restore interannual variability in fall X2
Purpose: (1) Improve habitat quality for delta smelt, juvenile striped bass; (2) Return variability to the extent and geographic location of low salinity zone habitat required by delta smelt and juvenile striped bass
Expected Outcomes/Performance Indicators: (1) Increased population abundances of delta smelt, Longfin smelt, and striped bass; (2) Increased distribution and dispersal of delta smelt and juvenile striped bass; (3) Shift distribution of delta smelt and juvenile striped bass population further downstream and away from known stressors; (4) Increase intra-annual variability of salinity to produce conditions less favorable for some invasive and stressors species particularly the toxic blue-green algae *Microcystis* and overbite clam.
Implementation readiness: High.
Comments: Habitat has shrunk in recent years because steady low fall outflows move the appropriate salinities up into river channels versus being further into Suisun Bay, resulting in fish being restricted in distribution to less total water area and moving them into closer proximity to export impacts. In earlier wet years, this habitat varied over a wide range of areas and geographic locations.

4. Implement short-term conveyance enhancements to reduce known conflicts with Delta ecology such as entrainment

Description: (1) Export on ebb tides only; (2) Greatly reduce export during high turbidity first fall/winter flush; (3) Others ideas likely possible
Purpose: (1) minimize entrainment of fish, primary and secondary production; (2) Promote delta smelt movement to Suisun; (3) Reduce delta smelt entrainment
Expected Outcomes/Performance Indicators: (1) Improved survival and recruitment of several fish species; (2) Improved access to prey base; (3) Increased delta smelt abundance
Implementation readiness: High. Define operational scenarios, utilize real-time monitoring instruments
Comments: Could yield immediate benefits with minimum investment

5. Provide cost share for subsidence reversal and carbon sequestration wetlands at Sherman, Twitchell, Jersey Islands

Description: (1) Demonstration project 200-1,000 acres to complete research and development transition from Twitchell Island Pilot to full scale implementation; (2) Full scale implementation. Construction involves interior berms and water control structures, planting, operations, exterior levee maintenance.
Purpose: (1) Reduce adverse ecological and water supply effects of levee failures; (2) Initiate subsidence reversal on key islands to reduce their vulnerability; (3) Provide alternate crops for subsided Delta agricultural lands; (4) Provide nominal wildlife habitats to support desirable species; (5) In the very long term (many decades), open islands to tidal action after subsidence reversal complete.
Expected Outcomes/Performance Indicators: (1) Positive ground surface accretion; (2) Acceptable levels of constituents in discharge water (methyl mercury, dissolved organic carbon); (3) Quantified mass of carbon sequestered per acre per year to provide carbon marketplace credits for sale; (4) Development of complete set of tools for quantifying mass of carbon sequestered.
Rough Costs: $ 30 M
Implementation readiness: High. USGS has been preparing for demonstration project implementation in coordination with DWR; awaits funding only.
Comments: Focus efforts on maximizing peat regeneration and carbon sequestration
Acreage estimates: depends on how much of which islands converted

6. Develop and implement ecologically-beneficial through-Delta conveyance system

Description: (1) Formulate a through-Delta conveyance approach that maximizes its benefits to the Delta ecosystem, including salmon migration, habitats and flows for Delta smelt and other listed species; (2) reverse the connectivity created over the past several decades from constructed waterways that have homogenized the Delta aquatic ecosystem; (3) Redesign diversions to be along major flow paths rather than at terminal ends of waterways so as to minimize entrainment; (4) Revise inflow and export operations to benefit aquatic species
Purpose: (1) Reduce the adverse effects of inflow reductions and exports; (2) Contribute to reversal of the constructed waterways that have homogenized the Delta aquatic ecosystem; (3) Maximize primary production and transport of that production to fish populations
Expected Outcomes/Performance Indicators: (1) Increased salmonid upmigration and juvenile outmigration; (2) Increased Delta smelt population abundances; (3) Reduced take at diversions; (4) Increased understanding of effects of various actions on the Delta ecosystem and on water supply
Implementation readiness: Moderate. New ideas beyond those considered by BDCP are essential. All ideas must be formulated through collaboration with hydrodynamicists and ecologists to work through probable benefits and impacts to aquatic species. Utilize advanced numerical modeling and other analytical tools to evaluate options thoroughly and without bias. Conduct focused field experiments on selected design aspects to test assumptions of outcomes.
Comments: Blend ideas coming from outside BDCP with resource agency concerns about breadth of benefits and detriments. Much work remains on this topic.

7. Reduce contaminant loadings

Description: Selenium, mercury, Pyrethroids, ammonium, heavy metals, persistent organic compounds, oil and grease, and other toxicants on SWRCB 303(d) list
Purpose: (1) Reduce adverse effects of contaminants
Expected Outcomes/Performance Indicators: (1) Improved habitat suitability for aquatic organisms; (2) Reduced toxicity to fish and wildlife resources and human receptors that consume fish and wildlife
Implementation readiness: Moderate to high.
Comments: Ongoing efforts to address certain contaminants. Ammonium and Pyrethroids effects most recent to gain better understanding of their adverse effects. Much work remains on this topic.

8. Experiment with targeted salinity intrusions to control invasive species and promote fish populations (needs completion)

Description: (1)
Purpose: (1) Test effectiveness at promoting conditions that support desirable aquatic species such as Delta smelt; (2) Test effectiveness at controlling Brazilian waterweed, water hyacinth, asian clam
Expected Outcomes/Performance Indicators: (1) Determine what if any approaches to variable salinity are effective at promoting viable populations of desirable species; (2) Determine what if any approaches to variable salinity are effective at controlling freshwater invasive species; (3) Through subsequent experiments, validate promising approaches
Implementation readiness:
Comments: Refer to outcomes from Variable Salinity workshop held at CBDA in 2007

9. Screen diversions where determined beneficial by fish biologists

Description: Install fish screens on in-Delta diversions at locations where benefits anticipated as determined by fish biologists
Purpose: (1) Reduce magnitude of entrainment
Expected Outcomes/Performance Indicators: (1) Reduced take of fish into diversions
Implementation readiness: High
Comments: Not all diversions may warrant screens. Operations and maintenance costs can be substantial and may not be cost-effective in the long term

10. Replace earthen portions of railroad with causeway across Yolo Bypass

Description: Replace extensive portions of the earthen railroad bed with causeway structure
Purpose: (1) Main purpose is to improve flood flow conveyance; (2) Secondary benefits to circulation and management flexibility for wildlife management
Expected Outcomes/Performance Indicators: (1)
Implementation readiness: Low. Extensive engineering required. Complex MOUs may be required
Comments: Amtrak line recently upgraded for dual tracks between Davis and Sacramento

Acknowledgements and Author Biography

This document represents extensive input from a wide variety of individuals spanning several governmental and non-governmental organizations and draws upon not just their recent input but also upon their active involvement in Delta issues for years. At its core, this document synthesizes these many voices. Their input is more than gratefully acknowledged; without it, this document could not have been possible.

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