CALFED Bay-Delta Program
July 2000

Suisun Marsh Levee Investigation Report

Draft for July 24, 2000 Public Outreach Workshop

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LIST OF ACRONYMS

1-D	one-dimensional
1995 WQCP	1995 Water Quality Control Plan (also known as Bay-Delta Plan)
2-D	two-dimensional
ART	Agency Revision Team
BCDC	San Francisco Bay Conservation and Development Commission
CALFED	CALFED Bay-Delta Program
CCC	Contra Costa Canal
CVP	Central Valley Project
D-1485	Water Rights Decision 1485
DCC	Delta Cross Channel
DFG	California Department of Fish and Game
DICU	Delta island consumptive use
DSM1	Delta Simulation Model 1
DWR	California Department of Water Resources
EIS/EIR	Environmental Impact Statement/Environmental Impact Report
ESA	Endangered Species Act
EWH	extreme high water
IEPHPWT	Interagency Ecological Program Hydrodynamics Project Work Team
Investigation Report	Suisun Marsh Levee Investigation Report
Investigation Team	Suisun Marsh Levee Investigation Team
Levee Program	Levee System Integrity Program
MAF	million acre-feet
MHHW	mean higher high water
MHW	mean high water
MLHW	mean lower high water
MOA	Memoranda of Agreement
MSCS	Multi-Species Conservation Strategy
NBA	North Bay Aqueduct
NCCPA	Natural Community Conservation Planning Act
NGVD	national geodetic vertical datum
ppt	parts per thousand
Program	CALFED Bay-Delta Program
Reclamation	U.S. Bureau of Reclamation
RMA	Resource Management Associates
SEW	Suisun Ecological Work Group
SMSCG	Suisun Marsh salinity control gates
SRCD	Suisun Resource Conservation District
SWP	State Water Project
TDS	total dissolved solids
USCS	U.S. Soil Conservation Service, a former title for the Natural Resource Conservation Service
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Services

ACKNOWLEDGMENTS

This report is a collaborative effort of the Suisun Marsh Levee Investigation Team. The following individuals are key participants in the Investigation Team:

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Special acknowledgment is due Suisun Resource Conservation District (SRCD) for input to the Investigation Team and considerable assistance with public outreach. Gil Cosio of MBK provided the cost estimate information for Section IX. Bruce Wickland of SRCD assisted with Section X. California Department of Water Resource's (DWR's) Suisun Marsh Planning Branch prepared Section V and Appendix A. John DeGeorge and Richard Rachiele of Resource Management Associates (RMA) prepared Section VI and Appendix B. DWR and RMA collaborated on preparation of Section VII. Terry Mills of CALFED prepared Section III and the biological and physical setting appendix, with input from DWR's Suisun Marsh Planning Branch.

I. Summary and Findings

Overview

The mission of the CALFED Bay-Delta Program (Program or CALFED) is to develop a long-term comprehensive plan that will restore ecosystem health and improve water management for beneficial uses of the Bay-Delta system. The Program has identified six solution principles as fundamental guides for evaluating alternative solutions:

- *Reduce conflicts in the system* - Solutions will reduce major conflicts among beneficial uses of water.
- *Be equitable* - Solutions will focus on solving problems in all problem areas. Improvements for some problems will not be made without corresponding improvements for other problems.
- *Be affordable* - Solutions will be implementable and maintainable within the foreseeable resources of the Program and stakeholders.
- *Be durable* - Solutions will have political and economic staying power and will sustain the resources they were designed to protect and enhance.
- *Be implementable* - Solutions will have broad public acceptance and legal feasibility, and will be timely and relatively simple to implement compared with other alternatives.
- *Result in no significant redirected impacts* - Solutions will not solve problems in the Bay-Delta system by redirecting significant negative impacts, when viewed in their entirety, within the Bay-Delta or to other regions of California.

The Program addresses problems in four resource areas: ecosystem quality, water quality, levee system integrity, and water supply reliability. Each resource area forms a component of the Bay-Delta solution that is evaluated at a programmatic level in the CALFED Programmatic Environmental Impact Statement/Environmental Impact Report (EIS/EIR). The complex and comprehensive nature of a Bay-Delta solution requires a composition of many different programs, projects, and actions that address the four problem areas and will be implemented over time.

The foundation of every CALFED alternative includes six common programs: Ecosystem Restoration, Water Use Efficiency, Water Quality, Water Transfers, Watershed Management, and Levee System Integrity. CALFED also includes two variable programs, Storage and Conveyance. Each of the individual common program elements is a major program on its own, and each element represents a significant investment in and improvement to the Bay-Delta system.

The overall Levee System Integrity Program (Levee Program) objective is to reduce the risk to land use and associated economic activities, water supply, infrastructure, and ecosystem from catastrophic breaching of Delta levees. Levee Program actions currently focus on the legal Delta. The goal is to provide long-term protection for multiple Delta resources by maintaining and improving the integrity of the Delta levee system. In addition, the Levee Program aims to integrate ecosystem restoration and Delta conveyance actions with levee improvement activities. Improvements in the reliability of water quality will be a natural by-product of the program. Levee Program goals will be achieved through implementation of the Levee System Integrity Program Plan.

The specific elements of the Levee Program include the:

- Delta Levee Base Level Protection Plan
- Delta Levee Special Improvement Projects
- Delta Levee Subsidence Control Plan
- Delta Levee Emergency Management and Response Plan
- Delta Levee Risk Assessment and Risk Management Strategy

Please refer to the Levee System Integrity Program Plan technical appendix to the CALFED Programmatic EIS/EIR for more information.

Suisun Marsh Levees Investigation

The Suisun Marsh is a principal waterfowl wintering area in California. It is a brackish marsh, consisting of approximately 88,000 acres of tidal marsh, managed wetlands, and waterways.

The Suisun Marsh area received heightened attention in February 1998, when numerous exterior levee breaches resulted in inundation of over 22,000 acres and threatened the integrity of California Department of Water Resources (DWR)/U.S. Bureau of Reclamation (Reclamation) facilities. DWR and Reclamation provided emergency repair resources at a cost of approximately $1.1 million dollars. Extensive damage also was sustained during this event by California Department of Fish and Game (DFG) property and private properties.

The Suisun Marsh Levees Investigation was undertaken to determine the merits of including Suisun Marsh levees as a component of the Levee Program. The Suisun Marsh Levee Investigation Team (Investigation Team) was assembled at the request of the CALFED Policy Group to conduct modeling analysis, ecosystem restoration research, and public outreach in order to determine whether including a Suisun Marsh levees component in the Levee Program would contribute to the overall objectives of the CALFED Program in a cost-effective manner.

This Suisun Marsh Levees Investigation Report (Investigation Report) provides detail on the modeling, research, and outreach efforts of the Team. The Investigation Team has developed the information needed for the CALFED Program to make an informed decision on whether spending money on Suisun Marsh levees is a cost-effective way to meet its primary objectives and solution principles.

The Team has identified significant links between Suisun Marsh Levee maintenance and achievement of CALFED Program goals, particularly regarding water quality (transport of ocean-derived salts), water supply reliability, and ecosystem restoration. Furthermore, modeling research indicates a significant risk of water quality impacts in the Delta if Suisun Marsh levees are inadequately maintained and breach.

Recommendations

The Investigation Team recommends that Suisun Marsh levees be included in the Levee Program component of the CALFED Program.

A detailed explanation of the rationale for the above recommendation is included in Section X, "Analysis of Modeling and Research Results." In addition, the Team has outlined recommended elements for a Suisun Marsh Levee Program in Section XI, "Conclusion and Recommendations," based on the Investigation research and public outreach efforts.

Contents of the Report

This Investigation Report consists of 11 sections and 3 technical appendices:

- Section I, "Summary and Findings," provides an overview, presents the recommendations of the Suisun Marsh levee Investigation Team, and describes the content of the Investigation Report.
- Section II, "Investigation Background," provides the rationale and background for investigating whether the Suisun Marsh levees should be included in the CALFED Levee Program.
- Section III, "Suisun Marsh," discusses the physical and biological characteristics of the Suisun Marsh.
- Section IV, "Investigation Considerations," addresses factors considered in the Investigation, such as the linkage between the Investigation and achievement of CALFED objectives.
- Section V, "DWR Modeling Results," summarizes the approach, assumptions, and results of one-dimensional modeling of several levee breach scenarios in the Suisun Marsh.
- Section VI, "RMA Modeling Results," describes a corroborative two-dimensional modeling effort for the Suisun Marsh.
- Section VII, "Model Reconciliation," summarizes the results for the one- and two-dimensional modeling efforts for the Suisun Marsh.
- Section VIII, "Public Outreach and Other Research," describes the outreach efforts for the Investigation.

- Section IX, "Cost Estimates for a Suisun Marsh Levee Program," describes factors to be considered in establishing a levee program. The section also provides rough estimates of the costs for levee maintenance and habitat creation in the Marsh.
- Section X, "Analysis of Modeling and Research Results," summarizes the Investigation results and costs estimates in terms of the Investigation goal: developing the information needed for CALFED to make an informed decision on whether spending money on Suisun Marsh levees is a cost-effective way to meet the Program's primary goals and solution principles.
- Section XI, "Conclusions and Staff Recommendations," contains the recommendations of the Investigation Team.
- Section XII, "References," includes the sources cited in this report.
- Three technical appendices contain additional information on the modeling effort and the biological, regulatory, and physical setting of Suisun Marsh.

II. Investigation Background

Introduction

The Suisun Marsh is a principal waterfowl wintering area in California. It is a brackish marsh, consisting of approximately 88,000 acres of tidal marsh, managed wetlands, and waterways. Two types of levees make up the levee system in the Suisun Marsh: interior and exterior levees. Interior levees are lower and are used to control and spread water or separate ponds within the boundaries of the diked marshland. These levees enable landowners to individually manage their property in order to enhance waterfowl habitat. The exterior levees are larger and protect the marshland against tidal inundation and uncontrolled flooding.

The Suisun Marsh area received heightened attention in February 1998, when numerous exterior levee breaches resulted in inundation of over 22,000 acres and threatened the integrity of California Department of Water Resources (DWR)/U.S. Bureau of Reclamation (Reclamation) facilities, including Roaring River Distribution System, the Morrow Island Distribution System, and the Suisun Marsh Salinity Control Gates (SMSCG). DWR and Reclamation provided emergency repair resources at a cost of approximately $1.1 million dollars. Extensive damage also was sustained by DFG and private properties during this event.

Suisun Marsh Levee Investigation

Basis for the Investigation

The Agency Revision Team (ART) process was established in early 1998 to discuss and, if possible, resolve issues of the CALFED agencies regarding the CALFED Program that arose during preparation of the Draft Programmatic EIS/EIR. The issues that could not be resolved by ART then were elevated to the CALFED Management Team and Policy Group for resolution. As a member of the ART, DFG advocated including the Suisun Marsh levees as a component of the Levee Program.

DFG recommended that selected elements of the Levee Program be extended to the Suisun Marsh and that sufficient additional funding be included in the CALFED Levee Program to assure no conflict with Delta needs. This recommendation included extending the Base Level Protection Plan, Special Improvements Projects, and Emergency Management Plan elements of the Levee Program to the Marsh. Other elements, such as the Subsidence Control Plan and Seismic Risk Assessment, were not recommended for inclusion. (Detail on the specific elements of the CALFED Levee Program is provided in the Levee System Integrity Program Plan, a technical appendix to the CALFED Programmatic EIS/EIR.)

DFG's rationale was that this option ensured meeting the seasonal wetland implementation objectives and targets for the Suisun Marsh contained in the Ecosystem Restoration Program. Expanding the program to the Suisun Marsh also would foster support for the CALFED Program from stakeholders in the Marsh. A sudden failure of levees in the Marsh would not necessarily guarantee that the best available lands would be voluntarily transformed into tidally influenced wetlands. In addition, a break could threaten the integrity of other internal levees that are not built to serve the role as an external levee. Further levee failure and subsequent habitat changes could delay the Ecosystem Restoration Program's overall ability to achieve its goals, objectives, and targets. Improved levees would help to ensure that conversion to tidal wetlands would not be due to levee failure but instead would be planned with consideration of landowner support, Ecosystem Restoration Program targets, regional wetland goals, and endangered species recovery plans. It was stressed that the conversion of managed seasonal wetlands to tidally influenced wetland would require that willing participants be found. It was also recognized that increased costs to the CALFED Program were unknown and would need to be evaluated.

The ART expressed four major concerns with including Suisun Marsh Levees in the CALFED Program:

- *Uncertainty of linkage to CALFED objectives.* There was uncertainty as to whether or not Suisun Marsh levees provided the same benefits as Delta levees to the CALFED objectives.

- *Competition for funds.* It was recognized that expansion of the Levee Program into the Suisun Marsh could result in the limited funding available to the current Levee Program being diluted further and could result in insufficient funding for the Delta itself. Delta stakeholders generally are opposed to any action that would diminish the available funding needed to protect the Delta's levees.

- *Lack of coordination between levee work and tidal and seasonal wetland strategies.* ART members were concerned that funds could be expended unnecessarily because of future actions to restore tidal wetlands in order to achieve Ecosystem Restoration Program targets. Maintaining and rehabilitating Suisun Marsh levees that could be torn down a few years later would result in an inefficient use of public funds. Levee work could interfere with achieving tidal wetlands restoration targets.

- *Inadequate expansion of the Levee Program into the Suisun Marsh.* It was thought that the scope of the proposed program expansion may have been inadequate. If the expansion included only the Emergency Response portion of the program, opportunities would be lost to make relatively minor repairs and maintenance that would avoid costly levee breaks in the future.

The issue of whether to include the Suisun Marsh levees in the CALFED Program was not resolved during the ART Process and consequently was elevated to the CALFED Management Team and Policy Group. At its July 1998 meeting, the Management Team generally supported the addition of the Suisun Marsh levees but asked that additional information be provided at the Policy Group meeting on the linkages of Suisun Marsh levees to the CALFED Program mission and objectives, and the feasibility of adding the levees in the time frame of the June 1999 Draft Programmatic EIS/EIR.

In spring 1998, the CALFED Policy Group adopted inclusion of the Suisun Marsh levees in the CALFED Levee Program as an optional strategy to achieve CALFED goals but required that more information be gathered to address concerns raised during the ART process. Additional information would enable the

CALFED agencies to make an informed decision of whether spending money on Suisun Marsh levees is a cost-effective way to meet CALFED Program primary objectives and solution principles. This action provided the impetus for the Suisun Marsh Levee Investigation effort.

While the Investigation Team was conducting its research and modeling, DFG prepared a summary of potential impacts for the June 1999 Draft Programmatic EIS/EIR. This summary provided the necessary legal programmatic documentation for the potential impacts associated with including the Suisun Marsh levees in the CALFED Program should further research indicate fully adopting the strategy.

Geographic Scope of the Investigation

The scope of this Investigation includes the boundaries of the Suisun Marsh area as represented by the Suisun Resource Conservation District (SRCD). The Suisun Marsh is located in southern Solano County, south of the cities of Fairfield and Suisun City. The Marsh is bounded on the south by Suisun Bay, Honker Bay, and the confluence of the Sacramento and San Joaquin Rivers. On the west, the Marsh extends west of Highway 680 to the city limits of the City of Fairfield. On the north, the Marsh is bound by the Southern Pacific Railroad embankment to the city of Suisun City, and then by Highway 12 to Shiloh Road. On the east, the Marsh is bound by Shiloh Road south of Highway 12 to Collinsville.

Investigation Goals and Tasks

The goal of the Suisun Marsh Levee Investigation is to develop the information needed for the CALFED agencies to make an informed decision on whether spending money on Suisun Marsh levees is a cost-effective way to meet the Program's primary objectives and solution principles.

The primary objectives of the CALFED Program include:

- *Ecosystem Quality:* Improve and increase aquatic and terrestrial habitats and improve ecological functions in the Bay-Delta to support sustainable populations of diverse and valuable plant and animal species.

- *Water Supply*: Reduce the mismatch between Bay-Delta water supplies and the current and projected beneficial uses dependent on the Bay-Delta system.

- *Water Quality*: Provide good water quality for all beneficial uses.

- *Vulnerability of Delta Functions.* Reduce the risk to land use and associated economic activities, water supply, infrastructure, and the ecosystem from catastrophic breaching of Delta levees.

Considering these objectives, specific tasks were identified to gather information regarding areas of greatest potential benefit to the CALFED Program from inclusion of Suisun Marsh levees. The areas of greatest potential benefit from including a Suisun Marsh levee program are ecosystem quality, water quality, and water supply reliability. Investigation tasks developed to gather this information are presented below.

Ecosystem Quality

Ensuring the integrity of exterior levees in the Suisun Marsh is critical to sustaining seasonal wetland values provided by the Marsh's managed wetlands. Improved levees also would ensure that conversion to tidal wetlands will not be due to levee failure but instead will be planned with consideration of landowner support, Ecosystem Restoration Program targets, regional wetland goals, and endangered species recovery plans.

The Investigation Team recognized that quantification of potential ecosystem benefits in the Suisun Marsh would require development of habitat scenarios. These scenarios would be necessary to perform model runs to assess potential water supply reliability, water quality, and Ecosystem Restoration Program benefits. Scenarios were developed considering Ecosystem Restoration Program targets, regional wetland goals, and endangered species recovery plans.

TASK 1: Develop scenarios showing how many acres of tidal wetlands and other habitat types could be established in the Suisun Marsh, considering landowner support, Ecosystem Restoration Program targets, regional wetland goals, and endangered species recovery plans.

Water Supply Reliability and Water Quality

Ensuring the integrity of the exterior levees in the Suisun Marsh may be critical to sustaining water quality and therefore water supply reliability in the Delta. Preliminary modeling results indicated that large levee breaches on Suisun Bay tend to increase salinity in Suisun Bay and the Delta. In contrast, small levee breaches in certain areas of the Marsh may lead to reduction in Delta salinity of up to 10%.

This preliminary finding needed to be verified and quantified. Model runs also needed to be performed using the various habitat scenarios mentioned in TASK 1 to assess the potential water supply reliability and water quality benefits of each scenario.

TASK 2: Continue Suisun Marsh modeling including 2-D model verification of preliminary results.

TASK 3: Quantify potential water quality benefits from habitat scenarios developed in TASK 1.

COST ESTIMATES

Approximate cost estimates needed to be performed to gage the potential magnitude of costs for levee maintenance and habitat creation in the Marsh.

TASK 4: Develop cost estimates to breach levees as necessary, upgrade and maintain all other levees, mitigate lost managed wetlands, and perform other associated activities to implement the potential scenarios. Quantify the geotechnical and site access problems. Quantify the Emergency Response Program liabilities and benefits.

Results from completion of the above tasks are presented in the various sections of this Investigation Report.

CONDUCT OF THE INVESTIGATION

A kick-off meeting for the Suisun Marsh Levee Investigation Team was held on January 15, 1999. The group included DFG, SRCD, and DWR's Environmental Services Office–Suisun Marsh Branch staff. Following suggestions on additional parties to be contacted for input, the San Francisco Bay Conservation and Development Commission (BCDC), Solano County, and Reclamation also were included.

DWR had performed Suisun Marsh modeling following the extensive flooding that occurred due to breaks from the February 1998 floods. At the time the Investigation effort was initiated, DWR's Environmental Services Office was producing a report to summarize the results of the Suisun Marsh modeling. (The completed report is entitled "Preliminary Evaluation of the Impacts of Suisun Marsh Levee Breaches on Hydrodynamics and Salinity Trends in the Suisun Bay, Suisun Marsh, and the Delta" and was dated February 1999). It was suggested that a team of modelers be assembled for the modeling review to assess potential water quality benefits. This effort became the starting point for the Investigation. Detailed results of the modeling review are presented in Sections V, VI, and VII of this report.

The following individuals are key participants in the Suisun Marsh Levee Investigation Team:

Rob Cooke, CALFED (Levee Program Manager)
Gwen Knittweis, CALFED (Chair)
Chris Enright, DWR (Modeling)
Kamyar Guivetchi, DWR (Modeling)
Terry J. Mills, CALFED (Ecosystem Restoration)
Jim Starr, DFG (Ecosystem Restoration)
Gilbert Cosio, MBK (Engineering and Cost Estimates)
Steven Chappell, SRCD
Curt Schmutte, DWR
Dave Gore, Reclamation
Arnold Lenk, Local landowner representative and SRCD Board Member
Bruce Wickland, SRCD

It was intended that the group be well rounded to ensure sensitivity to numerous stakeholder concerns. Individuals who were unable to attend the meetings and meeting participants were kept informed of Investigation developments by an e-mail reflector that was set up for the Suisun Marsh Levee Investigation.

The reflector included the key Team participants, as well as representatives of Solano County, the BCDC, Reclamation, DWR, DFG, and the SRCD.

For specific analysis efforts, sub-teams were formed as needed. For example, a sub-team of biologists was formed to focus on interpreting the results of modeling analysis in terms of CALFED Ecosystem Restoration Program goals and impacts on the existing environment.

The Investigation Team organized a public outreach effort, the results of which are described in Section VIII of this report. Some Investigation oversight was provided by the Levees and Channels

Technical Team, a group formed to provide technical input and oversight for the CALFED Levee Program.

III. The Suisun Marsh

This section describes the need for restoration and the physical and biological setting for the Suisun Marsh. Additional information on the biological, physical, and regulatory setting for the Suisun Marsh is included in Appendix C.

Need for Restoration

The mission of the CALFED Program is to develop a long-term comprehensive plan to 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. Programs to address problems in the four resource areas have been designed and integrated to fulfill the CALFED mission.

Ecosystem goals presented in the Strategic Plan for Ecosystem Restoration will guide the Ecosystem Restoration Program during its implementation phase. Strategic goals include the following:

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 the Bay-Delta estuary and its watershed; and minimize the need for future endangered species listings by reversing downward population trends of native species that are not listed.

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

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

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

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

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

7. The Ecosystem Restoration Program addresses these strategic goals by restoration of ecological processes associated with streamflow, stream channels, watersheds, and floodplains. These

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processes create and maintain habitats essential to the life history of species dependent on the Delta. In addition, the Program aims to reduce the effects of stressors that inhibit ecological processes, habitats, and species.

These goals are being pursued in the Suisun Marsh and are described in more detail in the July 2000 Ecosystem Restoration Program Plan, Volume 2 – "Visions for Ecological Management Zones." The vision for the Suisun Bay and Marsh Ecological Management Unit is to restore tidal marsh and to restore and enhance managed marsh, riparian forest, grassland, and other habitats. (Please refer to the Ecosystem Restoration Program Plan technical appendix to the CALFED Programmatic EIS/EIR for more information.)

Efforts and opportunities to restore tidal action to selected managed wetlands and promote natural riparian and wetland succession in Suisun Marsh will be expanded. Shallow-water, wetland, and riparian habitats within the marsh and along the shorelines of the Bay will be protected and improved, where possible. Upland habitats adjacent to riparian and wetland habitats also will be protected and improved. Efforts will focus on increasing the acreage open to tidal flows (for example, by removing or opening levees) and providing connectivity among habitat areas to aid in the recovery of species, such as the salt marsh harvest mouse, clapper rail, and black rail. Those habitat areas will provide essential shelter and nesting cover during high tides. Improving marsh and slough habitats will benefit chinook salmon, striped bass, delta smelt, splittail, and other estuarine resident fish in the marsh and Suisun Bay.

GEOGRAPHIC SCOPE

The geographic scope of the Ecosystem Restoration Program is defined by the interdependence and linkage of the ecological zones that encompass the Central Valley. These ecological zones include the upland river-riparian systems, alluvial river-riparian systems, the Delta, and Greater San Francisco. The geographic scope defines the locations where actions might be implemented to maintain, protect, restore, or enhance important ecological processes, habitats, and species. Ecological attributes of some rivers or watersheds are valued more than those of other areas. These ecological values include the condition of important ecological processes and how well they support a diversity of habitats and biotic communities. The communities include the fish, wildlife, and plants that occupy or use the habitats within these local areas.

The Suisun Marsh/North San Francisco Bay Ecological Management Zone is the westernmost zone of the Ecosystem Restoration Program. Its eastern boundary is the Collinsville area, and to the west the zone is bounded by the northwestern end of San Pablo Bay. The northern boundary follows the ridge tops of the Coast Ranges and includes the Petaluma River, Sonoma Creek, Napa River, Suisun Bay and Marsh, and San Pablo Bay. This Ecological Management Zone is composed of five Ecological Management Units: Suisun Bay and Marsh, Napa River, Sonoma Creek, Petaluma River, and San Pablo Bay.

The boundaries of the Suisun Bay and Marsh Ecological Management Unit are Collinsville on the east, the Contra Costa County shoreline on the south, the Benicia Bridge on the west, and the ridge tops of the Coast Ranges on the north. The marshland and bay are in a valley, bordered on the north and south by the Coast Ranges. The predominant habitat types in this zone are tidal perennial aquatic habitat, tidal brackish emergent wetland, seasonal nontidal wetland, and grassland. The Marsh is primarily a managed wetland, with levees to control water level and seasonal flooding with fresh water.

MULTI-SPECIES CONSERVATION STRATEGY

CALFED has developed a Multi-Species Conservation Strategy (MSCS) to serve as the platform for compliance with the federal and state Endangered Species Acts (ESAs) and the state's Natural Community Conservation Planning Act (NCCPA). The MSCS has identified a subset of species that are (1) federally and state-listed, proposed, or candidate species, or (2) are other species identified by CALFED that may be affected by and for which the CALFED Program and the Ecosystem Restoration Program have responsibility related to recovery of the species, contributing to their recovery, or maintaining existing populations. Those species in the "recover species" designation depend on habitat conditions in Suisun Bay, the Delta, Sacramento River, San Joaquin River, and many of their tributary streams. For these reasons, the primary geographic focus of the Ecosystem Restoration Program is the Sacramento-San Joaquin Delta, Suisun Bay, the Sacramento River below Shasta Dam, the San Joaquin River below the confluence with the Merced River, and their major tributary watersheds directly connected to the Bay-Delta system below major dams and reservoirs. (Please refer to theMSCS technical appendix to the CALFED Programmatic EIS/EIR for more information.)

MSCS-evaluated species dependent on Suisun Marsh include the following species:

- California clapper rail
- California black rail
- Suisun song sparrow
- Salt marsh common yellowthroat
- Salt marsh harvest mouse
- Suisun ornate shrew
- Mason's lilaeopsis
- Soft bird's-beak
- Suisun thistle
- Delta tule pea
- Suisun Marsh aster

In addition, evaluated fish species that use Suisun Marsh and it tidally influenced habitats include all runs of chinook salmon (winter, fall, spring, late-fall), steelhead, delta smelt, splittail, longfin smelt, and green and white sturgeon.

The Suisun Marsh restoration program is designed to either recover, contribute to recovery, or maintain these species through restoration of natural ecological processes where feasible, restoration or enhancement of tidally influenced habitats, and elimination or reduction of stressors.

Physical Environment

The Suisun Marsh is located in southern Solano County, California, west of the Sacramento-San Joaquin Delta and north of Suisun Bay. The Marsh is within the Ecosystem Restoration Program's Suisun Marsh/North San Francisco Bay Ecological Management Zone and part of the Suisun Bay and Marsh Ecological Management Unit. The Marsh is bounded on the south by Suisun Bay, Honker Bay, and the confluence of the Sacramento and San Joaquin Rivers. On the west, the Marsh is bounded by State Highway 21, running from Benicia to Cordelia; on the north, by Cordelia Road to Suisun City, around the Potrero Hills to Denverton; and on the east, from Denverton along Shiloh Road to Collinsville (Ramlit 1983). The boundaries of the study area include Suisun Marsh, Suisun Bay, Honker Bay, Grizzly Bay, and the sloughs and channels contained therein. The watershed encompassing the Marsh is about 355 square miles: including 253 square mile of upland area and 102 square miles of marsh (DFG 1975).

The Suisun Marsh is ecologically distinct and situated in an environmentally sensitive area between the predominately fresh-water ecosystem of the Sacramento-San Joaquin Delta and the saline water ecosystem of greater San Francisco Bay. It is the largest contiguous estuarine marsh remaining in the United States and is recognized by the State of California for its biological importance (DWR 1999a). The Marsh is a complex land-water area of tidal wetlands, diked seasonal ponds, sloughs, and upland grasslands that comprise over 10% of the remaining wetlands in California. The Marsh is categorized as brackish due to the combined influences of saline ocean water from Suisun Bay and fresh water from the Sacramento-San Joaquin Delta (DWR 1999b). The Marsh provides a variety of habitats for many species of plants, fish, and wildlife and is very important to wintering and nesting waterfowl of the Pacific Flyway.

Suisun Marsh is adjacent to the Sacramento Valley and lies within a large notch in the Coast Ranges. The Marsh occupies a relatively narrow and broken plain just to the north of Suisun Bay. The Marsh includes a network of tidal sloughs that are primarily tributaries of the two major sloughs: Montezuma and Suisun Sloughs. About 90% of the marshland is enclosed by a system of low levees. Levees range in height from 4 to 8 feet above ground level. Most of the Marsh lies at an elevation at or below mean tide elevation. Hills surrounding the Marsh on the north and west rise to an elevation of 800 to 1,100 feet above the Marsh. To the east, the Potrero and Montezuma Hills rise 300 to 400 feet above the Marsh. Drainage from the hills is through the Marsh and into Suisun Bay. Major streams carrying runoff from surrounding hills and floodplains are Green Valley, Suisun, Ledgewood, Laurel, McCoy, Union, and Denverton Creeks (USCS 1975).

Suisun Marsh originally was formed by the deposition of silt from floodwater of Suisun Slough, Montezuma Slough, and the Sacramento-San Joaquin Rivers. Prior to development and modification, the Marsh consisted of islands separated by a network of tidal sloughs. Large portions of these islands were submerged daily by the high tides, while even larger tracts of land were submerged during seasonal high tides and winter flood events.

The salinity of the water in the sloughs of the Suisun Marsh varied considerably with season and from year to year. High winter and spring outflows from the Delta and local streams flooded the Suisun Marsh and provided fresh water in its channels. During low outflow periods, fresh water in the Marsh channels gradually were replaced by saline water from the Bay, which resulted in high salinity for up to 5 months each year.

Levee construction in Suisun Marsh began in the 1860s after Congress granted to the states all swamps, marshes, and sloughs; subsequent state legislation transferred "swamp land" into private ownership to be drained for development. Following the initial construction of low sod levees and filling of some smaller sloughs with material borrowed from higher ground, salt grass replaced aquatic vegetation and the marshlands were more effectively used for cattle grazing. In addition to diking and draining, the Suisun Marsh has been modified over the years by natural erosion, upstream hydraulic mining, channel erosion, and changes in Delta outflow. During the 1860s, reclamation increased rapidly and more than 20 reclamation districts were formed. Between 1860 and 1880, each of these districts completed partial reclamation systems, with levees that protected enclosed lands from normal tidal flooding. The bulk of reclamation was completed before 1920; by 1930, 44,600 acres had been developed in Suisun Marsh.

The availability of fresh water in Suisun Marsh depends on precipitation and use in the Sacramento and San Joaquin River basins. The average annual outflow from these basins prior to water development was 33.6 million acre-feet (MAF). Fresh-water outflows, resulting primarily from winter storms, prevented sea water from entering marsh channels except during certain months. During these months, the Delta flows were greatly reduced, allowing salt-water intrusion for brief periods.

As marsh reclamation began, extensive water development for agricultural and municipal uses was occurring in the Central Valley. Construction of dams began before 1870 and continued at an increasing rate until an unprecedented level between 1940 and 1970. Initially, these developments did not substantially alter the natural runoff pattern into Suisun Bay. By 1930, however, storage and diversion capabilities reached 10 MAF.

Fresh water is important to maintaining Suisun Marsh as a brackish-water marsh because the Marsh occupies a transitional location between the fresh-water ecosystem of the Delta and the saline ecosystem of San Francisco Bay. During periods of low fresh-water outflows, salt-water intrusion into the Marsh becomes a problem. The numerous upstream diversions throughout the Sacramento and San Joaquin River basins have effectively reduced the fresh-water flows through the Delta and the Suisun Marsh. The primary sources of fresh water to Suisun Marsh are the Sacramento River, San Joaquin River, imported water, groundwater, surface water drainage, and municipal wastewater discharges (DFG 1975).

Existing Marsh Levees

The majority of the Suisun Marsh is situated at or below mean tide elevation. To protect marshland from uncontrolled tidal inundation and flooding, human-made levees have been added over the years to augment the natural levees throughout the Marsh. Approximately 90% of the marshland is enclosed by a system of low levees, ranging in height from 4 to 8 feet above ground level. This system of levees allows the management of water quality and waterfowl habitat in the Marsh (Ramlit and Associates 1983).

Two types of levees comprise the levee system in the Marsh. Interior levees are the lower levees used to control and spread water or separate ponds within the boundaries of the diked marshland. These levees enable property owners to apply some degree of individual water management within the leveed portions of their property to enhance waterfowl habitat. The exterior levees are the larger levees that protect the marshland against tidal inundation and uncontrolled flooding (Ramlit and Associates 1983). The total measured length of exterior levees in the Suisun Marsh is 228.8 miles (Ramlit and Associates 1983).

The exterior levees have been built up progressively over the years, generally with little effort to design them to any specific engineering standards. The levees have been constructed along channels, most often using material dredged from adjacent waterways. Dredging typically is done with either a clamshell or drag-line dredge and provides a relatively inexpensive way of obtaining and placing fill material. Other less common construction methods involve the importation of fill material either by truck or barge.

The finished levees vary considerably in their shape, stability, and the degree of protection they provide against tidal action. Furthermore, over time, these levees have exhibited deterioration or outright failure. These problems generally are attributed to consolidation of soils, erosion, overtopping, or seepage.

Organic and peat soils, which underlie most of the exterior levees, exhibit significant consolidation with time due to the added weight of the levee fill. This problem is particularly significant in the southeastern part of the Marsh, where settling of levees may sometimes equal the height of the placed fill. Under these conditions, levees need to be raised and widened periodically to maintain sufficient levee height and structural integrity.

Wave action and tidal currents are the primary erosional forces in the Marsh that affect the exterior levees. Unprotected exterior levee sideslopes may be undercut, scoured, or washed away. Flatter sideslopes and bank protection with rip-rap and/or vegetation are typical measures to reduce levee erosion problems.

Overtopping of low-lying levees occurs occasionally during periods of extreme high tides and /or heavy runoff. Not all levee sections in the Marsh are sufficiently high to protect against overtopping under extreme conditions. Some levee sections are stable enough to withstand periodic overtopping without major damage. Less stable sections, however, may be completely eroded or washed away from the scouring action of the overtopping flood waters.

Seepage through rodent holes and cracks in the levee may allow excessive movement of tidal water through the levee. Eventually, this may lead to major piping and erosion problems. Rodent burrowing problems are most likely to occur where levees are bounded on both sides by water – on the exterior side by tidal sloughs and on the landward side by irrigation ditches or ponds.

Ecological Resources and Interactions

The Suisun Marsh presently contains approximately 52,000 acres of diked wetland, 6,300 acres of un-managed tidal wetlands, 30,000 acres of bays and sloughs, and 27,000 acres of upland grasslands. Most of the diked wetlands are managed for wetland-dependent wildlife; acreage devoted to grazing and agriculture is very small. DFG manages about 15,000 acres of tidal wetlands, diked wetlands, and upland grasslands. Table III-1 provides a description of habitat types used in the Ecosystem Restoration Program Plan for the Suisun Marsh.

VEGETATION

Vegetation patterns and vegetative growth depend on many physical features of the Suisun Marsh, including climate, topography, elevation, geology, soil type, soil salinity, and moisture.

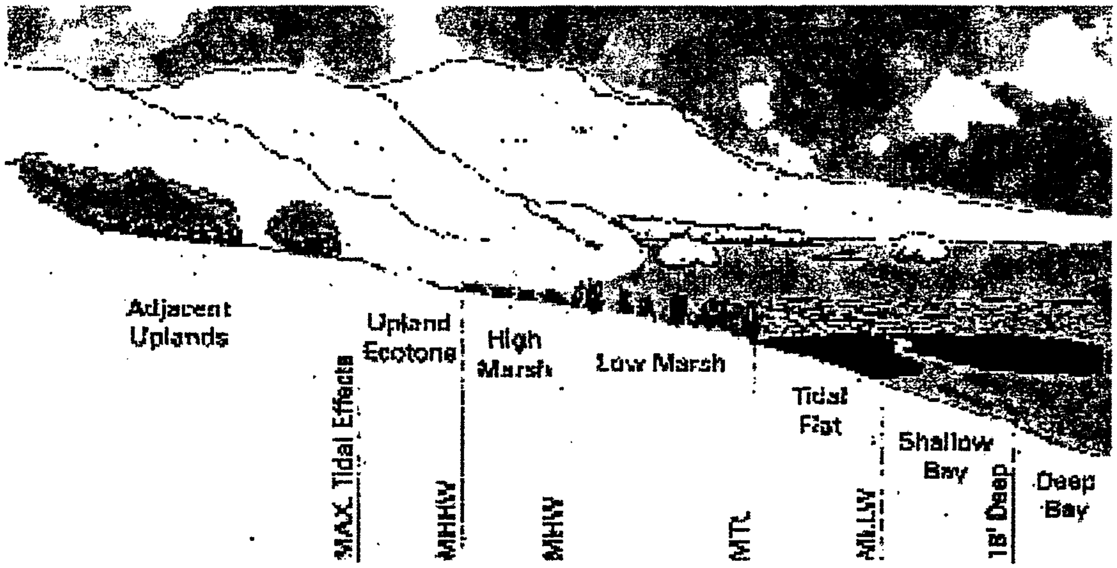
Saline emergent wetlands within the Suisun Marsh typically have been described as undiked tidal wetlands, diked seasonal wetlands, and diked permanent wetlands.

Table III-1. Description of Habitat Types in the Ecosystem Restoration Program Plan for Suisun Marsh

Ecosystem Restoration Program Habitat Types	Description
Tidal perennial aquatic	Tidal perennial aquatic habitat is defined as deep-water aquatic (greater than 3 meters deep from mean low low tide), shallow aquatic (less than or equal to 3 meters deep from mean low low tide), and unvegetated intertidal zones (mudflats) of estuarine bays, river channels and sloughs. This designation also includes tidal sloughs and channels.
Nontidal perennial aquatic	Nontidal perennial aquatic habitat is defined as portions of permanent bodies of water that do not support emergent vegetation and that are not subject to tidal exchange, including lakes, ponds, oxbows, gravel pits, and flooded islands.
Saline emergent wetland	Saline emergent habitat includes the portions of San Francisco, San Pablo, and Suisun Bays and the Delta that support emergent wetland plant species tolerant of saline or brackish conditions within the intertidal zone or located on lands that historically were subject to tidal exchange (diked wetlands).
Seasonal wetland	Seasonal wetlands include both natural seasonal wetlands and managed seasonal wetlands. Vernal pools are a type of natural seasonal wetlands and are discussed separately. Managed seasonal wetlands include wetlands dominated by native or non-native herbaceous plants, excluding croplands farmed for profit, that are flooded and drained by land managers during specific periods to enhance habitat values for specific wildlife species. Ditches and drains associated with managed seasonal wetlands are included in this habitat type.
Vernal pool	Vernal pools and other non-managed seasonal wetlands have natural hydrologic conditions that are dominated by herbaceous vegetation and annually pond surface water or maintain saturated soils at the ground surface for a portion of year of sufficient duration to support facultative or obligate wetland plant species. Alkaline and saline seasonal wetlands that were not historically part of a tidal regime are included.
Riparian and riverine aquatic	Riparian and riverine aquatic habitat includes all successional stages of woody vegetation generally dominated by willow, Fremont cottonwood, valley oak, or sycamore within the active and historical floodplain.
Perennial grassland	Perennial grassland includes upland vegetation communities dominated by native and introduced perennial grasses and forbs, including non-irrigated and irrigated pasturelands.

UNDIKED TIDAL WETLANDS

Historically, the Suisun Marsh was a brackish tidal basin encompassing more that 74,000 acres of natural tidal wetlands. Presently, the extent of natural tidal wetlands has been reduced to about 6,500 acres (DWR 1994). These remaining tidal marshes are subject to tidal cycle inundation regimes resulting in irregular exposure from the ebb and flood tides. The brackish tidal marshes are dominated by dense stands of native, intertidal emergent vegetation. Plant heights vary from low-growing prostrate species to plants over 8 feet tall, creating a complex structural mosaic of wildlife habitat. The characteristics of these habitats vary with elevation and distance from the channel or water sources.



About 92% of the estuary's tidal marshes have been lost to filling or conversion. Many wildlife species that depend on this habitat type are endangered or are candidate species under the state or federal ESAs. Dependent species include those listed earlier in this section under "Multi-Species Conservation Strategy."

The few remaining tidal marshes in Suisun Marsh include the portion of Hill Slough Wildlife Area east of McCoy Creek, Peytonia Slough Ecological Reserve, Solano County Farmlands and Open Space Foundation's Rush Ranch north of Cutoff Slough, a small portion of DFG's Joice Island, Roe Island, portions of Ryer Island, and fragmented small wetland areas along the Contra Costa shoreline.

The two primary types of tidal wetlands in Suisun Marsh are described as "relict tidal marshes" and "fringe tidal marshes." Relict tidal marshes are characterized by a fully developed natural marsh hydrology with small first-order channels in the high marsh grading into large tidal sloughs at the low marsh zone. The marsh vegetation zone can be divided into smaller, more descriptive units. These include the low marsh, middle marsh, and high marsh. The low marsh occurs from about mean lower high water (MLHW) to mean high water (MHW). Low brackish tidal marsh vegetation typically is dominated by perennial emergent monocots up to 2 meters tall that are tolerant of extended periods of tidal submergence. The dominant plants in the low marsh include hardstem bulrush and California bulrush. Other plant species found in the low marsh include low club rush, pickleweed, common reed, and common cattail. Plants in the low marsh are inundated once or twice a day. Soil salinity does not fluctuate as in the middle marsh and high marsh zones; dominant plants in the low marsh tend to occur in large, monospecific stands with narrow strips of the less common species. The low marsh is one component of the Ecosystem Restoration Program's saline emergent wetland habitat.

Terms Used in Discussing Tides in Suisun Marsh	
ELLW -	Extreme Lower Low Water. Lowest level to which tides recede and separate the intertidal from the subtidal.
MLLW -	Mean Lower Low Water. Average level of the lower of the two daily low tides.
MLW -	Mean Low Water. Average height of all low tides.
MHW -	Mean High Water. Average height of all high tides.
MHHW -	Mean Higher High Water. Average height of the higher of the two daily high tides.
EHHW -	Extreme Higher High Water. Extreme high

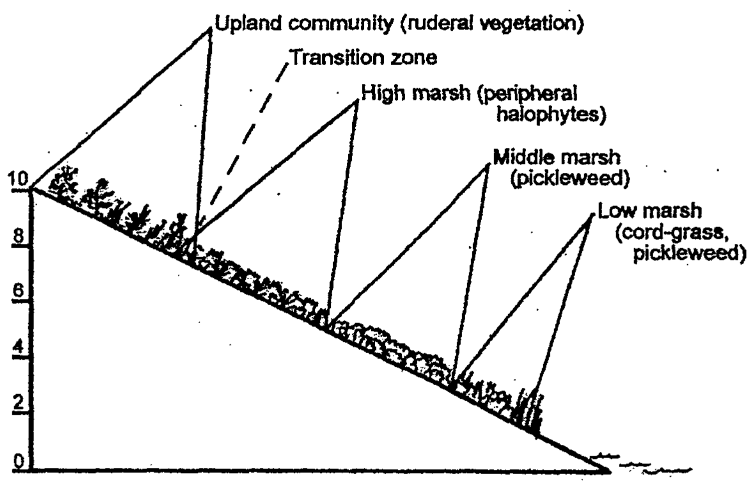
The middle marsh extends from about MHW to mean higher high water (MHHW). Dominant plant species include pickleweed, American bulrush, and saltgrass. Other less dominant plant species include fleshy jaumea, sea milkwort, baltic rush, Mexican rush, alkali bulrush, narrow leaf cattail, and even less commonly, sneezeweed and marsh gumplant. Middle marsh plants are inundated by tides at least once per 24-hour period and are not subject to the high soil salinities present in the high marsh. Pickleweed often reaches its most robust form in the middle marsh. The middle marsh is another component of the Ecosystem Restoration Program's saline emergent wetland habitat. Combined, the low marsh and middle marsh encompass the majority of habitats that are described as saline emergent wetlands.

The high marsh extends approximately from MHHW to extreme high water (EWH). Pickleweed and saltgrass dominate a varied group of plants, which also includes native fat hen, saltmarsh dodder, fleshy jaumea, seaside arrowgrass, and alkali heath and the introduced plants brass buttons and rabbitsfoot grass. Plants in this zone must tolerate high salinity, as salt is deposited during intermittent inundation and accumulated during long periods of soil water evaporation. Species diversity in the high marsh is greater than in the low and middle marsh zones. The high marsh provides the last component of the saline emergent wetland habitat and is the first layer of transitional habitat that extends into the adjacent uplands.

Fringe tidal wetlands are found on the outboard sides of levees of diked wetlands. They front the tidal sloughs and bayshores of Suisun Marsh, Grizzly Bay, Honker Bay, and Suisun Bay. The fringe marshes are typically less than 300 meters wide and do not exhibit the complex vegetational zonation observed in the relict tidal marsh areas. Fringe marshes are important and are occupied by such listed species as the California clapper rail, Suisun song sparrow, Mason's lilaeopsis, Delta tule pea, and Suisun Marsh aster.

DIKED SEASONAL WETLANDS

The primary wetland type in Suisun Marsh is the diked, seasonal wetlands that are managed for resident and migratory waterfowl and other resident wildlife habitat. The character of wetland habitat in these managed marshes reflects the water management and waterfowl habitat objectives. The single most important factor influencing plant composition and cover in these



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wetlands is the length of soil submergence provided through water management. Other abiotic factors, such as channel water salinity, soil salinity, and soil characteristics, also influence these plant communities. Of these factors, soil salinity may be managed with implementation of leach cycles. Active water management achieved by muting tidal flow through water control structures can result in moist soil management regimes that are critical to plant community diversity. The water management plans for these wetlands specify flooding for use by migratory waterfowl and for soil salinity control in spring. The primary water management schemes in Suisun Marsh are late drawdown and early drawdown schedules, with leach cycles required to manage the soil salt balance. Late drawdown water management favors vegetation that requires a lengthy period of submergence. This management promotes a wide variety of key wildlife habitat and food plants, including cattail, alkali bulrush, and tules. Early drawdown water management favors primarily fat hen, pickleweed, purselane, and brass buttons—all of which require a short period of flooding. This management regime suppresses obligate wetland species such as cattails and tules. The short flooding period also provides growth conditions for pickleweed, which harbors important aquatic invertebrate waterfowl food sources. Seasonal wetlands of this nature also support the endangered salt marsh harvest mouse and many other plant and wildlife species.

DIKED PERMANENT WETLANDS

A small percentage of diked waterfowl habitat is dedicated to permanent flooding. The most critical ecological factor limiting the variety of plants in permanent ponds is the continuous state of inundation. Moist soil management in seasonal wetlands is preferable for providing food and habitat resources for wintering waterfowl and resident wildlife. Shallow permanent ponds support local breeding mallards and a variety of other wildlife species, such as western pond turtle, river otter, heron, egret, and other water-dependent wildlife.

SUISUN TIDAL WETLAND PLANT COMMUNITY

The largest remnant historical brackish tidal wetland is at the Solano County Farmlands and Open Space Foundation's Rush Ranch. This wetland is approximately 1,000 acres.

Tides, Circulation, and Flushing

The tides have a dominant and pervasive influence on the wetlands of Suisun Marsh, maintaining wetlands equilibrium or near-equilibrium as marshes and mud flats are alternately built up and eroded by tidal action. The physical structure of the wetlands in turn influence the flora and fauna. Mudflats created during drawdown of managed, seasonal wetlands provide critical spring habitat for shorebirds.

The San Francisco Bay Region, including the Suisun Marsh Subregion, has mixed tides. There are typically two tides (two high and two low tides) each day; and there is a large inequality in high-water heights, low-water heights, or both. Because of the configuration of the Bay, the low-water portion of the tidal cycle is always longer than the high-water portion. This long ebb results in exposure of large areas of tidelands over an extended period of time (USFWS 1979). Tidal heights also are influenced by wind and the amount of fresh-water runoff entering the Bay, as well as by the shoreline configuration.

Hydrologic circulation and flushing of the Bay depends on tides and fresh-water inflow. Circulation is mainly a physical/tidal process. Tidal exchange through the Golden Gate replaces about 24% of the Bay water each 12½ hours. Tidal flushing at the extremities of the Bay is slight; during times of high evaporation, salinity in sloughs and at Bay extremities may be greater than sea water. However, fresh-water inflow causes salinity gradients from fresh to marine. Fresh-water inflow from the Sacramento-San Joaquin Delta is a dominant force in flushing the Bay, but other tributaries to the Bay are essential to their particular estuaries. Fresh-water inflow from the Delta has overriding effects in flushing brackish water, suspended solids, and sediments from Suisun Bay and San Pablo Bay.

Fresh water from the Sacramento and San Joaquin Rivers mixes with salt water from the ocean to establish a salinity gradient in the Bay, which varies from year to year as well as from season to season with changes in rainfall and controlled Delta outflow. Fresh-water inflow also conveys large amounts of nutrients, which contribute to high biological productivity in the Bay.

Salt ponds and the Suisun Marsh represent the extremes of the salinity spectrum found in the study area. Marsh habitat may be subdivided according to salinity: salt marsh, above 30 parts per thousand (ppt) total dissolved solids (TDS); brackish marsh, 0.5 to 30 ppt TDS; and fresh-water marsh, less than 0.5 ppt TDS. The mean annual salinity in the Bay grades from less than 1 ppt near Antioch, from 15 to 17 ppt near the Carquinez Bridge, to 25 ppt at Point San Pablo, to about 29 ppt in Central and South San Francisco Bay, and to about 31 ppt at the Golden Gate.

Seasonally, there are large differences in flows from the streams surrounding the Bay Region, including the Sacramento and San Joaquin Rivers. During periods of high Delta outflow, salinity at the Carquinez Bridge may be less than 5 ppt and less than 20 ppt in the South Bay. During high Delta outflow, the Bay is stratified with lower salinity water on the surface, perhaps to depths of 15 to 30 feet with sea water at greater depths.

Large areas of wetland habitat depend on the seasonal inflow of low-salinity water to maintain brackish water marsh. Suisun Marsh is the prime example. Brackish water is required to grow the highly productive alkali bulrush. If sufficient fresh water is not released from the Delta, the Marsh would convert to plant assemblages more suited for higher salinities.

IV. Investigation Considerations

Potential Linkages to CALFED Objectives

A key focus of the Investigation has been identifying linkage between pursuing a Levee Program in the Suisun Marsh and the achievement of CALFED objectives. The areas of greatest potential benefit to the CALFED Program associated with a Suisun Marsh levee program are ecosystem quality, water quality, and water supply reliability.

Study Methodology

As a starting point for developing linkage to CALFED objectives, the Investigation focused on ongoing modeling being performed by DWR's Environmental Services Office. To further examine the modeled salinity response to levee breaches and to see whether it could be correlated with CALFED Ecosystem Restoration Program goals, potential breach scenarios were developed. The scenarios were developed by a sub-team of biologists, taking into consideration Ecosystem Restoration Program targets and endangered species recovery plans. The scenarios were designed to represent a wide geographical range and proximity to bays and channels, and were assigned relatively equal volumes. It is stressed that the role of the Investigation is to gather information; as such, some regional assumptions needed to be made as a starting point for modeling. No preference for breaching of any Marsh location or intended designation of any specific parcels for conversion was indicated by the scenarios developed.

From the model run results, general conclusions were reached regarding salinity response (presented in Sections V, V, and VII of this report. A sub-team of biologists analyzed the potential of these breach scenarios to also support Ecosystem Restoration Program goals. This analysis is presented in Section X of this report, "Analysis of Modeling and Research Results." Other considerations, such as public outreach (presented in Section VIII) and the results of the cost estimate (presented in Section X), were factored in to arrive at Investigation conclusions.

Other Considerations

In arriving at the Investigation conclusions outlined in Section XI, "Conclusions and Staff Recommendations," numerous items were taken into consideration including, but not limited to, the results of modeling and the cost estimate analysis, CALFED Ecosystem Restoration Program and MSCS targets, local landowner input, and existing agreements and regulatory constraints. For example, provisions of the Suisun Marsh Preservation Agreement were considered. In addition, potential impacts on DWR infrastructure including the Roaring River Distribution System, Morrow Island Distribution System, and the Suisun Marsh Salinity Control Gates were considered.

Key points regarding any potential CALFED Suisun Marsh efforts that arose early in the Investigation process and were presented during the initial public outreach workshops include:

- Any program would be based on willing landowner participation.
- It is not intended that tidal wetlands be created at the expense of managed wetlands.
- More intensive levee maintenance must be part of any package.
- Any program would avoid reducing the existing funding for in-Delta levees.

A summary of additional comments and questions gathered from the public outreach process is presented in Section VIII.

V. DWR Modeling Results

Introduction

The Investigation Team used the DWRDSM1 Suisun Marsh Version model to evaluate hydrodynamic and salinity impacts of controlled and uncontrolled levee breaches in the Suisun Marsh. This chapter reports result highlights and analysis. Appendix A is a complete graphical reporting of the results and can be viewed at http://www. iep.water.ca.gov/suisun/CALFEDlevee.

This section summarizes the approach, assumptions, and results of modeling several levee breach scenarios in the Suisun Marsh. Levee breach scenarios are designed to answer the following two questions:

- Should Suisun Marsh levees be included in the CALFED Levee Program?
- If Suisun Marsh levees are included in the program, are there opportunities for water quality improvement and ecosystem restoration?

Background

Extreme climatic conditions caused extensive levee overtopping and breaching in the Suisun Marsh in February 1998. DWR and Reclamation cooperated in providing flood fight assistance to private landowners in the Suisun Marsh on the assumption that breached levees, allowed to persist, would grow and cause increasing salinity in Suisun Bay and possibly the Delta.

DWR modelers tested this assumption by considering the impact of various breach sizes and locations during consecutive historical drought years (water years 1991 and 1992). Results indicated that salinity tends to increase in the region of levee breaches but may decrease far from breaches (for example, the Delta) when breach size is kept small. In contrast, unrepaired large breaches increase salinity widely (DWR 1999).

Modeling results were presented to CALFED (the levees and Channels Technical Team) in June 1998. At about the same time, the ART suggested inclusion of Suisun Marsh levees in the CALFED Levee Program. CALFED subsequently adopted Suisun Marsh levees as an optional strategy for achieving levee goals and initiated the Suisun Marsh Levee Investigation.

The Investigation Team was established to conduct focused modeling and biological analysis on the impact of Suisun Marsh levee breaches. This chapter summarizes the modeling. Appendix A (http://www.iep.water.ca.gov/suisun/CALFEDLevee/) provides full graphical documentation of modeling studies conducted by the Team. Lessons learned from the Suisun Marsh flood modeling analysis were carried over to the Suisun Marsh Levee Investigation Team analysis.

Modeling Approach

For modeling purposes, a sub-group of the Team convened to identify areas of the Marsh that could be converted to tidal marsh (~5,000 acres) or shallow-water habitat (~2,000 acres), consistent with the CALFED Ecosystem Restoration Program. Modeling scenarios were conducted for each individual area shown in Table V-1. Flooded areas were delineated to represent different areas of the Marsh and proximity to bays or channels. No preference for particular Marsh locations is intended. Flooded islands were assigned relatively equal surface area and volume.

Table V-1. Flooded Area Dimensions as Modeled Using DWRDSM1

Shallow-Water Habitat Options	Flooded Area (acres)	Length (feet)	Top Width (feet)	Actual Depth (feet, NGVD)	Standard Deviation (feet, NGVD)	Depth as Modeled (feet, NGVD)
Morrow Island	2,225	7,354	13,179	-1.51	0.37	-3.34
Grizzly Island	3,778	9,428	12,594	-1.83	0.2	-3.14
Simmons Island	2,237	8,486	11,483	-1.64	0.65	-3.24
Wheeler Island	1,848	4,735	17,000	-1.44	0.2	-3.04
Chipps Island	987	6,600	6,514	No Data	NC	-3.14
Van Sickle Island	2,168	10,000	9,443	-2.61	0.48	-2.94
Tidal Marsh Options	**Number of Breaches**	**Flooded Area (acres)**	**Flooded Area Avg Length (feet)**	**Flooded Area Avg Top Width (feet)**	**Actual Avg Depth (feet, NGVD)**	**Depth as Modeled (feet, NGVD)**
Western option	3	3,971	10,361	16,696	-1.14	-2.71
Northwest option	3	5,434	9,117	25,964	-0.87	-2.26
Central option	3	5,789	7,849	32,126	-2.04	-2.37
Northeast option	4	5,763	6,934	36,204	-1.29	-2.37

Note:

NGVD = national geodetic vertical datum (a measurement comparable to sea level).

[a] Based on weighted mean depths for each breached sub-area.

The simulation period selected for analysis is water years 1991 and 1992. These drought years offer a range of hydrology, but summer and fall periods provide "worst-case" salinity response conditions. Model input data are the historical data for the 1991-1992 water years. Daily average river flows, project exports, and facilities operations are used as input to the model as they occurred historically. As in the prototype, the model is driven by the historical tide at the Golden Gate for water years 1991-1992.

Modeling Scenarios

A total of six shallow-water habitat options (Figure V-1) and four tidal marsh options (Figure V-2) were chosen for levee breach modeling analysis. Modeling was conducted on each breach scenario individually.

Two breach configurations were tested for each breach location to assess the difference between "unrepaired" and "controlled" levee breaches.

"Unrepaired" levee breaches represent those that are not repaired at an early stage and become large over time. A nominal breach width of 5,000 feet and breach depth of 3 feet below the national geodetic vertical datum (NGVD - a measurement comparable to sea level) was chosen. This configuration is intended to address question number 1 above under "Purpose." That is, should Suisun Marsh levees be included in the CALFED Levee Program?

"Controlled" levee breach scenarios help to assess the potential for shallow-water habitat and tidal marsh conversion and associated water quality benefits. A nominal breach width of 100 feet and breach depth of 20 feet below NGVD was chosen. The implication is that maintenance of this breach configuration would require engineered reinforcement of adjacent levees. This configuration addresses question number 2 above under "Purpose." That is, if Suisun Marsh levees are added to the program, are there opportunities for water quality improvement and ecosystem restoration?

Figures V-1 and V-2 also show the location of levee breaches as modeled. One breach is used in each of the shallow-water habitat options (Figure V-1), while three breaches are applied to each tidal marsh option—recognizing that internal levee systems would prevent full inundation of those areas otherwise (Figure V-2). Constant land elevations for flooded acreage are assumed and estimated from available survey data. An important assumption is that land elevations were lowered by 0.3 to 1.8 feet to accommodate the model requirement that land surfaces not de-water.

Highlights of Modeling Results

HYDRODYNAMIC IMPACTS OF SUISUN MARSH LEVEE BREACHES

All scenarios investigated indicate that Suisun Marsh levee breaches tend to reduce tidal range in Suisun Bay and the Delta. As an example, Figure V-3 shows the simulated tidal prism between the Golden Gate and Freeport along the Sacramento River. The plot shows that, following a breach, high tides tend not to be as high, and low tides not as low. 100-foot levee breaches reduce tidal range up to 3 inches, 5,000-foot levee breaches reduce tidal range somewhat less, between 0 and 2 inches. Related to reduced tidal range, tidal energy[1] also is reduced.

Diminished tidal range and energy translates to reduced tidal excursion. That is, the distance a passive object travels on flood and ebb tides is reduced by a small amount.

[1] Tidal energy is measured as root mean squared tide height. Refer to Appendix A for more information.

Figure V-1. Suisun Marsh Levee Breach Study
Shallow-Water Habitat Areas

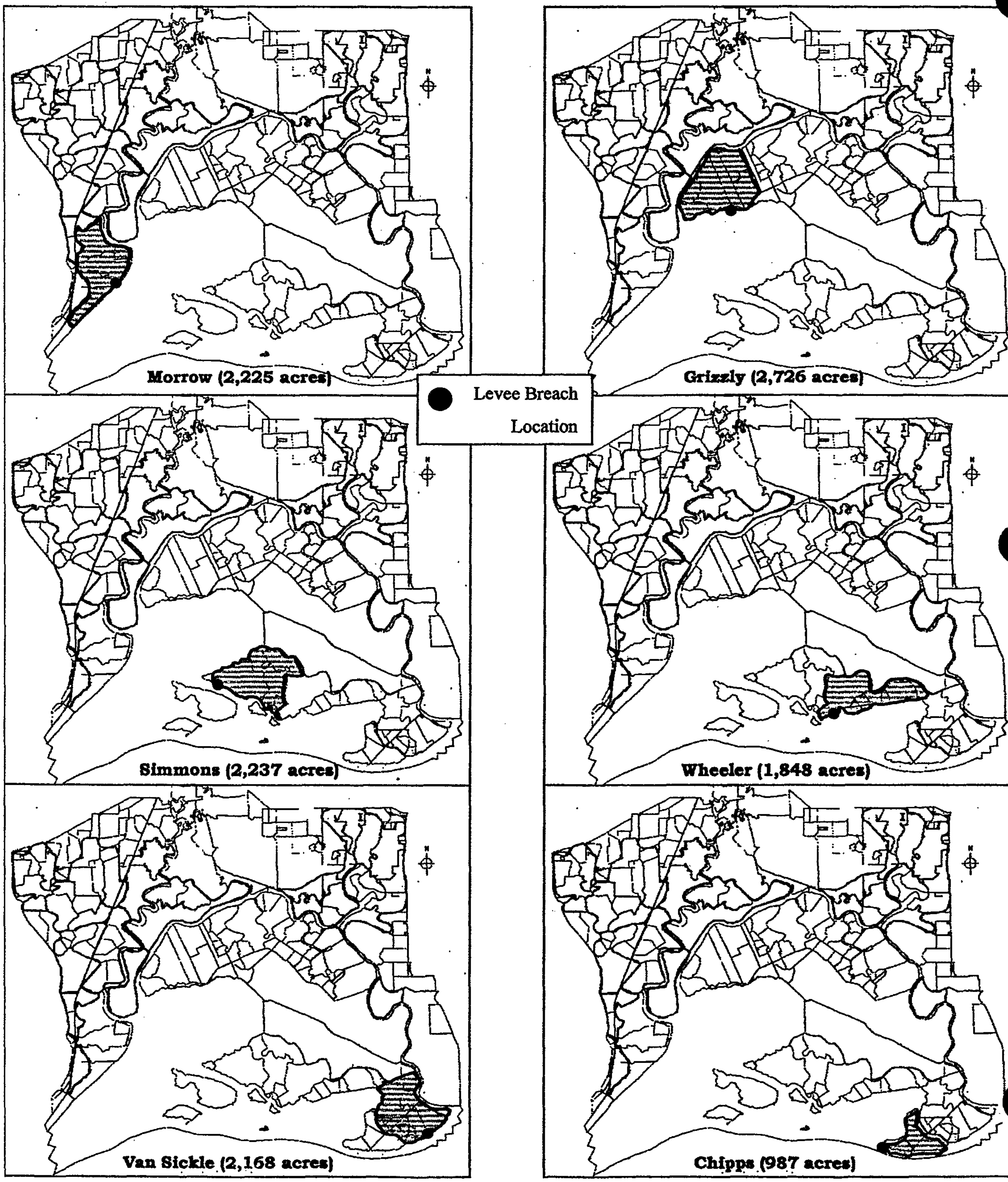

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Figure V-2. Suisun Marsh Levee Breach Study
Tidal Marsh Areas

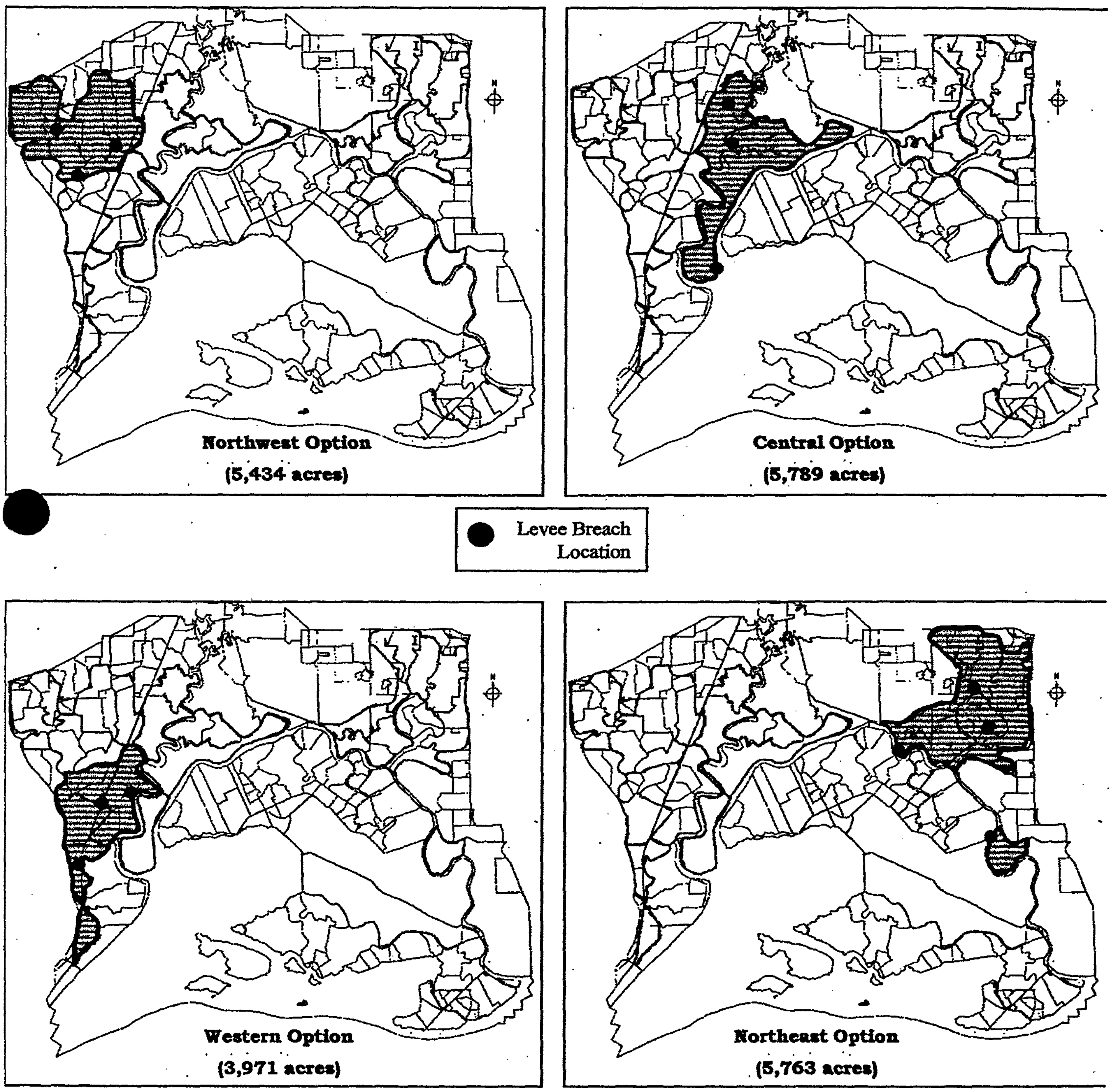
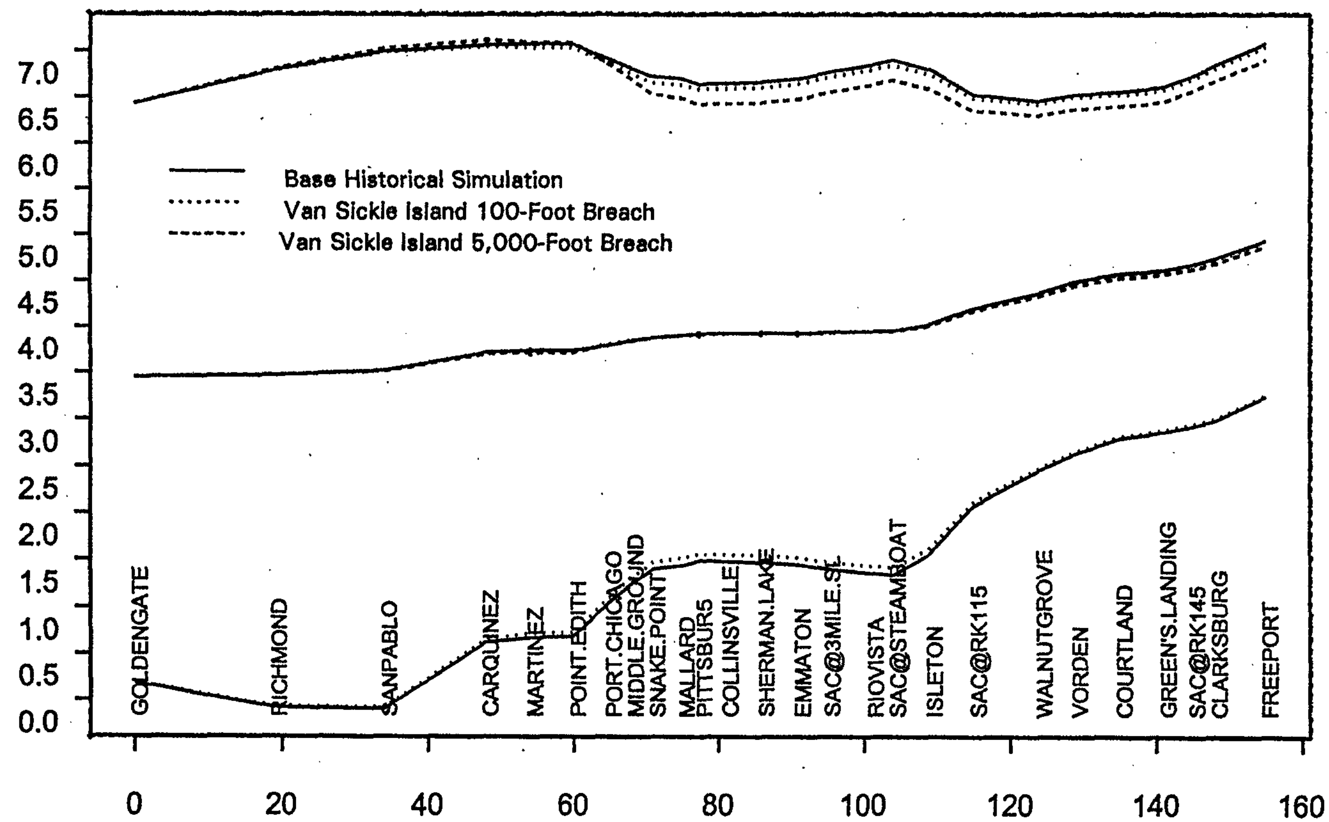


Figure V-3. 28-Day Average Tidal Amplitude for July 1992 at Van Sickle Island Breach - Golden Gate to Freeport via Sacramento River



E —0 3 9 5 1 0

SALINITY TRANSPORT IMPACTS OF SUISUN MARSH LEVEE BREACHES

Salinity impacts of Suisun Marsh levee breaches are more complex. In general, salinity tends to increase in the region of levee breaches. Far away from the breach site, salinity decreases in some cases.

The particular salinity response is a complex function of breach size, location, and inundated volume. Large (unrepaired) breaches on Suisun Bay tend to increase salinity over a wide area, including the Delta. Small (controlled) breaches increase local salinity but generally reduce salinity away from the breach site, including the Delta.

The salinity response is also sensitive to breach location. In general, small levee breaches away from main channels of the estuary (such as off-tidal sloughs) or adjacent to relatively shallow areas result in greater overall salinity reduction compared to breaches adjacent to hydrodynamically energetic (deep) channels. As an example, the 100-foot Grizzly Island breach (from shallow Grizzly Bay) reduces salinity between Martinez and the central Delta, while the 100-foot Van Sickle Island breach (from the relatively deep lower Sacramento River) substantially increases salinity in Suisun Bay and the west Delta before giving way to reduced salinity in the north and south Delta (Figure V-4).

Large levee breaches on Suisun Bay tend to increase Suisun Bay and Delta salinity regardless of location. In contrast, interior Marsh breaches increased local salinity but reduced salinity further away (including the Delta). This general pattern holds whether breaches are large or small.

SUMMARY OF HYDRODYNAMIC AND SALINITY IMPACTS

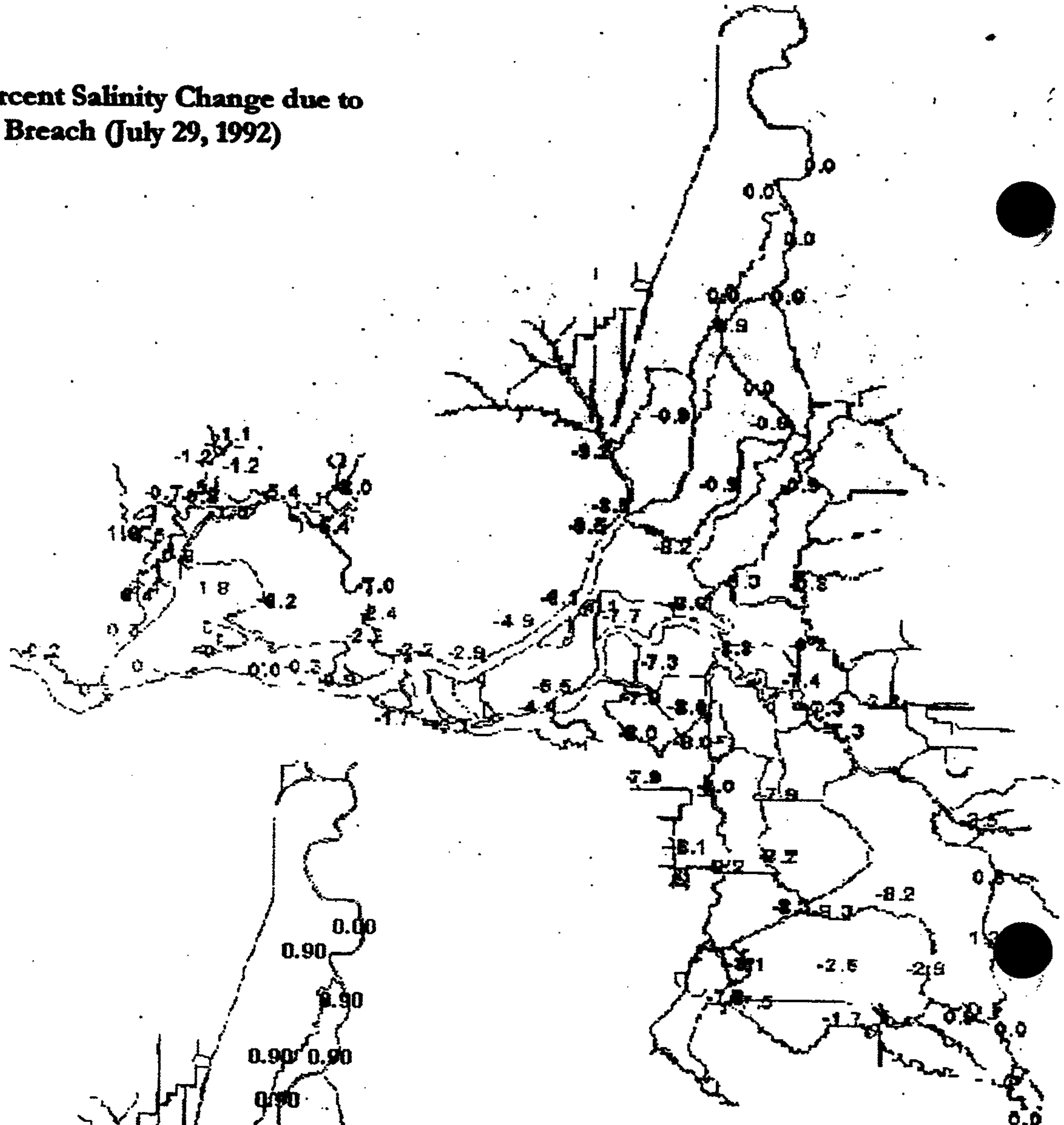
Tables V-2 and V-3 present concise summaries of modeling results for each of the 10 scenarios. Table V-2 summarizes the hydrodynamic and salinity responses of the system to each of the 100-foot levee breach scenarios. Table V-3 summarizes the hydrodynamic and salinity responses of the system to each of the 5,000- foot levee breach scenarios. Mean, minimum, and maximum salinity percentage change from the base condition are represented for six general regions: Suisun Bay; western Suisun Marsh; eastern Suisun Marsh; and the west, south, and north Delta areas. Additionally, the average position of X2 (a measurement of salinity) is calculated for the period February through June 1992, and the difference between the base case and each scenario is reported. Finally, the number of days X2 is downstream of Collinsville, Chipps Island, and Port Chicago is compared for the base condition and each scenario.

All graphical results for this study are presented in Appendix A, which can be viewed at http://www.iep.water.ca.gov/suisun/CALFEDLevee/.

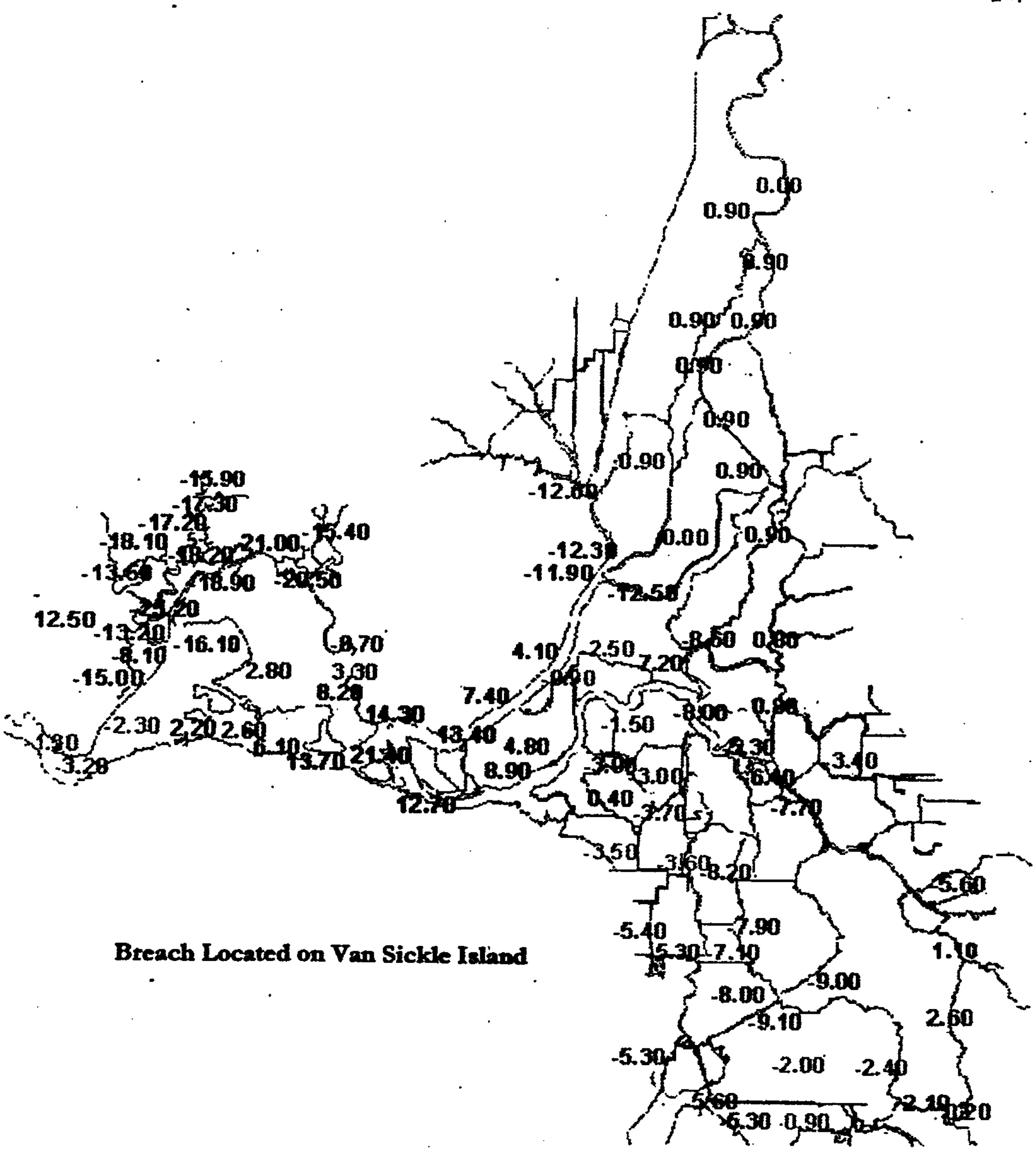
Conclusions

The salinity response to levee breaches in the Suisun Marsh is a result of the interplay of opposing hydrodynamic phenomena. First, the addition of large tracts of inundated land dissipates tidal energy,

Figure V-4. Percent Salinity Change due to 100-Foot Breach (July 29, 1992)



Breach Located on Grizzly Island



Breach Located on Van Sickle Island

Change From Base Condition

- <+20%
- +16-20%
- +11-15%
- +6-10%
- +0-5
- 0.0
- -0-5%
- -6-10%
- -11-15%
- -16-20%
- <-20%

E —0 3 9 5 1 2

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Table V-2. Suisun Marsh Scenarios Evaluation--Matrix100-Foot Breaches
Mean, Minimum, and Maximum Percent Change From Base on July 29, 1992 1/

Percent Salinity Change From Base (Mean, Min, Max) 2/	Scenario	Morrow Is. SWH	Grizzly Is. SWH	Simmons Is SWH	Wheeler Is. SWH	Chipps Is. SWH	Van Sickle Is. SWH
	Suisun Bay	0.5(-0.1,1.8)	0.1(-0.9,1.8)	0.6(-0.2,1.3)	1.0(-0.2,3.4)	0.7(-0.3,3.2)	-0.1(-16.1,13.7)
	Western Marsh	0.7(-3.9,6.7)	0.1(-5.4,6.4)	-0.2(-3.3,4.7)	0.2(-1.0,0.9)	0.3(0.0,1.1)	-16.6(-25.2,-8.1)
	Eastern Marsh	-4.2(-6.2,-1.7)	-5.4(-8.0,-2.2)	-1.9(-4.5,0.6)	1.7(-1.1,3.9)	2.4(0.2,4.6)	-5.0(-20.5,8.2)
	West Delta	-1.6(-3.8,0.5)	-2.9(-5.5,0.0)	-0.7(-3.2,0.8)	1.4(-0.5,2.8)	3.0(0.7,3.7)	10.9(2.6,21.4)
	North Delta	-2.6(-7.3,0.0)	-3.5(-9.5,0.0)	-2.7(-8.1,0.0)	-1.7(-5.7,0.0)	0.2(-1.0,2.3)	-2.7(-12.6,4.1)
	South Delta	-4.4(-6.6,1.3)	-5.8(-8.6,1.3)	-4.3(-6.6,1.3)	-2.6(-4.7,1.0)	0.4(-0.7,3.1)	-3.5(-9.1,8.9)
X2 Difference From Base (KM) 3/		0.69	0.75	0.73	0.62	0.33	0.42
X2 Standard Differences (days) 4/		0/-1/-1	0/-1/-1	0/-1/-1	0/-1/-1	0/-1/0	0/0/0
Tidal Range Difference		-0.59	-0.65	-0.55	-0.46	-0.21	-2.21

Percent Salinity Change From Base (Mean, Min, Max)	Scenario	Western Option TM	Northwest Option TM	Central Option TM	Northeast Option TM
	Suisun Bay	-0.9(-1.9,-0.1)	-0.9(-2.1,-0.1)	-0.9(-2.2,-0.0)	-1.0(-1.8,0.1)
	Western Marsh	4.5(1.3,10.4)	10.7(2.5,21.4)	10.1(2.5,20.1)	-1.4(-6.0,4.4)
	Eastern Marsh	-0.7(-9.0,5.7)	2.0(-8.4,9.6)	2.1(-8.3,9.5)	-11.0(-28.5,6.4)
	West Delta	-3.9(-5.5,-1.4)	-4.6(-6.7,-1.6)	-4.7(-6.7,-1.6)	-2.9(-5.5,-1.4)
	North Delta	-2.8(-7.6,0.0)	-3.3(-8.8,0.0)	-3.3(-8.8,0.0)	-3.2(-9.1,0.0)
	South Delta	-5.2(-7.5,0.7)	-6.1(-8.7,0.7)	-6.1(-8.8,0.7)	-6.5(-9.4,0.7)
X2 Difference From Base (KM) 3/		-0.33	-0.2	-0.58	-0.74
X2 Standard Differences (days) 4/		0/0/3	0/0/3	0/0/3	0/0/5
Tidal Range Difference		-0.6	-0.78	-0.78	-1.74

1/ Based on DWRDSM1 Suisun Marsh version.

2/ Mean, minimum, and maximum salinity change for the indicated region by the indicated levee breach scenario.

3/ Average X2 (February through May 1992): scenario minus base condition in kilometers.

4/ Number of days X2 is downstream of Port Chicago, Chipps Island, and Collinsville: scenario minus base condition in days.

Table V-3. Suisun Marsh Scenarios Evaluation Matrix--5,000-Foot Breaches
Mean, Minimum, and Maximum Percent Change From Base on July 29, 1992 1/

Scenario		Morrow Is. SWH	Grizzly Is. SWH	Simmons Is. SWH	Wheeler Is. SWH	Chipps Is. SWH	Van Sickle Is. SWH
Percent Salinity Change From Base (Mean, Min, Max) 2/	Suisun Bay	4.7(0.0,11.7)	3.5(0.1,7.1)	2.9(-0.1,7.7)	2.5(-0.1,7.0)	1.5(-0.2,6.0)	0.9(-0.4,5.7)
	Western Marsh	5.6(5.0,6.4)	5.9(4.7,10.2)	-0.9(-1.5,-0.3)	0.9(0.4,1.3)	0.3(0.0,0.9)	0.4(0.0,1.0)
	Eastern Marsh	4.2(3.1,5.8)	6.0(5.3,7.3)	3.8(-0.9,9.1)	5.5(0.9,10.3)	2.9(0.3,5.8)	5.3(1.6,8.2)
	West Delta	5.7(4.6,6.4)	6.3(4.4,7.4)	7.3(3.4,8.5)	7.2(2.2,8.2)	4.4(0.8,5.2)	5.8(-0.1,7.6)
	North Delta	0.8(-0.5,4.6)	0.5(-1.9,4.8)	1.2(0.0,6.6)	1.4(0.0,6.7)	1.0(0.0,4.2)	0.7(-1.9,5.8)
	South Delta	1.8(-0.7,3.6)	1.2(-1.4,3.4)	2.6(-0.7,5.0)	3.0(0.0,6.0)	1.9(0.0,4.3)	1.7(-1.4,5.1)
X2 Difference From Base (KM) 3/		0.69	0.75	0.73	0.62	0.33	0.42
X2 Standard Differences (days) 4/		0/-1/-1	0/-1/-1	0/-1/-1	0/-1/-1	0/-1/0	0/0/0

Scenario		Western Option TM	Northwest Option TM	Central Option TM	Northeast Option TM
Percent Salinity Change From Base (Mean, Min, Max) 2/	Suisun Bay	-0.1 (-0.6,0.2)	-0.1 (-0.5,0.1)	0.1 (-0.7,0.9)	-1.2 (-2.2,-0.1)
	Western Marsh	3.8 (0.0,9.7)	6.4 (0.3,10.9)	11.9 (3.5,20.2)	-6.9 (-13.6,-0.3)
	Eastern Marsh	-4.1 (-8.2,0.3)	-1.3 (-2.5,-0.2)	-1.0 (-14.0,11.3)	-1.3 (-28.9,22.5)
	West Delta	-2.1 (-4.1,-0.4)	-1.1 (-1.8,-0.2)	-3.4 (-6.9,-0.3)	-3.1 (-7.1,-1.5)
	North Delta	-2.3 (-6.7,0.0)	-0.8 (-2.4,0.0)	-3.8 (-11.5,1.8)	-4.6 (-13.6,0.0)
	South Delta	-4.4 (-6.3,0.7)	-1.7 (-2.6,0.3)	-7.2 (-10.4,1.0)	-8.1 (-12.0,1.0)
X2 Difference From Base (KM) 3/		-0.33	-0.2	-0.58	-0.74
X2 Standard Differences (days) 4/		0/0/0	0/0/0	0/0/3	0/0/3

1/ Based on DWRDSM1 Suisun Marsh Version.

2/ Mean, minimum, and maximum salinity change for the indicated region by the indicated levee breach scenario.

3/ Average X2 (February through May 1992): scenario minus base condition in kilometers.

4/ Number of days X2 is downstream of Port Chicago, Chipps Island, and Collinsville: scenario minus base condition in days.

resulting in diminished tidal range and tidal excursion. Through hydrodynamic pathways, upstream salt mixing is reduced. Second, the geometry of levee breaches and differences in tidal exchange on inundated lands compared to the adjacent channel tends to increase the mechanical mixing of salt. Similar to the shape of an implement used to stir a can of paint, the geometry of breached areas differentially affects salt mixing. Whether salinity increases or decreases depends on the breach size, inundated area size, breach location, and where in the system salinity is observed.

VI. RMA Modeling Results

Introduction

Mathematical modeling of the hydrodynamic and water quality impacts of Suisun Marsh levee breaches was performed using the RMA finite element model. This effort is in support of initial Suisun Marsh levee breach modeling done by DWR using the one-dimensional (1-D) DWRDSM1 model. This section refers to plots that have been made available on the RMA web site at http://www.rmanet.com under the heading "CALFED Suisun Marsh Levee Breach Modeling Study" under "San Francisco Bay and Delta, California."

Background

During the February 1998 storm, exterior levees along Grizzly Bay, Honker Bay, and Lower Sacramento River sustained 11 major breaches of approximately 100 feet each. The DWR Suisun Marsh Planning Section conducted a hydrodynamic and salinity modeling analysis to evaluate the potential impacts on the Marsh and Delta if the Suisun Marsh levee breaches were not repaired. Historical 1991-1992 drought hydrology was used with the February 1998 flood geometry including 11 100-foot wide, 20-foot deep breaches. A second "no action" scenario allowed the breaches to expand to approximately 23% of the Suisun Marsh exterior levee perimeter. Additional modeling was performed to investigate the benefits and costs of including Suisun Marsh levees in the CALFED Levee Program. Base case salinity was simulated for water years 1991 and 1992 with no breaches. For comparison, 20 levee breach alternatives (10 breach locations, each with two different breach sizes) were simulated and the results compared with the base case. The model results indicated that salinity response is sensitive to breach size and location, and that maintenance of Bay levees in the Suisun Marsh is critical for Delta water quality control.

Further corroborative results were deemed necessary to confirm the DWR model results and investigate the effect of some of the assumptions and approximations that were used in the 1-D model.

The RMA San Francisco Bay and Delta model has been used for many studies in the system, including analysis of the fate and transport of treated wastewater discharges, and marina deposition and dredging. Several examples of applications of the RMA models in the San Francisco Bay include:

- Hydrodynamic and water quality transport modeling was performed for the City of Palo Alto to evaluate impacts of the treated wastewater discharge from the Palo Alto Regional Water Quality Control Plant to South San Francisco Bay. The RMA finite element models for hydrodynamic and water quality transport modeling were used to simulate the time-dependent dilution of the discharge plume and its impacts on dissolved copper concentrations in the South Bay.

- RMA used its two-dimensional (2-D) depth-averaged finite element models for flow and water quality to quantify instantaneous and 24-hour average values of wastewater dilution near the Novato Sanitary District outfall. Discharges also were evaluated for dissolved copper.
- To quantify the water quality impacts of increasing South Bay Systems Authority discharge through an existing outfall to the South San Francisco Bay, RMA performed numerical simulations using two-dimensional finite element hydrodynamic and water quality models.
- The RMA hydrodynamic and water quality models were used to evaluate the Impacts of the Bay Area Dischargers Association discharges on dissolved copper levels throughout the San Francisco Bay.

Objectives

The objectives of the Suisun Marsh levee breach modeling study using the RMA finite element model of the San Francisco Bay and Delta are:

- Corroborate DWR results.
- Determine the salinity response associated with levee breaches.
- Peform mechanisms analysis.

Approach

To corroborate the DWR Suisun Marsh levee breach 1-D model results, the existing RMA model of San Francisco Bay and Delta was modified to include additional detail in the Delta and Suisun Marsh areas. Reconnaissance-level calibration for flow and salinity was performed. A base case and six levee breach scenarios (three breach locations, each with two different breach sizes) were simulated, using the RMA model with constant hydrology representing 1992 average summer conditions. These results were compared with the DWR 1-D model results for the same period. Because of the complexity of the RMA model, a 2-year simulation as performed by DWR could not be accomplished in a reasonable amount of time using the RMA model. The 4-month dry-weather period from June to September 1992 was simulated for comparison with DWR results for the same period. Summer conditions were chosen because they represent the worst-case scenario for salinity concentrations, and because the 2-D depth-averaged model is most applicable during low-flow periods when there is less vertical stratification.

MODEL CONFIGURATION

The existing RMA model of the San Francisco Bay and Delta has been improved for application to the Suisun Marsh levee breach analysis. More detailed information on the existing RMA model of the San Francisco Bay-Delta and its improvements and assumptions for purposes of this Investigation is provided in Appendix B.

MODEL CALIBRATION

The RMA San Francisco Bay and Delta model has been calibrated during several previous studies. The hydrodynamic model was calibrated to current velocity and stage measurements taken at numerous locations in the South, Lower, Central, San Pablo, and Suisun Bays—under a variety of hydrologic conditions. The water quality model has been calibrated using dye tracer study data in the South Bay and San Pablo Bay, dissolved copper concentration data throughout San Francisco Bay, and summer salinity data throughout the Bay. For the current study, a reconnaissance-level hydrodynamic and salinity calibration has been performed with emphasis on the Suisun Bay and Delta. Detailed information on the calibration methodology and assumptions is provided in Appendix B.

LEVEE BREACH ANALYSIS

Three of the ten levee breach locations investigated by DWR were chosen for additional modeling using the RMA model. Each location was simulated with a wide and a narrow levee breach, for a total of six simulations. Information on RMA model grid modifications and model assumptions for this additional modeling is provided in Appendix B.

Results

Generally, the wide levee breaches produced overall increases in salinity. The Van Sickle Island levee breach is the worst case. The largest decreases in salinity accompanied the Grizzly Island narrow levee breach.

Salinity Time Series. Salinity time series plots are available on the RMA web site at http://www.rmanet.com under "CALFED Suisun Marsh Levee Breach Modeling Study" under "San Francisco Bay and Delta, California." (The plots are under the sub-heading "Salinity Time Series" under "Levee Breach Simulation.") Plots are shown for each breach scenario at Collinsville, Rio Vista, and Old River near Delta Mendota Canal. These plots indicate that the Van Sickle Island wide breach is the worst case. Salinity increases are seen at each location. The Van Sickle narrow breach shows salinity increases at Collinsville and Delta Mendota Canal, and only a small decrease at Rio Vista. The Morrow Island wide breach increases salinity at Collinsville and slightly at Delta Mendota Canal, and produces a small decrease at Rio Vista. The Morrow Island narrow breach and Grizzly Island wide breach result in salinity decreases at Rio Vista and Delta Mendota Canal, and a small increase at Collinsville. Grizzly Island, with a narrow breach, produces the best results with decreases at each location.

Salinity Difference Contours. Salinity difference contour plots are available on the RMA web site at http://www.rmanet.com under "CALFED Suisun Marsh Levee Breach Modeling Study" under "San Francisco Bay and Delta, California." (The plots are under the sub-heading "Salinity Difference Contours" under "Levee Breach Simulation.") The plots exhibit the percentage change from the base condition (without levee breaches) for October 1, 1992. For the Morrow Island narrow breach case, the model shows 2-3% salinity increases in Suisun Bay and 1-4% salinity decreases in the central and south Delta. The largest salinity decreases occurs on the Sacramento River upstream of Rio Vista where salinity decreases

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nearly 4%. For the wide breach case, the model predicts salinity increases between 3 and 6%. Salinity increases spread into the central and south Delta at about 1-3% increase.

For the Grizzly Island narrow breach case, the model shows 1-2% salinity increases in Suisun Bay and 3-6% salinity decreases in the central and south Delta. Again, the largest salinity decreases occur on the Sacramento River upstream of Rio Vista where salinity decreases nearly 7%. The cross-over between salinity increase and decrease occurs at the downstream end of Chipps Island in both models. For the wide breach case, Suisun Bay/Marsh salinity increases between 2 and 5%. Salinity increases turn to decreases at approximately Rio Vista, and south and west of Contra Costa canal intake. Decreases in the south Delta are about 1%.

For the Van Sickle Island narrow breach case, the model shows 3-8% salinity increases in the region of the breach between Chipps Island and Jersey Point. Again, the largest salinity decreases occur on the Sacramento River upstream of Rio Vista where salinity decreases 3%. The model also predicts that salinity will increase about 1% over most of the central and south Delta. For the wide breach case, the model predicts significant salinity increases over most of Suisun Bay and the Delta. Increases of 7-11% are predicted in the west Delta, and 4-5% in the central and south Delta.

Salinity Difference Profiles. Salinity difference profiles are available on the RMA web site at http://www.rmanet.com under "CALFED Suisun Marsh Levee Breach Modeling Study" under "San Francisco Bay and Delta, California." (The plots are under the sub-heading "Salinity Difference Profiles" under "Levee Breach Simulation.") The profiles represent the change in salinity from the base condition for each breach scenario along the Sacramento River from the Golden Gate to Freeport, along the San Joaquin River from the Golden Gate to Vernalis, and along the Old River from Golden Gate to Vernalis. These plots have been produced for July 29, 1992 to correspond with DWR plots, and October 1, 1992 at the end of the simulation period. The same patterns of salinity increase and decrease are apparent on both dates.

Along the Sacramento River, peak salinity increase of 11% is seen near Collinsville for the Van Sickle Island wide breach case with almost no decrease anywhere along the profile. The Grizzly Island narrow breach shows a small increase near Port Chicago, and a 7% decrease near Rio Vista. The remaining scenarios show both moderate increases (3-6%) and decreases (3-4%) over the profile.

Along the San Joaquin River, again the Van Sickle Island wide breach peak increase is seen. The Grizzly Island narrow breach shows the largest decrease of about 4% near Andreas. The Grizzly Island wide breach and Morrow Island narrow breach scenarios show 3-5% increases in Suisun Bay and 1-2% decreases along the San Joaquin River. The Morrow Island wide breach and Van Sickle Island narrow breach scenarios show about a 6% increases in Suisun Bay and virtually no decrease along the San Joaquin River.

Along Old River, the Van Sickle Island wide breach shows significant salinity increases of 6-11% over the entire profile. Van Sickle Island narrow breach and Morrow Island wide breach show smaller increases of 1-6% over the profile. The Morrow Island narrow breach and Grizzly Island wide breach result in 1-2% decreases along the Old River, while the Grizzly Island narrow breach produces more than 4% salinity decreases along the Old River.

MECHANISMS ANALYSIS

Two competing mechanisms are responsible for observed water level and salinity response. These mechanisms exert differential influence, depending on location and breach geometry.

Reduction of Tidal Range

Model results suggest that adding tidal prism in the Suisun Bay region causes a small reduction in tidal range and excursion that tends to reduce salinity in the western Delta. The magnitude of the reduction depends on the placement and size of the levee breaches.

Stage profile plots from the Golden Gate to Freeport via the Sacramento River for high, low and mean tide for each breach scenario are available on the RMA web site at http://www.rmanet.com under "CALFED Suisun Marsh Levee Breach Modeling Study" under "San Francisco Bay and Delta, California." (The plots are under the sub-heading "Stage Profiles Along the Sacramento River" under "Analysis of Results.").

Tidal Trapping

Model results suggest that levee breaches, particularly near energetic channels, cause an increase in mixing by tidal trapping that tends to increase salinity in the western Delta. Again, the magnitude of the increase depends on the placement and size of the levee breaches.

A vector plot illustrating tidal trapping and a tidal trapping animation are available on the RMA web site at http://www.rmanet.com under "CALFED Suisun Marsh Levee Breach Modeling Study" under "San Francisco Bay and Delta, California." (The plots are under the sub-headings "Tidal Trapping, Van Sickle Wide" and "Tidal Trapping Animation" under "Analysis of Results.").

Conclusions

RECONNAISSANCE-LEVEL CALIBRATION

A reconnaissance-level calibration of the model has been performed with emphasis on flow, stage, and salinity in the Delta channels and upper Bay. Calibration results are reasonable, but further calibration is warranted.

COMPETING MECHANISMS

The impact of each levee breach configuration depends on the location and size of the breach due to two competing mechanisms: reduction of tidal range, resulting in reduced salinity in the western Delta; and tidal trapping, resulting in increased salinity in the western Delta.

SALINITY RESPONSES ASSOCIATED WITH SCENARIOS

Wide breaches generally negatively affect water quality. Due to tidal trapping, the Van Sickle Island breaches produce the most significant salinity increases, particularly in the south Delta and Suisun Marsh. The most favorable scenario is the Grizzly Island narrow breach, which results in significant decreases in salinity in the south Delta, the Sacramento River near Rio Vista, and the confluence area of the Sacramento and San Joaquin Rivers.

COMPARISON WITH DWR RESULTS

Salinity impacts of levee breaches produced by the 2-D depth-averaged RMA model are comparable to those produced by the DWR 1-D model—the most significant differences are in the Van Sickle Island breach results.

VII. Model Reconciliation

Introduction

The Investigation Team used the DWRDSM1 Suisun Marsh Version model to evaluate hydrodynamic and salinity impacts of controlled and uncontrolled levee breaches in the Suisun Marsh. However, the Team recognized the limitations of 1-D models for this type of analysis. CALFED let a contract to RMA Associates to provide corroborative modeling and analysis of physical mechanisms. This section summarizes the approach and assumptions used for corroborative modeling of tidal marsh and shallow-water habitat restoration levee breach scenarios in the Suisun Marsh. Comparative results are presented, along with a summary of peer review outreach. Figures referenced in this section (and section text) can be viewed at http://www.iep.water.ca.gov/suisun/CALFEDlevee under the heading "Modeling Hydrodynamics and Salinity Impacts of Suisun Marsh Levee Breaches: Comparative Analysis Using the DWRDSM1 and RMA 2/11 Models."

Background

The Suisun Marsh Levee Investigation Team was established to gather information on the costs and benefits of including Suisun Marsh levees in the CALFED Program. The Investigation focused modeling and biological analysis on the impact of Suisun Marsh levee breaches. Initial modeling analysis was performed by DWR, using DSM1—a 1-D hydrodynamic model. The Team recognized the need for an independent modeling assessment since the complexity of the task is at the limit of any 1-D model's capability.

CALFED let a contract to RMA Associates of Suisun City, California, for mathematical modeling services and analysis of the long-term impacts of Suisun Marsh levee breaches on Bay-Delta hydrodynamic and water quality. The contract specified that RMA would provide verification and examination of modeling analysis completed by DWR on the hydrodynamic and salinity impacts of Suisun Marsh and western Delta island levee breaches. Two specific products were requested:

- Conduct specific model studies to verify 1-D model result trends obtained by DWR.
- Identify and report the physical mechanisms controlling changes in salt transport that result from levee breaches.

RMA possesses unique qualifications for completing the requested analysis because (1) RMA uses an established 2-D modeling system complete with hydrodynamics, salinity, and sediment transport along with advanced graphical display capability; (2) RMA has extensive experience modeling hydrodynamics, water quality, and sediment transport in the San Francisco Bay Delta system; and (3) the RMA model is the only higher dimensional model that considers the entire tidal extent of the Bay-Delta system.

The contract with RMA included the following specifications:

- RMA would conduct six model runs, including simulation of narrow and wide levee breaches on Morrow, Grizzly, and Van Sickle Islands in the Suisun Marsh.
- RMA would provide CALFED the executable model code, input files, post-processing, and graphical analysis tools necessary to reproduce all modeling results.
- Background documentation of the proposed model's numerical scheme and calibration/verification would be provided to CALFED in a manner suitable for technical report publication.
- All background documentation would be presented to the Interagency Ecological Program Hydrodynamics Project Work Team (IEPHPWT) for review.
- RMA's approach for modeling long-term salinity trends in the Bay-Delta, including initial conditions, boundary conditions, and simulation period, would be presented and approved through the IEPHPWT.
- RMA would attend two meetings of the IEPHPWT: a kick-off meeting to discuss the modeling approach and attributes of the model, and a final meeting to discuss the results of the study and response mechanisms.
- RMA would attend one meeting of the CALFED Suisun Marsh Levee Investigation Team to present results.
- RMA would prepare a technical report, documenting the modeling analysis.

Modeling Approach

Corroboration of independent modeling results requires that the models be applied in as similar a fashion as possible. RMA simplified the historical modeling approach taken by DWR because the 2-D model currently is unable to simulate long historical sequences in a reasonable time. Tenable computational efficiency was achieved by executing the model only for the June 1 through September 30, 1992, period. Initial salinity conditions were generated with a 3-month historical simulation of the March through April period, using daily historical system inflows, exports, and facilities operations. The initial salinity for March 1 was generated from a diffusion solution based on field salinity data on that day. After June 1, all inputs were averaged for the June 1 through September 30 period, including rimflows, exports, agricultural depletions, and facilities operations. The June 1992 tide was repeated for each of the four simulation months.

DWR staff worked closely with RMA staff to develop the modeling approach described above. For comparable results, DWR modified the historical data set to mimic the RMA approach. Historical input data for June 1 through September 30, 1992, was averaged; and the Golden Gate tide was modified so that the June 1 through June 29 tide repeated through September.

Results

Figure VII-1[1] shows the 10 Suisun Marsh locations where DWR simulated the impact of narrow and wide levee breaches. As specified in the contract, RMA simulated narrow and wide breaches on Morrow Island, Grizzly Island, and Van Sickle Island. These alternatives are considered "shallow-water habitat" options because tidal restoration would result in entirely inundated areas. Future collaborative modeling work with RMA will include analysis of tidal marsh options.

Three types of modeling output were agreed on for comparison of output between the two models:

- Spatial salinity distribution
- Axis salinity
- Tidal prism

SPATIAL SALINITY DISTRIBUTION

Figures VII-2 through VII-7[1] compare late water-year 1992 salinity distribution change. The plots exhibit the percentage change from the base condition (without levee breaches). The DWR plots are for July 29, 1992, while the RMA results are for October 1, 1992. RMA believes that the 2-D model is somewhat slow to propagate salinity into the Delta after wet periods. Examples of the RMA model hydrodynamic and salinity calibration can be seen in Section VI. RMA model results for July 29, 1992, also were produced but are not shown here. The results corroborate DWR model trends on July 29, 1992; however, the magnitude of salinity trends are somewhat less than the DSM1 model used by DWR. RMA and DWR agree that comparisons of RMA results on October 1, 1992, and DWR results on July 29, 1992, are representative.

Figures VII-2 and VII-3[1] compare DWR and RMA model results for narrow and wide levee breaches on Morrow Island. For the narrow breach case (Figure VII-2[1]), both models show 2-3% salinity increases in Suisun Bay and 1-4% salinity decreases in the central and south Delta. Both models agree that the largest salinity decreases occur on the Sacramento River upstream of Rio Vista, where salinity decreases 4% in the RMA model and 7% in DWR model. For the wide breach case (Figure VII-3[1]), the DWR model predicts Suisun Bay/Marsh salinity increases between 2 and 6%, while the RMA model predicts salinity increases between 3 and 6%. Salinity increases spread into the central and south Delta in both models at about 1-3% increase.

Figures VII-4 and VII-5[1] compare DWR and RMA model results for narrow and wide levee breaches on Grizzly Island. For the narrow breach case (Figure VII-4[1]), both models show 1-2% salinity increases in Suisun Bay and 3-6% salinity decreases in the central and south Delta. Again, both models agree that the largest salinity decreases occur on the Sacramento River upstream of Rio Vista, where salinity decreases

[1] Figures referenced in this section (and section text) can be viewed at http://www.iep.water. ca.gov/suisun/CALFEDlevee under the heading "Modeling Hydrodynamics and Salinity Impacts of Suisun Marsh Levee Breaches: Comparative Analysis Using the DWRDSM1 and RMA 2/11 Models.

7% in the RMA model and 8% in DWR model. The cross-over between salinity increase and decrease occurs at the downstream end of Chipps Island in both models. For the wide breach case (Figure VII-5[1]), the DWR model predicts Suisun Bay/Marsh salinity increases between 2 and 8%, while the RMA model predicts salinity increases between 2 and 5%. Salinity increases turn to decreases in both models at approximately Rio Vista, and south and west of the CCC intake. Decreases in the south Delta in both models are about 1%.

Figures VII-6 and VII-7[1] compare DWR and RMA model results for narrow and wide levee breaches on Van Sickle Island. For the narrow breach case (Figure VII-6[1]), both models show salinity increases in the region of the breach between Chipps Island and Jersey Point (2-6% in the DWR model, 3-8% in the RMA model). Again, both models agree that the largest salinity decreases occur on the Sacramento River upstream of Rio Vista, where salinity decreases 3% in the RMA model and 2% in DWR model. Both models also predict that salinity will increase over most of the central and south Delta (RMA about 1%, DWR 1-4%). For the wide breach case (Figure VII-7[1]), both models predict significant salinity increases over most of Suisun Bay and the Delta. RMA predicts increases of 7-11% in the west Delta, and 4-5% in the central and south Delta. DWR predicts increases of 9-13% in the west Delta, and 2-10% in the central and south Delta.

AXIS SALINITY

An "axis salinity" plot format was devised to clearly identify the cross-over point between salinity increase and decrease for each alternative. The plot also depicts the longitudinal magnitude of salinity change and enables a comparison of scenarios.

Figure VII-8[1] shows the salinity change distribution from the Golden Gate to Freeport along the Sacramento River. The x-axis is kilometers from the Golden Gate; the y-axis is percentage salinity change from the base (no breach) condition on July 29, 1992. Figure VII-8a[1] shows RMA model results; Figure VII-8b[1] shows DWR model results. The narrow and wide breach results are represented for each of the three scenario locations that RMA simulated. Visual comparison shows close agreement between the two models, both in magnitude of salinity change and in distribution of salinity trends. Figure VII-9[1] illustrates the salinity change distribution from the Golden Gate to Vernalis along the San Joaquin River. Similar salinity magnitude and trend corroboration is evident.

TIDAL PRISM

Modification of tidal range has been suggested as an important physical mechanism controlling the salinity response to breached islands. In general, levee breaches to newly inundated areas reduce tidal range as finite tidal energy propagating from the Golden Gate dissipates over larger area. Figure VII-10[1] (Morrow Island breach), Figure VII-11[1] (Grizzly Island breach), and Figure VII-12[1] (Van Sickle Island breach) depict the

[1]Figures referenced in this section (and section text) can be viewed at http://www.iep.water.ca.gov/suisun/CALFEDlevee under the heading "Modeling Hydrodynamics and Salinity Impacts of Suisun Marsh Levee Breaches: Comparative Analysis Using the DWRDSM1 and RMA 2/11 Models.

28-day average (June 21 - July 18, 1992) tidal prism from the Golden Gate to Freeport along the Sacramento River. Tidal range is reduced on the order of a few inches in both models. The models agree that narrow breaches tend to reduce tidal range marginally more than wide breaches, especially in the region of the breach itself.

Peer Review

The contract with RMA required that the approach taken for modeling long-term salinity trends in the Bay-Delta, including initial conditions, boundary conditions, and simulation period, would be presented and approved through the IEPHPWT. Hydrodynamics Team members include field and modeling hydrodynamic experts, and water quality transport experts from multiple state and federal agencies, water districts, and universities. At a kick-off meeting, RMA presented attributes of the model and their proposed modeling approach. Upon completion of work, RMA and DWR made a joint presentation to the Hydrodynamics Team on the material presented in this report. In addition, DWR and RMA presented the material in this report jointly to the CALFED Levees and Channels Technical Team, and to the 2000 Bay-Delta Modeling Forum Conference.

Conclusions

This chapter summarizes the approach and assumptions used for corroborative modeling of tidal marsh and shallow-water habitat restoration levee breach scenarios in the Suisun Marsh. RMA and DWR cooperated extensively to simulate comparable Suisun Marsh levee breach scenarios using independent numerical models of the Bay-Delta system. Results are considered favorably comparable, and the participants agree that the modeling results reported by DWR in Section V have been substantially corroborated. The participants also agree on the fundamental physical mechanisms driving salinity response to levee breaches in the Suisun Marsh (Sections V and VI). Significant peer review has been obtained on the approach, assumptions, and results. We believe that reviewers are in general agreement that the conclusions of the Investigation Team are supported by the modeling reported herein.

VIII. Public Outreach and Other Research

Recognizing that the success of any proposed Suisun Marsh Levee Program hinges on willing landowner participation, public outreach and landowner input was highly stressed in the Investigation effort. Information gathered from the public outreach process provided valuable input into the Suisun Marsh Levee Investigation. The Suisun Marsh Levee Investigation Team conducted a series of public outreach workshops, beginning in March 2000. The workshops were noticed by an extensive mailing to Suisun Marsh landowners and announcements in the SRCD newsletter. An overview of the CALFED Program and the Suisun Marsh Levee Investigation was presented at the workshop. Landowner input was solicited in the workshop and through mail-in comment forms.

Key concerns and questions from public outreach workshop participants included:

- How will conversion efforts affect hunting in the Marsh?
- How will levee breaches and resulting wetlands be maintained, especially considering the soil composition in the Marsh (peat and other poor structural materials)?
- What are the merits for managed wetlands versus tidal wetlands
- CALFED should first target government-owned lands for any conversion efforts.
- CALFED should make maintenance dredging possible in the current regulatory climate.
- Would neighbors of parcels that are converted to tidal wetlands experience localized water quality impacts?
- Landowners desire assurance that CALFED will deliver on its end of the "package deal."
- How might actions necessitate formation of Reclamation Districts?
- What is the minimum acreage requirement to participate in potential conversion activities?

Key points and comments that were received by mail include:

- CALFED should go slow in adoption of new management techniques because of the uncertainty involved.
- A "measure of merit" should be established for Marsh habitat, such as tons of protein per acre.
- CALFED should consider the expected decrease in waterfowl population from conversion actions.
- CALFED should consider plans for public access and how it may affect landowners.

- How much would CALFED pay for a club or conservation easement?
- Isolated properties may be more appropriate for conversion.
- CALFED needs to consider impacts on neighboring water management facilities (for example, tidal gate drainage capability) from conversion.
- Delta/southern California water interests need to demonstrate a financial interest in Marsh levees in case another catastrophic breach should affect water quality.

Other public outreach efforts included CALFED Program participation in the Suisun Marsh Field Day on June 3, 2000. CALFED representatives attended the event and provided information on the Suisun Marsh Levee Investigation and encouraged participation in the Suisun Marsh Levee Investigation public workshops.

In addition to public outreach efforts, the Investigation consulted the following source for information:

Ramlit and Associates. 1983. San Francisco Bay Shoreline Study. Suisun Marsh Levee Evaluation. Submitted to the Department of the Army, San Francisco District, Corps of Engineers, San Francisco, CA.

IX. Cost Estimates for a Suisun Marsh Levee Program

Introduction

Increasing tidal wetlands in the Suisun Marsh is an objective of the CALFED Ecosystem Restoration Plan. Post-1998 flood modeling analysis identified potential Delta salinity benefits with certain Marsh levee breach configurations. Subsequent analyses confirmed these results and suggested that other levee breach scenarios could result in water quality degradation. Therefore, the need for a Suisun Marsh levee rehabilitation and maintenance program was determined to warrant further investigation. This section describes the existing levee system, discusses factors to consider in an effective levee progam, and provides cost estimates for a Suisun Marsh levee rehabilitation and maintenance program.

Levee Program Model

Currently, there is no government assistance program for the Marsh levees. However, the Delta Levees Program is an example of a successful program that may serve as a model for a Suisun Marsh Levee Program. The Delta Levees Program consists of Subventions and Special Projects components. The Subventions Program provides annual funding that assists reclamation districts with their normal rehabilitation and maintenance. The State reimburses costs up to 75% after the local reclamation district has spent $1,000 per levee mile it maintains. For example, a reclamation district responsible for maintaining 5 miles of levee will receive up to 75% after the district has spent $5,000. Annual levee costs totaling $105,000 will cost the district only $30,000 after a reimbursement of $75,000. The Special Projects Program is a project-specific program that funds projects that are more critical than typical rehabilitation and/or will provide additional benefits to the public. An example of a Special Projects-funded project includes work on levees where failure of the levee would affect critical state or federal improvements, or improvement of the levee would provide environmental benefits. The government cost share for these projects may exceed 75%, based on an ability-to-pay study performed by each individual reclamation district.

Existing Suisun Marsh Levee System

The existing Suisun Marsh levee system consists of approximately 228.8 miles of exterior levees. These levees are generally smaller than the levees in the Delta because the marsh land protected by the levees has not experienced as much subsidence. In addition to exterior levees, many miles of interior levees exist to protect tracts from flooding of neighboring lands and enable landowners to individually manage their property in order to enhance waterfowl habitat.

Marsh management has adopted a standard levee configuration (Figure IX-1). This levee section was designed over 20 years ago and is the standard to which levees are rehabilitated and maintained. There is very little information on the stability of this levee section, especially in the areas with weak foundations.

Although the levees in the Marsh are not as large as Delta levees (which adds to their instability), the forces on the levees are significant. Levees facing Honker and Grizzly Bays resist wave forces caused by wind fetch extending many miles. In addition to wave action, many levees have extremely weak foundations. Much of the Marsh is underlain by thick layers of organic peats and clays that have sustained little consolidation. Therefore, any levee rehabilitation plan must take into account the unconsolidated nature of the foundation and its effect on rehabilitation and maintenance.

The existing regulatory process impedes levee rehabilitation in the Marsh. Most of the Marsh protected by levees is considered wetland habitat for endangered species. Consequently, it is difficult to extend a levee beyond its existing footprint. In addition, little adequate levee material exists in the Marsh. Historically, dredging has been performed to provide a fill material for levee rehabilitation and maintenance. However, the sloughs and channels adjacent to the levees now are considered habitat for special-status plants and animals.

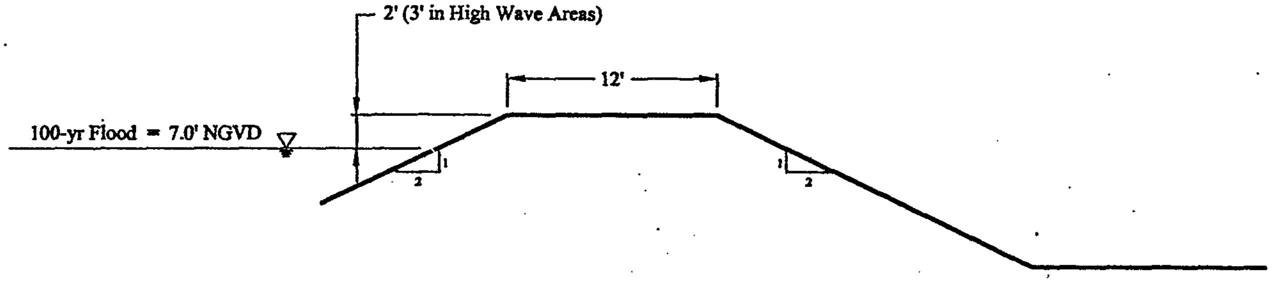
Suisun Marsh Levee Rehabilitation Program

The intent of a Suisun Marsh Levee Rehabilitation Program likely would be to attain the Marsh standard levee section over the entire 228.8 miles of exterior levee. In 1983, the U.S. Army Corps of Engineers (Corps) evaluated the need for levee rehabilitation in the Marsh (Ramlit and Associates 1983, referred to as the Ramlit Report). The Ramlit Report divided the Marsh levees into four rehabilitation classifications, based on the amount of work required to meet the standard section: major reconstruction, major repair, minor repair, and no repair.

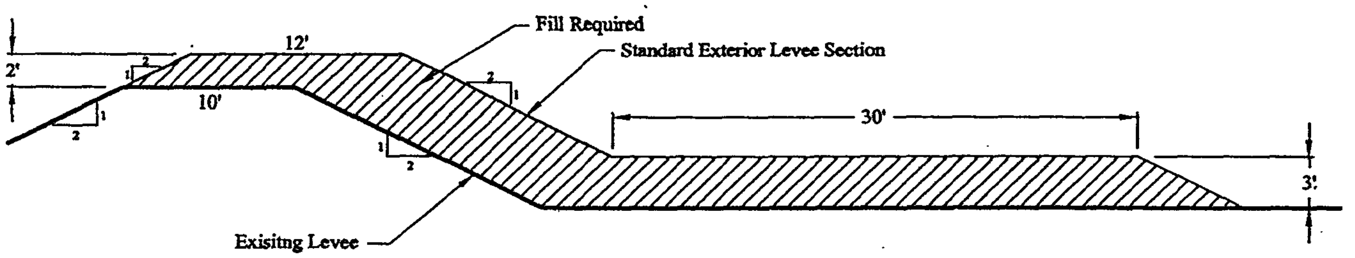
A total of 54.3 miles (24%) of the Marsh exterior levee system was designated as "major reconstruction." It was determined that these areas required 60% additional size to meet the minimum standard section. Figure IX-1 illustrates a generalized section describing what would be involved in the repair. Note that a buttress, or toe berm, has been added to the standard section. This feature was incorporated based on geotechnical review, using generalized foundation strengths. In addition, personal communication with DWR personnel verified the finding that addition of more than 1 foot of crown elevation would require the weight of the levee spread over a greater area.

The majority of the Marsh levee system (129.8 miles, or 56%) was classified in the Ramlit Report as "major repair." It was estimated that these levees would require 20-60% improvement to the meet the standard section. For this report, we are using the section shown in Figure IX-2 to represent the major repair levee. 38.7 miles, or 17% of the Marsh, was designated "minor repair" (less than 20% improvement) (Figure IX-2). The remaining 6.1 miles (3%) was determined to be in good shape and designated as "no repair."

The improvements described above will take several years to complete in some areas. The unconsolidated nature of much of the Marsh's foundation prohibits rehabilitation in one lift. A phased approach, using



Standard Suisun Marsh Exterior Levee Section



Major Reconstruction to meet Standard Section

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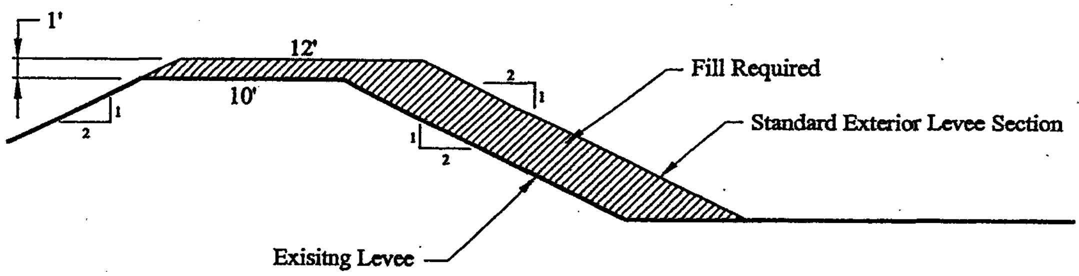
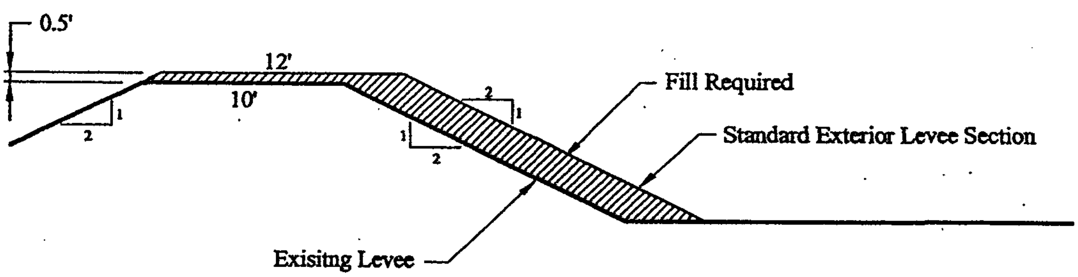
Sacramento, California 95817
(916) 456-4400

Figure IX-1.



Major Repair
to meet Standard Section



Minor Repair
to meet Standard Section

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Figure IX-2.

windrowed along the water side of the levee crown.

Suisun Marsh Levee Maintenance Program

The key to a good levee program is the ability to maintain a levee to its appropriate standard. The intent is to alleviate a minor problem before it becomes critical. Therefore, a Suisun Marsh Levee Program would need to incorporate a maintenance element to assist local reclamation districts. Maintenance items include inspections; surveys; rodent control; vegetation control; roadway maintenance; slip, revetment, and subsidence repair; shaping; flood preparation and planning; encroachment removal; and engineering and biological services.

Levee Rehabilitation and Maintenance Costs

Rehabilitation costs were estimated using the cross sections described above. The estimates take into account several construction phases that, in addition to fill material, require repeated treatments of road gravel and rip rap. The costs estimates are $3.48 million (in 2000 dollars) per mile for "major reconstruction," $1.58 million (in 2000 dollars) per mile for "major repair," and $650,000 (in 2000 dollars) per mile for "minor repair." Therefore, the total estimated rehabilitation cost over the entire Marsh exterior levee system is $419 million (in 2000 dollars).

Maintenance costs will vary, based on the current condition of the levee. Maintenance also varies based on the forces acting on the levee, such as high erosive forces and substantial consolidation of the foundation. The Delta, which has had an active levee program for over 25 years, currently requires between $5,000 and $15,000 per levee mile annually for maintenance. Because attaining this condition will require 30 or more years and the Suisun Marsh levees currently are in poor condition, the Suisun Marsh levees are estimated to require maintenance in the order of $15,000 (in 2000 dollars) per levee mile annually. Over the 228.8 miles of exterior levees in the Suisun Marsh, this amount equates to $3.43 million (in 2000 dollars) per year.

{Information regarding costs to create and maintain narrow breach scenarios and associated habitat conversion costs will be provided in subsequent drafts}

X. Analysis of Modeling and Research Results

Introduction

The analyses presented in this Investigation Report indicate that including the Suisun Marsh levees in the CALFED Program would contribute to achieving Program goals. Pursuit and implementation of detailed planning efforts in the Suisun Marsh for levee rehabilitation and maintenance would provide opportunity for water quality improvement and ecosystem restoration, which would support the goals of the CALFED Program.

The results of modeling to evaluate hydrodynamic and salinity impacts of controlled and uncontrolled levee breaches in the Suisun Marsh are presented in Sections V and VI. DWR's Suisun Marsh Branch performed 1-D modeling analysis, and RMA performed 2-D modeling analysis to corroborate the 1-D model results. (Section VII presents a comparative analysis of the modeling approaches.)

The following general conclusions were reached from the modeling analysis:

- Large levee breaches in the Suisun Marsh will increase salinity in Suisun Bay and the Delta.
- Small levee breaches in the Suisun Marsh may increase local salinity but decrease Delta salinity.
- Salinity response is sensitive to breach size and location, and the area or volume of inundation.

Water Quality and Water Supply Reliability

The first conclusion, that large levee breaches in the Suisun Marsh will increase salinity in Suisun Bay and the Delta, highlights the importance of providing maintenance for Suisun Marsh levees. Failures of Suisun Marsh levees could affect achievement of CALFED water quality goals. In addition, water supply reliability impacts are closely related to salinity impacts—increased salinity intrusion into the Delta may affect the ability of the water supply projects to pump water from the Delta and meet legal water quality requirements. The second conclusion, that small levee breaches in the Suisun Marsh may increase local salinity but decrease Delta salinity, illustrates the potential of a Suisun Marsh levee program to support water quality goals in the Delta. Tables V-2 and V-3 illustrate the modeling results on a regional basis. These tables present the mean, minimum, and maximum percent salinity change from base, X2 difference from base, and X2 standard difference for the different scenarios for 100-foot (small) and 5,000-foot (large) breach configurations for different geographical areas of the Marsh and Delta. X2 is significant because it is a parameter for establishing the outflow requirements of the state and federal water projects.

It is important to acknowledge that—for purposes of analysis—large, contiguous regions were selected for modeling, taking into account Ecosystem Restoration Program goals. Land conversion most likely would not occur this way. Ultimately, modeling will need to be performed for individual parcels as they are considered in more detailed planning efforts, in order to accurately quantify potential water quality benefits from any individual parcel conversion. The third general conclusion—that salinity response is sensitive to breach size and location and the area or volume of inundation—supports the need for more detailed planning efforts.

Ecosystem Restoration

The Investigation Team analyzed the hydrodynamic and salinity modeling results in terms of Ecosystem Restoration Program goals. The modeled scenarios originally were developed considering Ecosystem Restoration Program goals. To obtain a more accurate post-modeling estimate of the types of habitat created and the potential resultant Ecosystem Restoration Program benefits, the sub-team performed an analysis of the tidal marsh/shallow-water habitat options in the Suisun Marsh.

An examination of the several sources of information listed below indicates an elevation of 2.5 feet (NGVD) as a rough delineating line between tidal marsh and shallow-water habitat:

- Field observations of a currently breached Suisun Marsh island tidal datum diagram from the Baylands Ecosystem Habitat Goals report.
- Discussion with Karl Malamud-Roam, Marsh Specialist—Contra Costa Mosquito and Vector Control District.
- Data from the Suisun Marsh mean pond-bottom elevation survey.
- Suisun Marsh individual property management plans.
- U.S. Geological Services (USGS) topographic map with 5-foot contour lines.

Use of the 2.5-foot elevation (NGVD) in this report is believed to be consistent with areas already identified for potential conversion to shallow-water habitat by the Investigation Team.

Table X-1 illustrates the potential acres of habitat created for each option.

Table X-1. Potential Acres of Habitat Created for Each Option

Tidal Marsh Option	Tidal Marsh	Shallow-Water Habitat	Upland Habitat	Existing Tidal Marsh
Western option	1,063	2,295	589	250
Northeast option	2,529	1,593	2,178	656
Central option	2,046	2,691	45	698
Northwest option	979	3,192	1,034	209

Section III presents a detailed characterization of the Suisun Marsh environmental setting and the Ecosystem Restoration Program and MCSC goals for the area. Habitat goals outlined in the Ecosystem Restoration Program Plan include establishment of 1,500 acres of shallow water habitat and 5,000 to 7,000 acres of tidal marsh habitat.

The estimates in Table X-1 of potential acres of habitat created for each option illustrate the potential of a Suisun Marsh levee program to significantly support the Ecosystem Restoration Program habitat goals for the Suisun Marsh. Regarding the estimates of potential habitat created, it should be noted that there is no certainty that reestablishment of tidal exchange will restore marsh function to pre-restriction status. Physical factors that would influence functional recovery after conversion of managed wetlands to tidal marsh include:

- Tide height (relative to surface elevation)
- Salinity
- Water depth
- Frequency and duration of inundation

Other local factors, such as breach size, size of channel adjacent to the breach, tidal exchange (influenced by length of tidal excursion and tidal restrictions in the channel adjacent to the breach), and sediment deposition (accretion), also will influence recovery after conversion. Any site proposed for conversion would require an extensive hydrologic, ecological, and topographic survey (as well as modeling) to fully evaluate the chances of successfully achieving the proposed conversion goals.

The topographical survey would need to identify the presence of historical tidal channels, upland areas that might be converted to tidal wetland, and the availability of an upland buffer zone (high-tide refuge).

In addition, modeling would need to be performed to consider second-order impacts, such as increases in tidal stage near the breach, the effect of higher salinities on neighboring habitats, and effects on the flood/drain capabilities of adjacent landowners. Increased volume in the sloughs also could cause scouring on local levees.

Cost Estimates

Cost estimates for Suisun Marsh levee rehabilitation and maintenance are presented in Section IX.

{Full analysis of cost estimate information will be completed in subsequent drafts.}

Actual cost and benefits will vary, depending on many other factors. Other factors that must be considered include landowner willingness to participate, regulatory agency requirements, maintenance requirements, and adjacent landowner impacts. **{Subsequent draft will include more detailed discussion of these items.}**

The goal of the Suisun Marsh Levee Investigation is to develop the information needed for CALFED to make an informed decision on whether spending money on Suisun Marsh levees is a cost-effective way to meet the Program's primary objectives and solution principles. This modeling and cost analysis has been simplified to provide an overview of the potential benefits of including the Suisun Marsh levees in the CALFED Program. More detailed planning will be necessary on a case-by-case basis, and actual realization of any benefits would occur only through balancing the factors listed above. This analysis illustrates the general merit of pursuing detailed planning efforts in the Suisun Marsh for levee maintenance that will maintain existing Delta water quality and provide the opportunity for water quality improvement and ecosystem restoration.

XI. Conclusions and Staff Recommendations

The Suisun Marsh Levee Investigation Team recommends that Suisun Marsh levees be included in the CALFED Bay-Delta Program. The Team has identified significant links between Suisun Marsh levee maintenance and achievement of CALFED Program goals, particularly regarding water quality and ecosystem restoration. Furthermore, modeling research indicates a significant risk of water quality impacts in the Delta if Suisun Marsh levees are inadequately maintained and breach.

Recommended elements of a Suisun Marsh Levee Program include:

- An interim plan that emphasizes establishment of an Emergency Response Program as an early implementation action and interim structural measures such as splash berms or other protective measures, to prevent levee damage prior to full levee maintenance program implementation.
- A Base Level Marsh-Wide Maintenance Program modeled on the current Delta Levee Subventions Program and the Base Level Levee Protection Program (outlined in the Levee System Integrity Program) that includes a similar local and non-local cost-share.
- A program for enhanced protection that is modeled on the current Special Flood Control Projects Program and the Special Projects Program outlined in the Levee System Integrity Program. A criterion for inclusion should be developed that is based on the enhanced water quality benefits or ecosystem benefits of including a particular levee area.
- Development of criteria and evaluation methodology for acceptable parcel characteristics, such as patch size or location, that could affect significant biological or water quality improvements through conversion to tidal wetlands or shallow-water habitat and qualify a parcel for habitat conversion.
- Application of focused research toward an engineering strategy for levee breaching and maintenance to convert to tidal wetlands or shallow-water habitat. Of particular concern is the complexity of successfully maintaining a narrow breach.
- Obtaining more accurate topographical data for the Suisun Marsh for planning purposes.
- An examination of sedimentation processes in the Marsh to explore possible means of creating sediment accretion throughout the Suisun Marsh in order to aid shallow-water habitat and tidal marsh creation in areas where the topography is currently inappropriate.
- Use of adaptive management techniques to pursue any tidal marsh conversion efforts. Implementation of pilot projects is highly desirable.
- Focusing first on lands in public ownership for habitat conversion opportunities.

- Addition of the Suisun Marsh levees to the CALFED Levee Program Risk Assessment and Risk Management Strategy.

- Development of and funding for an Emergency Response Element to address Suisun Marsh levees. This may include a recommendation that Corps jurisdiction be extended to the Marsh for emergency response as needed after local and state resources are exhausted. A chain of command for emergency response is not as well established in the Marsh as in the Delta.

- Structuring funding for improvements of Suisun Marsh levees to avoid competition with the already strained resources for the maintenance of levees currently included in the Delta Subventions Program.

- Simultaneous implementation of restoration and maintenance improvements.

XII. References

Ramlit and Associates. 1983. San Francisco Bay Shoreline Study. Suisun Marsh Levee Evaluation. Submitted to the Department of the Army, San Francisco District, Corps of Engineers, San Francisco, CA.

The following references will be provided in the next draft:

DFG 1975

DWR 1994

DWR 1999a

DWR 1999b

USCS 1975

USFWS 1979

Appendix A
DWR - ESO Modeling Results

Appendix A. DWR - ESO Modeling Results

A complete graphical reporting of the modeling results can be viewed on the Internet at http://www.iep.water.ca.gov/suisun/CALFEDlevee or can be obtained on CD by request.

Appendix B
RMA Modeling Results

Appendix B. RMA Modeling Results

RMA Modeling Background Information

Existing RMA Model, Improvements, and Assumptions for Investigation Purposes

Existing RMA Model of San Francisco Bay-Delta

RMA developed and maintains a numerical model of the San Francisco Bay and Sacramento-San Joaquin Delta system, using the RMA finite element software. The RMA model of the San Francisco Bay-Delta extends from the Golden Gate to Freeport on the Sacramento River and to Vernalis on the San Joaquin River. San Francisco Bay and Suisun Bay regions are represented using a two-dimensional (2-D) depth-averaged approximation, with Delta channels and tributary streams represented using a one-dimensional (1-D) cross-sectionally averaged approximation.

Improvements to Model Geometry

The existing finite element mesh of the San Francisco Bay and Sacramento-San Joaquin Delta has been improved to facilitate the Suisun Marsh levee breach study. The 1-D Delta and Suisun Marsh channels have been refined and made more accurate using current U.S. Geological Survey digital orthoquad maps and bathymetry data collected between 1934 and 1990. The most recent bathymetry data were used where available. The 2-D finite element mesh was refined in the Suisun Bay and extended into the confluence area of the Sacramento and San Joaquin Rivers to Rio Vista, Three Mile Slough, and Bradford Island. Frank's Tract is now represented in 2-D as well.

Figures B-1 and B-2 show the original Bay-Delta grid and the enhanced Bay-Delta grid, respectively. Figures B-3 and B-4 compare the original and enhanced meshes for the Delta and Suisun Bay, respectively.

Delta Gates and Flow Control Structures. The Suisun Marsh tide gate, Delta Cross Channel (DCC), south Delta barriers, and the Clifton Court Forebay radial gates have been added to the model.

Delta Island Consumptive Use. The Delta island consumptive use (DICU) approximation used by the DWR model was adopted for use in the RMA model.

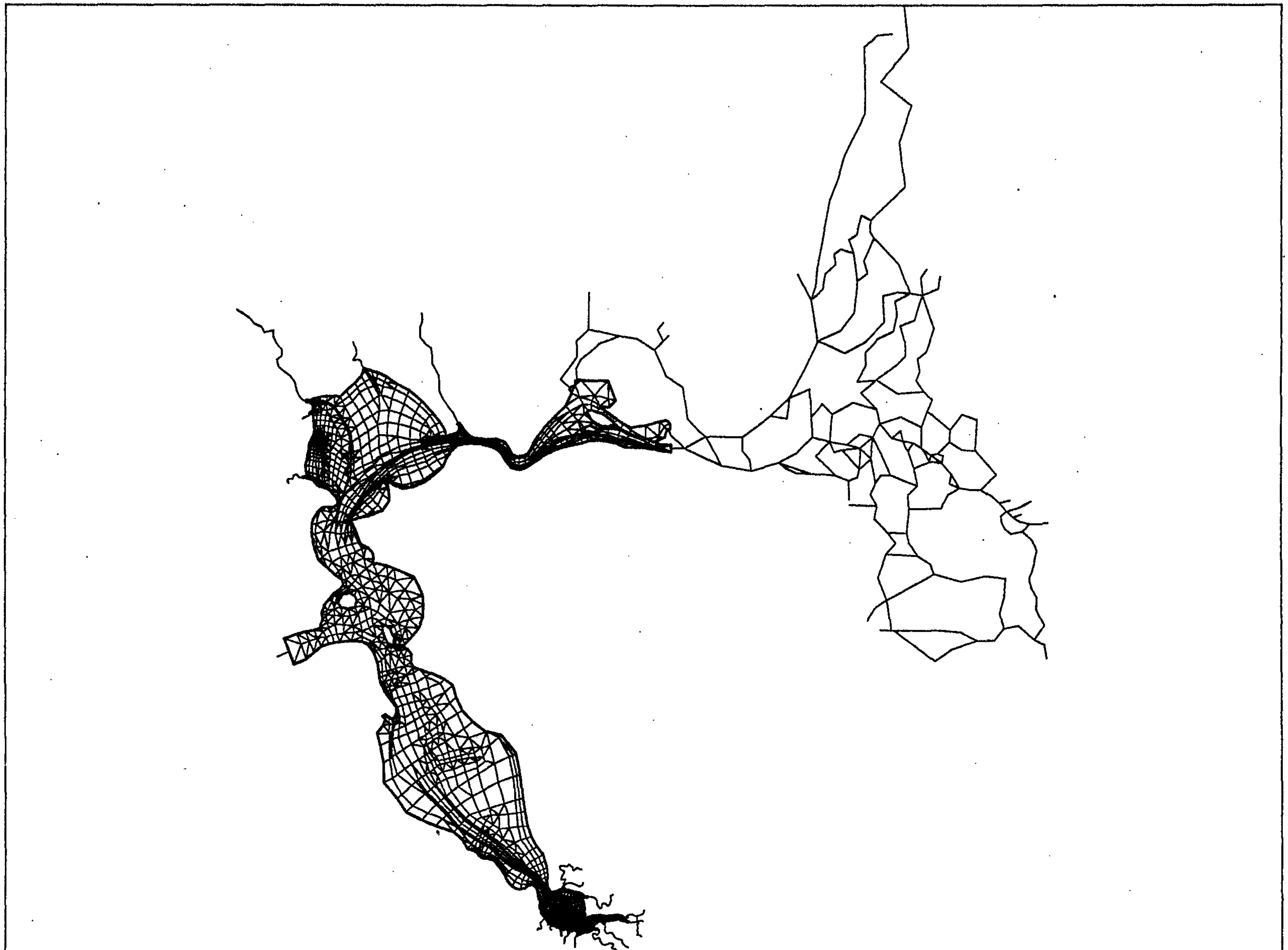


Figure B-1. San Francisco Bay and Delta Original Finite Element Mesh

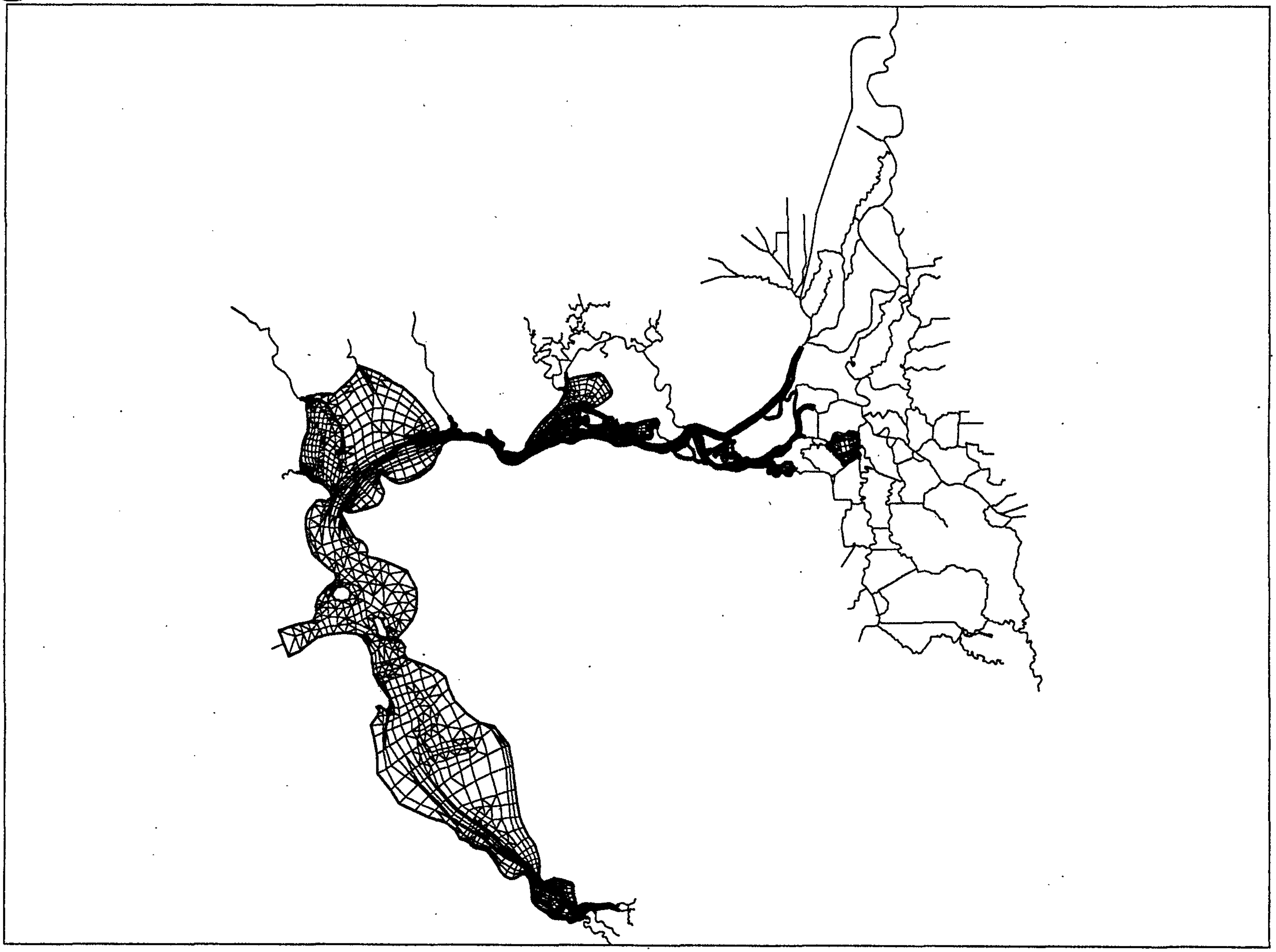


Figure B-2. San Francisco Bay and Delta Enhanced Finite Element Mesh

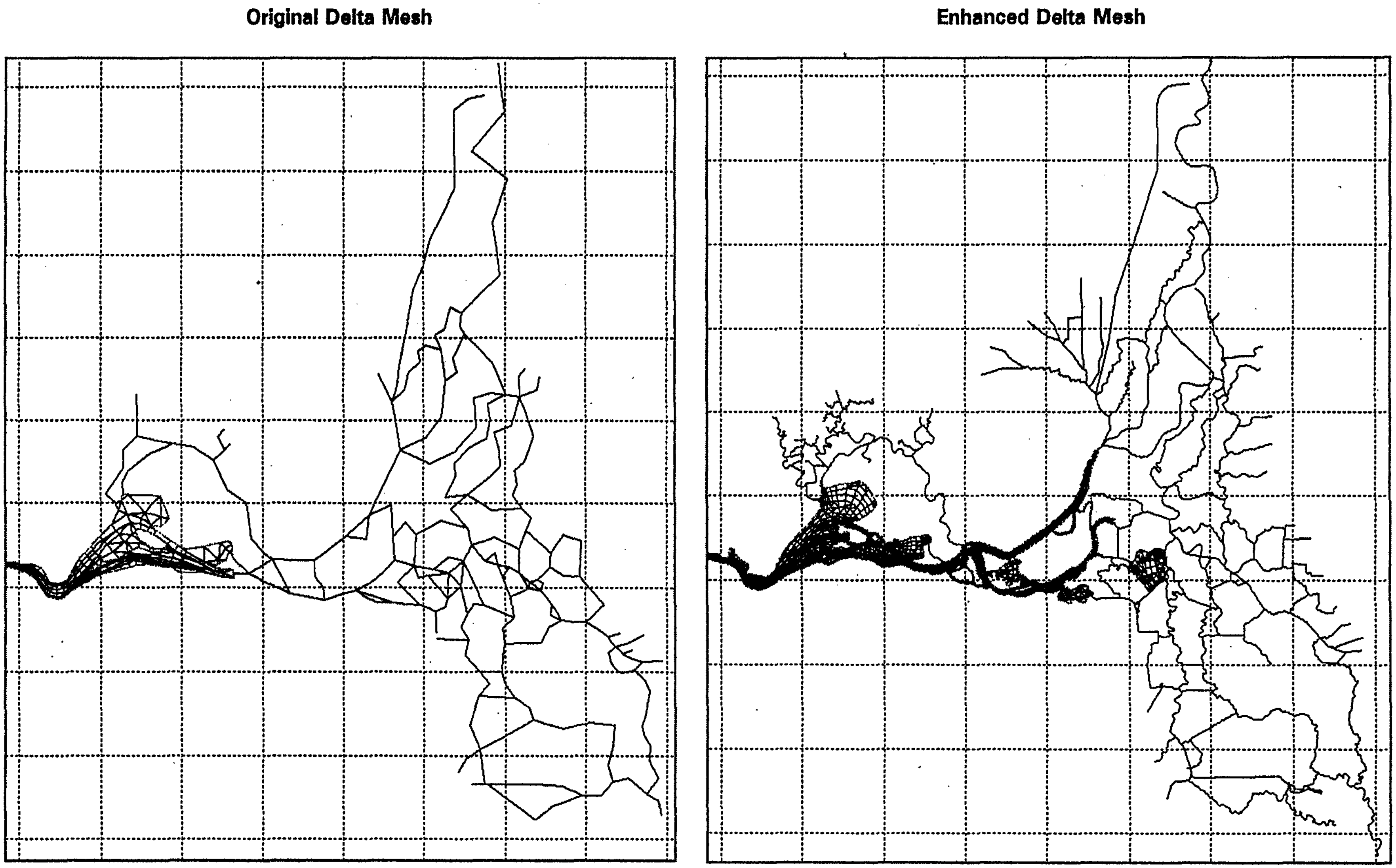


Figure B-3. Original and Enhanced Meshes for the Delta

Original Susiun Bay Mesh

Enhanced Suisun Bay Mesh

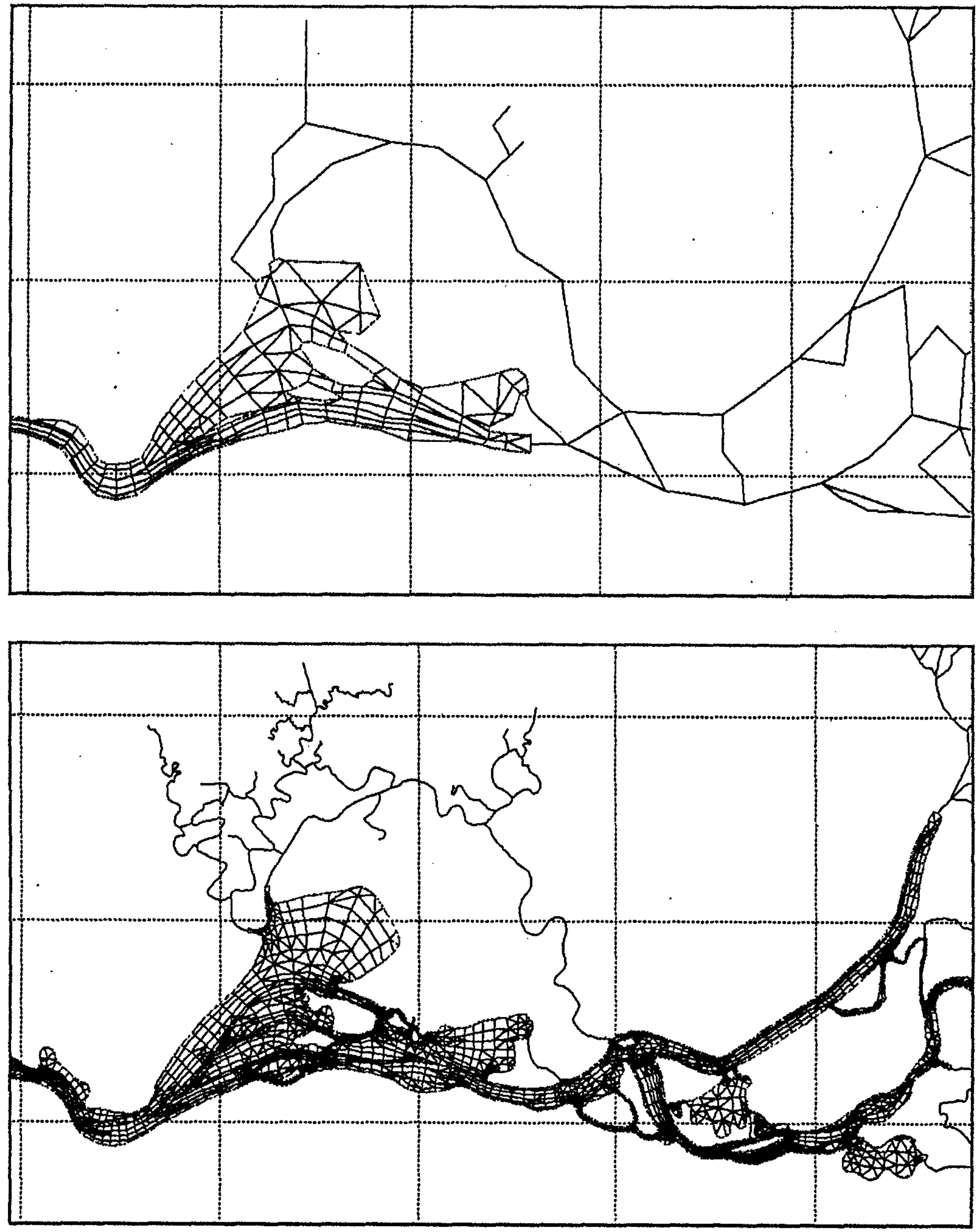


Figure B-4. Original and Enhanced Meshes for Suisun Bay

CALIBRATION METHODOLOGY AND ASSUMPTIONS

Calibration Periods

September 1998 hydrodynamic calibration was performed to take advantage of the data collected during the fall 1998 confluence study, when extensive flow and stage data were taken in the channels at the confluence of the Sacramento and San Joaquin Rivers. Additional calibration of hydrodynamics and salinity was performed for April-May 1992.

Boundary Conditions

Flows. Daily flows for the Sacramento River, San Joaquin River, Cosumnes River, Mokelumne River, and miscellaneous eastside daily flows were assigned using Dayflow data.

Exports. Daily average flows were used for the Central Valley Project (CVP), State Water Project (SWP) (pumps on/off at appropriate times), Contra Costa Canal (CCC), North Bay Aqueduct (NBA), and Yolo Bypass.

Salinity. Calibration period average salinities were assigned for the Sacramento River, San Joaquin River, Cosumnes River, Mokelumne River, and miscellaneous eastside flows.

Gates and Barriers. The model geometry includes the DCC, Montezuma Slough tide gates, Middle River barrier, and Old River barrier. In modeling, the gates and barriers open and close at appropriate times throughout the calibration periods, according to historical operation data.

Tide. The Golden Gate tide corresponding to the calibration period was used.

Delta Island Consumptive Use. The average for the calibration period was used for DICU.

Hydrodynamics

Confluence Study (September 1998). Initial calibration of the model hydrodynamics was performed for September 1998, with a focus on flows around the confluence area.

Computed and observed flow and stage plots are available on the RMA web site at http://www.rmanet.com.

Flow and Stage (April-May 1992). A second hydrodynamics calibration was performed for April-May 1992, using flow and stage data available from DWR and other agencies. Computed and observed stage and flow plots are available on the RMA web site at http://www.rmanet.com.

Salinity (April-May 1992). Salinity calibration was performed for April-May 1992, using electrical conductivity (EC - a measure of salinity) data available from DWR and other agencies. Computed and observed salinity plots are available on the RMA web site at http://www.rmanet.com.

RMA MODEL GRID MODIFICATIONS AND ASSUMPTIONS FOR CALFED LEVEE BREACH ANALYSIS

Grid Modifications for All Breaches

Six different grid alternatives were developed: one narrow breach (100 feet wide) and one wide breach (5,000 feet wide) each for Morrow Island, Grizzly Island, and Van Sickle Island.

Figures B-5 through B-7 present plots of each levee breach mesh configuration.

Simulation Period (June-September 1992)

Because of the complexity of the RMA model, a 2-year simulation as performed by DWR could not be accomplished in a reasonable amount of time using the RMA model. The 4-month dry-weather period from June to September 1992 was simulated for comparison with DWR results for the same period.

Boundary Conditions

Flows. Dayflow data were used to compute average flows for the simulation period for the Sacramento River, San Joaquin River, Cosumnes River, Mokelumne River, and miscellaneous eastside flows.

Figure B-8 presents a plot of Dayflow data with averages.

Exports. Simulation period average flows were used for the CVP, SWP (pump on/off using period average for all pump on times), CCC, NBA, and Yolo bypass.

Salinity. Simulation period average salinities were used for the Sacramento River, San Joaquin River, Cosumnes River, Mokelumne River, and miscellaneous eastside flows.

Gates and Barriers. The model geometry includes the DCC, Montezuma Slough tide gates, Middle River barrier, and Old River barrier. In modeling, the gates and barriers open and close at appropriate times throughout the calibration periods, according to historical operation data.

Tide. The 28-day repeating tide at Golden Gate from June 1-29, 1992, was used.

Figure B-9 presents the stage time series at Golden Gate, indicating the period of the 28-day repeating tide.

Delta Island Consumptive Use. The average of June, July, August, and September 1992 was used for DICU.

Van Sickle Island - Wide Breach

Van Sickle Island - Narrow Breach

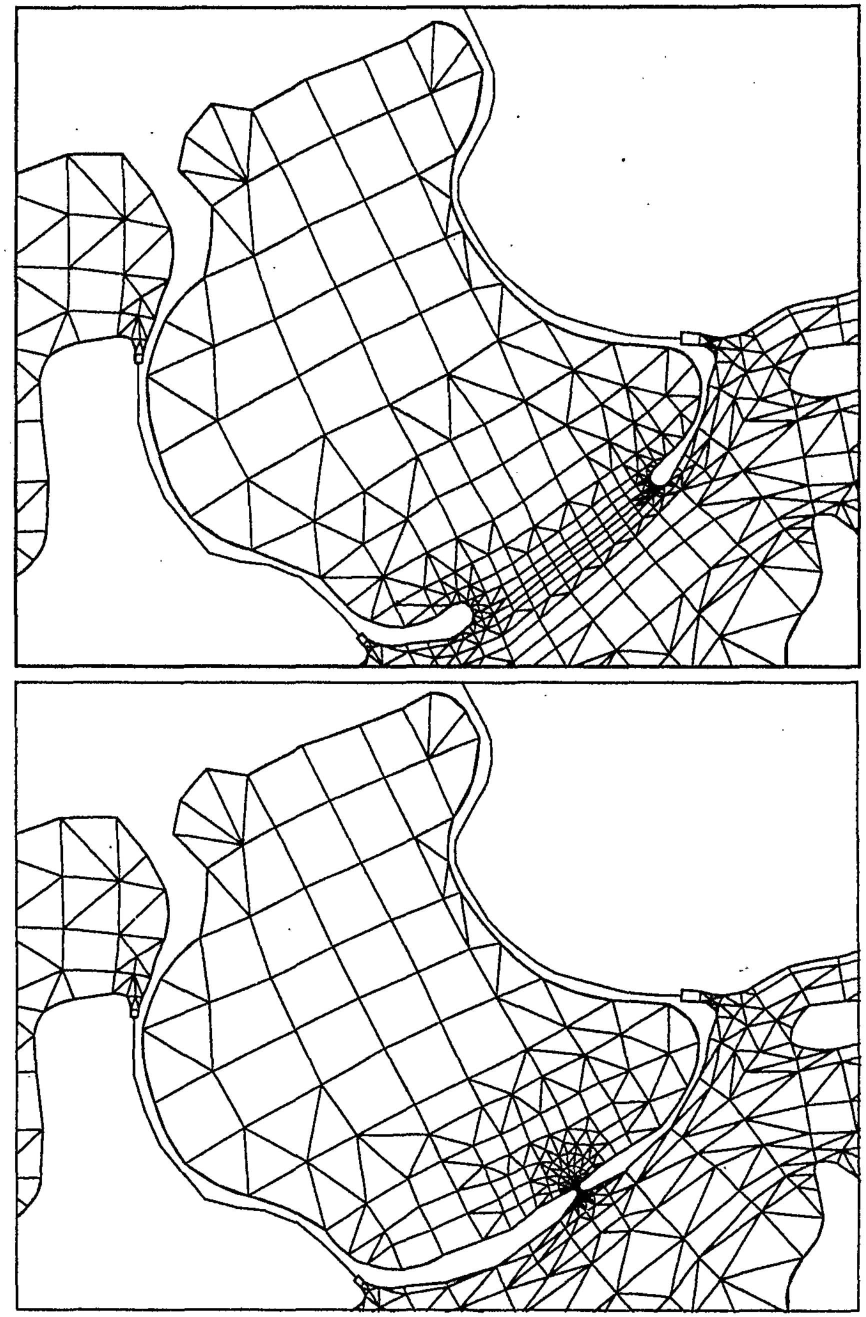


Figure B-5. Wide and Narrow Breach
Mesh Configurations for Van Sickle Island

E-039556

Morrow Island - Wide Breach

Morrow Island - Narrow Breach

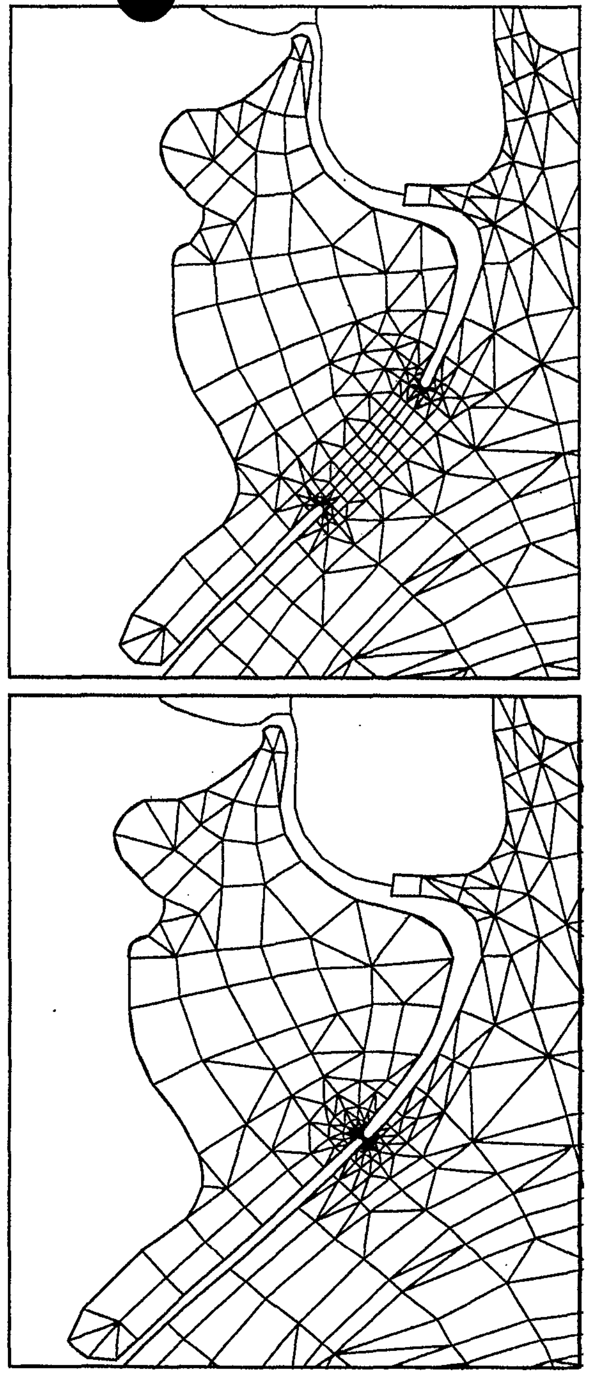
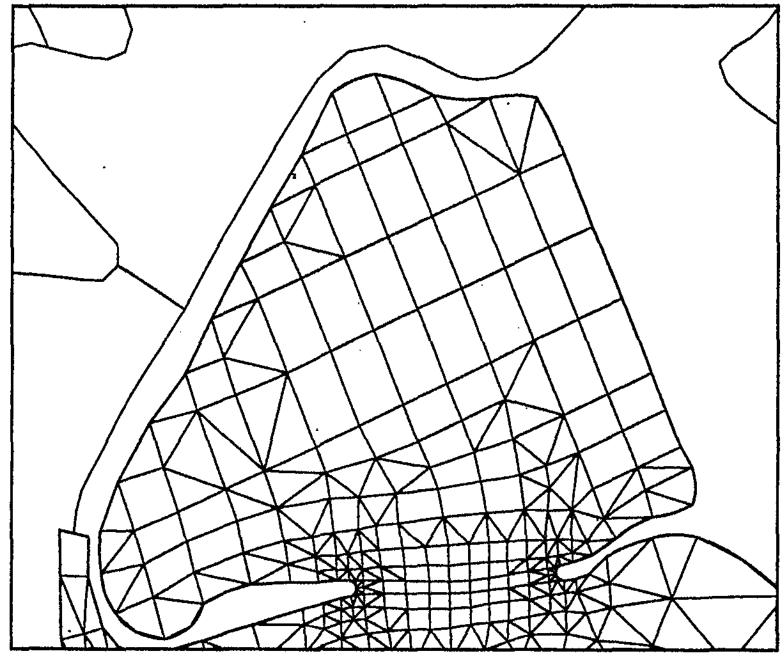


Figure B-6. Wide and Narrow Breach Mesh Configurations for Morrow Island

E-039557

E-039557

Grizzly Island - Wide Breach



Grizzly Island - Narrow Breach

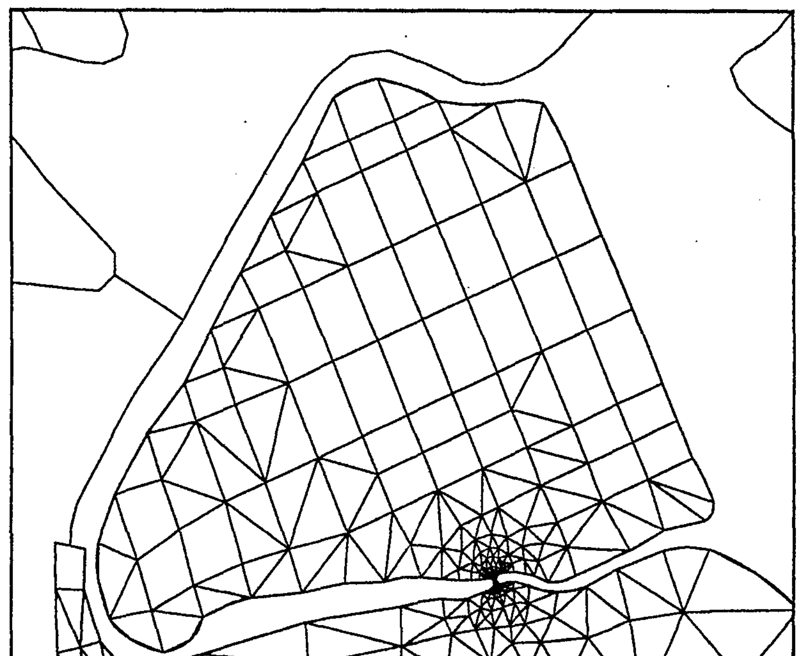


Figure B-7. Wide and Narrow Breach Mesh Configurations for Grizzly Island

E-039558

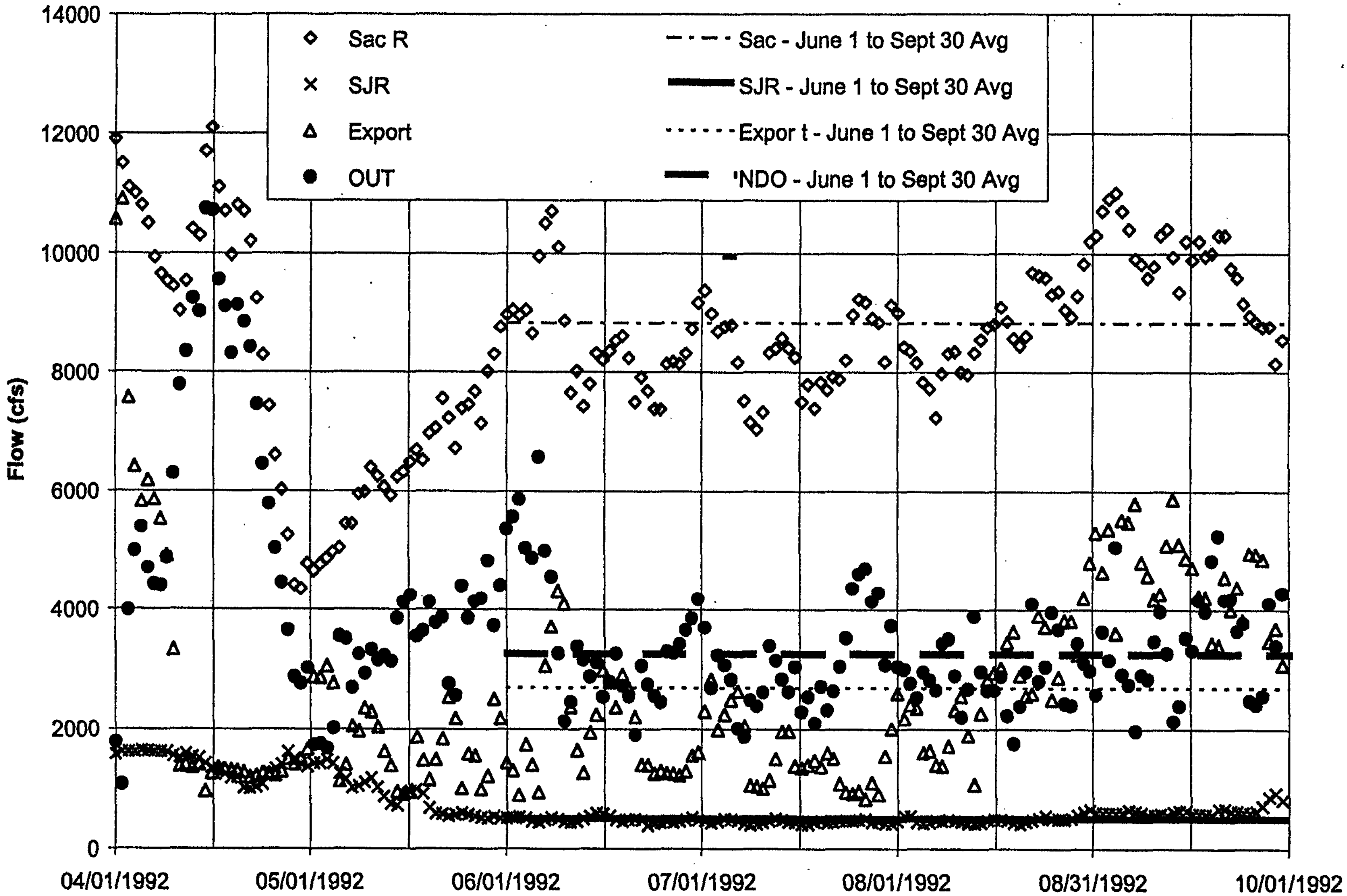


Figure B-8. Plot of 1992 Dayflow Data with Averages

E-039559

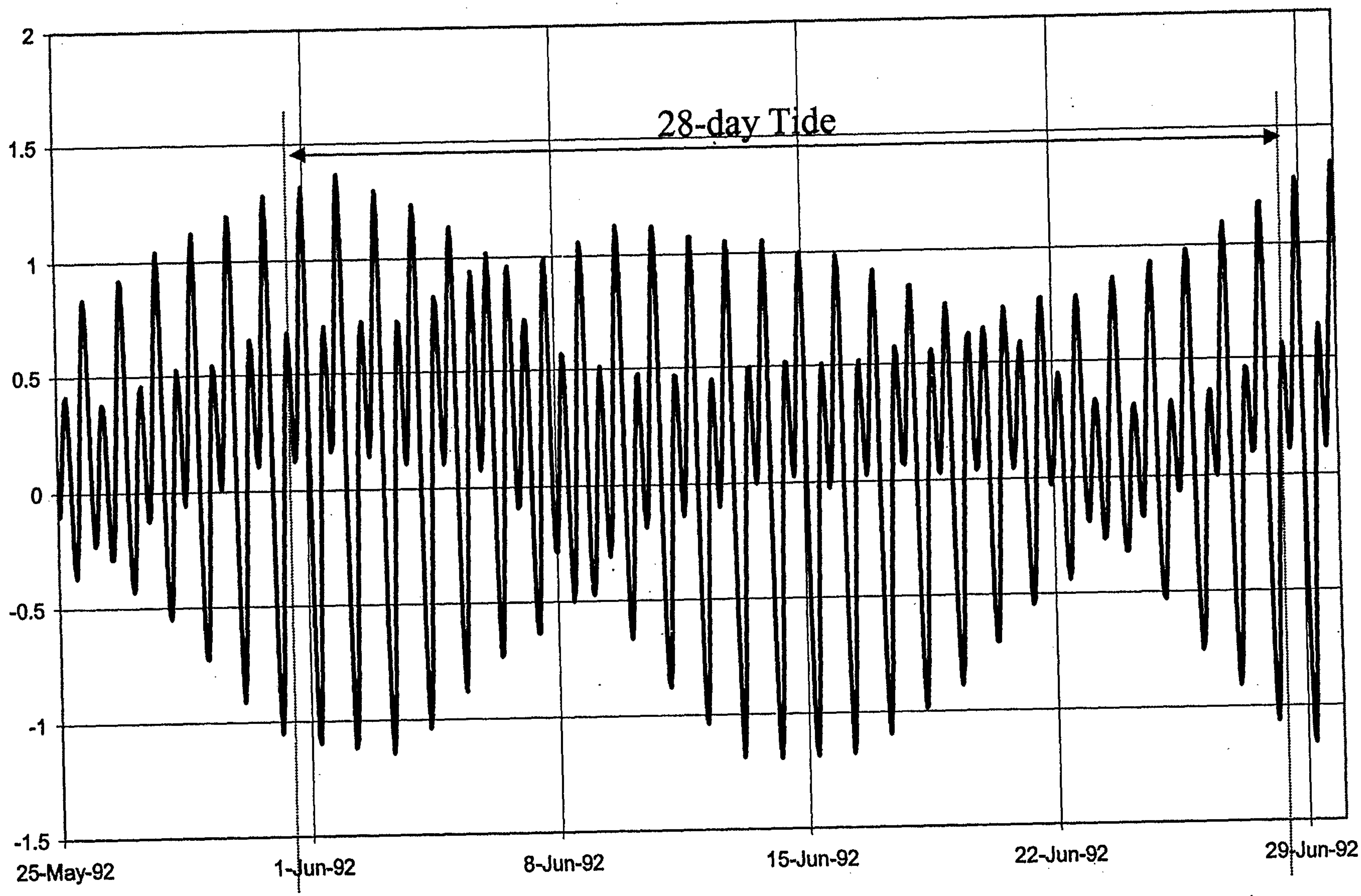


Figure B-9. Stage Time Series at Golden Gate

E-039560

Appendix C
Biological and Physical Setting

Appendix C. Biological and Physical Setting

This appendix accompanies Section III, "Suisun Marsh." The appendix provides detailed background information on:

- Construction facilities
- Legislative and and administrative environment
- Ecosystem typology
- CALFED Bay-Delta Program (CALFED) restoration targets for the Suisun Marsh.
- Multi-Species Conservation Strategy conservation measures

Constructed Facilities

The California Department of Water Resources (DWR) and the U.S. Bureau of Reclamation (Reclamation) have constructed facilities in the Suisun Marsh in order to improve the ability to provide lower salinity water to managed wetlands. These facilities were identified in the Plan of Protection for the Suisun Marsh and the 1987 Suisun Marsh Preservation Agreement (SMPA) as mitigation to maintain water quality for past and future diversions from the Delta. The initial facilities, including the Roaring River Distribution System, Morrow Island Distribution System, and Goodyear Slough Outfall, were constructed in 1979 and 1980. The Suisun Marsh Salinity Control Gates were installed and became operational in 1988. Other facilities constructed under the SMPA include the Cygnus Drain and the Lower Joice Island Diversion (DWR 1999b).

Roaring River Distribution System

The Roaring River Distribution System was constructed in 1979 and 1980 to provide wetland managers on Simmons, Hammond, Van Sickle, and Wheeler Islands with lower salinity water for approximately 5,000 acres of managed wetlands. Construction involved enlarging Roaring River and extending its western end. Excavated material was used to widen and strengthen the levees on both sides of the system. A bank of eight 60-inch-diameter culverts brings lower salinity water into the system from Montezuma Slough. The culverts are equipped with a fish screen at the intake to minimize diversion of fish into Roaring River Slough.

Morrow Island Distribution System

The Morrow Island Distribution System, in the western Suisun Marsh was constructed in 1980. The system is composed of two channels known as M-line and C-line. The channels divert water from Goodyear Slough to the easternmost area of Morrow Island. The purpose of the system is to allow wetland managers to fill their ponds with lower salinity water from Goodyear Slough or the Morrow Island Distribution System and drain into Grizzly Bay or Suisun Slough.

GOODYEAR SLOUGH OUTFALL

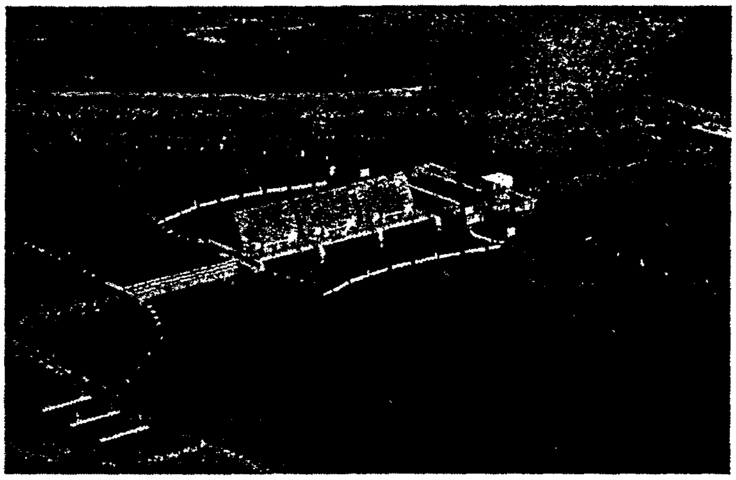
The Goodyear Slough Outfall was constructed to connect the south end of Goodyear Slough to Suisun Bay. Prior to construction of the outfall, Goodyear Slough was a dead-end run. The system was designed to increase circulation and reduce salinity in Goodyear Slough, and to provide lower salinity water to the wetland managers who flood their ponds with Goodyear Slough water.

LOWER JOICE ISLAND UNIT

The Lower Joice Island Unit consists of two 36-inch-diameter intake culverts on Montezuma Slough near Hunter Cut and two 36-inch diameter culverts on Suisun Slough, also near Hunter Cut. Both sets of culverts were required by the SMPA and installed in the existing levee in 1991. The facilities include combination gates on the slough side and flap gates on the landward side. The Lower Joice Island facility allows more rapid filling of the site and is connected to the existing distribution system on Individual Ownership Number 424. This facility enables the individual ownership to properly manage its wetlands on Lower Joice Island.

SUISUN MARSH SALINITY CONTROL GATES

The Suisun Marsh Salinity Control Gates (SMSCG) were completed and began operating in 1988. The facility consists of a boat dock, a series of three radial gates, and flashboards. SMGSCG operation during periods of lower Delta outflow contributes to restoring salinity patterns in the Suisun Marsh by restricting the flow of higher salinity water from Grizzly Bay into Montezuma Slough during incoming tides and retaining lower salinity Sacramento River water from the previous ebb tide. Operation of the SMSCG in this fashion lowers salinity in Suisun Marsh channels and results in a net movement of water from east to west. When Delta outflow is low to moderate and the SMSCG are not operating, net movement of water is from west to east, resulting in higher salinity water in Montezuma Slough.



CYGNUS UNIT

The Cygnus Unit includes the installation of a 36-inch-diameter drain gate with flashboard risers on Individual Ownership Number 415. This drain was authorized under Suisun Resource Conservation District's SRCD's regional general permit and was installed in 1991.

Legislative and Administrative Environment

SUISUN RESOURCE CONSERVATION DISTRICT

The SRCD was formed in 1962 by private landowners in Suisun Marsh. The function of the SRCD was to conduct administrative, regulatory, and technical duties that include representing landowner interests, obtaining environmental permits for routine maintenance, preparing wetland management plans for all private lands in the district, and providing technical expertise on Marsh management issues. The SRCD includes 52,000 acres of managed wetlands, 6,300 acres of unmanaged wetlands, 30,000 acres of bays and sloughs, and 27,700 acres of upland grasslands. There are 158 privately owned duck clubs in the Marsh, and the California Department of Fish and Game (DFG) manages about 15,000 acres of the managed and tidal wetlands.

1970 MEMORANDUM OF AGREEMENT

Reclamation, the U.S. Fish and Wildlife Service (USFWS), DWR, and DFG signed a memorandum of agreement (MOA) in 1970. One goal of the MOA was to identify and select a water supply and Suisun Marsh management plan that would protect and enhance waterfowl habitat.

1974 SUISUN MARSH PRESERVATION ACT

The California Legislature enacted the Nejedly-Bagley-Z'berg Suisun Marsh Preservation Act of 1974 to abate the threat of marsh urbanization. The act required DFG and the San Francisco Bay Conservation and Development Commission (BCDC) to develop a plan to protect the Suisun Marsh. In 1975, DFG released the fish and wildlife element of the Suisun Marsh Protection Plan. The plan contained an inventory of fish and wildlife species found in and around the Marsh, an interpretation of how the Marsh functions, and recommendations for protection of the Marsh.

1976 Suisun Marsh Protection Plan

In 1976, the BCDC submitted the Suisun Marsh Protection Plan to the Governor and Legislature. The protection plan divided the Marsh into primary and secondary management zones based on land use. Tidal wetlands and diked lands managed as wetlands were placed in the primary management zone; uplands and lands adjacent to the Suisun Marsh were classified as the secondary management zone. The purpose of the secondary management zone is to provide a buffer between urban development and wetland areas of the Marsh. Under the Suisun Marsh Protection Plan, the BCDC serves as the permitting agency for all major projects within the primary management zone and as an appellate body with limited functions in the secondary management area. The Suisun Marsh Protection Plan recommended that local agencies develop a plan of compliance, recommended and prioritized the acquisition of properties, proposed a tax assessment plan based on land use, and identified both state and federal sources of funding to achieve its objectives.

Assembly Bill 1717

The California Legislature passed Assembly Bill 1717 in 1977, which added the Suisun Marsh Preservation Act of 1974 to the Public Resources Code and implemented the recommended protection measures outlined in the Suisun Marsh Protection Plan. This act emphasized the importance of the Suisun Marsh as a unique and irreplaceable resource, particularly because of the habitat available for wintering waterfowl.

1978 Water Right Decision 1485

The State Water Resources Control Board (SWRCB) issued Water Rights Decision 1485 (D-1485) in 1978. D-1485 set channel water salinity standards for Suisun Marsh from October through May to preserve the area as a brackish-water tidal marsh and to provide optimum waterfowl food plant production. D-1485 also established operational conditions on water rights permits for the Central Valley Project (CVP) and State Water Project (SWP). In addition, D-1485 required Reclamation and DWR to develop and implement a plan to protect the Marsh.

1978 Agreement for the Initial Facilities

In 1978, DWR, DFG, and SRCD signed an agreement for construction, operation, and maintenance of facilities to partially restore and maintain the Suisun Marsh as a brackish-water marsh capable of producing high-quality food and habitat conditions for waterfowl and other marsh life. This agreement was intended to partially mitigate the adverse effects on the Suisun Marsh of operations of the state and federal water projects.

1984 Plan of Protection for Suisun Marsh

DWR published the Plan of Protection for Suisun Marsh in 1984. The plan included an Environmental Impact Report prepared in cooperation with DFG, SRCD, and Reclamation and was prepared in response to D-1485 Order 7. The protection plan was a proposal for staged implementation of a combination of activities, including monitoring, a wetlands management program for Suisun Marsh landowners, physical facilities, and supplemental releases of water from the CVP and SWP reservoirs.

1985 Amendment to D-1485

In 1985, the SWRCB modified elements of D-1485 to extend the effective dates and locations of criteria of the channel water quality standards.

1987 Suisun Marsh Preservation Agreement

The DWR, DFG, Reclamation, and the SRCD signed the SMPA in 1987 to mitigate the effects on Suisun Marsh salinity from the CVP, SWP, and other upstream diversions. Key provisions of the SMPA include:

- To assure that Reclamation and DWR maintain a water supply of adequate quantity and quality for managed wetlands within the Suisun Marsh. This provision is to mitigate adverse effects on these wetlands from operation of the CVP and SWP and a portion of the adverse effects of other upstream diversions.
- To improve Suisun Marsh wildlife habitat on these managed wetlands.
- To define the obligations of Reclamation and DWR necessary to assure the water supply, distribution, management facilities, and actions necessary to accomplish these objectives.
- To recognize that water users in the Suisun Marsh divert water for wildlife habitat management within the Suisun Marsh.

To meet these objectives, the SMPA established channel water salinity standards similar to those in D-1485 and a schedule for constructing large-scale facilities in Suisun Marsh that would allow the salinity standards to be met. As required by the SMPA, DWR and Reclamation constructed the Suisun Marsh Salinity Control Gates in 1988. The agencies constructed the Cygnus Unit in 1991 and the Lower Joice Unit in 1993. These facilities were in addition to the initial facilities constructed in 1980: Morrow Island Distribution System, Roaring River Distribution System, and the Goodyear Slough Outfall. In 1990, the two agencies began planning the Western Suisun Marsh Salinity Control Project, which was intended to fulfill the Plan of Protection for Suisun Marsh. The objective of the project was to develop facilities or activities in the western Suisun Marsh that would compensate for the higher channel salinities in that area of the Marsh.

DWR and Reclamation ceased work on the planning and environmental documentation for the western Suisun Marsh Salinity Control Project in 1995 because the increased outflows and the effective operation of the Suisun Marsh Salinity Control Structure achieved salinity targets.

SUISUN MARSH MONITORING AGREEMENT AND MITIGATION AGREEMENT

DWR, Reclamation, and DFG signed two additional agreements in 1987: the Suisun Marsh Mitigation Agreement and the Suisun Marsh Monitoring Agreement. The mitigation agreement addressed acquisition, development, operation, and maintenance of mitigation lands to compensate for loss or degradation of wildlife habitat resulting from construction of the Suisun Marsh Protection Agreement facilities and the effects of the CVP, SWP, and other diverters on the channel islands. The monitoring agreement requires implementation of the monitoring program described in the Plan of Protection for Suisun Marsh.

DECISION TO AMEND THE SUISUN MARSH PRESERVATION AGREEMENT

In 1995, DFG, DWR, Reclamation, and the SRCD Negotiation Team met to initiate the process of updating the SMPA. This effort was based on changed conditions resulting from effective operation of the Suisun Marsh Salinity Control Gates and increased Delta outflow under the 1995 Water Quality Control Plan (WQCP) (also referred to as the 1995 Bay-Delta Plan). The SMPA was amended previously on two occasions; this is the third amendment to the SMPA.

1995 WATER QUALITY CONTROL PLAN

In 1995, the SWRCB adopted the Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (SWRCB 1995). This plan established water quality control measures to contribute to the protection of beneficial uses in the Bay-Delta Estuary. The WQCP consists of the following: beneficial uses to be protected, water quality objectives for reasonable protection of beneficial uses, and a program of implementation to achieve the water quality objectives.

1995 WATER RIGHTS ORDER WR 95-6

In 1995, DWR and Reclamation filed a joint petition requesting changes to the water rights order that authorized diversion and use of waters affecting the San Francisco/Sacramento-San Joaquin Delta Estuary. The SWRCB received evidence at a public hearing and determined that Water Rights Order 95-6 (WR 95-6) would be an interim order until subsequent adoption of a comprehensive water rights decision that allocates final responsibilities for meeting the 1995 Bay-Delta objective.

The Suisun Ecological Workgroup (SEW) is an ad hoc multi-agency and multi-organizational technical workgroup convened at the request of the SWRCB, as a component of the Program of Implementation in the 1995 WQCP. SEW was convened to address the uncertainty of the effectiveness of the 1995 WQCP Delta outflow objectives on tidal wetlands.

According to the Program of Implementation, SEW is charged with the following:

- Evaluate beneficial uses and water quality objectives for the Suisun Bay and Suisun Marsh Ecosystem.
- Assess the effect on Suisun Bay and Suisun Marsh of the water quality objectives in the Draft WQCP and the federal Endangered Species Act biological opinion.
- Identify specific measures to implement the narrative objectives for tidal brackish marshes of Suisun Bay and make recommendations to the SWRCB regarding achievement of the objectives and development of numeric objectives to replace the narrative objectives.
- Identify and analyze public interest values and water quality needs to preserve and protect the Suisun Bay/Suisun Marsh ecosystem.
- Identify studies to be conducted that will help determine the types of actions necessary to protect the Suisun Bay area, including Suisun Marsh.
- Perform studies to evaluate the effects of urbanization in the Suisun Marsh on the Suisun Marsh ecosystem.
- Develop a sliding scale between the normal and deficiency objectives for the western Marsh.

WATER RIGHTS DECISION D-1641 (REVISED)

The 1995 Bay-Delta Plan contains water quality objectives (salinity objectives) for locations in Suisun Marsh in order to protect fish and wildlife beneficial uses. Decision-1641 addresses the circumstances surrounding the proposed third amendment to the SMPA , by relieving the DWR and Reclamation of the responsibility to meet the salinity objectives at two control stations in the western Suisun Marsh and by allowing variability in meeting the objectives.

Ecosystem Typology

The Ecosystem Restoration Program study area is divided into four ecological zones, based on similarities and differences in their respective attributes. The ecological zone designations follow:

- Upland River-Floodplain Ecological Zone
- Alluvial River-Floodplain Ecological Zone
- Delta Ecological Zone
- Greater San Francisco Bay Ecological Zone (including the Suisun Marsh)

Table C-1 provides information on the Greater San Francisco Bay Ecological Zone.

SPECIES DESIGNATIONS

The Multi-Species Conservation Strategy (MSCS) addresses all federally and state-listed, proposed, and candidate species that may be affected by the CALFED Program; other species identified by CALFED that may be affected by the Program and for which adequate information is available also are addressed in the MSCS. The term "evaluated species" is used to refer to all of the species addressed by the MSCS. Please refer to the MSCS technical appendix to the CALFED Programmatic EIS/EIR for more information and a complete list of evaluated species.

The MSCS also identifies 18 Natural Community Conservation Plan (NCCP) habitat types. These are broad habitat categories, each of which includes a number of habitat or vegetation types. The NCCP habitats are listed below. An asterisk indicates a habitat of interest in the Suisun Marsh:

- Tidal perennial aquatic*
- Valley riverine aquatic*
- Montane riverine aquatic
- Lacustrine*
- Saline emergent*
- Tidal freshwater emergent
- Nontidal freshwater emergent
- Natural seasonal wetland*
- Managed seasonal wetland*
- Valley/foothill riparian
- Montane riparian
- Grassland*
- Inland dune scrub
- Upland scrub
- Valley/foothill woodland and forest
- Montane woodland and forest
- Upland cropland
- Seasonally flooded agricultural land

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Table C-1. Ecological Zone: Greater San Francisco Bay by Indicator Type

Attribute	**Indicators**
	Hydrologic/Hydrodynamic
Fresh-water inflow	X2 location Salinity at selected locations throughout Bay
Spatial and temporal salinity patterns	Salinity at selected locations throughout Bay X2 location
Hydrodynamics	Water movement and vertical mixing at select locations throughout Bay
	Geomorphic
Sediment supply	Net sediment accretion rate relative to rate of sea-level rise at subtidal and intertidal sites Elevation at appropriate fixed sites in marshes and mudflats throughout Bay Compare to sea level
	Habitat
Habitat mosaic and connectivity	Extent and distribution of patches of all natural habitat types Presence and distribution of species requiring multiple habitats Presence and distribution of migratory fish species Number of unnatural barriers interfering with natural movements of native species, water flow, sediment transport and supply, and nutrient transport
Water/sediment quality	Toxicity: - concentrations in water and sediment - tissue concentrations - bioassays - biomarkers - bioindicators - contaminant loading Dissolved oxygen Turbidity-suspended solids Nutrients (N, P, C) Salinity/TDS
	Biological Communities
Community structure	Trends in abundance, diversity, composition, and distribution of native phytoplankton and zooplankton assemblages Trends in the abundance, diversity, composition, and distribution of benthic invertebrate assemblages Trends in abundance, reproductive success, diversity, composition, and distribution of native resident and migratory birds Trends in distribution, diversity, and structural complexity of native plant associations Trends in abundance, diversity, composition, distribution, and trophic structure of native resident and anadromous fishes Invasive introduced species: - measures of new invasions - abundance, spatial extent and distribution of selected species - number of selected species eradicated or exhibiting no net increase in distribution Population trends of selected listed species Fish and wildlife health

Table C-1. Continued

Attribute	Indicators
Community Energetics/ Nutrient Cycling	
Plankton productivity	Phytoplankton productivity Zooplankton productivity
Benthic invertebrate production	Benthic invertebrate productivity
Net transport/export of detrital organic matter from marshes to other habitats	Flux of detrital organic matter

Note: Ecosystem Typology: Greater San Francisco Bay, as defined here, is that part of the estuary between Chipps Island and the Golden Gate. The zone includes four major embayments: Suisun Bay and Marsh, San Pablo Bay, and central and south San Francisco Bay.

The following is a discussion and definition of each of the five species designations used in the Ecosystem Restoration Program Plan. These designations have evolved during the development of the Ecosystem Restoration Program. The present set of designations are those contained in the July 2000 Ecosystem Restoration Program Plan.

Recover

Recovery "R": For those species designated "R," the CALFED Program has established a goal to recover the species within the CALFED Ecosystem Restoration Program ecological management zones. A goal of "recovery" was assigned to those species whose range is entirely or nearly entirely within the area affected by the CALFED Program and for which CALFED could reasonably be expected to undertake all or most of the actions necessary to recover the species. The term "recover" means that the decline of a species is arrested or reversed, threats to the species are neutralized and, thus, the species' long-term survival in nature is assured. In the case of most species listed under the federal ESA, recovery is equivalent, at a minimum, to the requirements of delisting. Certain species, such as anadromous fish, are threatened by factors outside the geographic scope or purview of the CALFED Program (for example, harvest is regulated by international laws). CALFED may not be capable of completing all actions potentially necessary to recover the species; however, CALFED will implement all necessary recovery actions within the Ecosystem Restoration Program ecological management zones. For other species, CALFED may choose a goal that aims to achieve more than would be required for delisting (for example, restoration of a species and/or its habitat to a level beyond delisting requirements). The effort required to achieve the goal of recovery may be highly variable between species. In sum, a goal of recovery implies that CALFED will undertake all actions within the Ecosystem Restoration Program ecological management zones and Program scope that are necessary to recover the species.

CONTRIBUTE TO RECOVERY

Contribute to Recovery ("r"): For those species designated "r," the CALFED Program will make specific contributions toward the recovery of the species. The goal "contribute to recovery" was assigned to those species for which CALFED Program actions affect only a limited portion of the species range and/or CALFED Program actions have limited effects on the species. In the case of a species with a recovery plan, this designation may mean implementing some of the measures identified in the plan that are within the CALFED problem area and some of the measures that are outside the problem area. For species without a recovery plan, this designation would mean implementing specific measures that would benefit the species. In sum, a goal of contributing to a species' recovery implies that CALFED will undertake some of the actions within its geographic scope necessary to recover the species.

MAINTAIN

Maintain ("m"): For those species designated "m," the CALFED Program will undertake actions to maintain the species (this category is less rigorous than contribute to recovery). The goal "maintain" generally was assigned to species expected to be minimally affected by CALFED actions. For this category, CALFED will ensure that any adverse effects on the species are addressed commensurate with the level of effect on the species. Thus, CALFED Program actions may not actually contribute to the recovery of the species but would be expected, at a minimum, to not contribute to the need to list an unlisted species or degrade the status of an already listed species. CALFED will also maximize beneficial effects on these species to the extent practicable.

ENHANCE AND/OR CONSERVE BIOTIC COMMUNITIES

Enhance and/or Conserve Biotic Communities ("E"): For those communities designated "E," the Ecosystem Restoration Program will undertake actions to conserve and enhance their diversity, abundance, and distribution in a manner that contributes to their long-term sustainability without adversely affecting efforts to improve conditions for other at-risk species.

MAINTAIN AND/OR ENHANCE HARVESTED SPECIES

Maintain and/or Enhance Harvested Species ("H"): For those species designated "H," the CALFED Program will undertake actions to maintain the species at levels that support or enhance sustainable harvest rates. The goal "maintain harvested species" generally was assigned to species that are harvested for recreational or commercial purposes and that are not already covered under one of the four previous designations. A key to maintaining harvested surplus levels is to recognize the need to recover, contribute to recovery, or maintain other species. Thus, species interactions such as competition and predation, and habitat needs for space and flow, need to be balanced in favor of species designated for recovery, contribute to recovery, and maintain. Those three designations apply only to native species and assemblages, while the "maintain harvested surplus" species include some native species and non-native species. Thus, actions implemented to maintain harvested surplus would be expected, at a minimum, to not contribute to the need to list an unlisted species; degrade the status of an already listed species; or impair in any way efforts to recover, contribute to recovery, or maintain native species.

MSCS CONSERVATION MEASURES

The MSCS defines "conserve, conserving, and conservation" as the use of all methods and procedures that are necessary to bring any endangered species or threatened species to the point at which the measures provided pursuant to the federal and state ESAs are no longer necessary. These methods and procedures include, but are not limited to, all activities associated with scientific resources management—such as research, census, law enforcement, habitat acquisition, restoration and maintenance, propagation, live trapping and transplantation—and, in the extraordinary case where population pressures within a given ecosystem cannot be otherwise relieved, may include regulated taking.

Two types of conservation measures were developed under the MSCS: (1) measures to avoid, minimize, or compensate for CALFED Program impacts on NCCP communities and evaluated species; and (2) additional measures that ensure the Program meets the species conservation goals. The majority of measures designed to help the Program meet the species conservation goals incorporate and refine existing Ecosystem Restoration Program and other CALFED actions. The scope, location, and timing of a particular CALFED Program action or group of actions—as well as the current status, distribution, and needs of the affected species—will determine which conservation measures would be necessary to compensate for adverse impacts. NCCP habitat conservation measures primarily are directed at conserving the quality and quantity of natural habitats.

Generally, measures to avoid, minimize, and compensate adverse effects are addressed early in site-specific project development and are specific components of the project. The identification of additional measures to ensure the that species conservation goals are met are more global in nature and are developed to provide additional detail to Ecosystem Restoration Program programmatic actions.

{The preceding section and Table C-2 will either be expanded or deleted in the next draft.}

Table C-2. List of Species Comparing Strategic Plan/Ecosystem Restoration Program Classification, MSCS Designation, and Revised Ecosystem Restoration Program Designation

Species or Biotic Community	MSCS Designation[a]	Revised Ecosystem Restoration Program Designation
Delta smelt[b]	Recover	Recover
Longfin smelt[b]	Recover	Recover
Green sturgeon[b]	Recover	Recover
Sacramento splittail[b]	Recover	Recover
Winter-run chinook salmon[b]	Recover	Recover
Spring-run chinook salmon[b]	Recover	Recover
Central Valley fall-run chinook salmon[b]	Recover	Recover
Central Valley steelhead[b]	Recover	Recover
Mason's lilaeopsis[b]	Recover	Recover
Suisun Marsh aster[b]	Recover	Recover
Suisun thistle[b]	Recover	Recover

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Table C-2. Continued

Species or Biotic Community	MSCS Designation[a]	Revised Ecosystem Restoration Program Designation
Soft bird's-beak[b]	Recover	Recover
Antioch Dunes evening-primrose	Recover	Recover
Contra Costa wallflower	Recover	Recover
Lange's metalmark	Recover	Recover
Valley elderberry longhorn beetle	Recover	Recover
Suisun ornate shrew[b]	Recover	Recover
Suisun song sparrow[b]	Recover	Recover
San Pablo song sparrow	Recover	Recover
California clapper rail	Contribute to recovery	Contribute to recovery
California black rail[b]	Contribute to recovery	Contribute to recovery
Swainson's hawk	Contribute to recovery	Contribute to recovery
Salt marsh harvest mouse	Contribute to recovery	Contribute to recovery
San Pablo California vole	Contribute to recovery	Contribute to recovery
Sacramento perch	Contribute to recovery	Contribute to recovery
Delta green ground beetle	Contribute to recovery	Contribute to recovery
Salt marsh common yellowthroat	Contribute to recovery	Contribute to recovery
Bristly sedge	Contribute to recovery	Contribute to recovery
Point Reyes bird's-beak	Contribute to recovery	Contribute to recovery
Crampton's tuctoria	Contribute to recovery	Contribute to recovery
Delta tule pea	Contribute to recovery	Contribute to recovery
Delta mudwort	Contribute to recovery	Contribute to recovery
Alkali milk-vetch	Contribute to recovery	Contribute to recovery
Delta coyote-thistle	Contribute to recovery	Contribute to recovery
Western pond turtle	Maintain	Maintain
Western spadefoot toad	Maintain	Maintain
Lamprey family	Not evaluated[c]	Enhance and/or conserve
Native resident fishes	Not evaluated as a group[d]	Enhance and/or conserve
Native anuran amphibians	Not evaluated	Enhance and/or conserve
Migratory waterfowl	Not evaluated as a group	Enhance and/or conserve
Shorebird guild	Not evaluated as a group	Enhance and/or conserve
Wading bird guild	Not evaluated as a group	Enhance and/or conserve
Neotropical migratory birds	Not evaluated as a group	Enhance and/or conserve
Planktonic (foodweb) organisms	Not Considered[e]	Enhance and/or conserve
Aquatic habitat plant community	NCCP habitat equivalent[f]	Enhance and/or conserve
Tidal brackish and fresh-water marsh habitat plant community	NCCP habitat equivalent	Enhance and/or conserve
Seasonal wetland habitat plant community	NCCP habitat equivalent	Enhance and/or conserve
Inland dune habitat plant community	NCCP habitat equivalent	Enhance and/or conserve
White sturgeon	Not considered	Maintain harvest
Striped bass	Excluded[g]	Maintain harvest
American shad	Excluded	Maintain harvest

[a] "Recover," "contribute to recovery," "maintain," "enhance and/or conserve," and "maintain harvest" are defined in the text.

[b] Indicates that species is found in the Suisun Marsh.

[c] "Not evaluated" species are species initially considered for inclusion in the Multi-Species Conservation Strategy (MSCS) but not evaluated (for example, Kern brook lamprey, river lamprey, and Pacific lamprey were considered but not evaluated).

[d] "Not evaluated as a group" includes species assemblages described in the Ecosystem Restoration Program Plan but not evaluated as a group in the MSCS. Individual species, however, may have been considered or evaluated (for example, native resident fishes were not evaluated as a group in the MSCS, but Sacramento perch and hardhead were considered and evaluated in the MSCS).

Table C-2. Continued

- [e] "Not considered" species are native species that were screened from consideration by not being on any list of special-status species.
- [f] "NCCP habitat equivalent" denotes an Ecosystem Restoration Program plant community that is analogous to one or more of the 18 NCCP habitats—which are broad categories, each of which includes a number of habitat or vegetation types recognized in frequently used habitat classification systems.
- [g] "Excluded species" are non-native organisms not eligible for consideration under the state or federal Endangered Species Acts and thus excluded from consideration or evaluation under the MSCS.

CALFED Restoration Targets for the Suisun Marsh

The information below is from the July 2000 Ecosystem Restoration Program Plan technical appendix to the CALFED Programmatic EIS/EIR. The following habitats are most relevant in evaluating potential links to the CALFED objectives of including Suisun Marsh levees in the CALFED Program. Any habitat conversion in the Suisun Marsh like would produce the following habitat types:

HABITATS - GENERAL RATIONALE

Restoring tidally influenced wetlands is an essential focus of restoration efforts in the Suisun Marsh/North San Francisco Bay Ecological Management Zone. Habitats of particular interest include tidal perennial aquatic habitat, saline emergent wetlands, and tidal slough habitat. Restoration of these habitats will require a mosaic of habitats, including adjacent habitats that need to be comprised of seasonal wetlands, nontidal perennial aquatic habitats, perennial grasslands, and riparian habitats. Restoration targets were set with the realization of the difficulty in locating lands for restoration. In the Suisun Marsh, for example, the restoration of tidally influenced habitats likely will require the conversion of existing managed wetlands. The conversion of these existing fresh-water wetlands will be offset to the extent possible by restoration of existing degraded wetland habitats and improvement of existing unmanaged wetlands. Likewise, in the San Pablo Bay Ecological Management Unit, restoration of habitat will be constrained by the fact that the area is characterized by open bay and intertidal flats, with very limited opportunities for restoration of other shallow-water habitat types.

Tidal Perennial Aquatic Habitat

Target 1: Restore 1,500 acres of shallow-water habitat in the Suisun Marsh/North San Francisco Bay Ecological Management Zone.

Programmatic Action 1a: Develop a cooperative program to acquire and restore 1,500 acres of shallow-water habitat in the Suisun Bay and Marsh Ecological Management Unit.

Rationale: Restoring, improving, and protecting high-quality shallow-water habitat will provide foraging habitat for juvenile fish in this ecological management zone. These areas typically provide high primary and secondary productivity, and support nutrient-cycling functions that can sustain high-quality foraging conditions. Opening new areas to tidal flows also will help to restore a more natural tidal action to the Bay-Delta. These tide-influenced areas also provide high-quality foraging habitat for (1) waterfowl that use mudflat or submergent vegetation growing in shallow water; and (2) diving ducks, such as canvasback and scaup, that consume clams in these areas.

Nontidal Perennial Aquatic Habitat

Target 1: Develop 1,600 acres of deeper (3-6 feet deep) open-water areas to provide resting habitat for water birds and foraging habitat for diving ducks and other water birds that feed in deep water.

Programmatic Action 1a: Develop a cooperative program to acquire and develop 400 acres of deeper open-water areas adjacent to restored saline emergent wetland habitats in the Suisun Bay and Ecological Management Unit.

Rationale: Restoring suitable resting areas for waterfowl and other wetland-dependent wildlife species will increase the over-winter survival rate of these populations. Other water-associated wildlife species also will benefit.

Tidal Sloughs

Target 1: Restore slough habitat for fish and associated wildlife species. Restore 5 miles of slough habitat in the near term, and 10 miles in the long term, in the Suisun Bay and Marsh Ecological Management Unit (30-61 acres).

Programmatic Action 1a: In association with wetland/marsh restoration efforts, construct sloughs in marsh/slough complexes by acquiring land and purchasing easements.

Rationale: Restoring, improving, and protecting slough habitat in the units of the Suisun Marsh/North San Francisco Bay Ecological Management Zone will help sustain high-quality shallow-water habitat that provides spawning habitat for native fish and foraging habitat for rearing juvenile fish. Restoring sloughs, along with tidally influenced freshwater areas and saline emergent marsh, will provide spawning habitat for native fish and foraging habitat for rearing juvenile fish; contribute to high levels of primary and secondary productivity; and support nutrient-cycling functions that can sustain high-quality foraging conditions. These sloughs also can provide resting sites for waterfowl and habitat for the western pond turtle. Tidal sloughs also can provide important loafing sites for waterfowl, particularly diving ducks in the North Bay. The miles of targeted sloughs represent a reasonable restoration level as indicated by maps available from the early 1900s and existing configurations in the ecological management units.

In general, tidal slough restoration should be located near tidal marsh restoration. Sloughs are a function of the marshes they traverse. The acreage of marsh and soils, sediments, and hydrodynamics will limit the amount of tidal marsh that can be restored.

Saline Emergent Wetlands

Target 1: Restore tidal action to 5,000 to 7,000 acres in the Suisun Bay and Marsh Ecological Management Unit.

Programmatic Action 1a: Develop a cooperative program to acquire, in fee-title or through a conservation easement, the land needed for tidal restoration and complete the needed steps to restore the wetlands to tidal action.

Target 2: Protect 6,200 acres of existing saline emergent wetlands in the Suisun Bay and Marsh Ecological Management Zone.

Programmatic Action 2a: Develop a cooperative program to acquire, in fee-title or through a conservation easement, existing wetlands subject to tidal action.

Target 3: Restore full tidal action to muted marsh areas along the north shore of the Contra Costa shoreline.

Programmatic Action 3a: Develop a cooperative program to evaluate, acquire (in fee-title or through a conservation easement), and restore existing muted wetlands to full tidal action.

Rationale: Restoring tidally influenced saline marsh in this ecological management zone will contribute to increasing levels of primary and secondary productivity and support nutrient-cycling functions that can sustain high-quality foraging. Increasing the area occupied by saline tidal marsh in each ecological management unit will help to support the proper aquatic habitat conditions for rearing and outmigrating juvenile chinook salmon, steelhead, and sturgeon and rearing delta smelt, striped bass, and splittail. Restoring high-quality saline marshes, both tidal and nontidal, will contribute to nutrient cycling, maintaining the foodweb, and supporting enhanced levels of primary and secondary production. Increasing the area occupied by nontidal saline marsh will contribute to subsidence control and island accretion (growth) efforts. Permanent saline marsh can help to arrest and, in some cases, reverse subsidence where peat oxidation has lowered land elevations to more than 15 feet below sea level. Increasing the area occupied by saline marsh will contribute to an ecosystem that can accommodate sea-level rise and provide a more natural tidal pattern and associated benefits to the foodweb and water quality of the Bay and Delta. Habitat conditions for wetland-associated wildlife will be improved.

The targets for saline emergent wetlands probably will be achieved or even exceeded by several ongoing programs. These include activities to restore saline emergent wetlands that are contained within land acquisition programs by the USFWS and DFG.

Seasonal Wetlands

Target 1: Assist in protecting and enhancing 40,000 to 50,000 acres of existing degraded seasonal wetland habitat in the Suisun Bay and Marsh Ecological Management Unit per the objectives of the Central Valley Habitat Joint Venture and the North American Waterfowl Management Plan.

Programmatic Action 1a: Support the cooperative program to improve management of up to 26,000 acres of degraded seasonal wetland habitat in the of the Suisun Bay and Marsh Ecological Management Unit.

Programmatic Action 1b: Support the development of a cooperative program to improve management of up to 32,000 acres of existing seasonal wetland habitat in the Suisun Bay and Marsh Ecological Management Unit.

Target 2: Acquire and convert 1,000 to 1,500 acres of existing farmed baylands in the Suisun Marsh to seasonal wetlands.

Programmatic Action 2a: Develop a cooperative program to acquire, in fee-title or through a conservation easement, existing farmed baylands and restore tidal action.

Rationale: Restoring wetland and riparian habitats in association with aquatic habitats is an essential restoration strategy element for this ecological management zone. This restoration is fundamental to supporting the foodweb and enhancing conditions for rearing chinook salmon, steelhead, sturgeon, juvenile delta smelt, striped bass, and splittail. Foodweb support functions for wildlife also will benefit.

Seasonal wetlands can help to reduce concentrations and loads of pesticide residues in water and sediments. These factors help to reduce sublethal and long-term impacts of specific contaminants for which it is difficult to document population-level impacts conclusively. Modifying agricultural practices and land uses on a large scale will reduce the concentrations of pesticide residues through a combined approach. This approach involves reducing the amount of pesticide applied and the amount reaching aquatic Suisun Marsh and San Francisco Bay habitats. This will be accomplished by biological and chemical processes in wetland systems that break down harmful pesticide residues. Improved inchannel flows in this ecological management unit resulting from seasonal reductions in water use and enhanced environmental water supplies also will help to reduce contaminant concentrations.

Restoring high-quality freshwater marsh and brackish marsh, both seasonal and permanent, will increase the production and availability of natural forage for waterfowl and other wildlife. It will increase the over-winter survival rates of wildlife populations in this ecological management zone and improve their body condition before they migrate. As a result, breeding success will be improved. Managing these habitats also will reduce the amount and concentrations of contaminants that could, upon entering the sloughs, interfere with efforts to restore aquatic ecosystem health.

Target 1 "enhance 40,000 to 50,000 acres of degraded seasonal wetland habitat" is consistent with the Central Valley Habitat Joint Venture and the North American Waterfowl Management Plan. Programmatic Action 1A "enhance 26,000 acres of degraded seasonal wetland habitat" already is being implemented by Ducks Unlimited as part of a grant through the North American Wetlands Conservation fund. The intent of the Ecosystem Restoration Program Plan is to remove the levees of some managed wetlands to allow the restoration of tidally influenced habitats and expand the acreages of wet meadows or pastures. The greatest need is to restore, where possible, tidal wetland areas. This may result in a need to replace any losses of managed wetlands by creating additional wetland areas. However, there may not be area for any additional acres of managed wetlands as the majority of agricultural lands already have been converted to managed wetlands.

The following acreages provided by the SRCD display the possible difficulty in creating additional managed wetlands.

Existing Land Use	Existing Acreage
Managed wetlands	52,000 acres
Unmanaged tidal wetlands	6,300 acres
Bays and sloughs	30,000 acres
Uplands and grasslands	27,700 acres

Vernal Pool

Target 1: Protect and manage vernal pools in the Suisun Bay and Marsh Ecological Management Unit that provide suitable habitat for listed fairy shrimp species, the Delta green ground beetle, and special-status plant species to assist in these species' recovery.

Programmatic Action 1a: Develop a cooperative program to acquire and manage 100 acres of vernal pools and 500 to 1,000 acres of adjacent buffer areas

Target 2: Restore vernal pools that have been degraded by agricultural activities to provide suitable habitat for special-status invertebrates and plants and amphibian, such as the spadefoot toad, to assist in the recovery of these populations.

Programmatic Action 2a: Develop a cooperative program to restore the quality of vernal pools and their adjacent habitats.

Rationale: Restoring wetland, riparian, and adjacent upland habitats in association with aquatic habitats is an essential restoration strategy element for the Suisun Marsh/North San Francisco Bay Ecological Management Zone. Restoring this habitat mosaic on a large scale will help to restore ecosystem processes and functions, and will provide additional protection to listed species associated with this habitat type.

Riparian and Shaded Riverine Aquatic Habitats

Target 1: Restore 10 to 15 linear miles of riparian habitat along riparian scrub and shrub vegetation corridors in each ecological management unit. In this restored habitat, 60% should be more than 15 yards wide, and 40% should be no less than 5 yards wide and 1 mile long.

Programmatic Action 1a: Coordinate with landowners and managers to restore and maintain 10 to 15 linear miles of riparian habitat along corridors of riparian scrub and shrub vegetation in each ecological management unit. Of this, 60% should be more than 15 yards wide, and 40% should be no less than 5 yards wide and 1 mile long (40-60 acres in each of 5 units).

Rationale: Many wildlife species, including several species listed as threatened or endangered under the state and federal ESAs and several special-status plant species in the Central Valley, depend on or are closely associated with riparian habitats. Riparian scrub and shrub will help to provide needed escape cover for these species during high-flow periods. Riparian vegetation in the western portion of the Suisun Marsh/North San Francisco Bay Ecological Management Zone is limited by water salinity. Riparian restoration most likely will occur in the upper reaches of the ecological management units in areas that may be tidally influenced but with low salinity.

Perennial Grasslands

Target 1: Restore 1,000 acres of perennial grasses in each ecological management unit associated with existing or proposed wetlands.

Programmatic Action 1a: Develop a cooperative program to restore perennial grasslands by acquiring conservation easements or purchasing land from willing sellers.

Rationale: Restoring wetland, riparian, and adjacent upland habitats in association with aquatic habitats is an essential restoration strategy element for this ecological management zone. Eliminating fragmentation and restoring connectivity will enhance habitat conditions for special-status species, such as the Suisun song sparrow, California black rail, and salt marsh harvest mouse. For instance, the habitats for these species have been degraded by the loss of adjacent, suitable escape cover that is needed by the salt marsh harvest mouse during periods of high flows or high tides. Fragmentation also has interfered with daily and seasonal migratory movements and genetic interchange within the population.

Multi-Species Conservation Strategy Conservation Measures

The MSCS provided conservation measures specifically designed for application in Suisun Marsh, as follows:

> The geographic priorities for implementing Ecosystem Restoration Program actions to protect, enhance, and restore saline emergent wetlands and associated habitats for the Suisun ornate shrew should be: (1) western Suisun Marsh, (2) Napa marshes and eastern Suisun Marsh, and (3) Sonoma marshes and Highway 37 marshes west of Sonoma Creek.
>
> The geographic priorities for implementing Ecosystem Restoration Program actions to protect, enhance, and restore saline emergent wetlands and associated habitats for the Suisun song sparrow should be: (1) western Suisun Marsh, (2) eastern Suisun Marsh, and (3) the Contra Costa shoreline.
>
> The geographic priorities for implementing Ecosystem Restoration Program actions to protect, enhance, and restore saline emergent wetlands and associated habitats for the salt marsh harvest mouse should be: (1) western Suisun Marsh; (2) Gallinas/Ignacio Marshes, Napa marshes, and eastern Suisun Marsh; (3) Sonoma marshes, Petaluma marshes, and Highway 37 marshes west of Sonoma Creek; (4) Point Pinole marshes; (5) Highway 37 marshes east of Sonoma Creek; and (6) the Contra Costa shoreline.
>
> The geographic priorities for implementing Ecosystem Restoration Program actions to protect, enhance, and restore saline emergent wetlands and associated habitats for the California black rail should be: (1) western Suisun Marsh; (2) Gallinas/Ignacio marshes, Napa marshes, and eastern Suisun Marsh; and (3) Sonoma marshes, Petaluma marshes, and Highway 37 marshes west of Sonoma Creek; (4) Point Pinole marshes; (5) Highway 37 marshes east of Sonoma Creek; and (6) the Contra Costa shoreline.
>
> To the extent practicable, direct Ecosystem Restoration Program salt marsh enhancement efforts toward existing degraded marshes that are of sufficient size and configuration to develop fourth-order tidal channels (marshes likely would need to be at least 1,000 acres in size).
>
> To the extent practicable, design salt marsh enhancements and restorations to provide low-angle upland slopes at the upper edge of marshes to provide for the establishment of

suitable and sufficient wetland to upland transition habitat. To the extent practicable, transition habitat zones should be at least 0.25 mile in width.