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Revised Draft
Environmental Impact Report/
Environmental Impact Statement

Delta Wetlands Project

Prepared for:

State Water Resources Control Board
Division of Water Rights

and

U.S. Army Corps of Engineers
Sacramento District

Prepared by:

Jones & Stokes
Sacramento, California

May 2000

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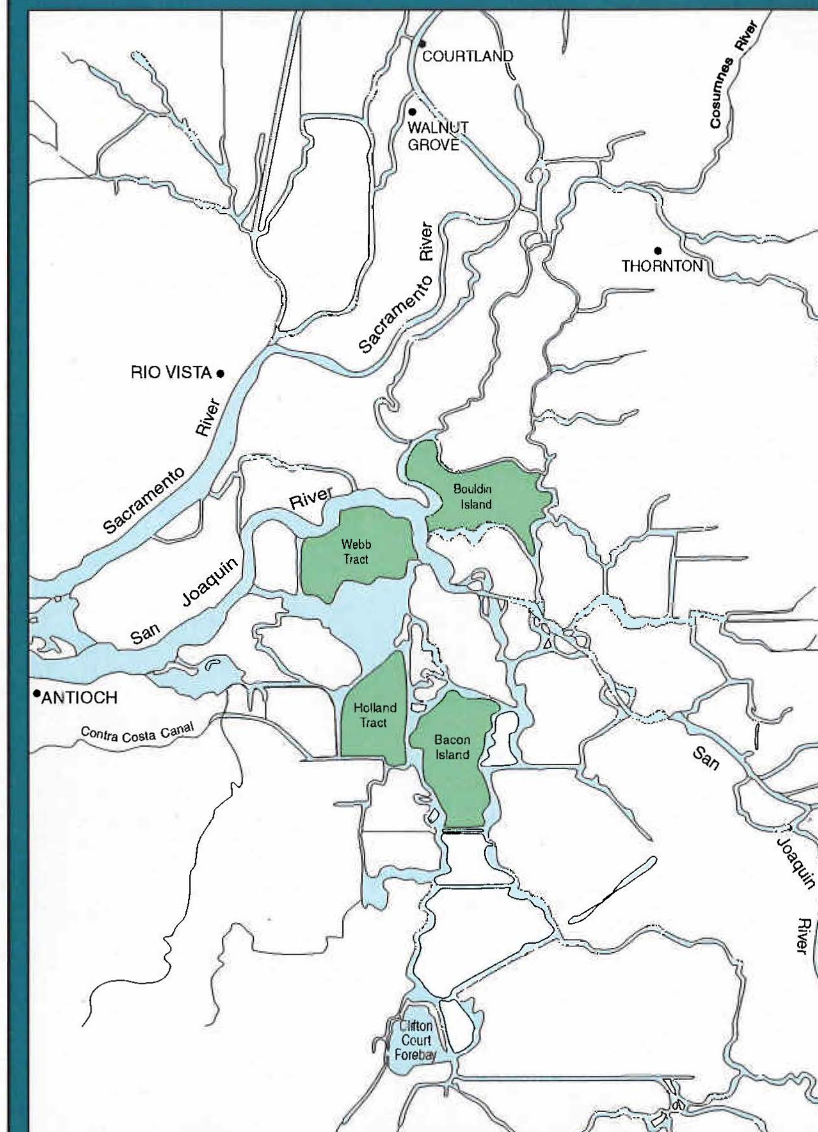

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Environmental Impact Report
and
Environmental Impact Statement
for the Delta Wetlands Project

Prepared for:

California State Water Resources Control Board
Division of Water Rights
P.O. Box 2000
Sacramento, CA 95812-2000
Contact: Jim Sutton
Telephone: 916/657-2190

and

U.S. Army Corps of Engineers
Regulatory Branch
1325 J Street, 14th Floor
Sacramento, CA 95814-2922
Contact: Mike Finan
Telephone: 916/557-5324

Prepared by:

Jones & Stokes
2600 V Street
Sacramento, CA 95818-1914
Contact: Aimee Dour-Smith
916/737-3000

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List of Acronyms

1995 DEIR/EIS	Delta Wetlands Project Draft Environmental Impact Report and Environmental Impact Statement
$\mu g/l$	micrograms per liter
μS	microsiemens
$\mu S/cm$	microsiemens per centimeter
AB	Assembly Bill
af	acre-foot
AFRP	Anadromous Fish Restoration Program
Bay-Delta	San Francisco Bay/Sacramento-San Joaquin Delta
Bcf	billion cubic feet
Bcf/day	billion cubic feet per day
Br^-	bromide
$CaCO_3$	calcium carbonate
CALFED	CALFED Bay-Delta Program
CCWD	Contra Costa Water District
CEQ	Council on Environmental Quality
CEQA	California Environmental Quality Act
cfs	cubic feet per second
$CHBr_3$	bromoform
$CHClBr_2$	dibromochloromethane
$CHCl_2Br$	dichlorobromomethane
$CHCl_3$	chloroform
Cl^-	chloride
Cl_2	chlorine
CO_2	carbon dioxide
COA	Coordinated Operations Agreement
CPUC	California Public Utilities Commission
C-THM	carbon portion, or carbon equivalent, of total trihalomethane concentration
CUWA	California Urban Water Agencies
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
DailySOS	Daily Standards and Operations Simulation Model
DBP	disinfection byproduct
DCC	Delta Cross Channel
Delta	Sacramento-San Joaquin Delta
DeltaDWQ	Delta Drainage Water Quality model
DeltaSOQ	Delta Standards, Operations, and Quality model
DeltaSOS	Delta Standards and Operations Simulation model
DFG	California Department of Fish and Game

DMC	Delta-Mendota Canal
DOC	dissolved organic carbon
DOT	U.S. Department of Transportation
DSOD	Division of Safety of Dams
DWR	California Department of Water Resources
EBMUD	East Bay Municipal Utility District
EC	electrical conductivity
EIR	environmental impact report
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act
ESU	Evolutionarily Significant Unit
ET	evapotranspiration
FEIR/EIS	final environmental impact report/environmental impact statement
FMWT	fall midwater trawl
FOC	final operations criteria
fps	feet per second
FS	factor of safety for slope stability
g	gram
GAC	granular activated carbon
g/m^2	grams per square meter
g/m^2/month	grams per square meter per month
g/m^2/yr	grams per square meter per year
g/m^3	grams per cubic meter
gpd	gallons per day
gpm	gallons per minute
HMP	habitat management plan
IEP	Interagency Ecological Program
ISI	Integrated Storage Investigation
kg	kilogram
kg/month	kilograms per month
km	kilometer
kwh	kilowatt-hour
lbs/ac/yr	pounds per acre per year
m	meter
m^2	square meter
MAF	million acre-feet
MAF/yr	million acre-feet per year
MCL	maximum contaminant level
mg/l	milligrams per liter
m/inch	meters per inch
mS/cm	millisiemens per centimeter
MWD	Metropolitan Water District of Southern California
MWQI	Municipal Water Quality Investigations
NEPA	National Environmental Policy Act
nm	nanometer
NMFS	National Marine Fisheries Service

O_3	ozone
OCAP	Delta Wetlands Operating Criteria and Plan
PG&E	Pacific Gas and Electric Company
PL	Public Law
POC	particulate organic matter
PP	pumping plant
ppb	parts per billion
ppm	parts per million
ppt	parts per thousand
psi	pounds per square inch
Reclamation	U.S. Bureau of Reclamation
REIR/REIS	revised draft environmental impact report/environmental impact statement
RPM	reasonable and prudent measure
SB	Senate Bill
SCVWD	Santa Clara Valley Water District
SDS	Simulated Disinfection System
SDWA	Safe Drinking Water Act
SMARTS	Special Multipurpose Applied Research Technology Station
SUVA	specific ultraviolet absorbance
SWP	State Water Project
SWRCB	California State Water Resources Control Board
TAF	thousand acre-feet
TAF/yr	thousand acre-feet per year
TDS	total dissolved solids
TFPC	total formation potential carbon
THM	trihalomethane
THMFP	THM formation potential
TOC	total organic carbon
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
URSGWC	URS Greiner Woodward Clyde
UVA	ultraviolet absorbance
VAMP	Vernalis Adaptive Management Plan
WQCP	Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary
WTP	water treatment plant

Executive Summary

INTRODUCTION AND PURPOSE OF THE REVISED DRAFT EIR/EIS

The revised draft environmental impact report and environmental impact statement (REIR/EIS) for the Delta Wetlands Project has been prepared under the direction of the State Water Resources Control Board (SWRCB) and the U.S. Army Corps of Engineers (USACE) in accordance with the provisions of the California Environmental Quality Act (CEQA) and the National Environmental Policy Act (NEPA).

The environmental impacts of the Delta Wetlands Project were previously analyzed in the 1995 Delta Wetlands Project Draft Environmental Impact Report and Environmental Impact Statement (1995 DEIR/EIS) (Jones & Stokes Associates 1995). The primary purpose of the REIR/EIS document is to recirculate, pursuant to Section 15088.5 of the CEQA Guidelines and Section 1502.9 of the Council on Environmental Quality NEPA Regulations, those parts of the CEQA/NEPA analysis for the project for which significant information has been developed since the 1995 DEIR/EIS was published. The REIR/EIS presents available new information on water quality, levee stability, seepage, and natural gas facilities and transmission pipelines and considers the relevance of this information to the analysis of potential project effects presented in the 1995 DEIR/EIS. In addition, the REIR/EIS presents the results of updated simulations of Delta Wetlands Project diversion and discharge operations; the new simulations reflect changes made to the proposed project as a result of state and federal Endangered Species Act (ESA) consultation and operational agreements reached between Delta Wetlands and other interested parties. The REIR/EIS also includes an updated assessment of fisheries that evaluates how these changes to the proposed project affect the 1995 DEIR/EIS conclusions about potential project effects on fish species.

PROJECT DESCRIPTION AND HISTORY

Overview of Project Purpose and Features

Delta Wetlands proposes a water storage and habitat enhancement project on four islands in the Sacramento-San Joaquin Delta (Delta). The project would involve the following components:

- diverting and storing water on Bacon Island and Webb Tract ("reservoir islands") for later discharge for export or to meet outflow or environmental requirements;

- diverting water seasonally to create and enhance wetlands and to manage wildlife habitat on Bouldin Island and most of Holland Tract ("habitat islands"); and

- building recreational facilities for boating and hunting along the perimeter levees on all four islands.

To operate its project, Delta Wetlands would improve and strengthen levees on all four islands and would install additional siphons and water pumps on the perimeters of the reservoir islands. Delta Wetlands would operate the habitat islands under a habitat management plan (HMP) to compensate for impacts on, and promote the recovery of, state-listed threatened or endangered wildlife species and other special-status species, and to provide additional wetlands and wildlife habitat in the Delta.

The Delta Wetlands Project islands also could be used for interim storage of water being transferred through the Delta from sellers upstream to buyers served by Delta exports or buyers who would use the water to meet Bay-Delta estuary outflow or environmental requirements (water transfers). Another option would be to use the islands to temporarily store water owned by parties other than Delta Wetlands for later use to meet scheduled Bay-Delta estuary outflow or environmental requirements or for export (water banking). Because no proposals exist for these types of uses of the project island facilities, the CEQA/NEPA analysis considers the water supply yield and environmental impacts of the project based only on water stored under Delta Wetlands' own appropriative water right permits and later conveyed to Delta channels.

In the 1995 DEIR/EIS and the REIR/EIS, the Delta Wetlands Project is analyzed as a stand-alone water storage facility, operated independently of the State Water Project (SWP) and the Central Valley Project (CVP), and without regard to the specific entities to which the water could be sold. Although potential opportunities exist to operate the Delta Wetlands Project in conjunction with the SWP and CVP or in coordination with the CALFED Bay-Delta Program (CALFED), no proposals have been made for which the SWRCB and USACE could reasonably assess the environmental effects, so discussion of such arrangements remains speculative.

Regulatory Compliance History

Delta Wetlands has applied to the SWRCB, Division of Water Rights, for new appropriative water rights to divert water, store it on the project reservoir islands, and discharge it to Delta channels for export or to meet Bay-Delta estuary outflow or environmental requirements. Delta Wetlands also has applied to USACE for a permit under Section 404 of the Clean Water Act for the discharge of dredged or fill materials into waters of the United States and under Section 10 of the Rivers and Harbors Act of 1899 for other project activities in navigable waters. The project must comply with CEQA and NEPA because it requires these discretionary approvals. The 1995 DEIR/EIS was prepared at the direction of the SWRCB and USACE to assess the environmental effects of the proposed project pursuant to CEQA and NEPA requirements. The document was distributed for public review and comment in September 1995. Numerous comment letters were received on the 1995 DEIR/EIS during the public comment period; many commenters expressed concerns about levee stability and seepage potential and project effects on fisheries and water quality.

While the 1995 DEIR/EIS was being prepared, the SWRCB and USACE prepared biological assessments that evaluated potential effects of the Delta Wetlands Project on fish and wildlife species listed or proposed for listing under the state and federal ESAs. The biological assessment for fish species concluded that the project could adversely affect several fish species that were listed or proposed for listing. The SWRCB initiated consultation with the California Department of Fish and Game (DFG) pursuant to the California ESA regarding project effects on delta smelt and winter-run chinook salmon. Pursuant to the federal ESA, USACE initiated formal consultation with the U.S. Fish and Wildlife Service (USFWS) regarding project effects on delta smelt and Sacramento splittail, and with the National Marine Fisheries Service (NMFS) regarding project effects on winter-run chinook salmon and steelhead.

As part of the consultation process, the SWRCB, USACE, USFWS, NMFS, DFG, and Delta Wetlands developed operating parameters for the Delta Wetlands Project, referred to as the Delta Wetlands "final operations criteria" (FOC), to protect these species. In May 1997, NMFS and USFWS issued no-jeopardy biological opinions that defined "reasonable and prudent measures" (RPMs) to be implemented by Delta Wetlands for protection of listed fish species. In August 1998, DFG issued a no-jeopardy biological opinion that specified additional RPMs for protection of fish species. The agencies' RPMs include the operating restrictions described in the FOC. The FOC and RPMs are now incorporated into the proposed Delta Wetlands Project description.

Also in 1997, the SWRCB convened a water right hearing to consider Delta Wetlands' petitions for new water rights and changes to existing water rights. Eighteen parties filed protests with the SWRCB against Delta Wetlands' water right applications. Delta Wetlands entered into stipulated agreements with five of these protestants. Four of the stipulated agreements affirm the seniority of the protesting parties' water rights and, to preclude interference with those senior water rights, outline general conditions under which the Delta Wetlands Project would operate. The fifth stipulated agreement precludes Delta Wetlands from interfering with the protesting party's ability to obtain water of a specified salinity level.

Delta Wetlands and several of the other parties presented evidence at the water right hearing on topics that included the potential effects of the Delta Wetlands Project on:

- levee stability;
- seepage to neighboring islands; and
- salinity and dissolved organic carbon (DOC) in Delta exports, and the resulting effects of increases in salinity and DOC on disinfection byproduct (DBP) formation at water treatment plants.

Additionally, Pacific Gas and Electric Company (PG&E) presented evidence regarding the potential for the Delta Wetlands Project to significantly affect PG&E's ability to maintain its gas line across Bacon Island. The East Bay Municipal Utility District (EBMUD) and DFG raised several issues about project effects on listed fish species. However, DFG's no-jeopardy biological opinion was issued subsequent to these proceedings, and the RPMs identified in the biological opinion, in addition to the FOC, adequately address these issues by providing for protection of listed fish species.

ISSUES ADDRESSED IN THE REVISED DRAFT EIR/EIS

The SWRCB and USACE have directed the preparation of the REIR/EIS to provide further clarification of the following issues:

- water quality, including project effects on DOC, trihalomethanes (THMs), and salinity;
- levee design and stability;
- seepage and proposed seepage control measures; and
- PG&E's gas line on Bacon Island.

In addition to these analyses, the REIR/EIS presents the results of updated simulations of Delta Wetlands Project discharge and diversion operations. It also includes an assessment of fisheries that updates the 1995 DEIR/EIS conclusions about potential project effects on fish species, and discusses new information on spring-run chinook salmon and fish predation at boat docks and other project facilities.

The REIR/EIS does not present a comprehensive analysis of the Delta Wetlands Project, but supplements the information presented in the 1995 DEIR/EIS in the following resource areas:

- water supply and operations,
- water quality,
- fisheries,
- levee stability and seepage, and
- natural gas facilities and transmission pipelines.

Together, the REIR/EIS and the 1995 DEIR/EIS provide the complete draft EIR/EIS analysis of potential environmental effects of the Delta Wetlands Project in compliance with CEQA and NEPA.

PROJECT ALTERNATIVES

The 1995 DEIR/EIS analyzed three project alternatives and a No-Project Alternative in an equal level of detail. The No-Project Alternative consists of intensified agricultural production on all four Delta Wetlands Project islands. Alternatives 1 and 2 both represent Delta Wetlands' proposed project, which consists of water storage on two reservoir islands and implementation of an HMP on two habitat islands, but these alternatives offer two different scenarios for the discharge of stored water. Under Alternative 3, all four Delta Wetlands Project islands would be used as reservoirs and limited compensation wetland habitat would be provided on Bouldin Island.

Alternative 2, with a higher amount of discharge pumping than Alternative 1, would have the maximum effect on fisheries associated with the proposed project. Alternative 2 was therefore used to represent the proposed project in the biological assessment for fish species (see Appendix F2 of the 1995 DEIR/EIS). The terms and conditions of the DFG, USFWS, and NMFS biological opinions are based on this alternative.

The REIR/EIS analysis has been performed to:

- confirm the results of the 1995 DEIR/EIS analysis,
- provide revised impact assessments,
- present new or revised mitigation measures where necessary, and
- indicate where mitigation measures recommended in the 1995 DEIR/EIS have been superseded by the FOC and RPMs.

Generally, the REIR/EIS evaluates the proposed project as represented by Alternative 2 (as modified by incorporation of the FOC, RPMs, and stipulated agreements) and discusses qualitatively how this assessment relates to evaluation of the other alternatives.

SUMMARY OF EVALUATIONS PRESENTED IN THE REVISED DRAFT EIR/EIS

Water Supply and Operations

The water supply and operations chapter (Chapter 3) provides information on the potential range of Delta Wetlands Project diversions and discharges based on the most current project description and on current assumptions for modeling Delta water supply, current regulatory standards, and an updated baseline water budget. Average monthly diversion, storage, and discharge values are reported from results of simulations performed using the Delta Standards and Operations Simulation (DeltaSOS) model. The results show that with the restrictions on project operations specified in the FOC and RPMs, opportunities for project diversions and discharges would be reduced compared with the results shown in the 1995 DEIR/EIS. Effects on consumptive use would be less than significant, as reported in the 1995 DEIR/EIS.

The results of simulations of daily Delta Wetlands Project operations are also presented. In comparison with the results of the monthly simulations, the results of the daily simulations show opportunities for diversion and discharge, and some constraints on diversions and discharge, that exist when project operations are modified at a daily time step in response to Delta conditions.

Water Quality

The evaluation of water quality (Chapter 4) provides new simulation results of project effects on salinity (electrical conductivity [EC], chloride [Cl^-], and bromide [Br^-]), DOC, and THMs. The assessment considers data from recent measurements of Delta water quality variables, new laboratory data on DOC loading from peat soil, and estimates of DOC loading provided during the water right hearing. The significance threshold for THM effects has been modified to reflect the more stringent rules for DBPs, including THMs, that the U.S. Environmental Protection Agency (EPA) adopted after the 1995 DEIR/EIS was released. The evaluation found that with the changes in project operations resulting from incorporation of the FOC and RPMs into the project, the salinity effects on exports and at Chipps Island are now less than significant. Project impacts on salinity at Jersey Point and Emmaton and on DOC and THMs are significant, as reported in the 1995 DEIR/EIS. The same mitigation measures that were recommended in the 1995 DEIR/EIS are recommended in the REIR/EIS to reduce these impacts to a less-than-significant level. The lead agencies could adjust the recommended mitigation to meet any other requirement adopted in the project's permit terms.

Fisheries

The REIR/EIS fisheries assessment (Chapter 5) discusses changes in 1995 DEIR/EIS impact conclusions that have resulted from incorporation of the FOC and RPMs into the proposed project. It also discusses new listings of fish species and evaluates new information on spring-run chinook salmon occurrence provided by DFG, data on Mokelumne River spring-run chinook salmon provided by EBMUD, and new information regarding potential increases in predation with the construction of Delta Wetlands boat docks and other facilities. The evaluation found that incorporating the FOC and RPMs into the project reduces the significant impacts identified in the 1995 DEIR/EIS to a less-than-significant level; therefore, the mitigation recommended in the 1995 DEIR/EIS is no longer required.

Levee Stability and Seepage

A new geotechnical evaluation of the proposed levee design and seepage-control system was performed for the REIR/EIS. The results are reported in Appendix H and summarized in Chapter 6. The new evaluation identifies the following as significant impacts:

- a potential decrease in long-term levee stability on the Delta Wetlands reservoir islands and
- a potential increase in seepage on adjacent islands resulting from project operations.

Mitigation is proposed to reduce both impacts to a less-than-significant level. In addition, the following impacts are identified as less than significant:

- a potential decrease in levee stability on the project islands during or immediately after project construction,
- potential property damage resulting from levee failure, and
- cumulative effects on Delta flood hazards.

Other impact conclusions in the 1995 DEIR/EIS have not changed.

Natural Gas Facilities and Transmission Pipelines

The evaluation of natural gas facilities and transmission pipelines addresses PG&E's concern that the proposed Delta Wetlands water storage operations could adversely affect PG&E's ability to use its easements, decrease the useful life of the pipeline, increase the threat of pipeline damage, and affect pipeline maintenance. The evaluation of new information in the REIR/EIS identifies the following new significant impacts:

- an increased risk of pipeline leak or rupture resulting from island inundation (for an inactive pipeline only),
- an increased risk of pipeline leak or rupture resulting from levee improvements, and
- potential interference with pipeline inspection procedures.

Mitigation is proposed to reduce these impacts to a less-than-significant level.

KNOWN AREAS OF CONTROVERSY

Several areas of controversy regarding potential Delta Wetlands Project effects were discussed in comments on the 1995 DEIR/EIS and were the subject of conflicting water right hearing testimony. Most of the issues that were related to project effects on protected fish species have since been resolved by incorporation into the project of the FOC and RPM measures described in the state and federal biological opinions. As described in the sections above, the REIR/EIS was prepared to present new information that has become available, since release of the 1995 DEIR/EIS, on the remaining controversial issues—project effects on DOC and THM formation, levee stability, seepage, and PG&E maintenance of gas lines. The following sections summarize the specific areas of controversy that remain with regard to these issues and, where appropriate, summarize discussions of these issues presented in the REIR/EIS.

Potential Project Effects on Dissolved Organic Carbon Levels in Delta Exports

There is much disagreement among experts regarding the amount of DOC loading to stored water that would occur under Delta Wetlands' proposed reservoir storage operations. Chapter 4 of the REIR/EIS:

- describes the range of DOC loading estimates that were presented in the 1995 DEIR/EIS,
- describes new data on Delta water quality collected since the 1995 DEIR/EIS was released, and
- reports the range of DOC loading estimates calculated from the results of laboratory experiments using flooded peat soil as well as those presented by expert witnesses in testimony at the SWRCB water right hearing.

Because substantial disagreement remains regarding the appropriate levels of DOC loading to use in estimates of Delta Wetlands Project effects, the analysis in Chapter 4 evaluates effects for a wide range of DOC loading estimates. The range encompasses the loading rates observed in Delta agricultural drainage and in field and laboratory studies of DOC loading from Delta island peat soil.

The mitigation presented in the 1995 DEIR/EIS and the REIR/EIS is designed to accommodate the uncertainty about DOC loading from the project islands; it consists of reducing and/or delaying project discharges to minimize effects on export DOC concentrations. Thus, the mitigation is designed to be effective regardless of the actual DOC loading rates observed under project implementation. The chapter describes how the proposed mitigation would be implemented to control Delta Wetlands Project effects on export DOC concentrations under extreme (worst-case) DOC loading conditions. It also discusses how the mitigation would be adjusted to meet any mitigation requirement specified in water right permit terms for the project.

Relationship of Dissolved Organic Carbon and Bromide in Exports to Disinfection Byproduct Concentrations in Treated Water

Commenters on the 1995 DEIR/EIS and parties to the water right hearing disputed the accuracy of the methods for determining the formation of DBPs, including THMs, as a function of export salinity (Br^-) and DOC concentration. They suggested that revised methods for predicting the relationship between DOC and salinity levels and the formation of THMs and other DBPs at municipal water treatment plants would yield a better estimate of project effects. Appendix G of the REIR/EIS describes the updated methods and discusses their shortcomings. The accuracy of these methods remains an area of controversy.

As described for DOC impacts in the previous section, the mitigation of impacts on THMs presented in the 1995 DEIR/EIS and the REIR/EIS consists of reducing and/or delaying project discharges to minimize effects on THM formation at treatment plants. This mitigation is designed to be effective regardless of the actual increases in Br^- and DOC concentrations observed under project implementation. Reductions and/or delays in discharges to export would control Delta Wetlands Project effects on export DOC concentrations and salinity to meet a mitigation requirement specified in the project's water right permit terms.

Appropriateness of the Significance Criteria Used in the CEQA/NEPA Impact Analysis for Water Quality

Several parties to the water right hearing and commenters on the 1995 DEIR/EIS questioned the adequacy of the significance thresholds used in the impact analysis for water quality, arguing that these thresholds would not ensure the protection of all beneficial uses, most notably municipal water uses. The challenges are based on the concern that natural variability differs among water quality constituents and that for certain constituents, any change may constitute an unacceptable degradation of resources that are already impaired.

This issue is addressed in the discussion of impact significance criteria in Chapter 4. The discussion explains that the significance criteria exceed the expectations of CEQA and NEPA:

- When regulatory standards exist for a given variable, the significance criteria are more restrictive than the established standards.

- In the case of variables for which no standards exist, the significance criteria encompass the range of natural variability, measurement errors, and modeling uncertainty.

Several commenters have not recognized the distinction between the CEQA/NEPA significance criteria and the mitigation requirements that the SWRCB would apply in water right permit terms. The CEQA/NEPA significance criteria are used to develop mitigation measures on a monthly time step in an evaluation based on monthly model results; in actual practice, the Delta Wetlands Project would be required to adjust operations each day in response to daily monitoring of actual

Delta conditions and the quality of water stored on the Delta Wetlands islands. The mitigation performance requirements used to trigger changes in project operations under the terms and conditions of a water right permit, therefore, may differ from the CEQA/NEPA significance criteria. As discussed in Chapter 4, the SWRCB has discretion in establishing the requirements used to condition the water right permits.

Potential for Increased Municipal Water Treatment Costs Resulting from Project Operations

Some commenters on the 1995 DEIR/EIS and parties to the water right hearing have argued that economic effects on treatment plant operators (i.e., increases in treatment costs) that could result from project-related increases in salinity and DOC concentrations should be considered significant impacts. This issue is discussed in the section on impact significance criteria in Chapter 4 and in that chapter's evaluation of project effects on THM formation.

The State CEQA Guidelines state that economic changes resulting from a project shall not be treated as significant effects on the environment except when the economic changes lead to environmental impacts. Similarly, NEPA requires discussion of economic effects only to the extent that they are interrelated with environmental impacts. CEQA and NEPA do not require a significance determination of the economic impacts on treatment plant operators. Potential effects on water treatment costs for downstream water users caused by Delta Wetlands operations are an economic issue outside the scope of this environmental analysis. However, the SWRCB may choose to establish a monitoring and compensation plan for these potential effects in water right terms and conditions.

Adequacy of the Proposed Levee Design for the Reservoir Islands

Several parties to the water right hearing and commenters on the 1995 DEIR/EIS questioned the adequacy of the proposed levee system and argued that an independent geotechnical evaluation should be performed to determine the stability of the proposed system under various stresses. The SWRCB and USACE directed that an independent analysis be performed and the results presented in the REIR/EIS. Appendix H presents the results of the analysis. These results and proposed mitigation are summarized in Chapter 6.

Effectiveness of the Proposed Interceptor Well System for Controlling Seepage to Neighboring Islands, and Adequacy of the Seepage Monitoring Program

Several parties to the water right hearing and commenters on the 1995 DEIR/EIS have argued that the proposed seepage-control system and seepage monitoring program would not adequately protect neighboring islands from seepage effects from flooded project reservoirs. These effects were simulated in the geotechnical evaluation performed for the REIR/EIS. The results, including proposed mitigation, are presented in Appendix H and Chapter 6.

Significance Criteria for the Evaluation of Effects on Levee Stability and Regulatory Standards to Be Applied to the Delta Wetlands Project Levees

Parties to the water right hearing have argued that the lead agencies should identify the levee standards, such as factors of safety (FSs), that would be applied to the Delta Wetlands Project's final levee design. This issue is addressed in Chapter 6 of the REIR/EIS. FSs are only one element used to regulate levees and dams; other design considerations are also used. USACE has published standards and guidelines for federal and local levees in the Delta; the California Department of Water Resources (DWR) has published guidelines for local levee rehabilitation in the Delta, and the Division of Safety of Dams (DSOD) establishes standards for dams.

The purpose of the CEQA/NEPA impact assessment is to determine the difference in levee stability between existing conditions and with-project conditions. The relative change in the FSs between the project and existing conditions is used as the basis for evaluating the impact of the proposed project. Because the analysis evaluates the change in levee conditions, a given FS standard cannot be used to determine the significance of the change. However, these standards will be considered during project approval and final design.

The lead agencies can choose to adopt a given standard to be applied to the final levee design for the Delta Wetlands islands. In the terms and conditions of project approval, the lead agencies may include standards or guidelines for the reservoir island levees that are more conservative than those proposed by Delta Wetlands. If the levees are determined to be "dams" as defined by the California Water Code (Sections 6002 through 6008), Delta Wetlands would be required to meet DSOD's standards and design review requirements. The determination of which standards apply to the project levees will depend on the final project design.

Effects on Pacific Gas and Electric Company's Ability to Use Its Bacon Island Easements, Provide Uninterrupted Gas Service, and Maintain Its Pipelines

During the Delta Wetlands water right hearing, PG&E presented testimony regarding its easements and natural gas pipelines that cross Bacon Island. The testimony focused on the ways in which proposed Delta Wetlands water storage operations could adversely affect PG&E's ability to use its easements, decrease the useful life of the pipeline, increase the threat of pipeline damage, and affect pipeline maintenance.

The future use of PG&E's easement is a private property right dispute that will be resolved independent of the SWRCB and USACE approval process; it is not addressed in the CEQA/NEPA evaluation. Issues related to the operation and maintenance of the pipeline on Bacon Island and the possibility of impacts on regional natural gas service are considered potential environmental effects. The REIR/EIS updates and supplements the discussions of these Bacon Island pipeline issues presented in the 1995 DEIR/EIS.

Viability of the Project Given the Lack of Identified Purchasers of Delta Wetlands Water

Several commenters on the 1995 DEIR/EIS and parties to the water right hearing have questioned the viability of the proposed project, arguing that without identified purchasers of project water, the proposed project is financially infeasible and, therefore, should not be approved by the lead agencies.

Identification of beneficial uses of project water and financial feasibility of the project are water right and public interest issues that are addressed through the SWRCB's water right hearing process and USACE's public interest review. These issues are beyond the scope of CEQA and NEPA requirements and the EIR/EIS process, and are not addressed in the REIR/EIS or the 1995 DEIR/EIS. The SWRCB, during its water right decision process, and USACE, during its public interest review, will consider the analyses of significant environmental effects presented in the 1995 DEIR/EIS and the REIR/EIS.

PUBLIC REVIEW PROCESS FOR THE REVISED DRAFT EIR/EIS

The REIR/EIS serves as a full-disclosure document for the public to ensure that interested parties have an opportunity to express their views and concerns about the environmental effects of the Delta Wetlands Project, as presented in the updated analysis. The REIR/EIS is being circulated for review by interested agencies and the public. The lead agencies will receive comments on the REIR/EIS until July 31, 2000.

In publishing the REIR/EIS, the SWRCB and USACE are recirculating for public review and comment only the revised environmental analysis presented in the REIR/EIS. Those portions of the analysis addressed in the 1995 DEIR/EIS that are not reevaluated in the REIR/EIS are not being recirculated for additional public comment.

After the comments have been assembled and reviewed, the SWRCB and USACE will prepare a final EIR/EIS (FEIR/EIS). The FEIR/EIS will include responses on environmental issues that have been raised in comments on the REIR/EIS as well as in comments received previously on the 1995 DEIR/EIS.

Chapter 1. Introduction and Project Background

PURPOSE OF THIS DOCUMENT

This revised draft environmental impact report/environmental impact statement (REIR/EIS) on the Delta Wetlands Project has been prepared under the direction of the State Water Resources Control Board (SWRCB) and the U.S. Army Corps of Engineers (USACE). The SWRCB and USACE are the lead agencies under the California Environmental Quality Act (CEQA) and the National Environmental Policy Act (NEPA), respectively.

The environmental impacts of the Delta Wetlands Project were previously analyzed in the 1995 Delta Wetlands Project Draft Environmental Impact Report and Environmental Impact Statement (1995 DEIR/EIS) (Jones & Stokes Associates 1995). During the public comment period on the 1995 DEIR/EIS, the SWRCB and USACE received numerous comment letters, many of which discussed water quality, fisheries, levee stability, and seepage issues. In 1997, the SWRCB convened a hearing to consider Delta Wetlands' water right applications for the project. Several parties presented conflicting testimony about the project's potential effects. Much of this testimony concerned stability of the proposed levees, seepage from the project reservoirs to neighboring islands, and the project's contributions to salinity and concentrations of dissolved organic carbon (DOC) in Delta waterways.

Because substantial controversy remains regarding the project's potential effects on levee stability, seepage, and water quality, the SWRCB and USACE believed that it would be prudent to identify available new information on these issues and to consider the relevance of this information to the analysis of potential project effects. The two lead agencies directed that a revised, quantitative analysis of geotechnical (levee stability and seepage) issues be developed to provide information to supplement the discussion of flood control features included in the 1995 DEIR/EIS.

The CEQA Guidelines (Section 15088.5) include the following guidance on recirculation of a draft environmental impact report (EIR) or portions of a draft EIR:

> [A] lead agency is required to recirculate an EIR when significant new information is added to the EIR after public notice is given of the availability of the draft EIR for public review under Section 15087 but before certification. . . . [T]he term "information" can include changes in the project or environmental setting as well as additional data or other information. New information added to an EIR is not "significant" unless the EIR is changed in a way that deprives the public of a meaningful opportunity to comment upon a substantial adverse environmental effect of the project or a feasible way to mitigate or avoid such an effect (including a feasible project alternative) that the project's proponents have declined to implement.

> . . . Recirculation is not required where the new information added to the EIR merely clarifies or amplifies or makes insignificant modifications in an adequate EIR. . . . If the revision is limited to a few chapters or portions of the EIR, the lead agency need only recirculate the chapters or portions that have been modified.

The Council of Environmental Quality's (CEQ's) NEPA Regulations (40 CFR 1502.9[c]) direct that agencies "[s]hall prepare supplements to either draft or final environmental impact statements if . . . [t]here are significant new circumstances or information relevant to environmental concerns and bearing on the proposed action or its impacts". They further direct that agencies "[m]ay also prepare supplements when the agency determines that the purposes of [NEPA] will be furthered by doing so".

Pursuant to Section 15088.5 of the CEQA Guidelines and Section 1502.9 of the CEQ NEPA Regulations, the SWRCB and USACE are recirculating those parts of the CEQA/NEPA analysis for the project for which significant information has been developed since the 1995 DEIR/EIS was published. These parts are the analyses of levee stability, seepage, water quality, and natural gas facilities and transmission pipelines.

The evaluation of water quality effects is based in part on the estimated timing and volumes of Delta Wetlands Project diversions and discharges. Therefore, the modeling of water supply and operations was also updated for this REIR/EIS, and the results of the modeling are presented for comparison with those of the 1995 DEIR/EIS. In addition, the fisheries assessment is updated with the most recent information available to address issues raised after the 1995 DEIR/EIS was published.

This REIR/EIS does not present a comprehensive analysis of the Delta Wetlands Project, but supplements the information presented in the 1995 DEIR/EIS. Together, the REIR/EIS and the 1995 DEIR/EIS provide the complete draft EIR/EIS analysis of potential environmental effects of the Delta Wetlands Project in compliance with CEQA and NEPA. Reviewers are therefore referred to the 1995 DEIR/EIS for background information on the project and for previously presented analyses. That document is hereby incorporated by reference.

This REIR/EIS does not include formal responses to comments on the 1995 DEIR/EIS, although it does address several issues raised in those comments. Formal responses to all comments on the 1995 DEIR/EIS will be presented in the final environmental impact report/environmental impact statement (FEIR/EIS) on the Delta Wetlands Project along with responses to comments on this REIR/EIS. Comments submitted on the 1995 DEIR/EIS do not need to be resubmitted.

PROJECT HISTORY

The Proposed Project

Project Description

Delta Wetlands proposes a water storage project on four islands in the Sacramento-San Joaquin Delta (Delta) (Figure 1-1). The project would involve diverting and storing water on two of the islands (Bacon Island and Webb Tract, or "reservoir islands") for later discharge for export or to meet outflow or environmental requirements for the San Francisco Bay/Sacramento-San Joaquin Delta (Bay-Delta) estuary. In addition, the project would involve diverting water seasonally to create and enhance wetlands and to manage wildlife habitat on the other two islands (Bouldin Island and most of Holland Tract, or "habitat islands") (Figure 1-2). Delta Wetlands also proposes to build recreational facilities for boating and hunting along the perimeter levees on all four Delta Wetlands Project islands.

The project islands are owned either wholly or partially by Delta Wetlands. To operate its project, Delta Wetlands would improve and strengthen levees on all four islands and would install additional siphons and water pumps on the perimeters of the reservoir islands. Delta Wetlands would operate the habitat islands under a habitat management plan (HMP) to compensate for impacts on, and promote the recovery of, state-listed threatened or endangered wildlife species and other special-status species, and to provide additional wetlands and wildlife habitat in the Delta. Figures 1-3 through 1-6 show the proposed project facilities on each island.

In the 1995 DEIR/EIS and this REIR/EIS, the Delta Wetlands Project is analyzed as a stand-alone water storage facility, operated independently of the State Water Project (SWP) and the Central Valley Project (CVP), and without regard to the specific entities to which the water could be sold. Several potential opportunities exist to operate the Delta Wetlands Project in conjunction with the CVP and the SWP or in coordination with the CALFED Bay-Delta Program (CALFED); however, no proposals have been made for which the SWRCB and USACE could reasonably assess the environmental effects, so discussion of such arrangements remains speculative.

The CEQA/NEPA analysis presented in the 1995 DEIR/EIS and this REIR/EIS does not analyze how state or federal facilities may be operated in the future in coordination with the Delta Wetlands Project. The impact analysis does, however, estimate the effects of project operations on operation of the SWP and CVP pumping facilities. Any coordinated arrangements with CALFED or the SWP or CVP may require additional environmental analysis. An analysis of the effects of such arrangements is beyond the scope of this REIR/EIS, but may be necessary before water from the Delta Wetlands Project is exported. A description of the potential relationship between CALFED and the Delta Wetlands Project or other similar in-Delta storage projects is provided in Chapter 2, "Changes to the Project Description, Alternatives Analyzed, and Future Conditions Considered".

The Delta Wetlands Project islands also could be used for interim storage of water being transferred through the Delta from sellers upstream to buyers served by Delta exports or buyers who would use it to meet Bay-Delta estuary outflow or environmental requirements (water transfers). Another option would be to use the islands to temporarily store water owned by parties other than Delta Wetlands for later use to meet scheduled Bay-Delta estuary outflow or environmental requirements or for export (water banking). However, no proposals exist for these types of uses of the project island facilities, so discussing such arrangements would be speculative. The 1995 DEIR/EIS and this REIR/EIS analysis consider the water supply yield of the project based only on water stored under Delta Wetlands' own appropriative water right permits and later conveyed to Delta channels. Delta Wetlands Project operations using transferred or banked water would require additional approvals from the SWRCB and, possibly, additional environmental documentation.

The changes that have been incorporated into the proposed project since preparation of the 1995 DEIR/EIS are described in Chapter 2.

Project Permit Requirements

Delta Wetlands has applied to the SWRCB, Division of Water Rights, for new appropriative water rights to divert water, store it on the project islands, and discharge it to Delta channels for export or to meet Bay-Delta estuary outflow or environmental requirements. Delta Wetlands Project fill activities associated with perimeter and interior levee work on the reservoir islands; habitat enhancement activities on the habitat islands; and construction of boat docks, pumps, and siphons in Delta channels would be considered discharges into waters of the United States. Delta Wetlands, therefore, also has applied to USACE for a permit under Section 404 of the Clean Water Act for the discharge of dredged or fill materials into waters of the United States and under Section 10 of the Rivers and Harbors Act of 1899 for other project activities in navigable waters.

Because the Delta Wetlands Project requires these discretionary approvals from the SWRCB and USACE, the project must comply with both CEQA and NEPA, with the SWRCB serving as the lead agency for CEQA compliance and USACE as the lead agency for NEPA compliance. Compliance with Section 7 of the federal Endangered Species Act (ESA), Section 106 of the National Historic Preservation Act, and other regulations is also required before USACE may issue a permit. Compliance with the California ESA also is required as part of the SWRCB permitting process. Various other permits and consultations are also required, as discussed in Chapter 4 of the 1995 DEIR/EIS. See Chapter 1 and Appendix 1 of the 1995 DEIR/EIS for details on Delta Wetlands' water right applications and the SWRCB water right process, and Chapters 1 and 4 of the 1995 DEIR/EIS for more information on the USACE permitting process.

Regulatory Compliance History

Table 1-1 shows an overview of the steps in the Delta Wetlands Project's history, which are described in this section, and those remaining in the project approval process, which are described under "Future Steps in the Consideration of Delta Wetlands' Applications", below.

The Water Right Process and CEQA/NEPA Compliance

Delta Wetlands originally applied for water rights to store water seasonally on all four of its project islands. The Delta Wetlands Project, as originally proposed, was analyzed in a draft EIR/EIS released in December 1990. In August 1993, Delta Wetlands submitted new water right applications that revised the project description to a proposal for two reservoir islands and two habitat islands (see "The Proposed Project", above). The 1995 DEIR/EIS was prepared at the direction of the SWRCB and USACE to assess the environmental effects of the Delta Wetlands Project based on the 1993 project description. The document was distributed for public review and comment in September 1995.

The lead agencies held a public meeting on October 11, 1995, to receive comments on the 1995 DEIR/EIS and accepted written comments on the document until December 21, 1995. Numerous comment letters were received; many commenters expressed concerns about levee stability and seepage potential and project effects on fisheries and water quality.

In 1997, the SWRCB convened a water right hearing to consider Delta Wetlands' petitions for new water rights and changes to existing water rights. Eighteen parties filed protests with the SWRCB against Delta Wetlands' water right applications. Delta Wetlands entered into stipulated agreements with five of these protestants. Four of the stipulated agreements affirm the seniority of the protesting parties' water rights and, to preclude interference with those senior water rights, outline general conditions under which the Delta Wetlands Project would operate. The fifth precludes Delta Wetlands' interference with the protesting party's ability to meet water quality criteria for salinity. These agreements are described in Appendix A.

As described in "Purpose of This Document" above, Delta Wetlands and several of the other parties presented evidence at the water right hearing. Topics included the potential effects of the Delta Wetlands Project on levee stability and seepage to neighboring islands, and the effects of the project on salinity and concentrations of DOC in Delta exports and the resulting effects of this increased salinity and DOC loading on treatment plant operations. Additionally, Pacific Gas and Electric Company (PG&E) presented evidence to show that the Delta Wetlands Project could significantly affect PG&E's ability to maintain its gas line across Bacon Island. The East Bay Municipal Utility District (EBMUD) and California Department of Fish and Game (DFG) raised questions regarding potential project effects on Mokelumne River salmon and predation of protected fish species at Delta Wetlands Project boat docks and other project facilities. (Other issues raised by DFG were subsequently addressed in DFG's biological opinion. See Appendix C.)

A broad range of assumptions and conclusions on these issues is reflected in the SWRCB's and USACE's administrative record. This REIR/EIS has been prepared to provide further clarification of these issues.

Endangered Species Act Consultation

At the same time that the 1995 DEIR/EIS was being prepared, the SWRCB and USACE prepared biological assessments that evaluated potential effects of the Delta Wetlands Project on fish and wildlife species listed or proposed for listing under the state and federal ESAs. The biological assessment for fish species concluded that the project could adversely affect several fish species that were listed or proposed for listing. The SWRCB began consultation with DFG pursuant to the California ESA about project effects on delta smelt and winter-run chinook salmon. Pursuant to the federal ESA, USACE began formal consultation with the U.S. Fish and Wildlife Service (USFWS) about project effects on delta smelt and Sacramento splittail, and with the National Marine Fisheries Service (NMFS) about project effects on winter-run chinook salmon and steelhead.

As part of the consultation process, the SWRCB, USACE, USFWS, NMFS, DFG, and Delta Wetlands held a series of meetings to cooperatively develop operating parameters for the Delta Wetlands Project that would protect these species. The outcome of the meetings was agreement on a set of "final operations criteria" (FOC) for the project. DFG, NMFS, and USFWS subsequently issued no-jeopardy biological opinions that defined "reasonable and prudent measures" (RPMs) to be implemented by Delta Wetlands for protection of the listed species. These measures included the operating restrictions described in the FOC. The final biological opinions for all three agencies are included in this REIR/EIS as Appendices C, D, and E.

CURRENT STATUS OF THE PROJECT

As described previously, the lead agencies determined that this REIR/EIS should be prepared to allow for recirculation of those parts of the environmental analysis for which significant new information exists, and to provide for additional public review of, and comment on, this information. The SWRCB water right proceeding has not yet been concluded. The SWRCB will hold further days of the public hearing. The lead agencies will receive oral and written comments on the REIR/EIS until July 31, 2000. A FEIR/EIS, including responses to comments on both the 1995 DEIR/EIS and this REIR/EIS, will be prepared. The water right hearing and the USACE permitting review process will continue after the CEQA/NEPA process is complete. Details of these processes are described below under "Public Review and Comment Period".

In addition, after the issuance of the biological opinions, splittail, steelhead (Central Valley Evolutionarily Significant Unit [ESU]), and spring-run chinook salmon were listed as threatened under the federal ESA, and spring-run chinook salmon was listed as threatened under the California ESA as well. Also, the requirements of Section 2090 of the California ESA have expired, resulting in the need to convert DFG's biological opinion to a take permit under the current requirements of the California ESA. The USFWS and NMFS biological opinions included conference opinions on splittail and steelhead, respectively, because these species were proposed for listing at the time when the opinions were issued. USFWS has adopted the conference opinion for splittail as its biological opinion. USACE has asked NMFS to adopt the conference opinion for steelhead as its biological opinion and, pursuant to Section 7 of the federal ESA, has requested consultation on the effects of the Delta Wetlands Project on spring-run chinook salmon. Delta Wetlands is coordinating with DFG to ensure that DFG's authorization covers spring-run chinook salmon and is consistent with the latest requirements of the California ESA. (See Chapter 5, "Fisheries".)

CONTENTS OF THE REVISED DRAFT EIR/EIS AND PUBLIC REVIEW PROCESS FOR THE DOCUMENT

Key Issues Addressed in This Document

This REIR/EIS addresses the following issues:

- water supply and operations;
- water quality, including project effects on DOC, trihalomethanes (THMs), and salinity;
- fisheries, including Mokelumne River anadromous fish, spring-run chinook salmon, and predation at boat docks and other project facilities;
- levee design and stability;
- seepage and proposed seepage control measures; and
- PG&E's gas line on Bacon Island.

For each of these subject areas, the REIR/EIS:

- summarizes significant issues raised in the comments on the 1995 DEIR/EIS and water right hearing evidence;
- identifies sources of new information and analysis to supplement the information presented in the 1995 DEIR/EIS;
- describes the qualitative and quantitative methods used to revise the analysis of environmental impacts; and
- presents the results of the revised analysis, including recommended changes to the impact conclusions and mitigation measures presented in the 1995 DEIR/EIS.

In addition, changes to the project description, in the form of restrictions described in the FOC, biological opinions, and stipulated agreements, are described in Chapter 2.

As noted above, the REIR/EIS does not include formal responses to comments on the 1995 DEIR/EIS. Responses to all comments received on both the 1995 DEIR/EIS and the REIR/EIS will be presented in a FEIR/EIS on the Delta Wetlands Project. Nevertheless, for some of the issue areas listed above, the new analyses presented in the REIR/EIS address many comments received on the 1995 DEIR/EIS.

Issues Not Addressed in This Document

The State CEQA Guidelines (Section 15088.5) state that recirculation is not required where the new information added to the EIR "merely clarifies or amplifies or makes insignificant modifications" to the document. The lead agencies have determined that for the resource topics listed below, significant new information is not required in response to comments received, and any issues raised regarding these topics will be addressed in the FEIR/EIS:

- vegetation and wetlands,
- wildlife,
- recreation and visual resources,
- land use and agriculture,
- traffic,
- cultural resources,
- mosquitos and public health, and
- air quality.

It should also be noted that this REIR/EIS and the 1995 DEIR/EIS do not address, and the FEIR/EIS will not address, water right issues raised during the hearing that are beyond the scope of CEQA and NEPA requirements and are therefore outside the scope of the EIR/EIS process. These issues include identification of beneficial uses, financial feasibility of the project, real property disputes, and applicability of existing water rights for proposed project operations. These issues are addressed through the SWRCB's water right hearing process and USACE's public interest review. The environmental documents inform the lead agencies about the proposed project's environmental impacts and recommend mitigation measures to lessen significant impacts. The SWRCB's water right decision and USACE's permit decision will take into consideration the EIR/EIS analysis of significant environmental effects.

Document Organization

Following is the organization of this REIR/EIS, in accordance with the State CEQA Guidelines and NEPA implementing regulations:

- Chapter 1. Introduction and Project Background
- Chapter 2. Changes to the Project Description, Alternatives Analyzed, and Future Conditions Considered
- Chapter 3. Water Supply and Operations
- Chapter 4. Water Quality
- Chapter 5. Fisheries
- Chapter 6. Levee Stability and Seepage
- Chapter 7. Natural Gas Facilities and Transmission Pipelines
- Chapter 8. Citations
- Chapter 9. Glossary
- Chapter 10. Report Preparers
- Appendices:
  - A. Summary of stipulated agreements
  - B. FOC
  - C, D, and E. Biological opinions
  - F. Daily simulations of project operations
  - G. Water quality assessment methods
  - H. Levee stability and seepage technical report
  - I. REIR/EIS distribution list

Public Review and Comment Period

This REIR/EIS serves as a full-disclosure document for the public to ensure that interested parties have an opportunity to express their views and concerns about the Delta Wetlands Project, as presented in the updated analysis in this document. The REIR/EIS is being circulated for public review through July 31, 2000. The public and interested agencies are encouraged to submit comments on the document. In publishing this REIR/EIS, the SWRCB and USACE are recirculating for public review and comment only the revised environmental analysis presented in the REIR/EIS. Those portions of the analysis addressed in the 1995 DEIR/EIS that are not reevaluated in the REIR/EIS are not being recirculated for additional public comment. Comments received on portions of the 1995 DEIR/EIS not included in the REIR/EIS will be addressed in the FEIR/EIS and do not need to be resubmitted. Comments on the REIR/EIS should be sent directly to the SWRCB or USACE, the joint lead agencies, at the following addresses:

Jim Sutton
State Water Resources Control Board
Division of Water Rights
P.O. Box 2000
Sacramento, CA 95812-2000

Mike Finan
U.S. Army Corps of Engineers
Regulatory Branch
1325 J Street, 14th Floor
Sacramento, CA 95814-2922

Once all comments have been assembled and reviewed, USACE and the SWRCB will prepare responses about environmental issues that have been raised in comments on this document as well as comments received previously on the 1995 DEIR/EIS. The FEIR/EIS will consist of the responses to comments, the 1995 DEIR/EIS, the REIR/EIS, and revisions to the analyses that are made in response to comments.

FUTURE STEPS IN THE CONSIDERATION OF DELTA WETLANDS' APPLICATIONS

The SWRCB will decide on Delta Wetlands' water right applications after it completes the further days of its water right hearing. USACE's processing of Delta Wetlands' application for a Section 404 and Section 10 permit was suspended in early 1999 after the SWRCB denied without prejudice Delta Wetlands' Section 401 water quality certification. With the resumption of work to prepare CEQA/NEPA documentation in the form of this REIR/EIS analysis, USACE's permit processing has resumed.

Before it can make a decision approving Delta Wetlands' permit applications, the SWRCB must certify that the FEIR/EIS was prepared in compliance with CEQA, was considered before the project was approved, and reflects the SWRCB's independent judgment. If the SWRCB approves the water right applications, it will make findings for each significant environmental effect identified in the 1995 DEIR/EIS and the REIR/EIS. The SWRCB also will include in the decision a statement of overriding considerations for any impacts determined to be significant and unavoidable. The SWRCB will also adopt a program for monitoring implementation of mitigation measures required as part of Delta Wetlands Project approval.

USACE will circulate the FEIR/EIS for public review. If USACE determines that the FEIR/EIS meets NEPA requirements, it will adopt the document. When it decides on Delta Wetlands' permit applications, USACE will prepare a Record of Decision regarding its determination, the alternatives analyzed, the mitigation measures required as a condition of permit approval, mitigation measures presented but not required, and monitoring and enforcement of the required mitigation measures.

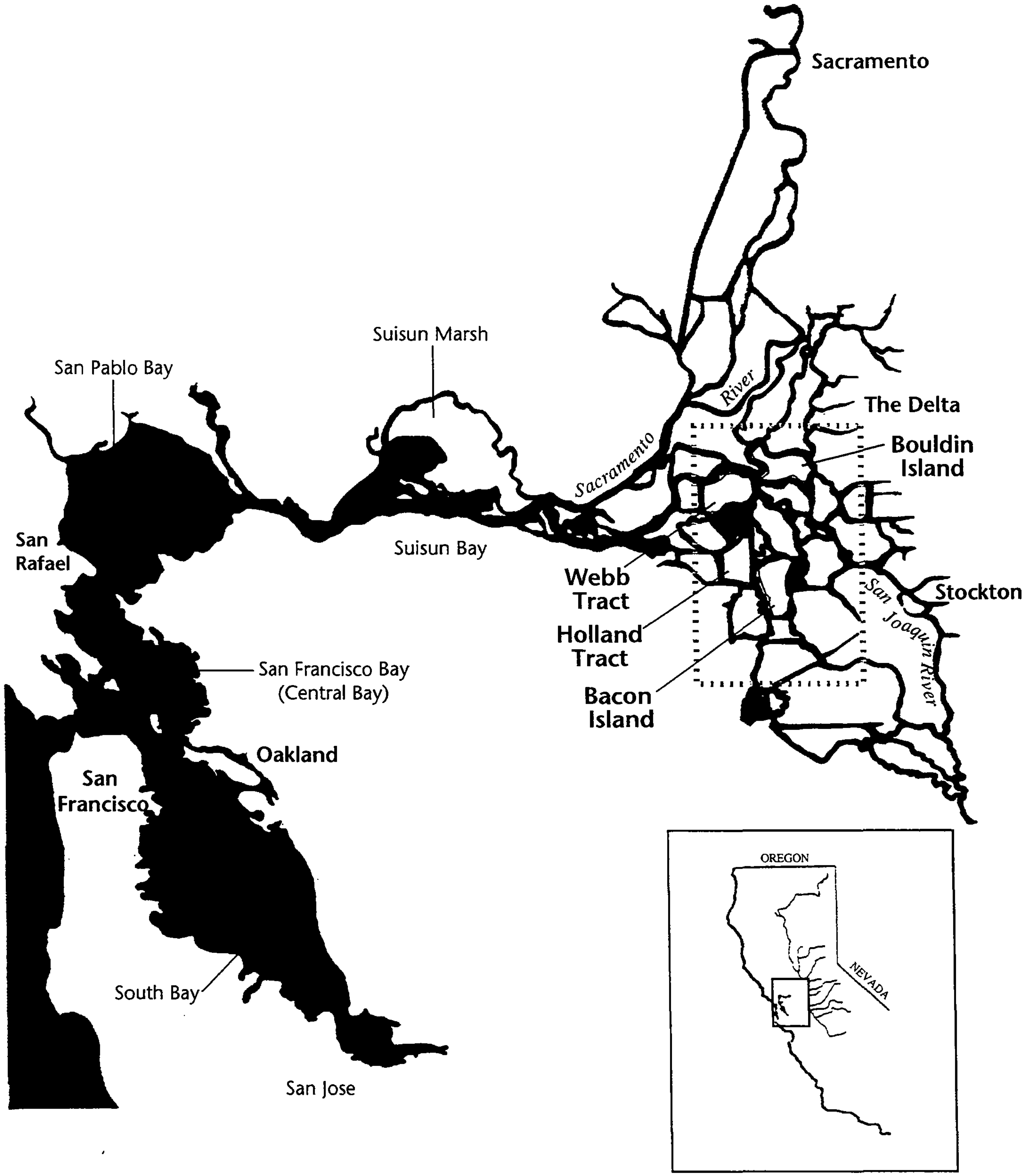
Table 1-1. Timeline of the Delta Wetlands Project

Year	CEQA/NEPA Process	Water Right Process	Section 404/Section 10 Process	Endangered Species Act (ESA) Process
1987		Water right applications filed with the SWRCB for storage of water on four islands		
1988			Department of Army application filed with USACE for discharge of dredged or fill material into waters of the United States and for effects on navigable waters of the United States	
1990	Draft EIR/EIS released (December)			
1993		New water right applications submitted for storage of water on two islands and creation of habitat on two islands		
1995	1995 DEIR/EIS released (September)			Biological assessment of project effects on state-listed and federally listed fish and wildlife species prepared California ESA consultation initiated by the SWRCB with DFG Federal ESA consultation initiated by USACE with USFWS and NMFS
1996	Comments received on 1995 DEIR/EIS			State and federal ESA consultation continues
1997		SWRCB water right hearing conducted to receive input on water right applications		No-jeopardy biological opinions issued by USFWS and NMFS
1998			SWRCB denies Section 401 certification without prejudice	Final no-jeopardy biological opinion issued by DFG
1999	The SWRCB and USACE determine that an REIR/EIS is required to present new information and to describe changes to the project resulting from the water right hearing and ESA consultations	Parties to the water right hearing invited to attend status meetings conducted by the SWRCB	USACE suspends processing of application due to the SWRCB's denial of Section 401 certification USACE resumes processing application with commencement of preparation of REIR/EIS	USACE consults with USFWS and NMFS about newly listed species; Delta Wetlands coordinates with DFG about newly listed species and changes to California ESA

Table 1-1. Continued

Year	CEQA/NEPA Process	Water Right Process	Section 404/Section 10 Process	Endangered Species Act (ESA) Process
2000	REIR/EIS issued for public review and comment *FEIR/EIS prepared, responding to comments received on the REIR/EIS and 1995 DEIR/EIS*	*After comments are received on the REIR/EIS, water right hearing proceedings continued by the SWRCB*		USFWS adopts conference opinion on splittail as biological opinion. *NMFS adopts conference opinion on steelhead as biological opinion; NMFS and DFG confirm that their authorizations apply to spring-run chinook salmon*
2001	*If the SWRCB approves the applications, it certifies the FEIR and adopts findings of fact and statement of overriding considerations for all significant and unavoidable impacts, and adopts mitigation monitoring program* *USACE circulates FEIS for public review and issues a Record of Decision (ROD)*	*After FEIR/EIS is prepared, the SWRCB releases a draft water right decision and receives comments on draft decision* *The SWRCB issues decision on water right permits*	*After FEIR/EIS is prepared and adopted, USACE confirms compliance with ESA, the National Historic Preservation Act, and Section 401* *After issuing a ROD, USACE decides whether to issue Department of Army permit*	

Note: *Italic type* indicates anticipated future actions.



Jones & Stokes

Figure 1-1
Delta Wetlands Project Location

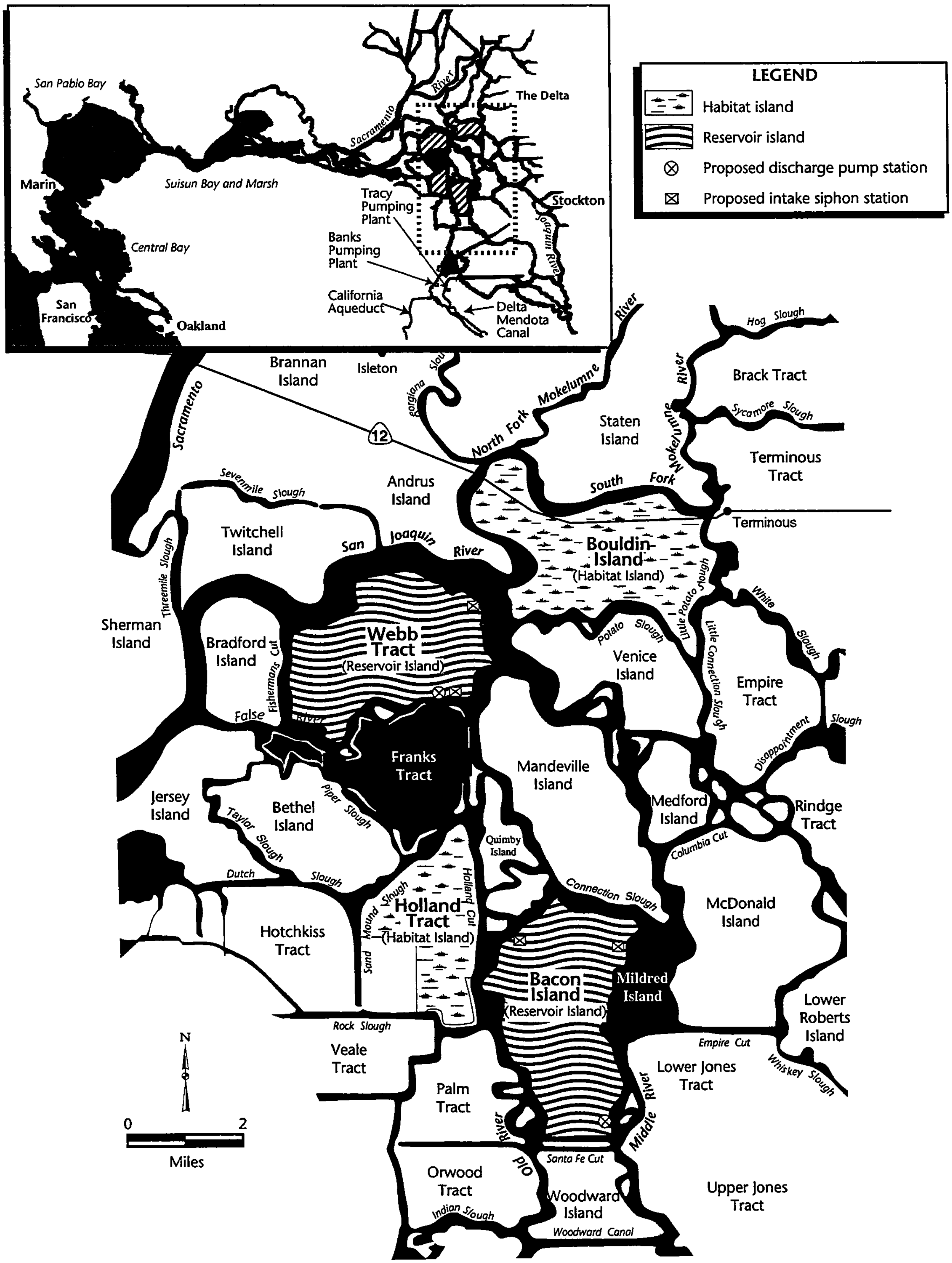


Figure 1-2
Delta Wetlands Project Islands

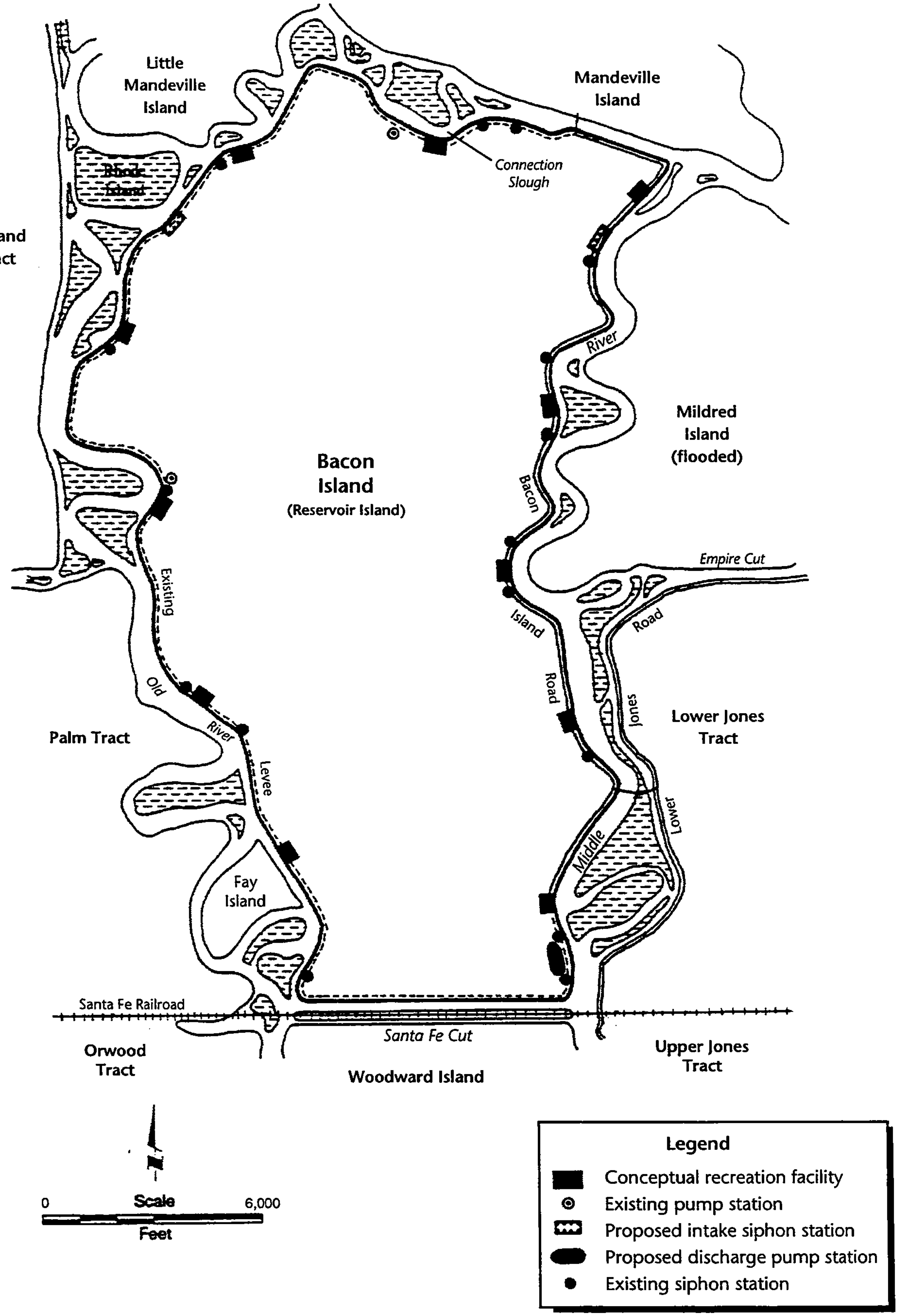


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Figure 1-3
Proposed Project Facilities on Bacon Island

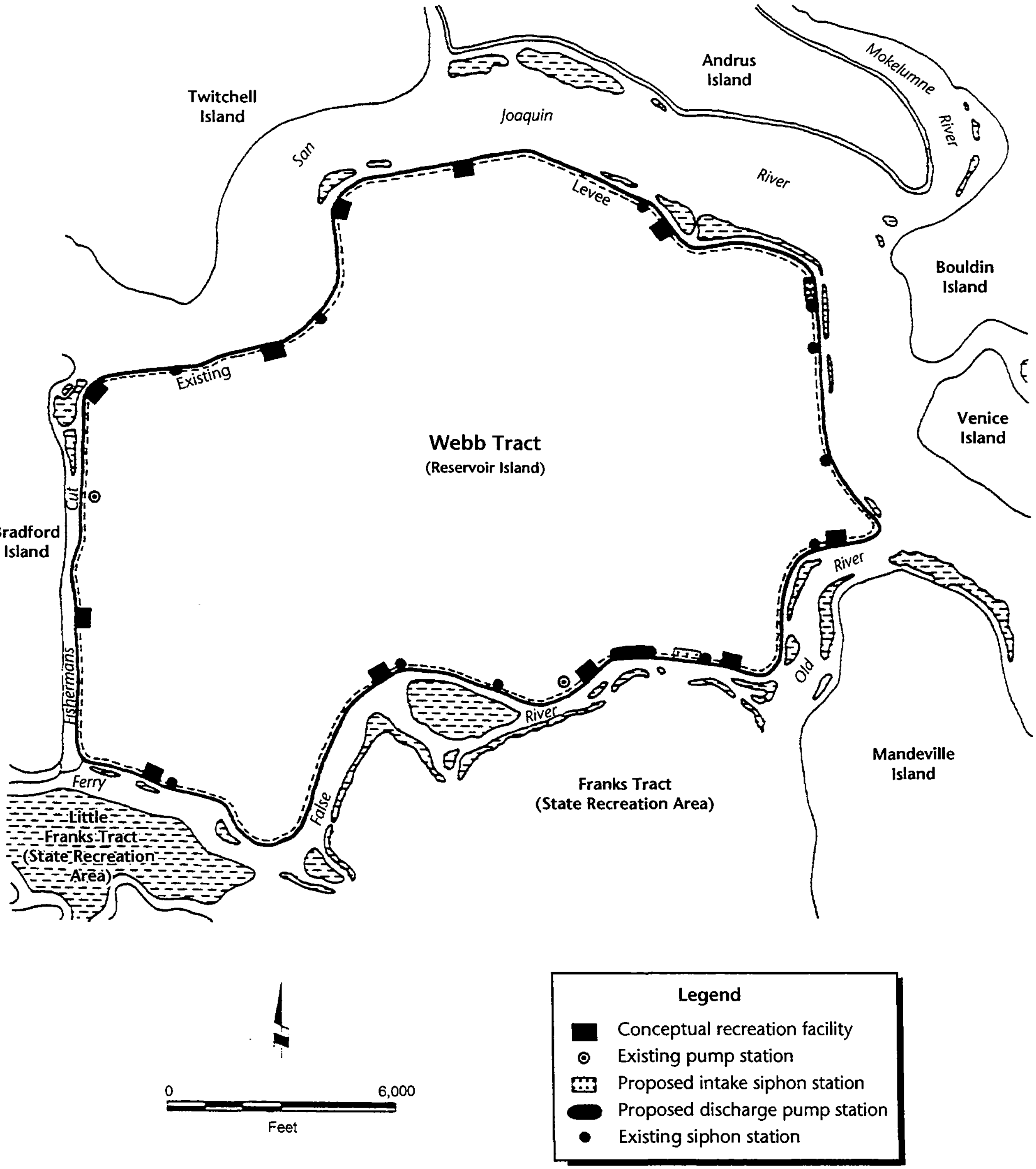

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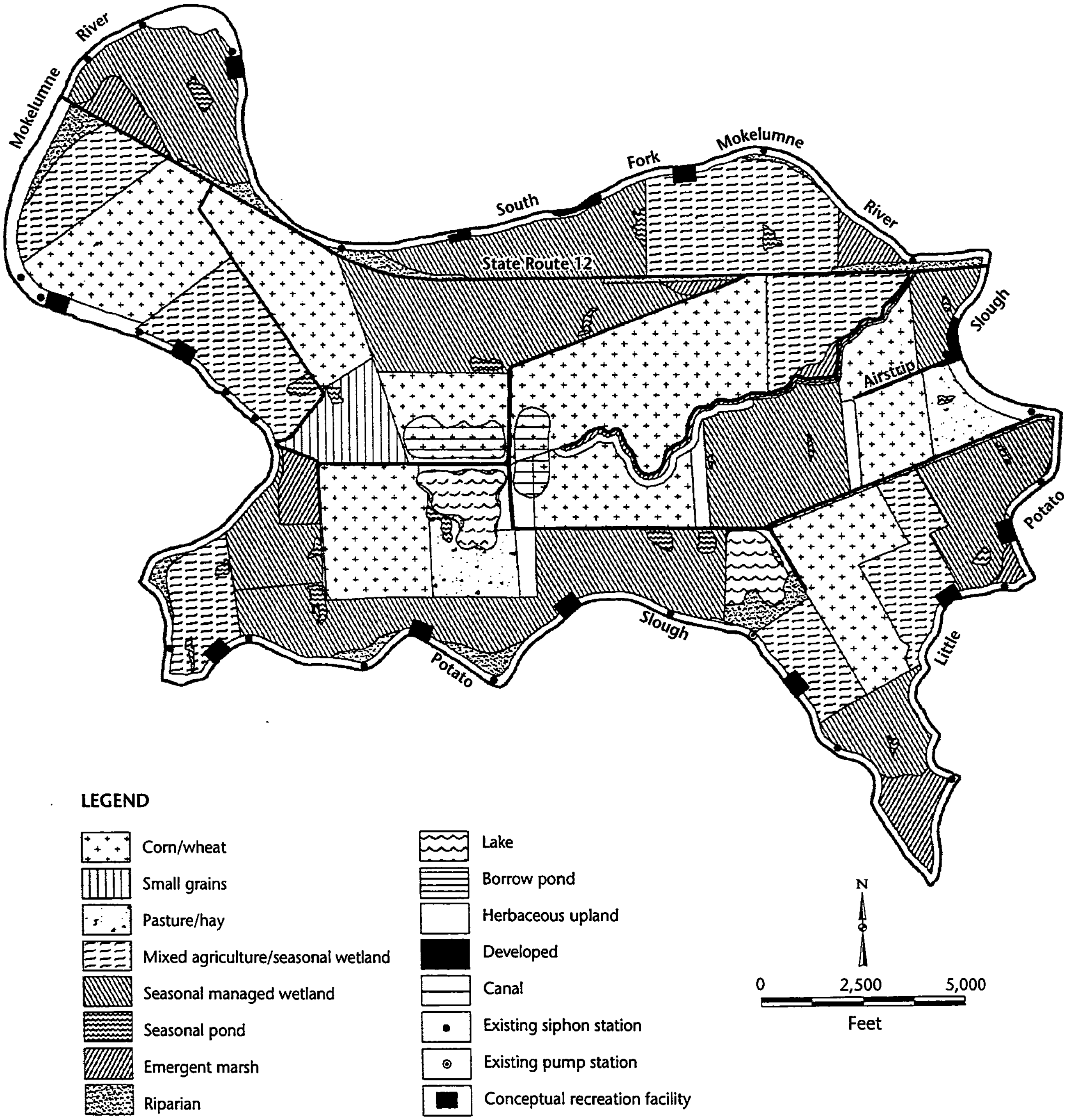
Figure 1-4
Proposed Project Facilities on Webb Tract



Jones & Stokes

Figure 1-5
Habitat Management Plan Habitats and Proposed Project Facilities on Bouldin Island

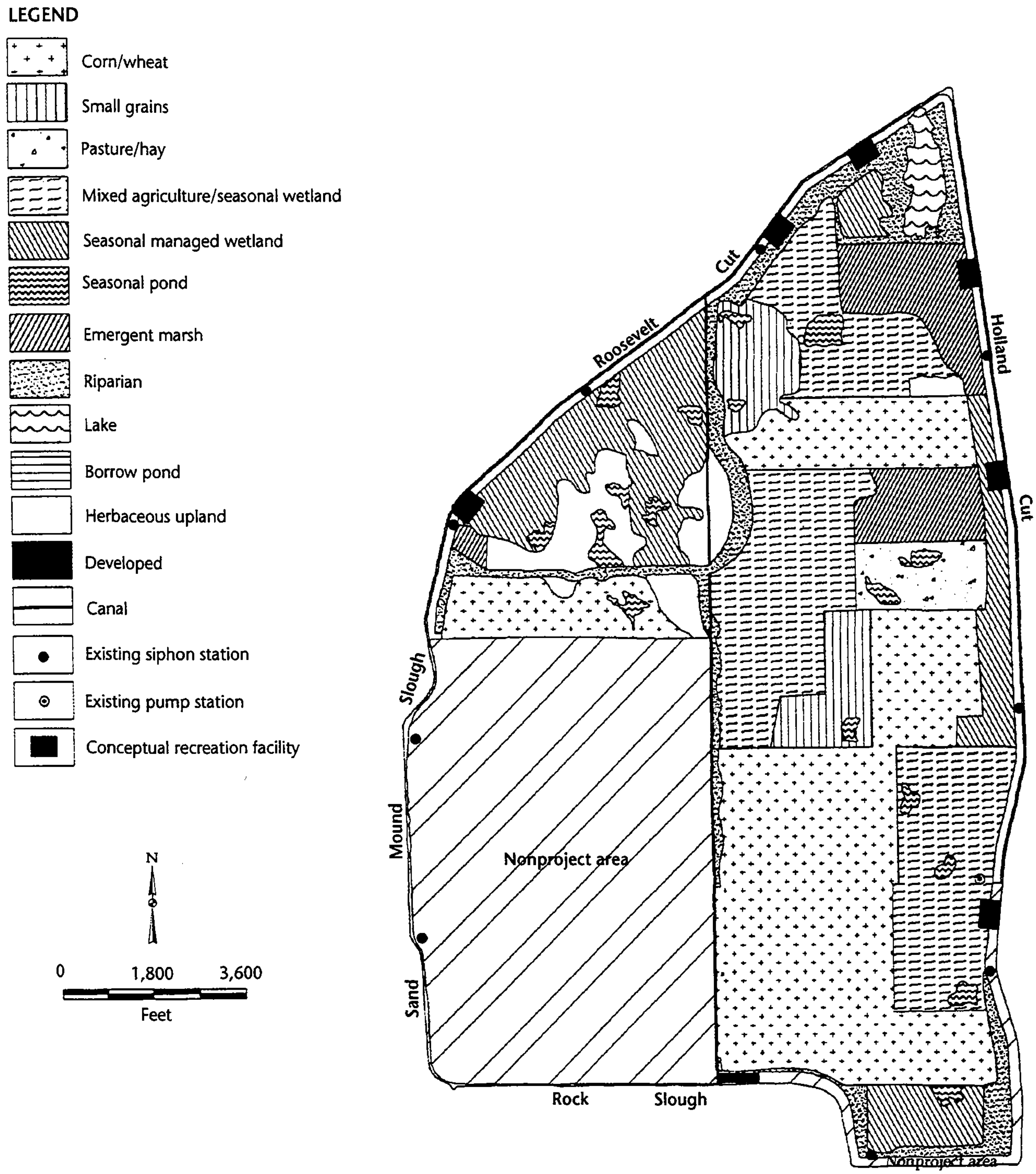


Figure 1-6
Habitat Management Plan Habitats and Proposed Project Facilities on Holland Tract

Chapter 2. Changes to the Project Description, Alternatives Analyzed, and Future Conditions Considered

Some differences exist between the Delta Wetlands Project as analyzed in this REIR/EIS and as analyzed in the 1995 DEIR/EIS. This chapter explains and summarizes those differences. The following are described below:

- the revisions to the project description since publication of the 1995 DEIR/EIS,
- the treatment of project alternatives in this REIR/EIS, and
- future conditions as analyzed in this REIR/EIS.

The latter discussion also describes the potential future relationship between the Delta Wetlands Project and CALFED, as requested by several parties in comments on the 1995 DEIR/EIS and at the SWRCB hearing on Delta Wetlands' water right applications.

REVISIONS TO THE PROJECT DESCRIPTION

An overview of the proposed project can be found under "Project Description" in Chapter 1, "Introduction and Project Background". Table 2-1 provides a summary comparison of the proposed project as evaluated in the 1995 DEIR/EIS and as evaluated in this REIR/EIS. As shown in Table 2-1, the major elements of the proposed project have not changed.

Two types of modifications to the Delta Wetlands Project as described in the 1995 DEIR/EIS have been incorporated into the proposed project description:

- Project operations would be restricted to ensure the protection of endangered and threatened fish species as described in terms set forth in the following, which were developed as a result of consultation pursuant to the California and federal ESAs:

  - Delta Wetlands FOC, also referred to as the Delta Wetlands Operating Criteria and Plan (OCAP); and

  - RPMs in the DFG, NMFS, and UFSWS biological opinions for the protection of fish species listed as threatened or endangered.

- Operations also would be restricted as specified in the stipulated agreements entered into by Delta Wetlands and the following parties to the SWRCB's water right hearing for the Delta Wetlands Project:

  - the U.S. Bureau of Reclamation (Reclamation),
  - the California Department of Water Resources (DWR),
  - Amador County,
  - the City of Stockton, and
  - North Delta Water Agency.

The terms of the FOC, biological opinions, and stipulated agreements limit potential project operations to increase protection of fisheries, affirm the senior water rights of other parties, or protect another party's ability to meet specific water quality criteria. These changes are generally considered to reduce environmental impacts, primarily because they may limit the timing and amounts of diversions and discharges to export. They therefore are considered beneficial and do not trigger the need to recirculate the EIR/EIS analysis. They have been included in the discussions in this REIR/EIS, however, to present reviewers with an updated assessment of the possible range of allowable project operations.

Other changes in conditions and assessment methods that have emerged since publication of the 1995 DEIR/EIS and that pertain to the evaluation of Delta Wetlands Project effects are described in the resource evaluation chapters rather than in this chapter. Examples of such changes include new listings of fish species under the California and federal ESAs, and updated assumptions about the Delta water budget that pertain to water supply and water quality modeling. These changes represent modifications to existing conditions rather than changes to the proposed project; they are presented as revisions to the affected environment, the setting within which the potential impacts of the project are analyzed.

Restrictions on Project Operations to Ensure the Protection of Fish

The FOC and biological opinion measures were developed in response to anticipated impacts of the proposed project, as analyzed in the 1995 DEIR/EIS, on fish species protected under the California and federal ESAs. Therefore, as described in Chapter 5, "Fisheries", some of these measures supersede mitigation measures proposed in the 1995 DEIR/EIS.

As discussed under "Endangered Species Act Consultation" in Chapter 1, Delta Wetlands, the SWRCB, USACE, DFG, NMFS, and USFWS, as part of the formal consultation process on the Delta Wetlands Project's effects on protected fish species, cooperatively developed operating parameters (referred to as the FOC) for the project to ensure the protection of these species. The FOC terms include many specific measures that define the flow and water quality conditions under which project diversions and discharges would be allowed, and describe mitigation that Delta Wetlands has agreed to incorporate into the proposed project. Table 2-2 summarizes the timing of restrictions on diversions and discharges specified in the FOC. Chapter 3, "Water Supply and

Operations", describes the incorporation of FOC and biological opinion terms into the modeling of Delta Wetlands Project operations. All the restrictions and mitigation measures included in the FOC and the biological opinions have been considered in the updated analysis of impacts on fisheries presented in Chapter 5, "Fisheries".

The full text of the FOC is provided in Appendix B. The biological opinions are included in Appendices C, D, and E.

Stipulated Agreements

As noted in Chapter 1, Delta Wetlands entered into stipulated agreements with Reclamation, DWR, Amador County, the City of Stockton, and North Delta Water Agency. The agreements affirm the seniority of these parties' water rights; they also outline general conditions under which the Delta Wetlands Project would operate to preclude interference with those water rights or with a party's ability to meet particular water quality criteria. For example, the agreement between Delta Wetlands and DWR includes three terms:

- Term 1, generally speaking, prohibits Delta Wetlands diversions when the Delta is determined to be in "balanced conditions"—that is, when all Delta inflow is required to meet Delta objectives and satisfy diversions by Contra Costa Water District (CCWD), the CVP, the SWP, and Delta riparian and senior appropriative water users.

- Term 2 limits the amount of water Delta Wetlands can take under "excess Delta conditions" to the amount by which the Delta is in excess as reasonably determined by DWR and Reclamation. This will be the amount of water that Delta Wetlands may divert "without putting the Delta back into balanced conditions".

- Term 3 requires Delta Wetlands to stop or reduce any reservoir releases if, as a result of these releases, the SWP or the CVP would have to modify operations to meet a legal requirement (e.g., ESA requirements, water rights terms and conditions such as export limits and salinity standards for exported water, or USACE requirements).

The terms of the stipulated agreements explicitly confirm the assumption of Delta Wetlands and the lead agencies that the Delta Wetlands Project would not be allowed to interfere with other parties' senior water rights and with SWP and CVP operations. Because this assumption has been part of the description of the proposed project, the agreements do not substantially change the project description or affect the analysis of project effects.

Appendix A summarizes the terms of the stipulated agreements entered into by Delta Wetlands and other parties to the water right hearing.

PROJECT ALTERNATIVES

The proposed project evaluated in this REIR/EIS is Alternative 2 described in the 1995 DEIR/EIS, as modified by the changes to the project description summarized above.

The 1995 DEIR/EIS analyzed three project alternatives and a No-Project Alternative in an equal level of detail. Alternatives 1 and 2 both represent Delta Wetlands' proposed project, consisting of water storage on two reservoir islands and implementation of an HMP on two habitat islands, but these alternatives offer two different scenarios for the discharge of stored water. Under Alternative 3, all four Delta Wetlands Project islands would be used as reservoirs and limited compensation wetland habitat would be provided on Bouldin Island.

Alternative 2, with the highest amount of discharge pumping, would have the maximum effect on fisheries associated with project discharges. Alternative 2 was therefore used to represent the proposed project in the biological assessment for fish species (see Appendix F2 of the 1995 DEIR/EIS). The terms and conditions of the DFG, USFWS, and NMFS biological opinions are based on this alternative.

Alternatives 1 and 2 feature identical project components and operations for diversion onto the reservoir islands; however, they have different operating criteria for discharge of stored water (i.e., frequency and volume of discharges) from the reservoir islands. The two alternatives' operating criteria differently interpret the method of applying the export limits specified in the 1995 Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (WQCP) to discharges of water from the Delta Wetlands Project islands. The export limits specify percentages of total Delta inflow that are allowed to be exported from the Delta. Delta Wetlands Project discharges to export may:

- count toward the percentage of inflow that is allowed to be exported (i.e., may be subject to strict interpretation of the export limits) or
- be in addition to the percentage allowed under the export limits (i.e., may not be subject to strict interpretation of the export limits).

Under Alternative 1, it was assumed that project discharges would be exported in any month when the SWP and CVP pumps have unused capacity within the permitted pumping rate and use of this capacity is limited by strict interpretation of the export limits. In other words, Delta Wetlands would be allowed to discharge water for export only if the amount of non-Delta Wetlands Project water being exported did not already constitute the percentage of inflow allowed under the export limits. Under Alternative 2, it was assumed that releases of water from the project islands would not be subject to strict interpretation of the export limits. Under this alternative, the SWP and CVP pumps would export Delta Wetlands discharges during any month when the pumps have unused capacity within the permitted pumping rate, even if the non-Delta Wetlands Project exports already constitute the allowable percentage. Both alternatives were assumed to operate in the context of current Delta facilities, demand for export, and operating constraints.

This REIR/EIS analysis is being performed to confirm the results of the 1995 DEIR/EIS analysis and to provide revised impact assessments and new or revised mitigation measures where necessary. Generally, the REIR/EIS evaluates the proposed project as represented by Alternative 2 (as modified) and describes any changes in the evaluation of the other alternatives from the 1995 DEIR/EIS.

FUTURE CONDITIONS AND RELATIONSHIP OF THE DELTA WETLANDS PROJECT TO OTHER PROJECTS

As noted in Chapter 1, for purposes of the 1995 DEIR/EIS and this REIR/EIS, the Delta Wetlands Project is analyzed as a stand-alone water storage facility, operated independently of the SWP and the CVP and without regard to the specific entities to which the water could be sold. Several potential opportunities exist to operate the Delta Wetlands Project in conjunction with the CVP and the SWP or in coordination with CALFED; however, no proposals have been made for which the SWRCB and USACE could reasonably assess the environmental effects, so discussion of such arrangements would be speculative.

The cumulative future scenario assumed in the REIR/EIS analysis of water supply and operations is based on the same assumptions as the cumulative future analysis presented in the 1995 DEIR/EIS. Full pumping capacity at Harvey O. Banks Pumping Plant (10,300 cubic feet per second [cfs]), although not presently permitted by USACE, is assumed to represent reasonably foreseeable future conditions. Demand for CVP/SWP water, however, is assumed to remain at the 1995 level.

The provision of new surface and groundwater storage has been identified as a possible action to be included in CALFED (CALFED Bay-Delta Program 1996, 1998). CALFED has identified the possibility of using in-Delta storage for diversions and to manage Delta flows; water would be stored or diverted at times when fish would not be adversely affected and pumping would be shifted to less sensitive periods. CALFED has identified 230 thousand acre-feet (TAF) of in-Delta storage on Delta islands as one of 14 possibilities for providing water supply, flood control, water quality, and ecosystem benefits (CALFED Bay-Delta Program 1998). The Delta Wetlands Project could be included as part of the CALFED in-Delta storage element.

As part of its water management strategy, CALFED has undertaken an Integrated Storage Investigation (ISI) to evaluate various types of water storage projects and the possible role in overall water management that may be fulfilled by in-Delta, onstream, and offstream water storage projects. The Delta Wetlands Project may be one option for in-Delta storage and is a candidate for consideration by the ISI. The ISI anticipates identifying by June 2000 those projects that warrant further study and conducting feasibility studies for 1 to 2 years after it identifies these projects for possible inclusion in CALFED's program. Some of the information presented in the 1995 DEIR/EIS and this REIR/EIS may be used by the ISI to determine whether the Delta Wetlands Project could be included in this program. However, assumed project operations under this program would differ from the independent operations analyzed in the 1995 DEIR/EIS and the REIR/EIS; therefore, CALFED would need to analyze the project separately.

In 1999, CALFED completed a draft programmatic environmental impact statement/environmental impact report (CALFED Bay-Delta Program 1999a), which provides a broad overview of the potential actions that the CALFED program could take. The document does not specifically address in-Delta storage in any detail. It broadly describes the environmental consequences of proposed actions and enables decision making regarding program direction and content. Subsequent actions, including implementation of in-Delta storage projects, will be subject to alternative analysis, environmental review, and permitting decisions before they can be implemented.

Table 2-1. Comparison of the Proposed Delta Wetlands Project Features as Evaluated in the 1995 DEIR/EIS and in the 2000 REIR/EIS

Project Feature	Proposed Project, as Evaluated in the 1995 DEIR/EIS	Proposed Project, as Evaluated in the 2000 REIR/EIS
Purpose	Potential year-round diversion and storage of water on Bacon Island and Webb Tract (reservoir islands) and wetland and wildlife habitat creation and management on Bouldin Island and most of Holland Tract (habitat islands). During periods of availability throughout the year, water would be diverted onto the reservoir islands to be stored for later sale or release. Incidental shallow-water management on reservoir islands to enhance forage and cover for waterfowl during nonstorage periods.	Same as in 1995 DEIR/EIS.
Diversion and discharge timing	1995 Water Quality Control Plan outflow requirements and objectives, permitted combined SWP and CVP pumping rate, and endangered species protection measures.	Same as in 1995 DEIR/EIS, plus terms of the Delta Wetlands final operations criteria (FOC) (see Table 2-2), biological opinions, and stipulated agreements between Delta Wetlands and other parties to the SWRCB's water right hearing.
Reservoir storage capacity[a]	Bacon Island: 118 thousand acre-feet (TAF). Webb Tract: 120 TAF.	Same as in 1995 DEIR/EIS.
Multiple storage utilized (multiple fillings and drawdown in one year, if possible)?	Yes.	Yes.
Pump station design	One discharge pump station on each reservoir island, with 40 new pumps (on Bacon Island) or 32 new pumps (on Webb Tract) with 36-inch-diameter pipes discharging to adjacent Delta channels. Typical spacing would be 25 feet on center. An assortment of axial-flow and mixed-flow pumps would be used.	Same as in 1995 DEIR/EIS.
Siphon station design	Two new stations for diversions installed along the perimeter of each reservoir island, each with 16 siphon pipes 36 inches in diameter and with fish screens to prevent entrainment of fish in diversions. Stations would be spaced at least 40 feet apart.	Same as in 1995 DEIR/EIS, with fish screen measures included in the FOC and biological opinions.

Table 2-1. Continued

Project Feature	Proposed Project, as Evaluated in the 1995 DEIR/EIS	Proposed Project, as Evaluated in the 2000 REIR/EIS
Diversion rate	Either reservoir island: maximum of 4,500 cubic feet per second (cfs) (9 TAF per day). Either habitat island: maximum of 200 cfs. Combined maximum daily average (all islands): 9,000 cfs. Combined maximum monthly average: 4,000 cfs (allowing for filling of both reservoir islands in one month).	Same as in 1995 DEIR/EIS, with restrictions specified in the FOC (see Table 2-2), biological opinions, and stipulated agreements.
Discharge rate	Either habitat island: maximum of 200 cfs. Combined maximum daily average (all islands): 6,000 cfs. Combined maximum monthly average: 4,000 cfs (allowing for emptying of both reservoir islands in one month).	Same as in 1995 DEIR/EIS, with restrictions specified in the FOC (see Table 2-2), biological opinions, and stipulated agreements.
Levee improvements	Perimeter levees raised and widened on reservoir islands to hold water at a maximum elevation of 6 feet above mean sea level. Levee improvements on all four Delta Wetlands Project islands designed to meet or exceed recommended standards for levees outlined in DWR Bulletin 192-82. Weekly inspections and ongoing maintenance.	Same as in 1995 DEIR/EIS.
Wetlands management	Wetlands and wildlife habitat created and managed year round on Bouldin Island and Holland Tract under a habitat management plan to offset the effects of water storage operations on wetlands and wildlife habitat.	Same as in 1995 DEIR/EIS.
Maximum number of recreation facilities[b]	Bacon Island: 11. Webb Tract: 11. Bouldin Island: 10. Holland Tract: 6.	Same as in 1995 DEIR/EIS.

Notes:

[a] Assuming a maximum pool elevation of 6 feet above mean sea level (based on National Geodetic Vertical Datum data).

[b] Each recreation facility would be constructed on approximately 5 acres along a perimeter levee and would include vehicle and boat access.

Table 2-2. Summary of Final Operations Criteria for the Delta Wetlands Project

Final Operations Criteria	Applicable Month											
	J	F	M	A	M	J	J	A	S	O	N	D
Annual export of Delta Wetlands stored water will not exceed 250,000 acre-feet *(Applies on an annual basis)*	■	■	■	■	■	■	■	■	■	■	■	■
Diversion Measures												
Maximum X2 value limits start of diversions									■	■	■	
Maximum X2 value limits magnitude of diversions	■	■	■						■	■	■	■
Diversions limited by a maximum allowable change in X2	■	■	■							■	■	■
Diversions to storage limited by QWEST (California Endangered Species Act)			■									
No diversion				■	■							
No diversion if delta smelt fall midwater trawl index <239		■	■	■	■	■						
Diversions limited to a percentage of Delta surplus	■	■	■			■	■	■	■	■	■	■
Diversions limited to a percentage of Delta outflow	■	■	■			■	■	■	■	■	■	■
Diversions limited to a percentage of San Joaquin River inflow	■	■	■									■
Diversions reduced when monitoring detects presence of delta smelt	■	■	■	■	■	■	■	■				■
Diversions limited if Delta Cross Channel is closed for fish protection	■										■	■
Topping-off diversions for evaporation limited						■	■	■	■	■		
Discharge Measures												
Bacon Island discharges for export limited to 50% of San Joaquin River inflow				■	■	■						
No Webb Tract discharges for export allowed	■	■	■	■	■	■						
No discharges for export or rediversion from habitat islands (Bouldin Island, Holland Tract) allowed	■	■	■	■	■	■	■	■	■	■	■	■
Discharges limited to a percentage of available unused export capacity		■	■	■	■	■	■					
Environmental water set aside and provided as a percentage of discharge		■	■	■	■	■						
Discharges reduced when monitoring detects presence of delta smelt				■	■	■	■	■				

Notes: QWEST = a calculated flow parameter representing net flow between the central and western Delta.
Shading represents periods when criterion applies.

Chapter 3. Water Supply and Operations

FOCUS OF THE REVISED DRAFT EIR/EIS ANALYSIS

This evaluation provides information on the potential range of Delta Wetlands Project diversion and discharge operations based on the most current project description, current assumptions for modeling Delta water supply, current regulatory standards, and an updated baseline (no-project) water budget.

Summary of Issues Addressed in This Chapter

The analysis presented in this chapter specifically addresses the following two questions, which represent the concerns expressed by stakeholders at the SWRCB water right hearing on the Delta Wetlands Project and in comments on the 1995 DEIR/EIS:

- What is the frequency, timing, and amount of water available to the Delta Wetlands Project, considering:
  - updated DWRSIM results from technical studies prepared in support of the CALFED no-action simulations;
  - upstream and in-Delta actions resulting from implementation of the Central Valley Project Improvement Act (CVPIA);
  - terms of the FOC and the USFWS, NMFS, and DFG biological opinions for the Delta Wetlands Project;
  - Delta Wetlands' settlement agreements with Reclamation, DWR, Amador County, the City of Stockton, and North Delta Water Agency; and
  - the proposed X2 restriction to preserve CCWD senior water rights consistent with the X2 restriction on CCWD operations described in the 1993 USFWS biological opinion for Los Vaqueros Project effects on delta smelt?

- What is the project's potential water supply, considering:

  - water availability (see above),
  - conveyance capacity for export water,
  - a range of south-of-Delta water demand assumptions, and
  - quality of water at the time of diversion and discharge?

The analysis presented below answers these questions by providing new estimates of monthly water availability and project yield using a revised Delta Standards and Operations Simulation (DeltaSOS) model. The updated DeltaSOS simulations themselves are based on a revised Delta water budget developed by DWR using its operations planning model, DWRSIM. The daily operations model DailySOS is used to confirm the adequacy of the DeltaSOS analysis. Results of the new simulations are compared with results presented in the 1995 DEIR/EIS. In addition, the impacts on consumptive use identified in the 1995 DEIR/EIS are reviewed in light of the updated information on project operations to determine whether there are any differences in severity of impacts.

Definition of Terms

The following are definitions of terms as they are used in this chapter:

- *Channel Depletion:* The water removed from Delta channels by diversions for irrigation and by open-water evaporation.

- *Consumptive Use:* Loss of water on the Delta Wetlands Project islands and other Delta islands through crop evapotranspiration (ET) and open-water evaporation and use for shallow-water management for wetlands and wildlife habitat. Rainfall and channel depletion supply the consumptive-use water.

- *Delta Exports:* The water pumped from the Delta to south-of-Delta users by DWR at Banks Pumping Plant and by Reclamation at the CVP Tracy Pumping Plant, and the amount diverted by CCWD at its Rock Slough and Old River intakes.

- *Inflow:* The total rate (cfs) or volume (TAF) of streamflow entering the Delta from the Sacramento and San Joaquin Rivers, Yolo Bypass, and the eastside streams.

- *Interruptible Demand*: An assumed additional demand for SWP water above the specified monthly demands. Interruptible demand is simulated as 84 TAF/month for 5 months, or 1,400 cfs/month during November through March when San Luis Reservoir is full. DWRSIM assumes that additional SWP deliveries are made to meet interruptible demand when there is unused export capacity and available water in the Delta.

- *Local Water Supply:* In the DWRSIM model, the assumed amount of captured rainfall in areas south of the Delta that can be used to satisfy CVP and SWP demands.

- *Outflow:* The water flowing out of the Delta into San Francisco Bay.

- *Project Yield:* Average annual water discharged for export from the Delta Wetlands Project islands. Reported in TAF per year (TAF/yr).

- *South-of-Delta Delivery Deficit:* Unmet demand, that is, total demand for CVP and SWP water minus total CVP and SWP deliveries. Total deliveries are calculated based on water exported from the Delta and the change in San Luis Reservoir storage. (When San Luis Reservoir storage drops, that amount is added to Delta exports to determine total CVP and SWP deliveries. When San Luis Reservoir storage increases, that amount is subtracted from Delta exports to determine total CVP and SWP deliveries.)

- *Surplus Delta Outflow:* Outflow in excess of the amount required to meet all monthly water demands, protect Delta salinity standards, and comply with the export/inflow objectives of the 1995 WQCP.

- *X2:* The mean daily location in the Bay-Delta estuary of the 2–parts-per-thousand-(ppt)–total dissolved solids (TDS) isohaline 1 meter off the bottom; an isohaline is a line connecting all points of equal salinity.

Overview of the Evaluation Methods Used: DeltaSOS, DWRSIM Water Budget, and Modeling Assumptions

DeltaSOS

As described in the 1995 DEIR/EIS, the DeltaSOS model was developed to represent possible Delta Wetlands Project operations (diversions and discharges) under various scenarios for Delta inflow conditions and regulatory standards. DeltaSOS modeling of the No-Project Alternative and project operations is based on the initial water budget developed from the results of simulations performed by DWR using the operations planning model DWRSIM for the water years 1922-1994. DWRSIM represents systemwide hydrology, including upstream reservoirs; inflows to the Delta; and Delta channel depletions, exports, and outflow. DeltaSOS is used to simulate monthly project operations as controlled by the DWRSIM Delta inflows, by appropriate Delta objectives and requirements, and by operating criteria specific to Delta Wetlands.

DeltaSOS has been updated for this analysis through the incorporation, to the extent possible, of the following:

- restrictions on project operations specified in the FOC, biological opinions, and stipulated agreements;

- restrictions on Delta Wetlands Project operations when CCWD's diversions to Los Vaqueros Reservoir are restricted because X2 is upstream of Chipps Island; and

- revised Delta standards resulting from implementation of the CVPIA.

These modifications are described below under "Revisions to DeltaSOS".

DWRSIM

DWRSIM simulates current conditions, including the operation of water storage facilities (reservoirs), regulatory standards (e.g., instream flow requirements), and assumed demand for exports, to estimate likely future Delta inflows, exports, and outflows under hydrologic conditions replicating those of the 73-year hydrologic record (water years 1922-1994).

Since publication of the 1995 DEIR/EIS, the implementation of state and federal programs has resulted in changes to the basic assumptions used for establishing baseline conditions in the Delta. The Anadromous Fish Restoration Program (AFRP) was implemented pursuant to the CVPIA, resulting in the establishment of several new Delta operating criteria and standards. Additionally, in response to the CALFED program, which state and federal agencies initiated in 1994 to resolve several Delta issues, and in response to other statewide planning efforts, DWR has conducted a series of DWRSIM modeling studies to establish new simulated baseline conditions for the Delta under the 1995 WQCP. These baseline conditions incorporate the new Delta operating criteria and standards established as a result of these programs. One of these studies, DWRSIM existing conditions study 1995-D06E-CALFED-771 (study 771 or run 771), completed in July 1998 for CALFED, is the currently accepted standard used by CALFED and other state water planners to represent baseline conditions. The results of study 771 are therefore used as the basis of the simulations of Delta Wetlands Project operations performed using DeltaSOS for the present evaluation. They replace the results of run 409, which provided the baseline water budget for the 1995 DEIR/EIS evaluation.

Similarities between DWRSIM Studies 409 and 771. DWRSIM study 771 is similar to study 409 in that both comply with the 1995 WQCP, use 1995 hydrology and demands, use south-of-Delta demands for SWP exports that vary according to Kern River flow and Los Angeles rainfall, and maintain minimum Trinity River flows below Lewiston Dam at 340 TAF/yr. Neither study provides for SWP pumping of water for the CVP.

Differences between DWRSIM Studies 409 and 771. The following assumptions were revised in DWRSIM study 771:

- A slightly different variable SWP demand is used, ranging from 2,644 to 3,529 TAF/yr.

- Maximum SWP interruptible demand is specified as 84 TAF/month for 5 months.

- New American River Water Forum demands have been added.

- South-of-Delta demands for CVP exports (including Level II refuge demand of 288 TAF/yr) are set at 3,433 TAF/yr.

- SWP export capacity from December through March is slightly higher than in DWRSIM study 409.

Many small changes in the FORTRAN code and parameters have also been made between studies 409 and 771 (362 different studies have been completed). In addition, three additional years of historical data (1992-1994) were added to the 70 years of data used in DWRSIM study 409.

The simulated Delta operating conditions of DWRSIM study 771 reflect new Delta operational objectives established for the AFRP, which is being implemented as part of the CVPIA. The adopted AFRP actions simulated in DWRSIM 771 include:

- export reduction requirements for the Vernalis Adaptive Management Plan (VAMP),

- the addition of days during the period from March through June when X2 must be at specified locations,

- minimum flow requirements for the Sacramento River at Freeport,

- required ramping of Delta exports in May,

- Delta Cross Channel (DCC) closure from October through January, and

- July export restrictions based on the X2 position in June.

These modifications are described in the next section.

REVISED DELTA MONTHLY WATER BUDGET SIMULATED BY DWRSIM

This section describes changes in the major DWRSIM input variables and simulated output between DWRSIM study 409, used for the 1995 DEIR/EIS, and DWRSIM study 771. The 25-year period of 1967-1991 was selected for comparison in the graphs referenced in this section because it represents a wide range of hydrologic year types, and because results covering this period are available from both studies.

The major hydrologic inputs for DWRSIM are the reservoir inflows and inflows from tributary streams. The Delta's two major tributary streams are the Sacramento and San Joaquin Rivers. DWRSIM simulates some, but not all, of the major tributary facilities. The simulation of upstream facility operations is important because some of these operations are controlled by Delta outflow requirements and export limits. The reservoir releases are also governed by flood control storage rules, instream flow requirements, power generation constraints, and upstream diversion targets.

Delta Inflows

Overview

Simulated Delta inflows consist of the combination of simulated upstream reservoir operations and local inflows, minus the simulated diversions along the upstream tributaries. Table 3-1 presents annual values for the Sacramento River and Yolo Bypass, the San Joaquin River and eastside streams, CCWD diversions and net channel depletion, CVP and SWP Delta exports, Delta outflow, and required Delta outflow for water years 1922-1994. Some Sacramento River inflow is diverted into the Yolo Bypass during high-flow periods. The San Joaquin River inflow at Vernalis includes contributions from the Stanislaus, Tuolumne, and Merced Rivers. Eastside streams include the Cosumnes, Mokelumne, and Calaveras Rivers. Sacramento River runoff and San Joaquin River runoff vary considerably from one water year to the next. Local runoff from rainfall events in the Delta can provide substantial flow in some years.

Comparison of Results from Studies 409 and 771

In general, annual average inflows simulated in DWRSIM study 771 do not differ appreciably from those simulated in DWRSIM study 409 because no new upstream storage or conveyance facilities have been constructed since the 1995 DEIR/EIS was prepared, and no major changes in facility operations are simulated. However, the estimates of required Delta outflows changed substantially in some years (see "Delta Outflow" below). DWRSIM 771 has generally lower required Delta outflows, allowing for slightly higher exports for the same inflows.

Sacramento River and Yolo Bypass. Effects of local inflows, Sacramento Valley irrigation diversions, and other consumptive uses are aggregated in the combined Sacramento River and Yolo Bypass inflows. The combined average annual inflow for 1922-1991 was 18,141 TAF/yr in study 409 and 18,086 TAF/yr in study 771 (Table 3-1). Figure 3-1 shows the monthly Sacramento River flows simulated for studies 409 and 771 for the 1967-1991 period. Low-flow periods are generally similar for the two DWRSIM studies. Table 3-2 provides the monthly Sacramento River and Yolo Bypass inflows for the 1967-1991 period for both DWRSIM studies; differences in the monthly and annual values are given for comparison purposes.

San Joaquin River and Eastside Streams. Fixed inputs are used for both the San Joaquin River and eastside streams in DWRSIM study 409, but the San Joaquin River tributary reservoir operations are simulated in study 771. The 70-year annual average inflow was 3,240 TAF in study 409 and 3,743 TAF in study 771 (Table 3-1). Figure 3-2 shows the simulated San Joaquin River flow at Vernalis for 1967-1991 in studies 409 and 771. Simulated flows during many of the peak- flow events are substantially larger in study 771 than in study 409. Summer flows in the two studies are generally similar. The magnitude of the simulated San Joaquin River changes is small relative to total Delta inflows. Table 3-3 provides the monthly San Joaquin River and eastside stream inflows for the 1967-1991 period for both DWRSIM studies; differences in the monthly and annual values are given for comparison purposes.

Contra Costa Water District and Agricultural Diversions. The estimates of CCWD diversions and net channel depletions for agricultural diversions in the Delta were generally the same in studies 409 and 771. Table 3-1 indicates that the 70-year average annual net Delta depletion with CCWD diversion was 1,079 TAF in study 409 and 1,140 TAF in study 771. The simulated depletion in dry water years was greater in study 771 than in study 409. For example, annual average simulated depletion was greater in study 771 than in study 409 by 68 TAF for the 1928-1934 dry-year period and by 108 TAF for the 1987-1991 dry-year period.

Delta Exports

Overview

DWRSIM simulates Delta exports and outflow after determining the amount of inflows needed for Delta channel depletion and required outflow. Delta export pumping and diversion occurs at five locations: CVP pumping at Tracy Pumping Plant, SWP pumping at Banks Pumping Plant, CCWD diversions at Rock Slough and Old River, and North Bay Aqueduct pumping at Barker Slough.

DWRSIM simulates Delta exports to meet downstream monthly demands and to fill San Luis Reservoir to meet seasonal demands, subject to 1995 WQCP and AFRP objectives for outflow and pumping limits. The magnitude of water supply demands is a major input assumption of DWRSIM that governs the amount of simulated Delta exports. Studies 409 and 771 both use simulated 1995 "level of development" for upstream diversions and estimated south-of-Delta demands.

Comparison of Results from Studies 409 and 771

DWRSIM-simulated demands range from 5.9 to 6.9 million acre-feet per year (MAF/yr) throughout the simulated period for study 409 and from 6.1 to 6.9 MAF/yr for study 771. Figure 3-3 compares Delta exports at the CVP Tracy Pumping Plant and the SWP Banks Pumping Plant for 1967-1991 as simulated for DWRSIM studies 409 and 771. Minimum pumping in April and May is slightly less in study 771 because of the assumed VAMP restrictions on pumping during this period, with combined pumping at 1,500 cfs in most years.

DWRSIM study 409 included CVP Delta export demands of 3.15 MAF/yr, with 145 TAF/yr to satisfy CCWD diversions. However, these CVP demands were not always satisfied in drier years in DWRSIM simulations. The SWP variable Delta export demands ranged from 2.6 to 3.6 MAF/yr, with an average of 2.85 MAF/yr. The maximum combined Delta export demand of 6.9 MAF/yr was assumed to occur in about 45% of simulated years. Exports were divided almost equally between the CVP and the SWP.

Table 3-4 lists the monthly combined CVP and SWP exports as simulated for studies 409 and 771; the monthly and annual differences between study 771 and study 409 values are shown for comparison. The combined exports are approximately 90 TAF higher on average in study 771 for the simulated 25-year period. Neither study 409 nor study 771 includes a joint point of diversion for the CVP to use the large pumps at Banks Pumping Plant to meet CVP demands and to fill the CVP share of San Luis Reservoir.

Delta Outflow

Overview

Figure 3-4 shows monthly Delta outflow for 1967-1991, as simulated by DWRSIM for studies 409 and 771. Differences between the two scenarios can be attributed to differences between estimates of Delta inflows, exports, or required Delta outflow.

Comparison of Results from Studies 409 and 771

Table 3-1 indicates an annual average simulated Delta outflow from 1922-1991 in study 771 of 15,102 TAF, 520 TAF greater than the 14,582 TAF average annual outflow simulated in study 409. Table 3-5 lists the monthly Delta outflows simulated for studies 409 and 771; the monthly and annual differences between study 771 and study 409 values are shown for comparison.

As Table 3-1 demonstrates, the estimated required Delta outflow for the two studies is similar, although study 409 and study 771 use somewhat different methods for estimating outflow requirements to satisfy Delta salinity objectives. The required Delta outflow under 1995 WQCP objectives is a combination of some fixed outflow objectives; salinity requirements at Emmaton, Jersey Point, and Rock Slough that are satisfied by equivalent outflow requirements; and X2 requirements that depend on the previous month's runoff. (Refer to the 1995 DEIR/EIS for more information about the WQCP.)

DWRSIM estimates the minimum outflow necessary to satisfy these combined objectives. The flow necessary to satisfy the salinity objectives is now calculated using a monthly procedure that incorporates the effective outflow-salinity relationships proposed by CCWD (i.e., "G-model"). Table 3-6 lists the monthly estimates of required Delta outflow for studies 409 and 771; the monthly and annual differences between study 771 and study 409 values are shown for comparison.

Surplus Outflow Available for Delta Wetlands Diversion

Overview

Surplus Delta outflow is outflow in excess of the amount required to meet all monthly water demands, protect Delta salinity standards, and comply with the export/inflow objectives of the 1995 WQCP. Not all surplus outflow may be available for Delta Wetlands Project diversions because such diversions are assumed to be subject to the 1995 WQCP "percent of inflow" export ratio limits (see Chapter 2 of the 1995 DEIR/EIS for a thorough description of assumptions about Delta Wetlands diversions).

Comparison of Results from Studies 409 and 771

Figure 3-5 shows the monthly pattern of available water for Delta Wetlands diversions. Because most of this surplus water is present during periods of relatively high flows, the estimates of water available for diversion by Delta Wetlands are similar for studies 409 and 771. (The monthly values for study 771 are listed in Table 3-11, which is discussed with the results later in this chapter.)

The availability of surplus Delta water in a few months during relatively dry years is important for estimating the Delta Wetlands Project's water supply potential. Upstream reservoirs may be able to store more of this runoff during some years and reduce the surplus flows entering the Delta. This reduced inflow may reduce simulated Delta Wetlands monthly diversions in some dry years. However, because the project is located in the Delta, any excess runoff from Sacramento or San Joaquin River tributaries can be diverted if conditions in the Delta satisfy the Delta Wetlands FOC and senior water rights are satisfied. The ability of Delta Wetlands to modify project operations to respond to daily changes in Delta conditions (i.e., storm events) is explored in the results section of this chapter under "Results: Daily Delta Wetlands Operations". Changes in operations based on daily changes in conditions would generally increase the Delta Wetlands water supply potential.

San Luis Reservoir Operations

Overview

San Luis Reservoir provides offstream storage for surplus water (i.e., water in excess of monthly demands) pumped from the Delta to the California Aqueduct and Delta-Mendota Canal (DMC) during periods of high runoff in winter and spring. San Luis Reservoir provides a source of water during the summer peak-demand period to allow more deliveries than could be pumped directly from the SWP and CVP Delta pumping plants. San Luis Reservoir facilitates the coordinated wheeling (conveyance) of state and federal water supplies allowed under the Coordinated Operations Agreement (COA) between DWR and Reclamation. However, neither study 409 nor study 771 includes any CVP wheeling (i.e., joint point of diversion).

San Luis Reservoir storage values were not evaluated for the 1995 DEIR/EIS because south-of-Delta water supply operations were not included in the DeltaSOS simulations. For the 1995 DEIR/EIS, water stored in Delta Wetlands facilities was simulated as being released for export if excess SWP and CVP export pumping and conveyance capacity was available within the specified export limits. This assumption allowed for estimation of the maximum potential environmental impacts caused by Delta Wetlands Project discharges. However, based on concerns raised at the water right hearing, south-of-Delta demands for water supply and storage in San Luis Reservoir have been considered in the REIR/EIS as constraints to simulated Delta Wetlands discharges for export.

The resulting project operations are simulated in the REIR/EIS analysis to provide reviewers with estimates of a range of potential project yields.

Comparison of Results from Studies 409 and 771

Figure 3-6 shows end-of-month combined CVP and SWP San Luis Reservoir storage for 1967-1991 as simulated by DWRSIM for study 409 and study 771. Table 3-7 compares monthly San Luis Reservoir storage values for these two studies during this same period. On average, end-of-month storage values in study 771 are lower than study 409 values, but this is not a consistent trend in all years. The largest differences occur in dry years. For example, simulated monthly San Luis Reservoir storage values in water year 1977 were 420 TAF less in study 771 than in study 409. In contrast, during the 1987 water year, the study 771 monthly values during the winter reservoir filling period (October to February) were 270 to 496 TAF greater than the study 409 values.

Table 3-8 lists the monthly combined CVP and SWP deliveries that have been calculated from the results of DWRSIM studies 409 and 771. Total deliveries are a combination of water exported from the Delta and water delivered from south-of-Delta storage (i.e., San Luis Reservoir storage). These total deliveries are calculated simply as the combined CVP and SWP exports minus the change in combined CVP and SWP San Luis Reservoir storage. Therefore, when the change in storage is negative (i.e., water is removed from storage), the monthly deliveries consist of the storage volume added to the exports; when the change in storage is positive (water is added to storage), the deliveries consist of the storage volume subtracted from the exports.

Other factors that influence total deliveries in the simulated conditions include SWP interruptible demands, evaporation and seepage losses, and local diversions. These factors were not included in study 409, but have been included in study 771. Table 3-9 lists the monthly deliveries for DWRSIM study 771 that were obtained by adjusting exports and San Luis Reservoir storage for these factors. The combined deliveries include SWP interruptible demands and the assumed evaporation and seepage losses from the canals and south-of-Delta reservoirs. In some wet years, some simulated demand for CVP deliveries is satisfied through San Joaquin River spills from Friant Dam (or from the Tulare Basin) and some simulated demand for SWP deliveries is met by means of diversions from the Kern River. The monthly deliveries shown in Table 3-9 are generally less than the estimated CVP and SWP demands, which are assumed in DWRSIM study 771 to vary with Kern River and Los Angeles rainfall conditions (i.e., rainfall in these areas is assumed to reduce demand for CVP and SWP deliveries).

Combined CVP and SWP Delivery Deficits for Study 771

Table 3-10 shows the monthly combined CVP and SWP delivery deficits (i.e., unmet demands) that resulted from the combination of hydrologic conditions, reservoir operations, and Delta objectives as simulated in DWRSIM study 771. Figure 3-7 shows the monthly combined CVP and SWP demands, deliveries, and corresponding delivery deficits for study 771.

The annual combined CVP and SWP delivery deficits ranged from 102 TAF to 4,485 TAF, with an average deficit of 1,205 TAF per year. Some years have relatively small deficits, and a few have large deficits. This suggests that there is commonly a deficit in meeting combined CVP and SWP south-of-Delta demands that could be partially satisfied with water supply from the Delta Wetlands Project. Figure 3-8 shows the annual demands, interruptible SWP supply, local inflow, and total combined CVP and SWP deliveries.

Because DWRSIM study 771 did not include any CVP wheeling export at the SWP Banks Pumping Plant, most of the simulated deficits were assigned to CVP contractors. DeltaSOS simulates only the combined exports and does not account for the distribution of deliveries and deficits to CVP and SWP contractors. DeltaSOS adjusts the DWRSIM results to simulate the export of all allowable water from the Delta for full CVP and SWP deliveries and storage of any surplus water in San Luis Reservoir. Exports may be reduced in subsequent months if San Luis Reservoir is filled under DeltaSOS simulations earlier than under DWRSIM simulations. These adjustments in combined exports increase deliveries, thereby reducing the original combined CVP and SWP deficits calculated by DWRSIM 771. The DeltaSOS adjustment in combined CVP and SWP exports ranged from 0 to 450 TAF per year and averaged about 110 TAF per year. This DeltaSOS adjustment is explained more fully under "South-of-Delta Demands and Deficits" in the section "Revisions to DeltaSOS", below.

Summary of the Comparison between Results from DWRSIM Studies 409 and 771

This comparison of results from DWRSIM study 771 and study 409 indicates that both simulations of the Delta and upstream reservoir operations provide a reasonable framework for evaluating likely future Delta Wetlands Project operations and assessing their potential environmental impacts. Delta Wetlands Project operations and potential water supply benefits are not substantially different under study 409 and study 771 conditions. Most of the changes in simulated Delta Wetlands Project operations are the result of incorporation of the FOC terms into DeltaSOS, as described below under "Revisions to DeltaSOS".

REVISED DELTA STANDARDS

Several of the Delta standards and operations criteria have been modified slightly since publication of the 1995 DEIR/EIS. Most of these modifications are AFRP recommendations for the use of CVP water under CVPIA Section (b)(2) for several Delta actions. Most of the adjustments to standards and criteria have been incorporated into DWRSIM study 771. Where necessary, DeltaSOS parameters were also modified to reflect these changes in regulatory operations of Delta water supply facilities and water quality protection standards. Adjustments made to DeltaSOS for consistency with the revised Delta criteria and standards are described below.

Minimum Sacramento River Flow at Freeport

The AFRP Delta actions include requiring Sacramento River flow at Freeport of 9,000 to 15,000 cfs in May. DWRSIM includes these specified Sacramento flows in its initial Delta water budget; therefore, further adjustment of the Sacramento River inflow values is not needed in DeltaSOS.

Delta Cross Channel and Georgiana Slough Operations

Operations of the DCC gates are controlled on a daily basis and may depend on either the Sacramento River inflow or Delta outflow at Chipps Island. Whenever Sacramento River inflow is greater than 25,000 cfs, the DCC is closed to protect the gate structure and downstream levees on the Mokelumne River. Original provisions of the 1995 WQCP called for the DCC to be closed 50% of the time from November through January and at all times from February through May. The revised AFRP rules call for the DCC to be closed from November through January. The DeltaSOS input matrix for DCC closure periods was modified accordingly to address this new standard. This modification does not change either the allowable SWP and CVP export pumping or the amount of water available for Delta Wetlands diversions.

X2 Position for Estuarine Habitat Protection

The 1995 WQCP includes a specified salinity standard to protect estuarine habitat in Suisun Bay. This standard is based on the location of X2, the mean daily bottom salinity gradient value of 2 ppt TDS, which is equivalent to approximately 3 mS/cm electrical conductivity (EC). During the February-through-June control period, X2 must be downstream of the confluence of the Sacramento and San Joaquin Rivers near Collinsville. In addition, for a certain number of days each month depending on runoff conditions, X2 must be downstream of Chipps Island and Roe Island. The AFRP action requires additional X2 days at Chipps Island from March through June. DWRSIM estimates the monthly minimum outflow necessary to satisfy the X2 standard. DeltaSOS uses the DWRSIM values for minimum Delta outflow.

Vernalis Adaptive Management Plan and Delta Export Pumping Restrictions

After the 1995 WQCP was put into effect, the VAMP was proposed and implemented to provide the April-through-May pulse-flow requirements for improving the migration of San Joaquin River chinook salmon juveniles. The VAMP flow requirement depends both on San Joaquin River flows during the pulse-flow period of April 15-May 15 and on the previous month's runoff conditions; these pulse-flow requirements differ slightly from the flows specified in the 1995 WQCP.

One recommended AFRP Delta action during the VAMP period would limit combined CVP and SWP pumping to less than the San Joaquin River flow (as allowed under the 1995 WQCP). The combined pumping would be 1,500 cfs during most years, but it would increase to 2,250 cfs in some wet years and would alternate between 3,000 cfs and 1,500 cfs in years with VAMP flows of greater than 7,000 cfs. These VAMP flows and the associated pumping restrictions have been included in DWRSIM study 771.

Because DWRSIM uses split-month calculations to estimate the allowable exports during the first half of April and the second half of May but does not save the split-month calculations, it is not possible for DeltaSOS to check the DWRSIM values during April or May. Therefore, DeltaSOS does not adjust the DWRSIM exports during these two months.

As a result, DeltaSOS cannot determine whether any unused pumping capacity is available for Delta Wetlands exports in the first half of April or the second half of May. These export restrictions during the VAMP period generally increase the delivery deficits because there is usually no opportunity to increase pumping during the summer period. The possibility of allowing some Delta Wetlands exports during the VAMP period is discussed under "Additional Considerations for Proposed Project Operations and Water Supply Potential" in the results section below.

REVISIONS TO DELTASOS

This section describes modifications made to DeltaSOS to incorporate the quantifiable terms of the FOC; the USFWS, NMFS, and DFG biological opinions; and the stipulated agreements.

Restrictions for Fish Protection

Delta Wetlands Project Diversion Criteria

Numerous terms limiting Delta Wetlands Project diversion and discharge operations are specified in the FOC; some additional restrictions are specified as RPMs in DFG's biological opinion. Several of these terms have been simulated with the monthly DeltaSOS model. Other terms depend on fish monitoring and daily flow or salinity conditions, which can only be approximated in DeltaSOS modeling of Delta Wetlands Project operations.

The FOC terms include the following restrictions on Delta Wetlands diversions:

- Initial diversions may not be conducted from September through November unless the X2 position is downstream of Chipps Island. X2 must be downstream of Chipps Island for 10 days if the initial diversion is made in the period from December through March. This condition was simulated in DeltaSOS with a minimum Delta outflow requirement of 9,000 cfs for the months of September through January.

- Delta Wetlands may not divert to storage from September through March unless X2 is west (i.e., downstream) of Collinsville. This term was simulated with a minimum required outflow of 7,100 cfs. If the delta smelt fall midwater trawl (FMWT) index value is less than 239, diversions cannot be made unless X2 is 1.4 kilometers (km) downstream of Collinsville (assumed to correspond to an outflow of 8,500 cfs). However, because the delta smelt FMWT index value cannot be calculated, this additional set of restrictions has not been included in the DeltaSOS modeling.

- Diversions may not cause the X2 position to move upstream more than 2.5 km from October through March. Because the relationship between X2 and outflow is logarithmic, this limitation has been simulated by limiting the Delta Wetlands diversions to be less than 25% of the outflow.

- No water may be diverted in April or May because many delta smelt and other fish species are present during these months. This no-diversion period is extended from February 15 through June if the delta smelt FMWT index is less than 239. As noted above, the FMWT index cannot be calculated and therefore cannot be included in DeltaSOS modeling. "Additional Considerations for Proposed Project Operations and Water Supply Potential", in the results section below, discusses qualitatively the effects of this restriction on Delta Wetlands Project operations.

- Diversions are limited to a specific fraction of Delta outflow, 25% from June through December and 15% from January through March.

- Between November and January, the diversion rate is limited to 3,000 cfs (rather than 4,000 cfs) if the DCC is closed for fish protection and Delta inflow is less than 30,000 cfs. This limitation was simulated based on monthly average inflow.

- Diversions are limited to a specified percentage of the total available water calculated from the 1995 WQCP objectives. Delta Wetlands may divert 90% of available surplus water during the months of August through January, 75% in February, and 50% in March. This provides a buffer of surplus water that may not be diverted by Delta Wetlands. These fractions are used in DeltaSOS calculations of maximum monthly diversions.

Another operations rule required by the DFG biological opinion limits Delta Wetlands Project diversions in March to a maximum rate of 550 cfs unless the previous day's QWEST is positive and is calculated to remain positive during the current day's diversions to storage. (QWEST is a calculated flow parameter that represents net flow between the central and western Delta.) A minimum QWEST flow in March is specified to minimize the upstream movement of juvenile fish life stages from the western Delta into the central Delta, where they would become vulnerable to potential entrainment losses at the export pumps and at Delta Wetlands' diversions. This rule effectively eliminates project diversions in March, except under very high flow conditions, because the DCC gates are closed for fish protection during this month and export capacity is high during this month; both of these factors reduce QWEST.

As described above, Delta Wetlands Project diversions are restricted on a daily basis by salinity conditions in the Delta (i.e., X2 and Delta outflow). The DeltaSOS monthly operations model is limited in its ability to represent daily salinity conditions and daily diversion restrictions. Additionally, Delta Wetlands discharges will be limited by the quality of water on the islands (see Chapter 4, "Water Quality"), so the quality of water at the Delta Wetlands diversion points would be a consideration for project operators. Diversion restrictions as a function of monthly modeled outflow (described above) usually result in low salinity (i.e., chloride [Cl^-]) levels in Delta channels during diversions. However, for monthly modeling purposes, diversions are also restricted until the previous month's Cl^- concentration is less than 150 milligrams per liter (mg/l). This criterion affects diversion activities in less than 5 of the simulated years (i.e., delaying diversions by one month). It is not a specific restriction in the FOC but is used as a tool in the monthly model to more closely represent daily project operations.

Delta Wetlands Project Discharge Criteria

The FOC terms prohibit Delta Wetlands Project discharges for export from Webb Tract from January through June. Delta Wetlands discharges from Bacon Island are limited by the FOC to 50% of San Joaquin River inflow during the period of April through June. Whether discharges from Bacon Island would be allowed during the VAMP export limitation period has not yet been determined. In addition, discharges from the Delta Wetlands reservoir islands are limited to 75% of the unused SWP and CVP pumping capacity in February and July and to 50% of the unused pumping capacity in March through June. Each of these monthly restrictions was specified in DeltaSOS.

Restrictions to Protect Other Parties' Senior Water Rights

Stipulated Agreements

As described in Chapter 2, Delta Wetlands entered into stipulated agreements with five parties protesting Delta Wetlands' water right applications; these agreements restrict Delta Wetlands diversion and discharge operations.

Agreements reached with DWR and Reclamation prevent diversions whenever DWR and Reclamation designate Delta conditions as being "in balance", meaning that all Delta inflow is required to meet Delta objectives and satisfy exports by the CVP and the SWP and diversions by CCWD and Delta riparian and senior appropriative water users. When Delta conditions are designated as being in balance, no additional water would be available for diversion by the Delta Wetlands Project under new water rights. When DWR and Reclamation determine that Delta conditions are "in excess" and when other terms and conditions are met, the Delta Wetlands Project would be allowed to divert available excess water for storage on the designated reservoir islands under new appropriative water rights.

Agreements with the City of Stockton and Amador County include narrative requirements that prevent Delta Wetlands operations from directly or indirectly depriving inhabitants of those jurisdictions of any water reasonably required for beneficial uses.

Delta Wetlands' agreement with North Delta Water Agency prohibits Delta Wetlands Project operations if the water quality criteria for salinity in effect pursuant to the "Contract Between State of California Department of Water Resources and North Delta Water Agency for the Assurance of a Dependable Water Supply of Suitable Quality" dated January 28, 1981, as amended, are not being met.

DeltaSOS simulates these agreements by allowing maximum possible CVP and SWP export pumping and fully satisfying in-Delta diversions by agricultural and senior appropriative water right users.

Contra Costa Water District

DeltaSOS was also modified to address the possibility that the SWRCB would restrict Delta Wetlands Project diversions to preserve CCWD's senior water rights, consistent with the X2 restriction on CCWD operations described in the 1993 USFWS biological opinion for Los Vaqueros Project effects on delta smelt.

To simulate this protection of CCWD's senior water rights, the minimum outflow in February and March is specified in DeltaSOS as 11,400 to maintain X2 downstream of Chipps Island so that Delta Wetlands diversions do not interfere with CCWD operations of Los Vaqueros Reservoir, which are limited by the biological opinion if X2 is upstream of Chipps Island.

South-of-Delta Demands and Deficits

For the 1995 DEIR/EIS, Delta Wetlands discharges for export were allowed whenever there was unused permitted pumping capacity at the SWP and CVP export pumping plants. In other words, in the DeltaSOS simulations of Delta Wetlands discharges for export, south-of-Delta demand was assumed to be unlimited.

The DeltaSOS simulation of maximum possible Delta exports was based on the assumption that all available water within the specified export pumping limits would be exported to satisfy combined CVP and SWP water demands or to serve as supplemental water supply that would be purchased by an existing SWP or CVP contractor. This assumption often resulted in additional exports that used the SWP pumping capacity to satisfy CVP demands and fill the CVP portion of San Luis Reservoir. This combined use of SWP pumping and CVP storage is sometimes referred to as "joint point of diversion" and has been approved by the SWRCB in Decision 1641 implementing the 1995 WQCP and the consolidated and conformed place of use (California State Water Resources Control Board 1999).

This assumption of maximum possible export pumping is similar to the SWP interruptible supply simulated in DWRSIM 771 as 84 TAF/month (i.e., 1,400 cfs) during the November-through-March period, whenever there is available water for SWP export beyond the specified monthly demands and SWP target storage in San Luis Reservoir. Because DWRSIM assumes that contractors will take this additional water whenever it is available during winter, it may be reasonably assumed that the Delta Wetlands Project water would be purchased when available.

DeltaSOS simulation of maximum possible Delta Wetlands Project discharges to export and the export of all available water by the combined CVP and SWP export pumps allows for estimation of the maximum environmental impacts that would result from discharge operations.

In response to comments on the 1995 DEIR/EIS analysis and questions raised in testimony at the SWRCB water right hearing, the lead agencies determined that presentation of a broader range of Delta Wetlands Project operations would be helpful. Delta Wetlands discharges to export could be assumed to be limited to the south-of-Delta delivery deficits simulated in DWRSIM (Figure 3-7). Therefore, DeltaSOS was modified to allow Delta Wetlands discharges for export to be limited to south-of-Delta CVP and SWP delivery deficits. Under this option, available water may not be exported if the specified CVP and SWP demands have already been satisfied. These specified CVP and SWP demands reflect the current (i.e., 1995) level of demands and upstream development; projected future levels of demand and upstream development have not been evaluated. Actual demands for Delta Wetlands exports may vary with delivery forecasts and with other hydrologic and economic conditions.

To incorporate south-of-Delta SWP and CVP delivery deficits, the delivery deficit information was extracted from the DWRSIM results and the Delta Wetlands exports were limited to these monthly delivery deficits in the simulations. The combined CVP and SWP demands and deliveries reflect the local inflow from the San Joaquin River and Tulare Basin that satisfy CVP demands in some years and the Kern River flows that satisfy SWP demands in some years. The evaporation and seepage losses from the canals and reservoirs must also be included in these overall demand and delivery values.

Table 3-9 lists the monthly deliveries (in cfs) and annual deliveries (in TAF) for the 1922-1994 period as simulated by DWRSIM study 771. The deliveries are generally highest in the summer months, but the monthly values vary greatly from one year to the next as governed by variable demands and the fluctuations in available water for CVP and SWP exports. Table 3-10 shows the monthly and annual delivery deficits from DWRSIM study 771 that were used to limit potential Delta Wetlands exports, for comparison with the simulation of unlimited Delta Wetlands exports. Based on the DWRSIM 771 results, the annual deficits in south-of-Delta deliveries are relatively high, ranging from 102 TAF in the wettest year (1983) to more than 4,000 TAF in extremely dry years (e.g., 1977 and 1991).

DeltaSOS then adjusts the initial DWRSIM results to increase the combined CVP and SWP exports to the maximum extent possible and to fill San Luis Reservoir within the export limits specified by the 1995 WQCP. The combined CVP and SWP demands, deliveries, and deficits as adjusted by DeltaSOS for combined export pumping capacity under study 771 conditions for 1967-1991 are shown in Figure 3-7.

Although the baseline DWRSIM 771 study did not simulate joint-point-of-diversion operations, water is often available for exports under a joint point of diversion to satisfy some of the CVP delivery deficits. Additional opportunities for delivery of CVP and SWP exports under a joint point of diversion were simulated by DeltaSOS; values ranged from 0 TAF to 450 TAF, with an average annual additional export of 110 TAF. Figure 3-8 shows annual average combined demands and deliveries for DWRSIM study 771 as adjusted by DeltaSOS for a joint point of diversion. Deficits are the difference between the two. The interruptible SWP deliveries are shown at the bottom; values range from 0 TAF in dry years to a maximum of 420 TAF in wet years. Interruptible supply increases the annual demand and delivery values. The annual delivery achieved with local inflows is also shown at the bottom to range from 0 TAF in most years to a maximum of more than 1 MAF (in 1983). These local inflows reduce the annual demand and delivery values. As shown in the figure, even with a joint point of diversion, delivery deficits exist in almost all years.

REVISED ANALYSIS OF DELTA WETLANDS WATER SUPPLY AND OPERATIONS

Two types of results for Delta Wetlands Project operations at a monthly time step are presented in this chapter, as in Chapter 3A of the 1995 DEIR/EIS. The first consists of the results of the DeltaSOS simulations, which show the potential range of Delta Wetlands water supply operations to provide information on the timing, frequency, and amount of project diversions and discharges. The second, based on these DeltaSOS simulation results, consists of results of the analysis of project impacts on Delta consumptive use.

These results are presented below following a description of the criteria for evaluating water supply effects and impact significance and an explanation of the scenarios evaluated in this analysis.

Measures of Potential Water Supply Effects and Criteria for Determining Impact Significance

Diversion and Discharge Operations and Water Supply

The following are the basic assumptions underlying the evaluation of the potential range of Delta Wetlands Project diversions and discharges and the resulting project yield:

- The Delta Wetlands Project would yield a water supply based only on water stored under its own appropriative permits and subsequently conveyed to Delta channels.

- The economic constraints of potential purchasers of Delta Wetlands Project water were not used as criteria for assessing impact significance.

- Permits granted by the SWRCB would specify that project diversions may not interfere with the diversion and use of water by other users with riparian or senior appropriative rights. Because DeltaSOS simulations of the Delta Wetlands alternatives were constrained to preclude interference with any riparian or senior appropriator, the Delta Wetlands Project presumably would have no significant impacts related to interference with senior water rights. Impacts on senior water rights were not used as criteria for assessing impact significance.

- DeltaSOS simulations of the No-Project Alternative and the proposed Delta Wetlands Project accounted for assumed constraints based on 1995 WQCP objectives, AFRP Delta actions, FOC and biological opinion terms, and terms of the stipulated agreements between Delta Wetlands and other parties that can be interpreted and simulated on a monthly basis. Delta Wetlands Project operations, as conditioned and limited by permits, would not be allowed to violate applicable Delta water quality objectives or fish and wildlife requirements or to interfere with other parties' compliance with these objectives and requirements.

- Delta Wetlands Project effects on Delta outflow were not used as criteria for assessing water supply impact significance; the specified 1995 WQCP objectives were presumed to adequately protect beneficial uses related to outflow. Potential effects of augmenting Delta outflow with purchased Delta Wetlands water during periods of reduced flows are assumed to be generally beneficial to the quality of the Delta water supply.

- Delta Wetlands Project effects on export water supply were not used as criteria for assessing impact significance because the addition or reduction of export water supply, by itself, is not a beneficial or adverse environmental impact.

- Potential impacts of the Delta Wetlands Project on water supply, water quality, and fisheries were not directly simulated at a daily time step because available information is not sufficient to allow accurate assessment of these potential daily effects. Therefore, Delta Wetlands Project effects on daily Delta flows were not used as criteria for assessing impact significance. Results of daily simulations are compared with monthly simulation results as part of the discussion and interpretation of the basic monthly findings.

An evaluation of DeltaSOS results is included here to provide useful information for document reviewers on the potential range of project operations. The estimates of diversions and discharges represented by these results are the basis for the analyses of project effects on water quality (Chapter 4), fisheries (Chapter 5), and Delta consumptive water use (below).

Delta Consumptive Use

In addition to the Delta boundary water budget based on the results of DWRSIM study 771, the evaluation of likely effects of Delta Wetlands Project operations relies on a water budget that represents water use on the project islands under no-project conditions (agricultural operations). This second water budget consists of estimates for rainfall, water evaporation, crop ET, soil moisture, seepage, applied irrigation and salt leaching water, and drainage water. The water budgets for the Delta Wetlands Project islands are fully described in Appendix A1 of the 1995 DEIR/EIS.

As described in Chapter 3A of the 1995 DEIR/EIS, the estimated water budget for the four Delta Wetlands Project islands under the No-Project Alternative indicates a net consumptive use of about 44 TAF per year (see Table A1-8 in Appendix A1 of the 1995 DEIR/EIS).

Under Delta Wetlands Project operations, consumptive water use would generally shift from irrigation diversions and crop ET, with minor amounts of open-water evaporation, to open-water evaporation during periods of storage on the reservoir islands and the seasonally flooded portions of the habitat islands, with minor amounts of irrigation diversions and crop ET.

A Delta Wetlands alternative is assumed to have a significant impact on Delta consumptive use if it would cause an increase in Delta lowland ET exceeding 1% of the No-Project Alternative ET from Delta lowlands (estimated as 890 TAF/yr). This assumed significance criterion could also be expressed as a change of greater than 20% of the consumptive use on the Delta Wetlands Project islands (i.e., 8.8 TAF/yr) because the project islands represent about 5% of the area of the Delta lowlands. A project alternative is considered to have a beneficial effect on Delta consumptive use if it would cause a decrease in Delta lowland ET.

Scenarios Evaluated in the Revised Analysis of Delta Wetlands Water Supply and Operations

The 1995 DEIR/EIS evaluated three alternatives for Delta Wetlands operations, as described in Chapter 2 of this REIR/EIS under "Project Alternatives". Alternatives 1 and 2 both represented Delta Wetlands' proposed project, consisting of water storage on two reservoir islands and implementation of an HMP on two habitat islands, but these alternatives offered two different scenarios for the discharge of stored water. Under Alternative 3, all four Delta Wetlands Project islands would be used as reservoirs and limited compensation wetland habitat would be provided on Bouldin Island. Alternative 2, with the largest amount of discharge pumping for export, would have the maximum effect on fisheries associated with project discharges. Therefore, Alternative 2 was used to represent the proposed project in the biological assessment for fish species and is the alternative on which the terms and conditions of the DFG, USFWS, and NMFS biological opinions are based. For this reason, the proposed project evaluated in this REIR/EIS is Alternative 2 from the 1995 DEIR/EIS, as modified by the changes to the project description summarized in Chapter 2.

The range of potential project operations under the proposed project, as described in this REIR/EIS, can be affected by several factors that either depend on natural conditions that cannot be simulated (e.g., occurrence of fish species) or that result from decisions that the SWRCB will make about allowable Delta Wetlands Project operations during the water right process. For example, if the FMWT delta smelt index is low, Delta Wetlands operations are more restricted than if the FWMT index is high. Alternatively, if Delta Wetlands is allowed to discharge water from Bacon Island for export in April and May (i.e., during the VAMP period), potential project water supply benefits will increase.

Figure 3-9 shows the relationship between the Delta Wetlands Project alternatives evaluated in the 1995 DEIR/EIS and the potential operations under the proposed project that are considered in this REIR/EIS evaluation. The 1995 DEIR/EIS considered three alternatives. The Delta inflows were taken from DWRSIM study 409, which incorporated the Delta objectives from the 1995 WQCP.

The proposed project in this REIR/EIS analysis of water supply and operations is represented by 1995 DEIR/EIS Alternative 2 with the revisions described in Chapter 2. The most consequential revision is the addition of the FOC terms. Delta inflows and other parameters are taken from DWRSIM study 771 for the no-project and with-project simulations. The analysis addresses a range of potential discharge operations for the proposed project. DeltaSOS simulation results are presented for two operational scenarios for discharge to export:

1. Project discharges are assumed to be exported if pumping capacity exists and FOC and other operating rules are met (i.e., not limited by south-of-Delta delivery deficits).

2. Project discharges to export are limited by the simulated delivery deficits (total CVP and SWP deliveries minus combined CVP and SWP demands) in addition to export capacity, FOC, and other operating rules (i.e., limited by south-of-Delta delivery deficits).

Figure 3-9 also illustrates other considerations or operating scenarios that would affect estimated project diversions, storage, and exports. These options are discussed qualitatively below.

Results: Monthly Delta Wetlands Project Operations

This section describes the results of the DeltaSOS simulations of project diversion, storage, and discharge operations and estimates project yield under different discharge scenarios.

Water Available for Diversion and Unused Pumping Capacity

The Delta Wetlands Project water supply simulation results can be described in two basic steps: determining the availability of water for Delta Wetlands diversion and determining the opportunities for Delta Wetlands discharge for export.

Water Available for Diversion. Table 3-11 lists the monthly (in cfs) and annual (in TAF) quantities of water available for Delta Wetlands diversions, as constrained by 1995 WQCP outflow and "percent of inflow" objectives with DWRSIM study 771 inflows. Because Delta Wetlands diversions are most likely to occur from October through March, the annual total volume is calculated for the October-March period. The results in Table 3-11 suggest that water will be available for diversion during at least one month in the majority of years. The annual amount of water available for Delta Wetlands diversions in the months of October through March ranges from 0 TAF in 10 dry years to more than 5,000 TAF in eight wet years. Under adjusted DWRSIM study 409, less than 100 TAF of water was available in 15 years out of 70. Table 3-11 indicates that for DWRSIM study 771, less than 100 TAF of water was available for diversions in 17 of the 73 study years (i.e., 23%). The quantity and timing of available water simulated by DeltaSOS using DWRSIM study 771 inflows and outflow requirements is similar to the results shown in the simulations previously performed for the 1995 DEIR/EIS using the results of DWRSIM study 409.

The FOC terms impose several additional limits on the available water that may be diverted by the Delta Wetlands Project. No diversions are allowed in April or May. The project can divert only a variable percentage of the available water in the other months. These FOC diversion limits are described above under "Restrictions for Fish Protection" in the section "Revisions to DeltaSOS".

Unused Pumping Capacity. Table 3-12 shows the simulated monthly unused CVP and SWP combined permitted export capacity for adjusted DWRSIM study 771. (Unused pumping capacity in April and May cannot be determined from DWRSIM study 771 because DWRSIM uses split-month calculations.) Because Delta Wetlands exports are most likely to occur from June through September, the unused pumping capacity during this period has been summarized. Unused pumping capacity was not discussed in the 1995 DEIR/EIS but was similar in magnitude and seasonal pattern to the results presented here.

Generally, enough unused permitted pumping capacity is simulated, after all possible CVP and SWP exports have been made, to allow the full Delta Wetlands project capacity of 238 TAF to be exported in most years. However, less than 100 TAF of unused export capacity is simulated from June through September in 9 of the 73 study years (12%). These are not the same years as those when limited amounts of water are available for Delta Wetlands diversions (which represent 23% of the years simulated). Project water supply potential is therefore reduced in 35% of years in the simulations by limits on either available water or unused pumping capacity.

Project Diversions, Storage, and Exports with Unlimited Demand

Table 3-13 shows the monthly simulated diversions for the proposed project with DWRSIM 771 inflows, net channel depletions, and required Delta outflow conditions. Table 3-14 shows the monthly storage values and Table 3-15 shows the discharges for export under the assumptions of maximum allowable Delta Wetlands exports for adjusted DWRSIM study 771, without limitation by south-of-Delta delivery deficits. (The table shows water years, but the 250-TAF annual export limit from the FOC is based on calendar years. Some years [e.g., 1971] in the table may appear to violate the FOC limit but do not on a calendar-year basis.)

This case represents the maximum potential Delta Wetlands operations under the proposed project, similar to the simulated Alternative 2 conditions described in the 1995 DEIR/EIS but as modified by the FOC and other operating rules. The annual average Delta Wetlands diversions would be 165 TAF (Table 3-13), and the water supply potential would average about 138 TAF per year (Table 3-15). The difference between simulated diversions and discharges for export provides an estimate of evaporation from the reservoir islands of 27 TAF. Table 3-14 indicates that Delta Wetlands storage will not be emptied every year; the simulation results show 12 years with a carryover storage of more than 50 TAF, as indicated by October storage volume.

Figure 3-10 shows the simulated annual Delta Wetlands diversions and discharges for export for the proposed project with exports unlimited by delivery deficits. In most years, diversions were slightly greater than discharges for export, reflecting evaporation losses during the storage period. The FOC terms limit the annual (January-December calendar year) discharge for export to less than 250 TAF. Years characterized by diversions that are much greater than discharges for export reflect carryover storage years.

Project Diversions, Storage, and Exports Limited by South-of-Delta Delivery Deficits

Tables 3-16 to 3-18 show the monthly simulated Delta Wetlands diversions, storage, and discharges for export under the assumption that Delta Wetlands exports are limited to remaining SWP and CVP delivery deficits for adjusted DWRSIM study 771. Delivery deficits are often smaller than the simulated Delta Wetlands discharges for export from June through September, causing Delta Wetlands exports to be delayed and/or reduced. For example, as shown in Table 3-10, delivery deficits in June are less than 2,000 cfs (the maximum allowed Delta Wetlands discharge for export under the FOC terms) in many years. In these years, Delta Wetlands discharges for export are delayed with the delivery-deficit assumption, resulting in evaporative losses and reduced total discharges for export. (Table 3-15 shows the discharges for export without the delivery-deficit limit.) The Delta Wetlands water supply operations are reduced in 22 of the 70 simulated years when compared to operations under unlimited-demand conditions. The annual average diversions would be 144 TAF, and the water supply potential would average about 114 TAF per year. Delta Wetlands carryover storage of more than 50 TAF is simulated in 16 years.

Figure 3-11 shows the simulated annual Delta Wetlands diversions and discharges for export for the proposed project with exports limited by south-of-Delta delivery deficits. In most years, diversions were slightly greater than discharges for export, reflecting evaporation losses during the storage period. In other years, diversions were much greater than discharges, indicating carryover storage on the reservoir islands. Diversions in subsequent years were much less than discharges.

Additional Considerations for Proposed Project Operations and Water Supply Potential

Several different Delta conditions and Delta Wetlands operating choices may affect operations in particular years. Some of these conditions are listed in Figure 3-9. Some conditions and operating choices would restrict diversions and reduce Delta Wetlands' water supply potential (i.e., yield) while others may increase potential water supply. The DeltaSOS monthly simulations described above are representative of the range of potential Delta Wetlands operations and provide the basis for evaluating environmental impacts resulting from the likely range of operations.

However, several Delta conditions may necessitate adjustments in these monthly estimates of likely operations. Because most of these cannot be calculated, these additional considerations were not included in the DeltaSOS modeling.

Delta Smelt Fall Midwater Trawl Index Restriction. The Delta Wetlands FOC terms include several additional restrictions on diversions whenever the FMWT index value is less than 239. If the value is less than 239, diversions could not be made unless X2 is 1.4 km downstream of Collinsville (assumed to correspond to an outflow of 8,500 cfs), and diversions are restricted from February 15 through June. When these restrictions are in place, Delta Wetlands water supply potential would decrease.

Bacon Island Export under the Vernalis Adaptive Management Program. The possible discharge and export of Bacon Island water during April and May (the VAMP period) would increase the Delta Wetlands water supply potential. Whether VAMP rules would apply to Delta Wetlands Project exports has not been determined.

Top-Off Allowance for Evaporative Losses. The allowance for diversions to replace evaporation losses from June through October, as described in the Delta Wetlands FOC, has not been included in the DeltaSOS simulation. This "topping-off" allowance would increase the Delta Wetlands water supply potential. "Topping off" could not violate senior water rights or water quality and outflow requirements, however. The SWRCB will determine during the water right process whether Delta Wetlands would be permitted to divert water to replace evaporation losses.

Delta Outflow Augmentation. For purposes of environmental impact assessment, Delta Wetlands Project operations modeling assumes that all Delta Wetlands water available for export would be exported. However, as indicated in the project purpose (see Chapter 2), Delta Wetlands Project water also may be released to improve Delta water quality and outflow benefits. For example, when Delta Wetlands exports are limited by export capacity or delivery deficits, the Delta Wetlands carryover storage could be reduced by the release of water during periods of relatively low Delta outflow to augment outflow or reduce salinity intrusion (i.e., through the CALFED Environmental Water Account). This could improve water quality and provide slightly improved estuarine habitat conditions. These Delta releases may reduce Delta Wetlands' water supply potential for exports (i.e., project yield) in some years compared to the simulated conditions because insufficient water may be available for diversions to refill the reservoir islands during the next winter. These Delta Wetlands releases for outflow are not assumed to replace the Delta outflow provided by CVP and SWP operations to satisfy the WQCP Delta outflow requirements.

Results: Daily Delta Wetlands Project Operations

Daily Delta Wetlands operations were evaluated in the 1995 DEIR/EIS using the DailySOS model (Appendix A4, "Possible Effects of Daily Delta Conditions on Delta Wetlands Project Operations and Impact Assessments"). The ability of Delta Wetlands to divert water to storage during periods of excess inflows and export during short periods of unused export pumping, while complying with the daily requirements established in the biological opinions, can be more realistically simulated with the daily model than with DeltaSOS. These daily simulations also provide a firm basis for the SWRCB's establishment of terms and conditions for allowable operation of the Delta Wetlands Project.

Appendix A4 of the 1995 DEIR/EIS compared the monthly and daily simulation results and determined that the monthly estimates of CVP and SWP exports were higher than the daily estimates because of inflow fluctuations resulting from storm events and because of the physical capacity of the pumping facilities. The daily Delta Wetlands Project operations were generally higher than the monthly estimates because there were short periods when diversions could be made during storm events and subsequent periods when Delta Wetlands exports could be made.

In this section, the daily rules for Delta Wetlands diversion and discharge are reviewed and the daily results are compared with the monthly results for the case of exports not subject to limitation by delivery deficits. The 10-year period of 1985-1994 is used to illustrate the potential daily Delta Wetlands operations as constrained by the rules contained in the FOC. Appendix F provides a narrative explanation of the DailySOS results for each year and represents the results graphically. The yearly results presented in Appendix F provide a more accurate picture of potential Delta Wetlands operations than the monthly model results; the yearly results can depict how project operations would respond to opportunities for diversions and discharges on a daily basis throughout the year.

Simulation Method

The FOC terms include rules that restrict the timing and magnitude of Delta Wetlands diversions to storage and discharges to export; those rules would be applied on a daily basis. In addition to the WQCP objectives that govern Delta exports (i.e., minimum required Delta outflow and maximum allowed exports as a percentage of inflow [E/I ratio]), several rules for Delta Wetlands diversions are applied. When more than one measure is applicable, the most restrictive is used. The FOC discharge measures differ for Bacon Island and Webb Tract, so the daily modeling simulated Bacon Island diversions, storage, and discharge separately from Webb Tract diversions, storage, and discharge. As simulated in the daily model, Bacon Island diversions would be made first, and diversions to Webb Tract would then be made using any remaining diversion capacity under the FOC rules. Several of the criteria are more restrictive if the FMWT delta smelt index is less than 239; however, because the FMWT index value cannot be calculated, the model assumes a FMWT index greater than 239 for the daily simulations. The Delta Wetlands diversion and discharge rules are described above under "Restrictions for Fish Protection" in the section "Revisions to DeltaSOS". Table 3-19 lists those rules and the ways in which they are applied in the daily operations model.

Daily Delta Wetlands operations were simulated using daily historical Delta inflows, CCWD diversions, and net channel depletions that were adjusted to match DWRSIM 771 simulated inflows, CCWD diversions, and net channel depletions. The daily pattern of inflows caused by storm events was preserved, but upstream adjustments in reservoir storage made by the monthly planning model were assumed to provide the most realistic future seasonal inflow pattern. Figure 3-12 illustrates this adjustment for 1985 Sacramento and San Joaquin River inflows. The daily values have been adjusted to match the DWRSIM monthly average. Adjustments in the Sacramento River flows are typically less than 2,000 cfs, with adjustments resulting in increases as well as decreases from the historical values. Adjustments in San Joaquin River flows typically reduce the flows to below historical values, except during the pulse flow (i.e., VAMP) period of April and May. Adjustments in river inflows for the other years are similar to those presented for 1985.

Summary of Daily Results

The 10-year sequence of daily simulations using the FOC for Delta Wetlands operations provides the most accurate picture of potential Delta Wetlands operations under highly variable Delta inflow and export conditions. Table 3-20 provides a summary comparison between the monthly and daily model results for Delta Wetlands diversions and Delta Wetlands exports for the 1985-1994 water year sequence. The daily model results confirm the monthly Delta Wetlands diversion and export values for moderately wet years (e.g., 1985, 1986, 1993). Like the monthly results, the daily simulations indicate that there are some years with very little or no available water for Delta Wetlands diversions (i.e., 1990, 1991, 1992). However, in 1989, the monthly model indicates no available water, but the daily model shows that there is some opportunity to divert during a limited major storm event once the X2 location is downstream of Chipps Island. The daily simulation of Delta Wetlands operations indicates that more Delta Wetlands exports could be made in some dry years (i.e., 1987, 1989, and 1994) than indicated by the monthly results. On the other hand, daily simulation of 1988 shows that X2 was not located downstream of Chipps Island for a sufficient length of time to allow Delta Wetlands diversions, so exports were much less in the daily results than the monthly results for that year.

Results: Cumulative Water Supply Conditions

For the 1995 DEIR/EIS, cumulative future conditions were simulated using DeltaSOS for each of the project alternatives, based on the assumption that the full SWP pumping capacity (10,300 cfs) was available in any month for combined CVP and SWP Delta exports. This availability of full pumping capacity is considered to be the most likely change in Delta facilities that would directly influence proposed Delta Wetlands operations. It may require approval and implementation of DWR's South Delta Project and a revised USACE permit for the SWP Banks Pumping Plant. This scenario represents the reasonably foreseeable future Delta conditions and regulatory standards. Results of the DeltaSOS simulations with DWRSIM 771 inflows and demands adjusted to the full SWP pumping capacity of 10,300 cfs were used to represent the baseline for cumulative future conditions.

For this REIR/EIS analysis, cumulative future conditions for the proposed project were simulated using DeltaSOS in the same way. The DeltaSOS simulations used DWRSIM 771 results showing likely future Delta inflows, exports, and outflows under hydrologic conditions replicating those of the 73-year hydrologic record (water years 1922-1994). The 1995 level of development and demands used in DWRSIM 771 was used for the cumulative-conditions scenario. Assumptions for maximum Delta Wetlands discharges to export in addition to maximum CVP and SWP exports (i.e., future increased demands) are briefly described for comparison with the 1995 DEIR/EIS results for cumulative future conditions.

The annual combined CVP and SWP demands, deliveries, and deficits as adjusted by DeltaSOS for baseline DWRSIM 771 conditions, but with full SWP export pumping capacity under cumulative conditions, are shown in Figure 3-13. Additional CVP and SWP exports as adjusted for cumulative conditions ranged from 0 TAF in dry years to more than 500 TAF in wet years, with an average of 220 TAF. The delivery deficits that Delta Wetlands water supply may satisfy are less under cumulative future conditions than under existing conditions because, with full use of SWP Banks pumping capacity, the combined CVP and SWP exports will be greater.

Cumulative water supply effects of the proposed Delta Wetlands Project were compared with simulated monthly Delta water supply conditions under cumulative conditions. Table 3-21 shows the monthly Delta Wetlands diversions as simulated for cumulative future conditions with full pumping capacity at Banks Pumping Plant and Delta Wetlands exports unlimited by delivery deficits. Average annual diversions would be 169 TAF. Table 3-22 shows the monthly Delta Wetlands storage values for these assumed cumulative future conditions. Carryover storage of more than 50 TAF would occur in only 3 years. Table 3-23 shows the monthly Delta Wetlands discharge for export for these cumulative future conditions. Average annual exports of 147 TAF are simulated.

These results indicate that Delta Wetlands would operate in fewer years under cumulative conditions than under existing conditions because of reduced availability of water for diversions in some years (24 years with diversions less than 100 TAF). However, because of the greater export pumping capacity, more Delta Wetlands exports were simulated in several of the years. Average Delta Wetlands discharges for export were simulated to be approximately 9 TAF/yr more (increase of 7%) under cumulative conditions than for the proposed project without south-of-Delta delivery deficit limitations.

The likely Delta Wetlands yield under cumulative future conditions might be slightly less when limited by simulated south-of-Delta delivery deficits. However, future south-of-Delta demands and delivery deficits are likely to be greater than the 1995 level of demand simulated in DWRSIM 771. The relative effects of limiting Delta Wetlands exports by south-of-Delta delivery deficits for cumulative conditions could be similar to those reported for project conditions. For example, project yield was 138 TAF under unlimited demand versus 114 TAF when limited by south-of-Delta delivery deficits. Similarly, under cumulative conditions, project yield was 147 TAF under unlimited demand, so project yield is estimated as 123 TAF when limited by south-of-Delta delivery deficits.

When compared to results presented in the 1995 DEIR/EIS, the potential yield from Delta Wetlands Project operations under cumulative conditions is reduced from an estimated average of 197 TAF to 147 TAF because the opportunities for Delta Wetlands diversions are reduced under DWRSIM study 771 conditions and because of limitations imposed by the FOC. However, the south-of-Delta water demands are expected to increase over time, and the project would provide an increment of storage that could be used to increase deliveries to CVP and SWP contractors.

Results: Delta Consumptive Use

Under the proposed project, land uses would change from irrigated agriculture to primarily water storage on the reservoir islands and to wildlife habitat on the habitat islands. These land use changes would reduce ET for the four islands from a total of 44 TAF/yr to 14 TAF/yr (estimated ET from the habitat islands). Additionally, an average of approximately 27 TAF/yr of evaporation would be lost from stored water on the reservoir islands during periods of water storage (i.e., Delta Wetlands diversions minus discharges for export). Therefore, total consumptive use for the proposed project is simulated to be about the same as under existing conditions. There is no change from the 1995 DEIR/EIS conclusion that the project would not have a significant impact on Delta consumptive use and that no mitigation is required.

Impact Evaluation of Project Alternatives from the 1995 Draft EIR/EIS

As described in Chapter 2, project operations under Alternative 1 in the 1995 DEIR/EIS were assumed to be the same as project operations under Alternative 2, except that discharges to export were assumed to be more restricted (i.e., by strict interpretation of the E/I ratio). As shown in the 1995 DEIR/EIS analysis, Alternative 1 operations provide fewer opportunities for Delta Wetlands discharges to export—potentially meaning a lower yield—than Alternative 2 operations (i.e., project yield was 14 TAF less under Alternative 1 than Alternative 2). Changes in simulated Alternative 1 project operations between the 1995 DEIR/EIS analysis and this REIR/EIS analysis are similar in magnitude and direction to the changes described above for the proposed project (i.e., Alternative 2). Therefore, Delta Wetlands discharges to exports under Alternative 1 would be less than previously reported in the 1995 DEIR/EIS, and the potential environmental impacts of Alternative 1 are slightly less than originally estimated. Based on the daily simulation of Delta Wetlands operations, the E/I export restriction would rarely limit Delta Wetlands discharges. The likely effect of applying the E/I export limit would be an increase in the period of Delta Wetlands discharges, resulting in increased evaporative losses on the Delta Wetlands islands. These evaporative losses are estimated to result in an average annual reduction in yield of less than 10 TAF compared with the Alternative 2 results.

Alternative 3, the four-reservoir-island alternative, has not changed since the 1995 DEIR/EIS was published. The FOC and biological opinion terms were developed for the two-reservoir-island operations represented by Alternative 2 in the 1995 DEIR/EIS and are not applicable to a four-reservoir-island alternative. New simulations of Alternative 3, which are based on the Delta water budget developed from DWRSIM study 771 and include AFRP actions, result in minor changes in project diversion, storage, and discharge operations. There is no change to the conclusions of the environmental impact analysis presented in the 1995 DEIR/EIS for Alternative 3.

Table 3-1. DeltaSOS Mean Annual Input Data from Historical Data, DWRSIM Study 409, and DWRSIM Study 771 (TAF)

	Historical Flows					DWRSIM Study 409 (1995 DEIR/EIS)						DWRSIM Study 771 (2000 REIR/EIS)					
Water Year	Sacramento + Yolo*	SJR + Eastside*	Depletion + CCWD*	CVP + SWP Exports	Delta Outflow	Sacramento + Yolo*	SJR + Eastside*	Depletion + CCWD*	CVP + SWP Exports	Delta Outflow	Required Outflow	Sacramento + Yolo*	SJR + Eastside*	Depletion + CCWD*	CVP + SWP Exports	Delta Outflow	Required Outflow
1922	-	-	-	0	28,838	15,460	4,080	1,035	6,193	12,313	6,112	16,271	4,131	1,000	6,522	12,879	6,356
1923	-	-	-	0	19,498	14,704	3,311	1,022	6,199	10,793	5,841	14,266	3,551	942	5,938	10,943	5,653
1924	-	-	-	0	4,972	8,667	1,462	1,421	4,548	4,161	4,069	7,900	1,352	1,431	3,604	4,219	3,921
1925	-	-	-	0	23,103	12,891	2,095	965	5,743	8,278	5,202	12,639	2,275	853	4,445	9,626	5,866
1926	-	-	-	0	14,889	11,974	1,903	1,129	5,741	7,007	5,013	11,426	1,769	1,287	5,157	6,756	4,397
1927	-	-	-	0	34,966	22,268	2,619	981	6,251	17,655	6,990	23,331	3,076	1,009	6,308	19,095	6,830
1928	-	-	-	0	22,064	19,474	2,286	1,152	6,336	14,271	6,674	18,710	2,640	1,257	6,114	13,985	5,961
1929	-	-	-	0	8,687	8,808	1,605	1,288	4,570	4,554	4,424	8,618	1,406	1,306	4,315	4,406	3,931
1930	-	1,734	812	0	15,038	10,947	1,470	1,173	5,016	6,229	5,059	11,322	1,404	1,134	5,080	6,516	4,775
1931	-	838	890	0	5,140	6,852	1,462	1,300	3,332	3,682	3,662	7,586	1,084	1,449	3,397	3,831	3,760
1932	-	4,605	673	0	16,600	8,787	2,244	1,045	4,153	5,833	5,197	8,616	2,755	1,107	3,933	6,322	5,151
1933	-	1,804	882	0	8,719	7,629	1,654	1,306	3,683	4,294	4,055	7,305	1,504	1,372	3,227	4,204	3,821
1934	-	1,362	844	0	8,798	8,330	1,507	1,260	3,742	4,835	4,539	8,487	1,299	1,377	3,577	4,830	4,477
1935	-	4,995	637	0	22,582	13,725	2,692	1,018	5,934	9,466	6,464	13,490	2,864	1,082	5,528	9,748	6,168
1936	-	6,598	402	0	25,092	14,769	3,205	945	6,162	10,867	6,257	15,255	4,276	1,070	6,056	12,408	6,472
1937	-	6,751	434	0	21,235	12,689	3,750	898	5,887	9,654	5,294	12,679	4,713	992	5,506	10,892	5,578
1938	-	13,085	381	0	52,788	36,820	7,100	719	6,235	36,966	8,137	36,707	10,362	789	6,729	39,557	7,471
1939	-	2,139	836	0	8,563	10,796	1,984	1,348	5,096	6,337	4,363	10,917	2,338	1,490	4,889	6,887	4,013
1940	-	6,114	480	0	30,910	22,241	2,655	792	6,428	17,675	7,256	21,570	3,829	922	5,988	18,490	7,253
1941	-	8,614	410	0	43,460	32,989	4,492	652	6,283	30,546	7,020	33,977	5,600	711	6,507	32,363	7,096
1942	-	7,763	338	0	36,995	30,494	4,146	900	5,957	27,783	6,681	30,385	5,261	987	6,077	28,588	6,689
1943	-	7,916	423	0	30,329	22,643	4,707	1,030	5,566	20,755	7,319	22,235	6,555	1,129	5,686	21,982	7,181
1944	-	2,316	735	0	10,787	11,595	2,039	1,192	5,937	6,505	4,959	11,629	2,436	1,305	5,286	7,479	4,191
1945	-	5,638	678	0	18,869	12,920	2,993	1,119	6,142	8,651	5,284	13,398	3,584	1,250	5,910	9,823	6,141
1946	-	4,725	816	0	21,938	17,663	2,871	1,222	6,299	13,013	6,288	16,859	3,677	1,323	6,249	12,967	6,015
1947	-	1,705	1,079	0	10,203	11,073	1,850	1,316	6,042	5,566	5,079	10,915	1,778	1,427	5,888	5,379	4,445
1948	-	2,257	962	0	16,167	13,157	1,785	1,237	6,310	7,394	5,494	12,622	1,829	1,258	5,911	7,287	4,622
1949	12,070	1,858	1,005	0	12,615	12,203	1,881	1,258	5,700	7,127	4,928	12,199	1,890	1,303	6,041	6,747	4,428
1950	14,324	2,793	1,066	0	15,257	12,940	2,043	1,259	6,159	7,564	5,606	13,002	2,237	1,337	6,221	7,685	5,096
1951	25,246	7,066	755	163	30,594	23,605	4,379	969	6,775	20,240	6,335	23,879	5,487	1,006	6,601	21,762	6,331
1952	32,046	9,627	589	165	40,431	30,744	4,800	810	6,936	27,799	7,996	30,899	6,998	834	6,633	30,439	7,675
1953	20,902	2,756	1,014	788	22,393	21,360	2,501	1,175	5,312	17,374	6,088	21,115	3,099	1,213	5,772	17,232	6,004
1954	18,349	2,434	1,101	1,022	19,167	20,648	1,943	1,304	6,382	14,904	7,031	19,938	2,027	1,352	6,205	14,414	6,718
1955	10,682	1,538	906	1,129	10,054	11,635	1,802	1,174	6,025	6,239	5,058	11,371	1,738	1,186	5,494	6,429	4,304
1956	32,232	8,645	572	722	39,798	30,078	4,762	837	6,833	27,171	6,230	30,508	6,803	862	6,796	29,659	6,491
1957	13,947	2,126	978	1,181	13,939	15,512	2,200	1,233	6,295	10,185	5,669	15,133	2,455	1,293	6,334	9,964	5,257
1958	36,120	8,463	159	658	43,825	35,187	5,061	581	7,056	32,611	7,277	35,637	6,310	577	6,861	34,513	6,653
1959	12,712	1,616	958	1,338	12,056	15,120	2,074	1,265	5,184	10,745	5,301	14,192	2,334	1,393	4,971	10,164	5,066

Water Year	Historical Flows: Sacramento + Yolo*	Historical Flows: SJR + Eastside*	Historical Flows: Depletion + CCWD*	Historical Flows: CVP + SWP Exports	Historical Flows: Delta Outflow	DWRSIM Study 409 (1995 DEIR/EIS): Sacramento + Yolo*	DWRSIM Study 409: SJR + Eastside*	DWRSIM Study 409: Depletion + CCWD*	DWRSIM Study 409: CVP + SWP Exports	DWRSIM Study 409: Delta Outflow	DWRSIM Study 409: Required Outflow	DWRSIM Study 771 (2000 REIR/EIS): Sacramento + Yolo*	DWRSIM Study 771: SJR + Eastside*	DWRSIM Study 771: Depletion + CCWD*	DWRSIM Study 771: CVP + SWP Exports	DWRSIM Study 771: Delta Outflow	DWRSIM Study 771: Required Outflow
1960	11,405	802	1,207	1,386	9,720	11,672	1,523	1,285	5,864	6,046	5,210	11,294	1,510	1,396	5,625	5,785	4,563
1961	11,673	542	1,048	1,485	9,700	11,682	1,357	1,252	5,784	6,003	5,104	11,866	1,172	1,298	5,735	6,001	4,312
1962	14,232	2,189	935	1,352	14,158	13,101	1,947	1,122	5,805	8,120	5,070	13,503	2,279	1,172	6,206	8,410	4,720
1963	24,626	4,177	499	1,339	27,006	23,586	2,679	897	6,661	18,708	7,339	23,549	3,008	857	7,187	18,510	6,855
1964	11,674	1,426	1,123	1,646	10,399	12,563	1,675	1,323	5,922	6,993	5,150	11,924	1,680	1,340	5,389	6,874	4,359
1965	26,194	5,451	830	1,469	29,388	24,106	3,550	1,082	6,660	19,914	6,680	24,487	4,774	1,065	7,068	21,130	6,857
1966	13,788	2,339	1,082	1,596	13,467	14,240	2,365	1,241	6,411	8,952	5,610	13,209	2,881	1,310	5,775	9,006	4,765
1967	27,933	7,289	461	1,254	33,561	24,830	4,609	760	6,875	21,804	7,564	25,998	6,632	745	7,084	24,807	7,639
1968	14,064	1,939	1,134	2,471	12,524	16,703	2,095	1,238	4,789	12,771	5,565	15,739	2,294	1,333	5,054	11,649	5,521
1969	29,684	12,572	502	2,879	38,936	29,451	7,387	814	6,439	29,584	7,978	30,183	11,340	865	6,435	34,229	7,478
1970	28,829	4,494	883	2,070	30,332	29,644	4,485	1,041	5,038	28,049	5,644	29,227	5,264	1,169	5,104	28,226	5,639
1971	24,150	2,682	818	2,834	23,223	22,122	2,443	1,105	6,822	16,637	7,103	22,062	2,787	1,132	6,763	16,959	7,051
1972	12,517	1,476	1,352	3,445	9,273	13,421	1,875	1,377	6,352	7,567	5,417	12,990	1,601	1,487	5,890	7,213	4,898
1973	24,679	3,824	532	3,369	24,643	23,309	3,340	653	6,618	19,378	6,830	23,318	4,043	724	6,879	19,762	6,804
1974	38,282	4,327	768	4,366	37,534	36,436	3,497	992	6,838	32,103	6,954	37,025	4,702	1,076	6,766	33,892	6,679
1975	20,920	3,954	934	3,910	20,070	21,389	3,209	1,122	6,503	16,973	6,636	21,026	4,091	1,186	6,773	17,168	6,653
1976	10,992	1,731	1,337	4,846	6,592	10,557	1,382	1,423	5,006	5,510	4,423	10,754	1,669	1,503	5,335	5,586	3,694
1977	5,506	446	1,337	2,081	2,542	6,939	1,167	1,387	3,057	3,662	3,662	6,825	1,290	1,453	2,695	3,965	3,965
1978	20,564	5,642	393	4,356	21,497	19,343	3,111	714	4,513	17,228	7,944	19,034	4,935	778	5,431	17,760	8,205
1979	13,206	3,648	834	4,476	11,571	14,143	2,993	1,059	5,813	10,264	5,852	14,134	3,854	1,123	5,651	11,219	5,816
1980	25,785	7,806	732	4,529	28,541	23,927	6,151	866	5,681	23,531	6,577	24,028	6,669	871	5,905	23,927	6,591
1981	11,641	2,052	1,066	4,728	7,919	13,220	2,258	1,284	5,595	8,599	5,116	12,865	2,198	1,404	4,767	8,891	4,618
1982	37,381	8,522	105	4,627	41,287	36,386	8,491	602	7,276	36,999	7,109	36,684	9,721	596	7,043	38,771	6,966
1983	49,079	20,014	51	4,405	64,732	49,206	20,669	249	5,421	64,201	6,206	49,309	19,397	239	5,294	63,181	6,413
1984	27,110	8,070	922	3,846	30,634	27,404	8,629	1,150	4,582	30,301	5,684	27,000	7,597	1,247	4,838	28,515	6,144
1985	12,381	2,574	1,053	5,478	8,465	13,248	2,321	1,139	5,942	8,488	5,075	12,721	1,919	1,229	5,716	7,700	4,502
1986	28,760	7,366	341	5,293	30,535	27,876	7,208	691	6,277	28,117	6,164	28,579	7,547	760	6,186	29,189	5,985
1987	10,079	2,194	1,131	5,050	6,113	11,045	1,985	1,318	5,816	5,896	4,826	10,887	1,695	1,421	5,054	6,111	4,206
1988	9,782	1,307	1,101	5,619	4,415	9,567	1,258	1,223	4,452	5,150	4,511	9,484	1,205	1,348	3,936	5,399	4,318
1989	12,306	1,279	1,023	5,975	6,608	11,878	1,330	1,270	5,285	6,653	4,823	11,593	1,279	1,377	4,871	6,657	4,374
1990	9,894	1,085	1,211	5,819	3,973	8,787	1,156	1,251	4,071	4,621	4,512	9,400	1,098	1,378	4,438	4,687	4,092
1991	7,626	877	941	3,185	4,377	8,700	1,228	1,256	3,813	4,860	4,094	8,334	1,179	1,335	2,666	5,510	4,055
1992	-	1,247	961	2,912	-	-	-	-	-	-	-	8,774	1,371	1,262	3,132	5,764	4,486
1993	-	-	-	-	-	-	-	-	-	-	-	19,349	3,523	625	6,157	16,090	8,402
1994	-	-	-	-	-	-	-	-	-	-	-	11,038	1,692	1,353	5,312	6,064	3,961
Avg ('22-'91)	19,892	4,419	798	1,691	20,644	18,141	3,240	1,079	5,720	14,582	5,810	18,086	3,743	1,140	5,590	15,102	5,586

* Notes: Sacramento + Yolo = Sacramento River and Yolo Bypass
SJR + Eastside = San Joaquin River and eastside streams
Depletion + CCWD = Contra Costa Water District diversions and net channel depletion
See "Notes and Acronyms" at end of tables section

Table 3-2. Comparison of Sacramento River and Yolo Bypass Inflows (cfs) between DWRSIM Studies 771 and 409

Water Year	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Total (TAF)
DWRSIM Study 409 (1995 DEIR/EIS)													
1967	12,680	15,473	41,319	46,741	59,682	56,679	43,818	46,199	40,864	15,589	12,698	19,813	24,830
1968	23,643	18,017	16,207	29,254	67,429	37,050	12,293	10,820	14,760	21,516	14,177	11,675	16,703
1969	14,078	12,574	23,151	111,492	111,153	52,937	43,896	44,733	25,335	13,042	12,083	23,658	29,451
1970	21,939	18,806	57,778	184,333	85,637	36,152	13,232	10,762	15,238	23,106	13,363	10,993	29,644
1971	13,723	22,988	67,713	53,426	29,159	52,059	19,441	31,548	22,990	23,192	13,662	16,761	22,122
1972	18,865	16,485	21,278	18,288	25,382	32,355	11,592	10,956	14,603	21,618	20,089	10,936	13,421
1973	15,127	23,028	27,877	72,678	88,679	56,526	17,416	17,979	19,696	22,972	12,753	11,608	23,309
1974	15,026	66,497	69,975	127,939	47,112	106,615	71,375	24,715	21,434	18,189	13,856	21,175	36,436
1975	22,724	17,840	18,043	16,081	64,541	83,394	22,644	32,443	25,262	20,252	13,015	18,274	21,389
1976	23,074	20,504	15,689	13,414	19,069	15,202	9,873	10,305	14,737	16,563	8,650	7,893	10,557
1977	8,183	11,104	18,131	8,303	13,468	10,403	9,127	6,787	7,009	9,003	6,316	7,178	6,939
1978	7,179	6,260	16,102	58,430	57,316	64,666	38,711	19,681	14,350	13,255	10,870	13,778	19,343
1979	18,469	15,924	10,638	25,785	40,922	30,818	16,689	15,571	20,572	17,819	11,205	10,001	14,143
1980	10,623	18,125	20,806	100,940	112,793	51,001	16,691	14,264	12,647	13,041	11,215	14,433	23,927
1981	17,286	14,254	16,319	25,675	28,599	32,518	14,686	10,889	13,654	20,878	14,221	10,145	13,220
1982	12,801	35,650	94,683	73,874	92,720	67,180	115,305	36,117	22,606	15,164	13,851	23,136	36,386
1983	30,060	41,797	68,882	78,120	141,232	200,690	79,835	59,449	52,097	23,412	15,591	24,410	49,206
1984	27,521	69,988	131,698	60,540	39,887	33,563	14,220	12,617	15,445	21,437	12,186	15,112	27,404
1985	18,599	35,922	26,287	14,443	19,838	17,790	9,859	13,784	13,489	20,965	17,901	10,706	13,248
1986	12,711	10,997	15,940	18,764	198,107	122,935	20,232	11,194	12,479	16,354	11,426	10,901	27,876
1987	10,638	12,133	9,495	12,911	19,356	32,272	13,457	11,495	13,656	21,261	16,142	10,254	11,045
1988	10,369	9,911	16,405	26,311	17,146	12,006	9,207	9,574	14,318	15,770	10,258	7,289	9,567
1989	7,179	9,446	11,759	12,971	13,986	39,617	22,383	14,636	13,464	21,670	19,283	10,483	11,878
1990	9,151	8,092	14,263	17,463	15,935	11,083	13,102	7,884	14,643	16,078	10,380	7,568	8,787
1991	7,159	7,716	9,364	10,525	13,924	29,237	14,113	8,058	13,814	12,442	9,529	8,320	8,700
DWRSIM Study 771 (2000 REIR/EIS)													
1967	11,270	19,007	40,723	51,132	59,437	57,832	42,904	46,009	45,274	21,012	18,085	18,217	25,998
1968	17,353	13,461	16,361	31,421	59,786	39,129	14,335	12,555	13,730	15,190	16,101	11,444	15,739
1969	12,149	14,200	25,110	110,525	110,357	52,790	42,534	48,155	27,678	18,085	16,832	21,847	30,183
1970	15,938	14,805	57,149	183,384	86,985	38,771	14,604	13,255	14,016	18,556	15,531	11,428	29,227
1971	11,921	23,628	63,492	54,400	28,647	52,351	21,360	29,713	23,746	21,728	17,190	17,494	22,062
1972	15,336	13,932	21,402	20,459	23,730	33,388	11,781	14,230	15,276	16,654	17,076	12,033	12,990
1973	13,108	21,494	26,200	76,372	87,526	56,596	20,099	15,369	20,318	21,061	13,791	14,553	23,318
1974	14,051	64,784	70,485	126,349	47,571	109,272	67,288	27,615	24,216	22,150	19,435	20,452	37,025
1975	16,475	13,764	17,743	18,410	59,833	83,658	26,922	27,452	28,048	20,313	18,101	17,780	21,026
1976	20,589	15,612	16,702	16,751	20,079	17,515	9,680	9,872	15,831	13,238	11,287	11,092	10,754
1977	11,108	8,823	8,977	8,928	13,342	8,083	9,999	7,383	11,058	8,717	8,847	7,848	6,825
1978	6,164	6,117	13,027	59,426	57,114	59,214	34,837	20,036	15,108	14,507	15,515	14,419	19,034
1979	14,393	12,722	12,604	27,338	41,827	32,640	18,234	12,864	21,796	17,011	10,815	12,016	14,134
1980	12,929	15,713	21,402	93,172	111,367	51,294	20,015	15,076	13,461	13,531	16,231	14,066	24,028
1981	11,775	10,470	16,979	29,046	30,033	30,656	17,746	12,328	13,999	13,840	15,678	10,688	12,865
1982	11,335	40,585	90,521	71,086	87,454	74,355	111,117	37,682	25,208	20,427	18,036	20,217	36,684
1983	23,045	35,577	67,346	80,454	140,714	195,451	81,405	58,889	59,289	27,826	24,037	23,242	49,309
1984	20,882	64,364	129,146	61,930	36,282	36,218	16,251	14,897	18,839	20,410	14,539	13,747	27,000
1985	13,287	31,560	23,956	17,125	21,697	21,955	12,906	13,011	13,814	13,482	16,117	11,932	12,721
1986	11,563	12,033	18,133	22,980	190,014	126,934	23,309	14,068	11,579	16,605	12,149	14,318	28,579
1987	12,604	11,226	12,311	15,564	21,697	28,379	12,554	10,034	15,579	14,198	16,393	9,915	10,887
1988	10,327	8,672	17,450	28,152	14,064	15,271	9,327	9,433	14,217	12,750	8,506	9,024	9,484
1989	9,075	9,966	10,165	13,417	11,794	41,910	25,914	13,401	13,226	14,133	16,767	12,386	11,593
1990	13,515	10,638	14,686	19,857	16,205	13,677	13,612	9,481	15,058	10,864	8,928	9,277	9,400
1991	8,701	8,235	8,164	7,985	12,244	32,591	17,158	9,498	8,503	7,904	8,213	8,940	8,334
Change: DWRSIM 771 - DWRSIM 409													
1967	-1,410	3,534	-596	4,391	-245	1,153	-914	-190	4,410	5,423	5,387	-1,596	1,167
1968	-6,290	-4,556	154	2,167	-7,643	2,079	2,042	1,735	-1,030	-6,326	1,924	-231	-964
1969	-1,929	1,626	1,959	-967	-796	-147	-1,362	3,422	2,343	5,043	4,749	-1,811	732
1970	-6,001	-4,001	-629	-949	1,348	2,619	1,372	2,493	-1,222	-4,550	2,168	435	-417
1971	-1,802	640	-4,221	974	-512	292	1,919	-1,835	756	-1,464	3,528	733	-60
1972	-3,529	-2,553	124	2,171	-1,652	1,033	189	3,274	673	-4,964	-3,013	1,097	-431
1973	-2,019	-1,534	-1,677	3,694	-1,153	70	2,683	-2,610	622	-1,911	1,038	2,945	9
1974	-975	-1,713	510	-1,590	459	2,657	-4,087	2,900	2,782	3,961	5,579	-723	589
1975	-6,249	-4,076	-300	2,329	-4,708	264	4,278	-4,991	2,786	61	5,086	-494	-363
1976	-2,485	-4,892	1,013	3,337	1,010	2,313	-193	-433	1,094	-3,325	2,637	3,199	198
1977	2,925	-2,281	-9,154	625	-126	-2,320	872	596	4,049	-286	2,531	670	-114
1978	-1,015	-143	-3,075	996	-202	-5,452	-3,874	355	758	1,252	4,645	641	-309
1979	-4,076	-3,202	1,966	1,553	905	1,822	1,545	-2,707	1,224	-808	-390	2,015	-9
1980	2,306	-2,412	596	-7,768	-1,426	293	3,324	812	814	490	5,016	-367	101
1981	-5,511	-3,784	660	3,371	1,434	-1,862	3,060	1,439	345	-7,038	1,457	543	-355
1982	-1,466	4,935	-4,162	-2,788	-5,266	7,175	-4,188	1,565	2,602	5,263	4,185	-2,919	298
1983	-7,015	-6,220	-1,536	2,334	-518	-5,239	1,570	-560	7,192	4,414	8,446	-1,168	103
1984	-6,639	-5,624	-2,552	1,390	-3,605	2,655	2,031	2,280	3,394	-1,027	2,353	-1,365	-405
1985	-5,312	-4,362	-2,331	2,682	1,859	4,165	3,047	-773	325	-7,483	-1,784	1,226	-527
1986	-1,148	1,036	2,193	4,216	-8,093	3,999	3,077	2,874	-900	251	723	3,417	703
1987	1,966	-907	2,816	2,653	2,341	-3,893	-903	-1,461	1,923	-7,063	251	-339	-158
1988	-42	-1,239	1,045	1,841	-3,082	3,265	120	-141	-101	-3,020	-1,752	1,735	-83
1989	1,896	520	-1,594	446	-2,192	2,293	3,531	-1,235	-238	-7,537	-2,516	1,903	-285
1990	4,364	2,546	423	2,394	270	2,594	510	1,597	415	-5,214	-1,452	1,709	613
1991	1,542	519	-1,200	-2,540	-1,680	3,354	3,045	1,440	-5,311	-4,538	-1,316	620	-366

Note: See "Notes and Acronyms" at end of tables section.

Table 3-3. Comparison of San Joaquin River and Eastside Stream Inflows (cfs) between DWRSIM Studies 771 and 409

Water Year	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Total (TAF)
DWRSIM Study 409 (1995 DEIR/EIS)													
1967	2,163	2,285	4,607	6,732	7,039	5,746	12,312	9,585	10,645	9,511	2,251	3,508	4,609
1968	4,058	2,290	2,802	3,036	4,613	3,565	4,291	3,202	2,163	2,017	1,330	1,360	2,095
1969	1,641	2,532	2,555	13,179	27,970	11,301	11,590	24,907	15,284	6,059	2,298	3,117	7,387
1970	8,283	4,208	5,047	21,274	10,411	6,234	5,998	4,607	2,667	2,063	1,983	1,563	4,485
1971	1,851	3,718	6,567	3,529	3,145	3,516	4,980	4,795	2,802	2,066	1,999	1,516	2,443
1972	2,260	2,170	2,968	2,476	3,109	2,752	4,459	3,365	2,165	2,032	1,298	2,022	1,875
1973	1,606	3,098	2,270	6,126	10,661	10,686	6,603	6,239	2,551	2,033	1,953	1,531	3,340
1974	2,566	4,156	5,710	8,513	4,286	7,570	8,363	7,097	3,893	2,124	2,078	1,605	3,497
1975	2,335	3,183	2,918	1,889	7,839	8,722	7,741	7,683	4,565	2,121	2,068	2,119	3,209
1976	2,569	3,048	2,381	1,121	1,340	2,049	2,398	2,387	2,111	1,339	1,099	1,072	1,382
1977	1,721	1,616	1,189	1,127	1,382	1,741	2,430	2,250	2,109	1,298	1,204	1,280	1,167
1978	1,779	1,511	1,873	6,100	6,865	6,312	8,783	7,081	5,196	2,108	2,186	1,776	3,111
1979	3,530	2,780	1,772	4,350	9,098	7,206	6,301	6,336	2,568	2,024	1,930	1,706	2,993
1980	2,354	3,750	2,793	16,699	24,189	24,976	7,187	6,869	4,739	2,521	2,241	3,640	6,151
1981	4,478	4,059	3,295	3,543	3,567	4,200	4,106	3,153	2,156	2,022	1,441	1,410	2,258
1982	1,537	2,639	4,246	11,796	14,264	20,962	36,202	24,293	9,727	5,948	3,354	5,768	8,491
1983	13,458	12,724	28,435	31,556	49,188	62,664	37,426	32,518	34,260	20,942	7,553	11,848	20,669
1984	18,450	18,643	30,960	28,088	13,948	9,620	6,721	4,949	3,592	2,435	2,676	2,944	8,629
1985	3,399	4,577	5,682	3,706	3,700	3,374	3,598	3,267	2,166	2,009	1,446	1,548	2,321
1986	2,130	2,826	2,817	2,564	28,698	36,518	20,598	9,361	5,580	2,600	2,647	3,134	7,208
1987	6,669	3,493	3,918	2,037	2,329	2,948	2,543	2,275	2,154	1,753	1,303	1,473	1,985
1988	1,643	1,895	2,110	1,566	1,053	1,489	2,410	2,308	2,159	1,537	1,297	1,383	1,258
1989	1,989	1,538	1,554	1,100	1,205	2,952	3,178	2,422	2,249	1,391	1,327	1,141	1,330
1990	1,570	1,316	1,083	1,319	1,421	1,685	2,528	2,275	1,939	1,327	1,259	1,444	1,156
1991	2,008	1,407	1,258	857	1,269	2,599	2,561	2,487	2,005	1,288	1,223	1,397	1,228
DWRSIM Study 771 (2000 REIR/EIS)													
1967	2,082	2,252	3,968	7,416	5,600	9,156	21,914	22,394	17,646	10,311	2,992	4,185	6,632
1968	5,351	2,302	2,472	2,651	5,424	4,342	5,109	3,480	1,798	1,740	1,691	1,664	2,294
1969	2,017	2,000	2,683	23,695	40,729	23,793	26,132	31,160	20,654	6,570	4,033	4,487	11,340
1970	5,904	3,378	4,521	27,469	12,550	10,506	6,957	6,001	3,008	2,212	2,244	2,504	5,264
1971	2,472	3,126	6,603	4,017	3,241	5,123	6,168	5,529	2,823	2,326	2,309	2,454	2,787
1972	2,163	1,983	2,927	2,179	2,712	2,196	3,227	2,862	1,731	1,464	1,626	1,462	1,601
1973	1,838	2,168	2,000	6,944	13,954	13,515	8,235	7,530	3,311	2,505	2,407	2,605	4,043
1974	3,692	4,470	6,310	12,571	6,536	11,710	11,344	8,262	4,554	2,781	2,732	2,975	4,702
1975	3,887	2,487	2,862	2,635	8,445	13,791	8,957	8,392	7,596	2,944	2,814	2,991	4,091
1976	4,602	2,353	2,244	1,984	2,451	2,212	2,891	2,716	1,580	1,578	1,529	1,529	1,669
1977	3,204	2,386	1,968	1,529	1,494	1,464	2,286	1,952	1,496	1,138	1,155	1,311	1,290
1978	1,545	1,529	1,919	6,473	9,345	14,003	18,167	12,490	7,865	3,350	2,082	3,025	4,935
1979	4,668	2,353	2,082	5,757	12,784	11,677	7,596	7,026	2,790	2,358	2,309	2,487	3,854
1980	2,765	2,218	2,667	20,719	27,468	17,483	8,201	8,896	8,924	4,879	2,651	3,664	6,669
1981	5,237	2,269	2,130	3,123	3,259	4,716	5,109	3,741	1,798	1,643	1,708	1,697	2,198
1982	1,968	2,806	3,724	15,824	25,766	22,768	40,450	19,939	12,033	5,481	3,919	6,436	9,721
1983	9,384	12,789	28,314	34,754	50,110	60,727	26,284	26,964	40,568	17,483	4,781	9,344	19,397
1984	8,148	21,007	32,803	19,060	12,778	8,001	7,075	5,920	3,311	2,505	2,553	2,756	7,597
1985	2,391	3,361	2,618	2,130	3,133	3,253	4,386	3,692	1,832	1,626	1,724	1,664	1,919
1986	1,984	2,201	2,326	2,830	40,099	34,868	11,747	10,457	10,503	2,683	2,602	2,790	7,547
1987	3,838	2,252	2,082	1,984	2,773	3,090	2,941	2,700	1,613	1,610	1,594	1,613	1,695
1988	1,691	1,832	2,065	1,838	1,512	1,447	2,218	2,049	1,496	1,138	1,171	1,512	1,205
1989	1,529	1,529	1,756	1,366	1,548	3,041	2,504	2,212	1,714	1,236	1,203	1,563	1,279
1990	1,529	1,529	1,366	1,529	1,711	1,756	2,168	1,773	1,260	1,041	1,073	1,462	1,098
1991	1,415	1,311	1,301	1,106	1,314	3,757	2,554	2,082	1,328	1,041	1,008	1,328	1,179
Change: DWRSIM 771 - DWRSIM 409													
1967	-81	-33	-639	684	-1,439	3,410	9,602	12,809	7,001	800	741	677	2,023
1968	1,293	12	-330	-385	811	777	818	278	-365	-277	361	304	199
1969	376	-532	128	10,516	12,759	12,492	14,542	6,253	5,370	511	1,735	1,370	3,953
1970	-2,379	-830	-526	6,195	2,139	4,272	959	1,394	341	149	261	941	779
1971	621	-592	36	488	96	1,607	1,188	734	21	260	310	938	344
1972	-97	-187	-41	-297	-397	-556	-1,232	-503	-434	-568	328	-560	-274
1973	232	-930	-270	818	3,293	2,829	1,632	1,291	760	472	454	1,074	703
1974	1,126	314	600	4,058	2,250	4,140	2,981	1,165	661	657	654	1,370	1,205
1975	1,552	-696	-56	746	606	5,069	1,216	709	3,031	823	746	872	882
1976	2,033	-695	-137	863	1,111	163	493	329	-531	239	430	457	287
1977	1,483	770	779	402	112	-277	-144	-298	-613	-160	-49	31	123
1978	-234	18	46	373	2,480	7,691	9,384	5,409	2,669	1,242	-104	1,249	1,823
1979	1,138	-427	310	1,407	3,686	4,471	1,295	690	222	334	379	781	862
1980	411	-1,532	-126	4,020	3,279	-7,493	1,014	2,027	4,185	2,358	410	24	517
1981	759	-1,790	-1,165	-420	-308	516	1,003	588	-358	-379	267	287	-60
1982	431	167	-522	4,028	11,502	1,806	4,248	-4,354	2,306	-467	565	668	1,230
1983	-4,074	65	-121	3,198	922	-1,937	-11,142	-5,554	6,308	-3,459	-2,772	-2,504	-1,271
1984	-10,302	2,364	1,843	-9,028	-1,170	-1,619	354	971	-281	70	-123	-188	-1,032
1985	-1,008	-1,216	-3,064	-1,576	-567	-121	788	425	-334	-383	278	116	-402
1986	-146	-625	-491	266	11,401	-1,650	-8,851	1,096	4,923	83	-45	-344	339
1987	-2,831	-1,241	-1,836	-53	444	142	398	425	-541	-143	291	140	-290
1988	48	-63	-45	272	459	-42	-192	-259	-663	-399	-126	129	-53
1989	-460	-9	202	266	343	89	-674	-210	-535	-155	-124	422	-51
1990	-41	213	283	210	290	71	-360	-502	-679	-286	-186	18	-58
1991	-593	-96	43	249	45	1,158	-7	-405	-677	-247	-215	-69	-49

Note: See "Notes and Acronyms" at end of tables section.

Table 3-4. Comparison of Combined CVP and SWP Exports (cfs) between DWRSIM Studies 771 and 409

Water Year	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Total (TAF)
DWRSIM Study 409 (1995 DEIR/EIS)													
1967	8,718	10,672	11,526	11,916	10,784	6,352	7,644	8,128	10,257	10,775	5,927	11,243	6,875
1968	9,342	7,641	6,876	4,239	4,835	6,480	4,666	3,870	5,924	11,287	7,538	6,684	4,789
1969	9,074	8,547	11,249	12,373	11,632	6,647	6,727	7,690	9,600	6,578	5,360	11,243	6,439
1970	11,027	7,887	7,427	4,700	4,822	6,543	5,990	4,706	6,268	11,287	6,324	6,526	5,038
1971	9,054	10,941	11,411	11,618	9,028	10,190	6,116	7,704	9,028	11,287	6,640	10,061	6,822
1972	11,027	10,941	11,264	10,891	8,473	8,443	4,578	3,924	5,870	11,287	11,287	7,294	6,352
1973	10,113	10,941	11,250	11,573	12,382	7,836	6,772	6,930	7,786	11,110	6,124	6,866	6,618
1974	10,863	10,941	11,352	11,037	8,319	8,492	8,550	8,701	8,864	8,065	6,913	11,243	6,838
1975	11,027	10,941	9,893	7,640	6,018	7,644	8,266	8,756	10,439	9,670	6,241	11,243	6,503
1976	11,027	10,941	10,586	8,462	8,468	6,038	3,070	3,268	5,896	7,623	3,547	4,042	5,006
1977	5,434	6,433	11,057	4,844	6,067	4,197	2,825	2,394	1,076	1,817	941	3,580	3,057
1978	4,415	3,326	10,812	10,363	5,453	5,280	6,313	6,696	6,613	2,839	4,473	8,219	4,513
1979	11,027	10,941	6,331	10,707	7,836	8,114	6,604	6,512	8,100	8,864	5,187	6,117	5,813
1980	7,828	10,941	11,332	12,621	8,081	6,096	6,262	6,772	5,681	3,232	4,873	10,445	5,681
1981	11,027	10,941	9,165	7,318	7,774	7,239	5,026	3,874	5,534	11,287	7,551	6,005	5,595
1982	8,382	10,941	11,217	12,015	11,725	8,742	8,607	9,742	11,277	8,589	8,123	11,243	7,276
1983	11,027	8,298	7,936	6,107	4,628	4,948	6,594	6,273	7,679	7,796	10,177	8,388	5,421
1984	7,062	5,299	5,242	3,218	4,144	6,341	6,270	5,104	6,664	10,505	5,856	10,243	4,582
1985	11,027	10,941	11,708	7,800	8,028	7,408	3,696	4,418	5,480	11,287	10,258	6,439	5,942
1986	8,726	7,912	11,320	11,410	12,821	10,247	8,347	7,354	6,322	6,447	5,051	8,075	6,277
1987	11,027	8,936	7,785	9,199	9,758	10,838	3,800	3,456	5,534	11,287	8,755	6,020	5,816
1988	6,587	6,114	11,175	11,273	6,370	4,724	2,964	3,114	5,768	7,321	4,885	3,498	4,452
1989	4,627	5,403	6,928	8,317	6,836	11,402	5,466	4,050	5,500	11,287	11,287	6,501	5,285
1990	5,470	3,927	7,841	11,255	6,076	4,468	3,620	2,804	5,804	7,330	5,021	3,857	4,071
1991	4,665	3,854	5,073	6,171	6,384	11,142	3,790	2,873	5,453	5,022	4,228	4,544	3,813
DWRSIM Study 771 (2000 REIR/EIS)													
1967	8,067	11,226	11,547	12,067	10,893	7,709	7,041	5,416	11,612	11,661	11,693	11,596	7,272
1968	9,172	8,672	8,164	7,725	6,884	7,221	4,336	3,318	5,781	5,936	11,384	8,302	5,243
1969	9,026	10,772	11,401	12,295	6,230	6,326	6,235	4,310	11,612	11,026	11,010	9,495	6,621
1970	8,018	7,445	6,668	7,725	8,481	7,188	5,126	4,115	6,302	8,213	9,237	9,075	5,285
1971	9,270	11,209	11,466	11,791	7,292	9,091	5,697	4,863	9,646	11,661	11,693	11,512	6,950
1972	11,466	10,587	11,368	8,831	8,779	9,091	3,411	2,911	6,302	7,302	11,693	9,108	6,085
1973	10,002	11,209	11,319	11,710	12,910	8,863	6,403	4,554	8,621	11,238	8,798	11,495	7,066
1974	11,433	11,226	11,579	8,034	8,805	8,310	6,235	4,310	10,419	11,661	11,693	11,528	6,952
1975	11,466	10,806	9,059	8,278	9,057	8,148	7,041	5,416	11,612	11,205	11,693	11,528	6,957
1976	11,466	11,226	10,311	8,294	8,675	7,156	3,059	2,488	6,403	6,473	7,871	8,167	5,526
1977	7,611	6,857	6,554	5,838	2,287	2,814	2,958	699	1,395	1,464	4,310	4,773	2,869
1978	960	3,411	9,904	12,132	12,946	7,432	6,235	4,310	8,403	5,529	10,213	11,612	5,616
1979	11,563	9,915	7,058	7,660	8,373	8,392	5,966	4,163	8,957	8,668	6,456	9,613	5,839
1980	10,490	11,209	11,417	8,652	6,606	5,692	5,395	3,562	8,184	6,538	11,693	11,478	6,089
1981	11,352	7,310	6,082	5,188	6,086	7,221	4,924	3,285	5,882	6,050	11,026	7,764	4,958
1982	8,473	11,209	11,368	12,880	9,795	9,059	6,235	4,310	11,612	11,661	11,693	11,528	7,229
1983	11,466	11,243	9,725	3,415	3,241	4,131	6,184	4,310	8,772	8,522	10,750	9,041	5,478
1984	7,660	6,974	4,261	5,253	5,441	7,188	4,571	3,204	8,100	10,522	9,042	11,058	5,024
1985	10,474	11,226	11,319	8,278	9,057	8,473	3,697	2,814	5,815	5,855	11,693	9,176	5,905
1986	8,424	9,293	11,368	11,579	12,874	9,075	6,235	3,610	8,083	7,026	6,603	11,411	6,370
1987	10,961	8,050	9,042	8,636	5,870	6,749	3,479	2,488	6,352	6,782	11,677	6,689	5,235
1988	6,863	5,294	11,287	11,433	4,242	4,293	2,806	2,358	5,092	5,090	3,757	5,663	4,113
1989	3,789	7,294	7,758	9,742	2,413	11,270	5,613	2,797	5,563	5,757	11,677	9,394	5,012
1990	10,034	6,873	10,604	11,384	6,752	5,627	3,580	2,391	5,663	3,334	4,131	5,899	4,602
1991	3,432	5,142	5,139	4,310	1,152	11,498	4,218	2,407	471	455	3,497	5,294	2,837
Change: DWRSIM 771 - DWRSIM 409													
1967	-651	554	21	151	109	1,357	-603	-2,712	1,355	886	5,766	353	397
1968	-170	1,031	1,288	3,486	2,049	741	-330	-552	-143	-5,351	3,846	1,618	453
1969	-48	2,225	152	-78	-5,402	-321	-492	-3,380	2,012	4,448	5,650	-1,748	182
1970	-3,009	-442	-759	3,025	3,659	645	-864	-591	34	-3,074	2,913	2,549	246
1971	216	268	55	173	-1,736	-1,099	-419	-2,841	618	374	5,053	1,451	127
1972	439	-354	104	-2,060	306	648	-1,167	-1,013	432	-3,985	406	1,814	-267
1973	-111	268	69	137	528	1,027	-369	-2,376	835	128	2,674	4,629	449
1974	570	285	227	-3,003	486	-182	-2,315	-4,391	1,555	3,596	4,780	285	114
1975	439	-135	-834	638	3,039	504	-1,225	-3,340	1,173	1,535	5,452	285	454
1976	439	285	-275	-168	207	1,118	-11	-780	507	-1,150	4,324	4,125	520
1977	2,177	424	-4,503	994	-3,780	-1,383	133	-1,695	319	-353	3,369	1,193	-187
1978	-3,455	85	-908	1,769	7,493	2,152	-78	-2,386	1,790	2,690	5,740	3,393	1,103
1979	536	-1,026	727	-3,047	537	278	-638	-2,349	857	-196	1,269	3,496	27
1980	2,662	268	85	-3,969	-1,475	-404	-867	-3,210	2,503	3,306	6,820	1,033	407
1981	325	-3,631	-3,083	-2,130	-1,688	-18	-102	-589	348	-5,237	3,475	1,759	-638
1982	91	268	151	865	-1,930	317	-2,372	-5,432	335	3,072	3,570	285	-47
1983	439	2,945	1,789	-2,692	-1,387	-817	-410	-1,963	1,093	726	573	653	57
1984	598	1,675	-981	2,035	1,297	847	-1,699	-1,900	1,436	17	3,186	815	442
1985	-553	285	-389	478	1,029	1,065	1	-1,604	335	-5,432	1,435	2,737	-37
1986	-302	1,381	48	169	53	-1,172	-2,112	-3,744	1,761	579	1,552	3,336	94
1987	-66	-886	1,257	-563	-3,888	-4,089	-321	-968	818	-4,505	2,922	669	-580
1988	276	-820	112	160	-2,128	-431	-158	-756	-676	-2,231	-1,128	2,165	-339
1989	-838	1,891	830	1,425	-4,423	-132	147	-1,253	63	-5,530	390	2,893	-274
1990	4,564	2,946	2,763	129	676	1,159	-40	-413	-141	-3,996	-890	2,042	531
1991	-1,233	1,288	66	-1,861	-5,232	356	428	-466	-4,982	-4,567	-731	750	-976

Note: See "Notes and Acronyms" at end of tables section.

Table 3-5. Comparison of Delta Outflow (cfs) between DWRSIM Studies 771 and 409

Water Year	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Total (TAF)
DWRSIM Study 409 (1995 DEIR/EIS)													
1967	4,506	6,538	34,816	46,682	55,505	56,651	48,507	45,279	37,462	9,803	5,741	9,902	21,804
1968	16,772	11,630	11,134	28,914	67,389	33,948	10,325	7,579	6,840	7,724	5,259	4,158	12,771
1969	5,157	5,675	13,929	116,820	130,914	56,981	47,434	59,410	26,877	8,002	5,741	13,407	29,584
1970	17,934	14,092	55,147	205,170	91,229	35,248	11,579	7,959	7,579	9,358	5,741	3,872	28,049
1971	5,063	15,618	64,439	45,778	22,775	44,856	16,812	26,487	12,689	9,449	5,741	6,040	16,637
1972	8,528	6,661	12,423	9,956	19,716	25,452	9,811	7,579	6,840	7,840	6,820	3,791	7,567
1973	5,618	15,492	18,954	72,356	89,859	59,498	15,653	14,634	10,301	9,373	5,302	4,147	19,378
1974	5,615	59,398	65,122	126,767	42,649	106,026	70,318	20,652	12,454	8,002	5,741	9,345	32,103
1975	12,707	9,012	10,182	10,316	67,661	85,520	20,861	28,861	15,245	8,263	5,741	6,958	16,973
1976	13,567	11,491	6,355	5,879	11,385	9,744	7,475	6,366	6,897	5,750	3,415	3,008	5,510
1977	2,992	5,211	7,186	4,505	8,083	6,897	6,897	4,505	4,000	4,001	3,415	3,008	3,662
1978	2,992	3,537	6,832	59,011	60,344	67,366	40,512	17,640	8,774	8,002	5,302	5,227	17,228
1979	9,352	6,861	4,984	21,446	44,456	29,641	15,028	12,903	10,882	6,505	4,668	3,397	10,264
1980	4,001	9,948	12,113	107,524	132,325	69,498	16,291	12,000	7,579	8,002	5,302	5,436	23,531
1981	9,134	6,252	9,481	22,569	24,089	29,667	12,223	7,579	6,117	7,090	4,831	3,492	8,599
1982	4,793	26,967	87,982	77,836	95,820	82,058	142,617	48,242	16,998	8,002	5,801	16,124	36,999
1983	31,393	46,767	89,976	107,902	189,090	262,789	110,435	83,414	74,552	32,036	9,719	26,029	64,201
1984	37,420	83,000	159,165	85,443	49,713	36,149	13,094	9,792	8,231	8,845	5,741	5,638	30,301
1985	9,792	29,597	19,994	10,628	15,513	14,122	8,185	10,012	6,117	7,164	5,807	3,758	8,488
1986	4,675	5,194	7,089	11,205	219,765	150,695	31,242	10,807	7,579	8,002	5,741	4,037	28,117
1987	4,677	5,554	4,598	5,767	12,344	24,487	10,473	7,579	6,117	7,205	5,409	3,515	5,896
1988	4,001	4,740	6,877	17,924	11,400	7,804	7,300	6,496	6,897	5,491	3,415	3,008	5,150
1989	2,992	4,648	5,565	5,788	8,175	31,151	18,361	10,268	6,117	7,264	6,120	3,818	6,653
1990	4,001	4,504	6,416	7,862	11,400	7,310	10,251	5,910	6,897	5,584	3,447	3,008	4,621
1991	2,992	4,187	4,532	5,025	8,258	21,264	11,259	5,362	7,037	4,215	3,415	3,008	4,860
DWRSIM Study 771 (2000 REIR/EIS)													
1967	4,033	10,487	35,486	46,903	49,408	58,580	63,154	62,337	46,147	12,848	5,595	8,117	24,320
1968	10,392	6,689	13,043	30,445	58,465	36,153	13,293	12,116	5,126	6,505	4,342	3,008	12,041
1969	4,033	4,924	17,841	125,650	146,746	70,241	66,163	73,184	29,527	8,001	5,757	11,915	34,027
1970	10,018	10,050	55,083	206,998	91,181	41,162	14,721	12,799	6,604	8,001	5,578	3,008	28,067
1971	4,033	16,469	58,791	45,260	24,650	46,806	23,981	30,526	13,764	8,001	4,911	3,882	16,958
1972	4,050	4,504	10,880	16,963	19,714	25,533	10,655	12,197	6,218	6,505	4,180	3,008	7,506
1973	4,342	16,368	22,004	77,478	91,469	55,799	23,780	15,727	10,234	8,001	4,586	3,479	20,107
1974	5,432	56,583	66,533	131,618	45,608	113,338	76,229	31,664	13,646	8,506	6,668	9,461	34,106
1975	7,725	4,588	9,010	15,174	62,930	89,399	31,880	29,274	17,108	8,001	5,952	5,344	17,279
1976	12,051	5,260	6,700	10,864	17,420	14,653	8,218	7,562	6,285	4,001	2,992	3,008	5,974
1977	5,302	3,496	3,497	4,863	11,668	6,522	6,773	6,896	6,873	4,001	2,992	3,008	3,975
1978	5,416	3,496	5,253	57,653	55,151	71,200	52,416	27,387	9,579	8,001	4,521	3,748	18,331
1979	4,017	4,537	4,505	24,427	47,715	35,177	21,309	13,482	11,024	6,505	4,001	3,008	10,842
1980	4,342	5,848	13,076	98,799	136,419	64,906	25,830	20,914	10,638	8,001	4,456	3,865	23,958
1981	4,163	4,504	8,766	26,509	27,315	27,973	18,620	10,539	5,277	4,993	3,497	3,008	8,758
1982	4,033	31,560	83,414	74,648	103,569	89,529	150,239	55,262	20,452	8,001	5,595	11,713	38,494
1983	20,085	39,156	86,390	115,160	190,824	257,170	106,865	83,658	84,816	31,258	15,125	21,208	63,454
1984	17,532	78,733	156,940	73,119	42,732	36,023	18,671	15,434	9,646	8,001	5,269	3,075	28,066
1985	4,375	24,805	19,565	14,051	18,042	19,500	13,780	10,994	5,344	4,993	3,497	3,008	8,564
1986	4,033	4,958	10,978	20,898	220,786	153,167	33,644	21,158	10,066	8,001	5,188	4,100	29,984
1987	4,017	4,521	4,977	9,368	19,878	23,452	10,050	7,904	6,218	4,993	3,497	3,008	6,147
1988	4,033	4,504	8,701	20,231	11,022	11,433	7,596	7,497	6,436	4,001	2,992	3,008	5,518
1989	5,464	3,496	3,497	5,107	11,146	36,690	23,410	9,530	5,310	4,993	3,497	3,664	6,987
1990	4,017	4,504	4,521	11,026	12,802	9,953	10,218	7,985	6,134	4,001	2,992	3,008	4,897
1991	5,481	3,496	3,497	4,749	11,974	29,469	16,520	7,351	5,865	4,001	2,992	3,008	5,937
Change: DWRSIM 771 - DWRSIM 409													
1967	-473	3,949	670	221	-6,097	1,929	14,647	17,058	8,685	3,045	-146	-1,785	2,516
1968	-6,380	-4,941	1,909	1,531	-8,924	2,205	2,968	4,537	-1,714	-1,219	-917	-1,150	-730
1969	-1,124	-751	3,912	8,830	15,832	13,260	18,729	13,774	2,650	-1	16	-1,492	4,443
1970	-7,916	-4,042	-64	1,828	-48	5,914	3,142	4,840	-975	-1,357	-163	-864	18
1971	-1,030	851	-5,648	-518	1,875	1,950	7,169	4,039	1,075	-1,448	-830	-2,158	321
1972	-4,478	-2,157	-1,543	7,007	-2	81	844	4,618	-622	-1,335	-2,640	-783	-61
1973	-1,276	876	3,050	5,122	1,610	-3,699	8,127	1,093	-67	-1,372	-716	-668	729
1974	-183	-2,815	1,411	4,851	2,959	7,312	5,911	11,012	1,192	504	927	116	2,003
1975	-4,982	-4,424	-1,172	4,858	-4,731	3,879	11,019	413	1,863	-262	211	-1,614	305
1976	-1,516	-6,231	345	4,985	6,035	4,909	743	1,196	-612	-1,749	-423	0	464
1977	2,310	-1,715	-3,689	358	3,585	-375	-124	2,391	2,873	0	-423	0	313
1978	2,424	-41	-1,579	-1,358	-5,193	3,834	11,904	9,747	805	-1	-781	-1,479	1,103
1979	-5,335	-2,324	-479	2,981	3,259	5,536	6,281	579	142	0	-667	-389	578
1980	341	-4,100	963	-8,725	4,094	-4,592	9,539	8,914	3,059	-1	-846	-1,571	427
1981	-4,971	-1,748	-715	3,940	3,226	-1,694	6,397	2,960	-840	-2,097	-1,334	-484	159
1982	-760	4,593	-4,568	-3,188	7,749	7,471	7,622	7,020	3,454	-1	-206	-4,411	1,495
1983	-11,308	-7,611	-3,586	7,258	1,734	-5,619	-3,570	244	10,264	-778	5,406	-4,821	-747
1984	-19,888	-4,267	-2,225	-12,324	-6,981	-126	5,577	5,642	1,415	-844	-472	-2,563	-2,236
1985	-5,417	-4,792	-429	3,423	2,529	5,378	5,595	982	-773	-2,171	-2,310	-750	76
1986	-642	-236	3,889	9,693	1,021	2,472	2,402	10,351	2,487	-1	-553	63	1,867
1987	-660	-1,033	379	3,601	7,534	-1,035	-423	325	101	-2,212	-1,912	-507	251
1988	32	-236	1,824	2,307	-378	3,629	296	1,001	-461	-1,490	-423	0	368
1989	2,472	-1,152	-2,068	-681	2,971	5,539	5,049	-738	-807	-2,271	-2,623	-154	334
1990	16	0	-1,895	3,164	1,402	2,643	-33	2,075	-763	-1,583	-455	0	276
1991	2,489	-691	-1,035	-276	3,716	8,205	5,261	1,989	-1,172	-214	-423	0	1,077

Note: See "Notes and Acronyms" at end of tables section.

Table 3-6. Comparison of Required Delta Outflow (cfs) between DWRSIM Studies 771 and 409

Water Year	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Total (TAF)
DWRSIM Study 409 (1995 DEIR/EIS)													
1967	4,506	6,538	7,120	6,001	24,954	14,889	15,102	11,288	15,427	8,002	5,741	5,795	7,564
1968	4,001	5,464	4,685	6,001	9,901	20,302	10,325	7,579	6,840	7,724	5,259	4,158	5,565
1969	5,157	5,675	6,705	6,001	22,447	15,373	10,822	20,587	19,795	8,002	5,741	5,921	7,978
1970	4,001	4,562	4,885	6,001	16,029	12,369	11,579	7,579	7,579	9,358	5,741	3,872	5,644
1971	5,063	5,876	5,719	8,484	22,775	15,023	16,279	9,466	7,822	9,449	5,741	6,040	7,103
1972	5,475	6,485	6,235	6,103	11,400	11,400	9,811	7,579	6,840	7,840	6,820	3,791	5,417
1973	5,618	5,947	7,461	6,001	23,408	16,464	10,742	8,440	10,301	9,373	5,302	4,147	6,830
1974	5,615	7,269	6,591	6,001	17,027	12,241	16,292	15,365	8,779	8,002	5,741	6,333	6,954
1975	5,398	6,266	5,984	6,001	11,400	19,282	15,699	7,722	12,026	8,263	5,741	6,212	6,636
1976	5,242	6,313	6,355	5,865	8,609	8,007	7,475	6,366	6,897	5,750	3,415	3,008	4,423
1977	2,992	5,211	7,186	4,505	8,083	6,897	6,897	4,505	4,000	4,001	3,415	3,008	3,662
1978	2,992	3,537	6,832	6,001	28,559	19,427	21,202	15,808	8,774	8,002	5,302	5,227	7,944
1979	5,026	6,316	4,984	6,294	11,400	16,369	13,576	7,579	10,882	6,505	4,668	3,397	5,852
1980	4,001	6,096	6,397	6,001	23,044	16,110	11,084	9,962	7,579	8,002	5,302	5,436	6,577
1981	4,597	6,062	5,589	6,001	11,276	9,935	12,223	7,579	6,117	7,090	4,831	3,492	5,116
1982	4,793	7,477	7,160	6,001	18,180	17,080	13,890	15,768	9,704	8,002	5,801	3,975	7,109
1983	4,001	4,504	4,505	6,001	16,285	13,554	11,748	10,940	14,572	8,002	5,741	3,008	6,206
1984	4,001	4,504	4,505	6,001	14,676	12,102	12,388	7,579	8,231	8,845	5,741	5,638	5,684
1985	4,950	7,066	7,108	6,001	7,382	10,891	7,863	10,012	6,117	7,164	5,807	3,758	5,075
1986	4,675	5,194	6,742	6,993	11,400	19,425	14,337	8,034	7,579	8,002	5,741	4,037	6,164
1987	4,001	5,554	4,598	5,767	8,363	11,400	10,473	7,579	6,117	7,205	5,409	3,515	4,826
1988	4,001	4,740	6,877	7,344	11,400	7,804	7,300	6,496	6,897	5,491	3,415	3,008	4,511
1989	2,992	4,648	5,565	5,788	8,175	8,765	10,416	10,268	6,117	7,264	6,120	3,818	4,823
1990	4,001	4,504	6,416	6,418	11,400	6,949	10,251	5,910	6,897	5,584	3,447	3,008	4,512
1991	2,992	4,187	4,532	5,025	8,258	8,566	11,259	5,362	7,037	4,215	3,415	3,008	4,094
DWRSIM Study 771 (2000 REIR/EIS)													
1967	4,001	4,504	4,505	6,001	25,460	18,280	17,998	13,807	17,041	8,001	4,001	3,008	7,639
1968	4,001	4,504	4,505	6,001	10,118	22,915	13,360	6,863	5,327	6,505	4,407	3,008	5,521
1969	4,001	4,504	4,505	6,001	22,273	15,759	13,360	19,304	19,175	8,001	4,050	3,008	7,478
1970	4,001	4,504	4,505	6,001	16,223	15,043	14,688	5,253	6,621	8,001	5,611	3,008	5,639
1971	4,001	4,504	4,505	6,001	24,272	17,190	18,704	13,320	8,352	8,001	5,009	3,008	7,051
1972	4,001	4,504	4,505	6,001	11,005	11,401	9,848	9,823	6,386	6,505	4,196	3,008	4,898
1973	4,001	4,504	4,505	6,001	24,434	17,890	14,352	11,043	10,453	8,001	4,586	3,008	6,804
1974	4,001	4,504	4,505	6,001	17,249	15,174	17,074	17,337	9,428	8,001	4,424	3,008	6,679
1975	4,001	4,504	4,505	6,001	11,398	22,785	18,066	9,986	13,276	8,001	4,733	3,008	6,653
1976	4,001	4,504	4,505	4,505	6,589	6,505	7,798	6,115	6,705	4,001	2,992	3,008	3,694
1977	5,464	3,496	3,497	4,733	12,010	5,643	7,092	6,896	6,890	4,001	2,992	3,008	3,965
1978	5,448	3,496	3,497	9,807	28,467	22,004	20,066	18,020	9,663	8,001	4,521	3,008	8,205
1979	4,001	4,504	4,505	4,505	11,146	18,296	15,747	8,994	11,192	6,505	4,001	3,008	5,816
1980	4,001	4,504	4,505	6,001	23,052	16,686	14,974	10,961	8,991	8,001	4,554	3,008	6,591
1981	4,001	4,504	4,505	6,001	10,479	9,351	13,192	7,692	5,310	4,993	3,497	3,008	4,618
1982	4,001	4,504	4,505	6,001	19,572	17,467	16,099	15,450	12,856	8,001	4,001	3,008	6,966
1983	4,001	4,504	4,505	6,001	17,033	13,856	11,814	13,368	16,200	8,001	4,001	3,008	6,413
1984	4,001	4,504	4,505	6,001	16,498	16,279	15,511	8,408	9,865	8,001	5,253	3,008	6,144
1985	4,001	4,504	4,505	6,001	7,274	11,401	9,041	11,010	5,378	4,993	3,497	3,008	4,502
1986	4,001	4,504	4,505	6,001	11,398	18,540	14,839	10,929	8,235	8,001	5,237	3,008	5,985
1987	4,001	4,504	4,505	4,505	7,400	11,401	9,949	5,318	6,638	4,993	3,497	3,008	4,206
1988	4,001	4,504	4,505	6,001	11,005	11,401	7,193	6,261	6,705	4,001	2,992	3,008	4,318
1989	5,464	3,496	3,497	4,733	10,821	7,725	9,949	10,002	5,310	4,993	3,497	3,008	4,374
1990	4,001	4,504	4,505	4,505	11,398	6,652	10,234	5,708	6,319	4,001	2,992	3,008	4,092
1991	5,448	3,496	3,497	4,733	11,974	5,643	10,655	5,773	5,983	4,001	2,992	3,008	4,055
Change: DWRSIM 771 - DWRSIM 409													
1967	-505	-2,034	-2,615	0	506	3,391	2,896	2,519	1,614	-1	-1,740	-2,787	75
1968	0	-960	-180	0	217	2,613	3,035	-716	-1,513	-1,219	-852	-1,150	-44
1969	-1,156	-1,171	-2,200	0	-174	386	2,538	-1,283	-620	-1	-1,691	-2,913	-500
1970	0	-58	-380	0	194	2,674	3,109	-2,326	-958	-1,357	-130	-864	-6
1971	-1,062	-1,372	-1,214	-2,483	1,497	2,167	2,425	3,854	530	-1,448	-732	-3,032	-52
1972	-1,474	-1,981	-1,730	-102	-395	1	37	2,244	-454	-1,335	-2,624	-783	-519
1973	-1,617	-1,443	-2,956	0	1,026	1,426	3,610	2,603	152	-1,372	-716	-1,139	-26
1974	-1,614	-2,765	-2,086	0	222	2,933	782	1,972	649	-1	-1,317	-3,325	-275
1975	-1,397	-1,762	-1,479	0	-2	3,503	2,367	2,264	1,250	-262	-1,008	-3,204	16
1976	-1,241	-1,809	-1,850	-1,360	-2,020	-1,502	323	-251	-192	-1,749	-423	0	-728
1977	2,472	-1,715	-3,689	228	3,927	-1,254	195	2,391	2,890	0	-423	0	303
1978	2,456	-41	-3,335	3,806	-92	2,577	-1,136	2,212	889	-1	-781	-2,219	261
1979	-1,025	-1,812	-479	-1,789	-254	1,927	2,171	1,415	310	0	-667	-389	-36
1980	0	-1,592	-1,892	0	8	576	3,890	999	1,412	-1	-748	-2,428	14
1981	-596	-1,558	-1,084	0	-797	-584	969	113	-807	-2,097	-1,334	-484	-498
1982	-792	-2,973	-2,655	0	1,392	387	2,209	-318	3,152	-1	-1,800	-967	-143
1983	0	0	0	0	748	302	66	2,428	1,628	-1	-1,740	0	207
1984	0	0	0	0	1,822	4,177	3,123	829	1,634	-844	-488	-2,630	460
1985	-949	-2,562	-2,603	0	-108	510	1,178	998	-739	-2,171	-2,310	-750	-574
1986	-674	-690	-2,237	-992	-2	-885	502	2,895	656	-1	-504	-1,029	-179
1987	0	-1,050	-93	-1,262	-963	1	-524	-2,261	521	-2,212	-1,912	-507	-619
1988	0	-236	-2,372	-1,343	-395	3,597	-107	-235	-192	-1,490	-423	0	-193
1989	2,472	-1,152	-2,068	-1,055	2,646	-1,040	-467	-266	-807	-2,271	-2,623	-810	-449
1990	0	0	-1,911	-1,913	-2	-297	-17	-202	-578	-1,583	-455	0	-420
1991	2,456	-691	-1,035	-292	3,716	-2,923	-604	411	-1,054	-214	-423	0	-39

Note: See "Notes and Acronyms" at end of tables section.

Table 3-7. Comparison of Combined SWP and CVP San Luis Reservoir Storage (TAF) between DWRSIM Studies 771 and 409

Water Year	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
	DWRSIM Study 409 (1995 DEIR/EIS)											
1967	675	949	1,277	1,699	1,994	2,038	2,038	2,038	1,928	1,786	1,372	1,643
1968	1,812	1,948	2,005	2,038	2,038	2,038	1,794	1,434	961	768	415	401
1969	673	847	1,138	1,616	1,970	2,038	2,038	2,038	1,935	1,671	1,235	1,519
1970	1,819	1,955	2,012	2,038	2,038	2,038	1,867	1,552	1,090	886	448	419
1971	689	1,003	1,299	1,724	1,891	2,026	1,799	1,597	1,254	999	531	668
1972	1,010	1,288	1,538	1,847	1,972	2,038	1,742	1,310	797	590	449	439
1973	737	1,025	1,292	1,687	2,019	2,038	1,858	1,692	1,359	1,117	637	603
1974	956	1,245	1,513	1,847	1,977	2,038	1,982	1,964	1,734	1,302	871	1,096
1975	1,458	1,748	1,876	2,038	2,038	2,038	1,939	1,798	1,564	1,206	713	918
1976	1,261	1,538	1,747	1,906	2,031	2,037	1,783	1,507	1,267	985	613	548
1977	661	707	966	1,219	1,269	1,349	1,349	1,302	1,098	910	699	751
1978	907	1,044	1,554	1,853	2,038	2,038	2,038	2,038	1,816	1,158	672	776
1979	1,181	1,512	1,516	1,847	1,972	2,038	1,913	1,805	1,471	1,125	624	578
1980	778	1,101	1,401	1,847	1,998	2,038	2,038	1,996	1,613	1,104	635	871
1981	1,277	1,607	1,717	1,883	2,007	2,038	1,816	1,455	960	767	415	361
1982	591	908	1,196	1,648	1,940	2,023	2,038	2,038	1,935	1,615	1,255	1,469
1983	1,739	1,875	1,936	2,038	2,038	2,038	2,038	2,038	1,935	1,793	1,684	1,821
1984	1,981	2,038	2,038	2,038	2,038	2,038	1,901	1,617	1,188	944	486	682
1985	1,079	1,401	1,657	1,847	1,972	2,016	1,677	1,330	834	643	458	404
1986	623	737	1,014	1,402	1,794	2,030	2,038	1,921	1,596	1,126	632	695
1987	1,067	1,243	1,304	1,564	1,768	1,986	1,662	1,257	798	640	418	366
1988	463	512	776	1,163	1,182	1,129	891	666	480	386	160	107
1989	179	263	387	679	813	1,114	953	691	347	318	344	380
1990	426	355	465	878	912	881	736	560	425	339	168	155
1991	258	320	369	559	699	1,130	1,030	829	648	548	185	164
	DWRSIM Study 771 (2000 REIR/EIS)											
1967	253	582	1,030	1,509	1,799	1,876	1,891	1,719	1,724	1,637	1,495	1,509
1968	1,565	1,725	1,869	1,990	2,038	2,038	1,802	1,388	937	454	374	353
1969	519	851	1,277	1,754	1,895	1,990	1,961	1,730	1,750	1,631	1,435	1,440
1970	1,490	1,617	1,755	1,879	2,037	2,038	1,849	1,485	1,066	724	510	533
1971	715	1,073	1,504	1,875	1,929	1,992	1,779	1,385	1,073	840	685	785
1972	1,041	1,311	1,661	1,806	1,945	2,024	1,695	1,206	728	270	152	163
1973	321	633	1,008	1,486	1,874	1,949	1,806	1,430	1,161	952	663	792
1974	1,074	1,403	1,703	1,871	1,998	2,038	1,888	1,498	1,297	1,083	946	1,068
1975	1,344	1,592	1,751	1,893	2,033	2,038	1,899	1,532	1,326	1,053	888	983
1976	1,237	1,544	1,710	1,851	2,010	2,038	1,771	1,354	1,016	662	440	415
1977	492	578	696	916	916	916	876	665	444	279	206	262
1978	138	197	684	1,329	1,809	1,951	1,961	1,768	1,510	927	677	820
1979	1,107	1,302	1,433	1,546	1,702	1,783	1,651	1,307	1,055	751	375	442
1980	705	1,071	1,505	1,764	1,937	2,038	2,038	1,838	1,657	1,361	1,340	1,533
1981	1,848	1,992	2,038	2,038	2,038	2,038	1,832	1,409	956	469	358	302
1982	432	789	1,211	1,721	1,876	1,969	1,899	1,605	1,528	1,313	1,154	1,253
1983	1,506	1,852	2,030	2,038	2,038	2,038	2,038	1,897	1,842	1,716	1,588	1,651
1984	1,822	2,004	2,038	2,038	2,038	2,038	1,816	1,396	1,081	878	649	795
1985	1,053	1,417	1,698	1,852	1,991	2,038	1,726	1,228	720	170	80	121
1986	142	331	709	1,222	1,733	1,985	1,989	1,744	1,622	1,265	933	1,096
1987	1,371	1,525	1,800	2,038	2,038	2,038	1,758	1,295	896	490	443	308
1988	321	408	728	1,255	1,276	1,276	1,102	836	628	398	130	123
1989	80	299	589	1,031	1,031	1,545	1,357	886	410	80	80	123
1990	262	343	639	1,155	1,349	1,431	1,306	1,046	879	551	315	312
1991	241	320	440	566	510	1,056	1,096	997	727	445	366	457
	Change: DWRSIM 771 - DWRSIM 409											
1967	-422	-367	-247	-190	-195	-162	-147	-319	-204	-149	123	-134
1968	-247	-223	-136	-48	0	0	8	-46	-24	-314	-41	-48
1969	-154	4	139	138	-75	-48	-77	-308	-185	-40	200	-79
1970	-329	-338	-257	-159	-1	0	-18	-67	-24	-162	62	114
1971	26	70	205	151	38	-34	-20	-212	-181	-159	154	117
1972	31	23	123	-41	-27	-14	-47	-104	-69	-320	-297	-276
1973	-416	-392	-284	-201	-145	-89	-52	-262	-198	-165	26	189
1974	118	158	190	24	21	0	-94	-466	-437	-219	75	-28
1975	-114	-156	-125	-145	-5	0	-40	-266	-238	-153	175	65
1976	-24	6	-37	-55	-21	1	-12	-153	-251	-323	-173	-133
1977	-169	-129	-270	-303	-353	-433	-473	-637	-654	-631	-493	-489
1978	-769	-847	-870	-524	-229	-87	-77	-270	-306	-231	5	44
1979	-74	-210	-83	-301	-270	-255	-262	-498	-416	-374	-249	-136
1980	-73	-30	104	-83	-61	0	0	-158	44	257	705	662
1981	571	385	321	155	31	0	16	-46	-4	-298	-57	-59
1982	-159	-119	15	73	-64	-54	-139	-433	-407	-302	-101	-216
1983	-233	-23	94	0	0	0	0	-141	-93	-77	-96	-170
1984	-159	-34	0	0	0	0	-85	-221	-107	-66	163	113
1985	-26	16	41	5	19	22	49	-102	-114	-473	-378	-283
1986	-481	-406	-305	-180	-61	-45	-49	-177	26	139	301	401
1987	304	282	496	474	270	52	96	38	98	-150	25	-58
1988	-142	-104	-48	92	94	147	211	170	148	12	-30	16
1989	-99	36	202	352	218	431	404	195	63	-238	-264	-257
1990	-164	-12	174	277	437	550	570	486	454	212	147	157
1991	-17	0	71	7	-189	-74	66	168	79	-103	181	293

Note: See "Notes and Acronyms" at end of tables section.

Table 3-8. Comparison of Combined CVP and SWP Deliveries (Banks + Tracy - San Luis Reservoir Storage Change) between DWRSIM Studies 771 and 409

Water Year	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Total (TAF)
DWRSIM Study 409 (1995 DEIR/EIS)													
1967	5,108	6,067	6,192	5,053	5,472	5,636	7,644	8,128	12,106	13,084	12,660	6,689	5,662
1968	6,594	5,355	5,949	3,702	4,835	6,480	8,766	9,725	13,873	14,426	13,279	6,919	6,028
1969	4,650	5,623	6,516	4,599	5,258	5,541	6,727	7,690	11,331	10,871	12,451	6,470	5,293
1970	6,148	5,601	6,500	4,277	4,822	6,543	8,864	9,829	14,032	14,605	13,447	7,013	6,135
1971	4,663	5,664	6,597	4,706	6,021	7,994	9,931	10,989	14,792	15,434	14,251	7,759	6,564
1972	5,465	6,269	7,198	5,866	6,300	7,370	9,552	10,950	14,491	14,653	13,580	7,462	6,586
1973	5,267	6,101	6,908	5,149	6,404	7,527	9,797	9,630	13,382	15,046	13,930	7,437	6,430
1974	5,122	6,084	6,993	5,605	5,978	7,500	9,491	8,994	12,729	15,091	13,922	7,462	6,333
1975	5,140	6,067	7,811	5,005	6,018	7,644	9,930	11,049	14,371	15,492	14,259	7,798	6,672
1976	5,449	6,286	7,187	5,876	6,295	5,940	7,339	7,757	9,929	12,209	9,597	5,134	5,370
1977	3,596	5,660	6,845	729	5,167	2,896	2,825	3,158	4,504	4,874	4,373	2,706	2,856
1978	1,878	1,024	2,518	5,500	2,122	5,280	6,313	6,696	10,344	13,540	12,377	6,471	4,468
1979	4,440	5,378	6,266	5,324	5,585	7,041	8,705	8,268	13,713	14,491	13,335	6,890	5,999
1980	4,575	5,513	6,453	5,368	5,456	5,445	6,262	7,455	12,117	11,510	12,500	6,479	5,378
1981	4,424	5,395	7,376	4,618	5,541	6,735	8,757	9,745	13,853	14,426	13,276	6,912	6,097
1982	4,641	5,614	6,533	4,664	6,467	7,392	8,355	9,742	13,008	13,793	13,978	7,647	6,144
1983	6,636	6,012	6,944	4,448	4,628	4,948	6,594	6,273	9,410	10,105	11,950	6,086	5,070
1984	4,460	4,341	5,242	3,218	4,144	6,341	8,572	9,723	13,873	14,473	13,305	6,949	5,710
1985	4,571	5,530	7,545	4,710	5,777	6,692	9,393	10,061	13,815	14,393	13,267	7,346	6,220
1986	5,164	5,996	6,815	5,100	5,763	6,409	8,213	9,257	11,784	14,091	13,085	7,016	5,954
1987	4,977	5,978	6,793	4,971	6,085	7,293	9,245	10,043	13,248	13,857	12,365	6,894	6,139
1988	5,009	5,291	6,882	4,979	6,040	5,586	6,964	6,773	8,894	8,850	8,560	4,389	4,719
1989	3,456	3,991	4,911	3,568	4,423	6,507	8,172	8,311	11,281	11,759	10,864	5,896	5,016
1990	4,722	5,120	6,052	4,538	5,464	4,972	6,057	5,666	8,073	8,729	7,802	4,075	4,300
1991	2,990	2,812	4,276	3,081	3,863	4,133	5,471	6,142	8,495	6,648	10,132	4,897	3,797
DWRSIM Study 771 (2000 REIR/EIS)													
1967	6,652	5,462	4,066	4,098	5,510	6,310	6,604	7,936	11,192	12,702	13,596	11,041	5,742
1968	7,969	5,747	5,627	5,595	5,980	7,058	8,134	9,758	12,991	13,336	12,295	8,319	6,203
1969	6,034	4,958	4,277	4,375	3,547	4,635	6,554	7,790	10,940	12,588	13,791	9,075	5,343
1970	6,928	5,075	4,245	5,546	5,474	7,091	8,117	9,758	12,991	13,401	12,328	8,369	5,992
1971	6,034	4,958	4,261	5,595	6,158	7,904	9,092	10,994	14,553	15,076	13,807	9,512	6,513
1972	7,009	5,815	5,481	6,310	6,224	7,644	8,756	10,587	13,948	14,295	13,206	8,588	6,508
1973	7,140	5,731	5,042	3,789	5,762	7,497	8,621	10,376	12,789	14,263	13,092	8,991	6,220
1974	6,554	5,445	6,505	5,139	6,356	7,562	8,571	10,376	13,444	14,767	13,515	9,142	6,478
1975	6,700	6,403	6,278	5,790	6,374	7,969	9,193	11,108	14,738	15,271	13,970	9,613	6,842
1976	7,058	5,831	7,416	5,822	5,754	6,489	7,310	8,961	11,764	11,856	11,140	8,251	5,892
1977	6,050	5,159	4,407	2,098	2,125	2,618	3,462	3,887	4,840	3,806	5,220	3,546	2,849
1978	2,716	2,218	1,789	1,496	4,105	4,977	5,899	7,172	12,369	14,621	13,889	8,873	4,834
1979	6,619	6,386	4,733	5,660	5,402	6,928	7,999	9,465	12,839	13,238	12,181	8,151	6,009
1980	5,920	4,823	4,163	4,277	3,460	3,952	5,226	6,538	10,873	10,978	11,628	7,898	4,811
1981	5,952	4,638	5,123	5,025	5,924	7,058	8,201	9,872	13,159	13,580	12,425	8,386	5,994
1982	6,066	4,974	4,310	4,424	6,842	7,400	7,226	8,815	12,570	14,783	13,873	9,545	6,083
1983	7,074	5,176	6,635	3,139	3,079	3,984	6,016	6,326	9,361	10,197	12,441	7,646	4,892
1984	4,602	3,680	3,497	5,074	5,302	7,042	8,134	9,758	13,058	13,450	12,360	8,268	5,685
1985	5,985	4,857	6,554	5,595	6,392	7,562	8,772	10,604	14,016	14,442	12,750	8,151	6,376
1986	7,790	5,882	5,025	3,106	3,547	4,830	5,999	7,302	9,781	12,458	11,596	8,335	5,168
1987	6,196	5,210	4,424	4,619	5,726	6,603	7,999	9,742	12,722	13,011	12,051	8,638	5,849
1988	6,375	3,613	5,904	2,732	3,755	4,163	5,596	6,456	8,268	8,294	7,741	5,495	4,126
1989	4,472	3,613	2,879	2,423	2,305	2,814	8,604	10,197	13,243	10,766	11,287	8,352	4,884
1990	7,514	5,025	5,611	2,879	3,115	4,066	5,495	6,359	8,201	8,619	7,725	5,647	4,239
1991	4,326	3,596	2,992	2,098	1,981	2,423	3,361	3,757	4,739	4,716	4,489	3,479	2,531
Change: DWRSIM 771 - DWRSIM 409													
1967	1,544	-606	-2,126	-955	37	674	-1,040	-192	-913	-383	936	4,352	80
1968	1,375	392	-322	1,892	1,145	578	-633	33	-882	-1,090	-984	1,399	175
1969	1,383	-665	-2,239	-224	-1,711	-906	-173	100	-391	1,716	1,340	2,605	50
1970	780	-526	-2,255	1,269	652	548	-747	-71	-1,042	-1,204	-1,120	1,356	-142
1971	1,371	-707	-2,336	888	137	-91	-839	5	-239	-358	-444	1,753	-52
1972	1,544	-454	-1,717	444	-76	274	-797	-362	-543	-358	-374	1,125	-78
1973	1,873	-370	-1,866	-1,360	-642	-30	-1,176	746	-593	-783	-838	1,553	-210
1974	1,432	-639	-488	-466	378	62	-920	1,382	715	-324	-408	1,680	145
1975	1,561	335	-1,534	784	356	325	-737	59	367	-221	-289	1,815	170
1976	1,610	-454	229	-54	-541	549	-28	1,204	1,834	-353	1,543	3,117	522
1977	2,454	-501	-2,438	1,369	-3,042	-278	637	729	336	-1,069	848	840	-7
1978	838	1,195	-729	-4,004	1,983	-303	-414	476	2,025	1,080	1,512	2,402	366
1979	2,179	1,008	-1,533	336	-184	-113	-705	1,197	-874	-1,253	-1,154	1,261	10
1980	1,344	-690	-2,290	-1,090	-1,996	-1,494	-1,036	-917	-1,244	-532	-872	1,420	-567
1981	1,528	-757	-2,253	407	383	323	-556	127	-694	-846	-851	1,473	-103
1982	1,425	-639	-2,223	-240	375	8	-1,129	-927	-438	990	-105	1,899	-61
1983	439	-836	-309	-1,309	-1,549	-964	-578	53	-49	92	492	1,561	-178
1984	143	-661	-1,745	1,856	1,158	701	-439	35	-816	-1,024	-945	1,319	-25
1985	1,414	-673	-991	885	615	870	-621	542	200	48	-516	804	156
1986	2,626	-114	-1,790	-1,994	-2,216	-1,579	-2,213	-1,955	-2,003	-1,633	-1,489	1,319	-787
1987	1,219	-769	-2,369	-352	-359	-690	-1,246	-301	-526	-846	-314	1,744	-290
1988	1,366	-1,677	-978	-2,247	-2,285	-1,423	-1,367	-317	-626	-556	-819	1,107	-593
1989	1,016	-378	-2,033	-1,145	-2,119	-3,693	433	1,886	1,962	-992	423	2,456	-132
1990	2,792	-95	-441	-1,660	-2,349	-906	-561	693	128	-109	-77	1,571	-61
1991	1,336	784	-1,284	-983	-1,883	-1,709	-2,109	-2,385	-3,756	-1,932	-5,643	-1,418	-1,266

Note: See "Notes and Acronyms" at end of tables section.

Table 3-9. South-of-Delta SWP and CVP Deliveries (Exports/Interruptible/Local/Changes in Reservoirs) (cfs) for DWRSIM Study 771

Water Year	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Total (TAF)
1922	7,011	5,600	5,038	4,611	5,665	6,692	7,939	8,860	13,069	14,720	13,331	8,715	6,109
1923	6,377	5,129	6,844	5,456	4,458	6,286	8,645	10,210	13,540	13,955	12,859	8,799	6,188
1924	6,474	5,297	4,583	3,179	2,757	3,570	4,729	5,559	7,104	7,076	6,793	5,237	3,762
1925	3,856	3,348	2,761	1,521	2,099	5,164	6,998	8,226	10,734	11,207	10,095	6,850	4,396
1926	5,255	4,188	3,607	2,968	3,090	5,359	7,199	9,088	11,927	12,183	11,298	8,077	5,082
1927	5,938	4,944	4,209	3,228	6,853	7,392	8,577	10,291	13,473	14,297	13,054	8,631	6,087
1928	6,247	5,079	5,738	5,554	5,886	7,180	8,426	10,178	13,523	13,890	12,811	8,782	6,232
1929	6,442	5,297	4,567	3,066	3,306	4,334	5,838	6,795	8,784	8,979	8,306	5,993	4,326
1930	4,555	3,734	3,136	2,415	3,900	5,180	7,670	9,104	11,826	12,118	11,200	8,144	5,007
1931	6,117	5,079	4,339	2,561	2,658	3,326	4,578	5,299	6,784	6,068	6,891	4,850	3,532
1932	3,677	3,096	2,550	1,830	3,348	4,497	6,090	7,120	9,221	9,402	8,680	6,228	3,966
1933	4,702	3,885	3,266	2,285	2,370	2,724	4,527	5,266	6,717	6,653	6,322	4,850	3,232
1934	3,628	3,129	2,550	1,683	2,478	3,976	5,368	6,258	8,045	8,166	7,558	5,556	3,523
1935	4,246	3,532	2,957	2,074	3,090	4,172	7,653	10,259	13,775	14,183	13,054	8,749	5,294
1936	6,312	5,179	4,485	2,968	3,383	7,684	7,922	9,234	13,557	14,004	12,843	8,598	5,802
1937	6,198	5,112	4,388	3,245	4,944	6,497	6,292	7,039	12,028	13,370	12,290	8,211	5,407
1938	5,954	4,826	3,786	5,668	5,376	6,611	7,065	8,193	11,557	13,679	13,900	10,866	5,881
1939	8,101	6,272	5,673	5,651	5,611	6,513	7,636	9,218	12,280	12,557	11,623	7,909	5,976
1940	5,743	4,658	3,965	2,545	3,696	6,530	9,031	10,649	14,195	14,639	13,152	9,135	5,909
1941	6,718	5,566	4,648	3,635	4,800	6,269	8,897	9,055	12,565	14,411	10,176	8,497	5,746
1942	7,808	4,911	4,144	5,424	5,665	6,985	8,056	9,657	11,322	14,021	12,778	8,396	5,983
1943	7,775	6,053	5,364	4,968	6,079	5,863	7,351	7,039	12,028	13,272	12,209	8,245	5,807
1944	6,019	4,877	4,193	5,847	5,365	6,790	7,788	9,397	12,549	12,866	11,900	8,009	5,768
1945	5,808	4,709	4,030	3,749	5,755	7,034	8,157	9,803	12,649	13,516	12,420	8,329	5,790
1946	6,052	4,927	4,241	6,253	5,106	7,505	8,846	10,665	14,179	14,704	13,445	9,018	6,331
1947	6,653	5,415	4,746	4,106	5,611	6,627	8,830	10,698	14,179	13,939	12,095	9,152	6,157
1948	7,710	6,289	5,055	2,757	2,740	3,261	6,326	11,153	14,666	14,801	13,071	9,808	5,891
1949	7,938	6,087	5,347	3,537	3,558	4,806	8,359	9,852	12,868	13,289	12,193	8,530	5,814
1950	6,474	5,280	4,583	2,805	3,810	5,261	8,661	10,275	13,456	13,874	12,794	9,018	5,810
1951	6,751	5,465	4,388	6,221	6,745	7,636	8,779	10,633	14,061	14,508	13,347	9,253	6,503
1952	6,848	5,633	4,843	4,611	4,565	6,172	6,796	7,949	11,238	15,126	13,705	8,951	5,818
1953	6,865	5,011	4,404	5,700	6,151	7,001	8,309	10,080	13,473	13,972	12,778	8,497	6,168
1954	6,182	6,860	5,429	5,651	6,601	7,587	8,981	10,861	14,363	14,850	13,624	9,354	6,657
1955	6,930	5,684	4,973	4,269	5,629	5,814	7,418	8,942	11,691	12,069	11,087	7,741	5,565
1956	5,808	4,726	3,737	4,090	6,704	6,839	8,712	10,129	13,725	15,338	14,014	9,539	6,236
1957	7,076	5,784	5,412	6,448	6,385	7,603	8,729	10,584	13,977	14,395	13,282	9,219	6,570
1958	6,832	5,616	4,876	5,944	5,791	7,327	7,670	8,519	10,582	14,183	12,924	8,581	5,964
1959	8,946	6,171	5,461	5,245	5,953	5,895	8,275	9,934	13,254	13,712	11,022	8,346	6,167
1960	6,100	4,961	4,290	2,968	2,844	6,660	8,443	10,259	13,439	13,809	12,469	8,967	5,744
1961	6,702	5,549	4,811	3,212	4,152	6,237	8,140	9,820	12,817	12,606	10,729	8,514	5,628
1962	6,426	5,280	4,567	2,838	2,730	7,733	9,535	11,479	15,271	15,679	12,453	9,976	6,273
1963	7,320	6,087	5,364	4,497	6,403	7,359	8,577	10,389	13,221	14,769	13,494	9,068	6,428
1964	6,686	5,616	6,941	5,782	5,174	5,830	8,594	10,194	13,439	12,963	11,249	8,329	6,081
1965	7,418	6,137	4,859	3,781	5,358	7,424	7,804	10,291	13,574	14,037	12,908	9,001	6,190
1966	6,686	5,482	7,088	5,326	6,457	7,636	8,863	10,682	14,195	14,541	11,444	9,001	6,480
1967	6,621	5,431	4,030	4,074	5,485	6,237	6,561	7,933	11,170	12,687	13,575	10,950	5,717
1968	7,971	5,684	5,559	5,586	5,852	7,001	8,090	9,738	12,969	13,370	12,258	8,261	6,174
1969	6,003	4,911	4,225	4,350	3,504	4,578	6,510	7,754	10,902	12,524	13,754	8,984	5,309
1970	6,897	5,028	4,176	5,521	5,467	6,969	8,073	9,722	12,985	13,386	12,274	8,261	5,959
1971	6,019	4,911	4,209	5,554	6,133	7,847	9,065	10,958	14,498	15,061	13,770	9,438	6,484
1972	7,011	5,734	5,461	6,253	6,182	7,571	8,678	10,535	13,876	14,281	13,120	8,665	6,478
1973	6,979	5,667	4,990	3,765	5,899	7,408	8,577	10,340	12,733	14,199	13,054	8,934	6,187
1974	6,539	5,381	6,437	5,115	6,331	7,440	8,561	10,340	13,406	14,752	13,477	9,085	6,447
1975	6,686	6,322	6,226	5,765	6,349	7,847	9,166	11,072	14,700	15,257	13,965	9,505	6,809
1976	7,060	5,768	7,380	5,798	5,660	6,351	7,132	8,779	11,490	11,614	10,924	8,060	5,793
1977	5,938	5,062	4,306	2,074	2,099	2,578	3,418	3,867	4,835	3,547	5,183	3,506	2,800
1978	2,701	2,154	1,769	1,472	4,080	4,936	5,855	7,136	12,347	14,622	13,868	8,816	4,812
1979	6,572	6,356	4,664	5,635	5,376	6,871	7,956	9,446	12,801	13,191	12,144	8,093	5,979
1980	5,905	4,759	4,111	4,253	3,418	3,846	5,166	6,502	10,834	10,947	11,591	7,841	4,777
1981	5,889	4,591	5,071	4,985	5,917	7,018	8,174	9,836	13,120	13,533	12,388	8,295	5,962
1982	6,052	4,927	4,258	4,383	6,835	7,343	7,199	8,779	12,498	14,769	13,851	9,488	6,056
1983	7,027	5,129	6,583	3,098	3,018	3,928	5,956	6,291	9,305	10,166	12,404	7,556	4,854
1984	4,588	3,633	3,445	5,050	5,261	6,985	8,107	9,722	12,985	13,419	12,323	8,194	5,654
1985	5,986	4,810	6,502	5,570	6,367	7,489	8,729	10,584	13,977	14,378	12,745	8,093	6,349
1986	7,775	5,818	4,990	3,082	3,450	4,790	5,956	7,283	9,776	12,476	11,607	8,278	5,145
1987	6,198	5,179	4,306	4,529	5,683	6,546	7,905	9,592	12,549	12,850	11,884	8,497	5,775
1988	6,328	3,936	5,656	2,724	3,748	4,172	5,620	6,470	8,364	8,589	7,834	5,539	4,162
1989	4,246	3,432	2,892	2,415	2,244	2,757	8,577	10,161	13,221	10,947	11,266	8,295	4,854
1990	7,483	4,188	5,998	3,488	3,090	4,025	5,435	6,339	8,146	8,280	7,655	5,606	4,207
1991	4,279	3,532	2,957	2,074	1,955	2,366	3,301	3,705	4,717	4,669	4,451	3,422	2,499
1992	2,620	2,104	1,737	1,342	1,905	3,131	5,267	6,128	7,893	7,987	7,444	5,505	3,201
1993	4,198	3,482	2,924	2,318	4,962	7,782	8,897	9,608	13,288	14,980	13,152	8,698	5,689
1994	6,344	5,095	6,844	5,440	5,575	5,229	7,972	9,348	12,448	11,483	10,778	7,942	5,701
Minimum	2,620	2,104	1,737	1,342	1,905	2,366	3,301	3,705	4,717	3,547	4,451	3,422	2,499
Average	6,209	4,994	4,629	4,081	4,698	5,971	7,493	8,947	12,010	12,662	11,677	8,155	5,522
Maximum	8,946	6,860	7,380	6,448	6,853	7,847	9,535	11,479	15,271	15,679	14,014	10,950	6,809

Note: See "Notes and Acronyms" at end of tables section.

Table 3-10. South-of-Delta SWP and CVP Delivery Deficits (cfs) for DWRSIM Study 771

Water Year	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Total (TAF)
1922	360	335	305	43	1,141	506	429	464	677	802	629	262	359
1923	206	124	191	317	717	799	1,101	1,212	1,736	2,070	1,605	649	647
1924	525	328	461	1,982	3,493	3,797	5,290	6,208	8,565	9,345	8,063	4,616	3,178
1925	3,450	2,570	2,575	3,641	4,274	2,204	3,022	3,541	4,936	5,182	4,713	2,969	2,599
1926	2,068	1,747	1,729	1,960	3,022	1,748	2,536	2,302	3,299	3,771	3,094	1,372	1,728
1927	1,027	664	835	1,418	691	457	647	707	1,013	1,208	938	380	603
1928	314	192	256	447	1,136	951	1,118	1,244	1,770	2,119	1,654	665	716
1929	542	328	477	2,096	3,068	3,033	4,181	4,972	6,885	7,443	6,551	3,843	2,620
1930	2,751	2,184	2,201	2,747	2,474	2,187	2,349	2,663	3,843	4,287	3,623	1,725	1,993
1931	1,206	856	998	2,600	3,716	4,041	5,442	6,452	8,868	9,768	8,405	4,952	3,457
1932	3,646	2,805	2,787	2,817	2,345	2,297	3,304	3,819	5,456	5,995	5,162	2,649	2,599
1933	1,816	1,331	1,427	2,626	3,724	4,383	5,208	6,108	8,492	9,268	8,022	4,515	3,434
1934	3,303	2,462	2,494	3,479	3,878	3,391	4,652	5,509	7,608	8,223	7,234	4,246	3,408
1935	3,044	2,385	2,380	2,573	2,707	2,622	1,840	1,000	1,450	1,761	1,345	531	1,426
1936	428	276	400	1,679	1,789	652	899	984	1,400	1,680	1,312	531	726
1937	428	259	368	1,061	2,061	1,238	1,017	1,130	1,618	1,940	1,491	598	797
1938	493	309	433	703	747	7	0	0	0	0	0	0	162
1939	0	8	18	30	1,090	1,205	1,454	1,602	2,291	2,737	2,126	867	810
1940	688	428	611	2,366	2,284	717	882	968	1,400	1,664	1,573	531	851
1941	428	259	368	597	593	1	1	0	0	233	2,922	0	326
1942	6	0	21	30	730	733	1,017	756	1,081	1,306	1,003	413	428
1943	339	209	302	471	744	815	1,118	1,228	1,753	2,103	1,638	665	687
1944	542	331	470	755	1,288	945	1,302	1,423	2,038	2,444	1,898	783	858
1945	623	377	546	898	1,412	815	1,050	1,163	1,669	1,989	1,540	632	767
1946	515	309	451	724	735	642	697	756	1,081	1,306	1,003	413	521
1947	330	210	298	1,055	2,149	1,813	1,151	1,260	1,803	2,168	2,126	682	908
1948	542	343	481	2,422	3,545	4,123	3,660	838	1,215	1,485	1,134	430	1,220
1949	363	225	335	1,673	2,834	2,561	1,660	1,898	2,784	3,084	2,631	1,288	1,287
1950	848	654	754	2,357	2,564	2,106	1,358	1,492	2,196	2,515	2,046	835	1,190
1951	588	369	526	779	727	772	1,050	1,163	1,652	1,973	1,540	632	710
1952	509	318	445	691	57	0	0	0	0	0	0	0	122
1953	3	10	25	26	709	817	899	886	1,282	1,534	1,182	481	474
1954	401	242	354	551	835	805	849	935	1,349	1,615	1,247	514	585
1955	411	268	363	1,049	1,437	1,455	2,116	2,449	3,518	3,885	3,322	1,692	1,325
1956	1,173	883	981	860	764	441	613	675	980	1,160	906	363	591
1957	298	184	266	421	1,088	805	1,101	1,212	1,736	2,087	1,621	665	693
1958	525	335	461	732	1,070	473	647	707	1,013	1,208	938	380	512
1959	314	196	291	443	907	671	933	1,033	1,467	1,761	2,825	565	688
1960	450	276	403	2,194	3,406	2,090	1,375	1,508	2,213	2,564	2,290	835	1,183
1961	588	385	526	1,950	2,474	2,220	1,677	1,947	2,835	3,767	4,046	1,305	1,431
1962	881	654	770	2,324	3,644	1,147	630	691	997	1,241	2,922	380	982
1963	298	192	254	431	735	799	664	740	1,047	1,257	971	397	470
1964	314	194	282	454	990	1,042	1,437	1,586	2,257	3,014	2,922	850	926
1965	688	436	591	1,186	1,070	1,439	2,013	1,475	2,112	2,385	1,964	902	981
1966	669	469	591	691	717	496	681	740	1,064	1,452	2,922	397	657
1967	330	194	282	459	693	782	781	138	190	233	174	77	261
1968	54	49	76	101	799	817	1,118	1,228	1,753	2,103	1,638	665	627
1969	548	326	468	739	446	0	0	0	0	0	0	0	152
1970	3	10	25	26	781	850	1,134	1,244	1,770	2,119	1,654	682	621
1971	548	326	484	746	493	561	765	838	1,198	1,436	1,117	447	541
1972	363	234	315	519	1,129	838	1,139	1,228	1,776	2,119	1,639	665	722
1973	556	352	477	1,195	943	750	1,000	1,098	1,568	1,875	1,459	598	716
1974	477	292	412	675	843	691	681	756	1,081	1,290	1,003	413	520
1975	330	210	298	470	1,088	545	664	724	1,030	1,241	955	397	480
1976	314	201	282	454	1,615	1,911	2,685	2,988	4,179	4,792	3,916	1,793	1,516
1977	1,369	873	1,030	3,072	4,274	4,773	6,568	7,867	10,767	12,110	10,193	6,296	4,175
1978	4,670	3,679	3,567	2,988	1,205	717	513	0	0	0	0	0	1,046
1979	0	0	0	30	1,378	847	1,101	1,212	1,753	2,087	1,621	665	645
1980	525	327	464	743	1,156	799	1,085	1,195	1,719	2,054	1,589	649	742
1981	531	326	470	735	889	801	1,034	1,130	1,618	1,940	1,508	615	700
1982	499	309	435	678	709	799	647	707	1,013	1,208	938	380	502
1983	319	192	284	434	467	1	1	0	0	0	0	0	102
1984	6	0	21	30	870	717	983	1,098	1,568	1,875	1,459	598	557
1985	477	293	416	665	1,070	903	1,101	1,212	1,719	2,070	1,654	649	738
1986	525	335	461	1,785	1,967	1,221	1,689	1,862	2,643	3,144	2,467	1,035	1,154
1987	818	494	660	1,413	1,825	1,862	1,912	2,175	3,104	3,539	2,924	1,356	1,332
1988	995	705	851	2,519	2,502	3,196	4,383	5,265	7,271	7,768	6,941	4,246	2,814
1989	3,044	2,452	2,445	2,747	4,130	4,611	1,442	1,589	2,415	4,320	3,526	919	2,030
1990	588	385	559	2,357	3,302	3,407	4,568	5,411	7,490	8,093	7,136	4,213	2,866
1991	3,028	2,385	2,380	3,072	4,400	4,985	6,685	8,030	10,935	11,704	10,340	6,397	4,485
1992	4,751	3,746	3,600	3,570	4,092	3,976	4,468	5,262	7,332	7,967	6,981	3,910	3,599
1993	2,751	2,109	2,120	2,235	781	408	244	252	375	444	711	145	759
1994	119	74	91	186	1,180	961	1,319	1,456	2,089	3,762	2,922	800	903
Minimum	0	0	0	26	57	0	0	0	0	0	0	0	102
Average	924	668	754	1,301	1,734	1,493	1,709	1,855	2,614	3,015	2,652	1,247	1,205
Maximum	4,751	3,746	3,600	3,641	4,400	4,985	6,685	8,030	10,935	12,110	10,340	6,397	4,485

Note: See "Notes and Acronyms" at end of tables section.

Table 3-11. Available Water for Delta Wetlands Diversions under the 1995 Water Quality Control Plan and Delta Wetlands Final Operations Criteria (cfs)

Delta Wetlands%	90%	90%	90%	90%	75%	50%	0%	0%	50%	75%	90%	90%	
Water Year	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Oct - Mar (TAF)
1922	0	0	416	2,102	2,783	2,376	0	0	2,024	0	0	0	461
1923	0	0	14,793	14,456	0	0	0	0	0	51	0	0	1,755
1924	0	0	0	0	0	0	0	0	0	0	0	0	0
1925	0	0	0	0	7,038	0	0	0	0	0	0	0	422
1926	0	0	0	109	2,128	0	0	0	0	0	0	0	134
1927	0	3,199	0	9,823	19,849	2,314	0	0	0	0	0	0	2,111
1928	0	1,218	0	7,132	2,213	6,505	0	0	0	0	0	0	1,024
1929	0	0	0	0	0	0	0	0	0	0	0	0	0
1930	0	0	0	4,583	0	0	0	0	0	0	0	0	275
1931	0	0	0	0	0	0	0	0	0	0	0	0	0
1932	0	0	1,639	2,613	0	0	0	0	0	0	0	0	255
1933	0	0	0	0	0	0	0	0	0	0	0	0	0
1934	0	0	0	187	0	0	0	0	0	0	0	0	11
1935	0	0	0	8,347	0	0	0	0	0	0	0	0	501
1936	0	0	0	11,104	11,508	991	0	0	0	0	0	0	1,416
1937	0	0	0	0	4,068	5,623	0	0	0	0	0	0	582
1938	0	4,954	16,329	14,297	34,940	23,535	0	0	3,733	0	46	0	5,643
1939	2,728	0	4,084	6,033	960	0	0	0	0	0	0	0	828
1940	0	0	0	7,990	7,278	6,453	0	0	0	64	0	0	1,303
1941	0	0	12,873	19,842	25,504	8,897	0	0	160	0	924	0	4,027
1942	943	0	18,671	30,505	26,316	2,435	0	0	1,021	0	60	0	4,732
1943	0	1,611	9,493	33,337	12,955	13,773	0	0	0	0	0	0	4,270
1944	0	0	0	3,019	4,826	807	0	0	0	0	0	0	519
1945	0	0	0	0	6,376	3,221	0	0	0	0	0	0	576
1946	0	0	19,160	15,044	0	422	0	0	0	51	0	0	2,078
1947	0	0	0	0	0	0	0	0	0	0	75	0	0
1948	0	0	0	0	0	0	0	0	0	51	60	0	0
1949	0	0	0	0	0	913	0	0	0	64	0	0	55
1950	0	0	0	3,154	1,809	0	0	0	0	39	46	0	298
1951	0	17,887	30,714	25,622	11,740	2,904	0	0	0	0	46	0	5,332
1952	0	0	14,999	26,244	18,474	10,332	0	0	3,724	3,272	2,844	616	4,203
1953	35	0	19,142	24,419	4,286	582	0	0	0	0	60	0	2,908
1954	0	0	0	11,483	11,922	2,065	0	0	0	0	46	0	1,528
1955	0	0	6,181	5,280	0	0	0	0	0	0	0	0	688
1956	0	0	26,198	44,925	16,820	3,143	0	0	0	51	60	0	5,465
1957	3,036	0	0	302	3,746	1,932	0	0	0	51	0	0	541
1958	0	0	4,922	12,589	21,123	12,257	0	0	3,362	613	3,168	0	3,053
1959	328	0	0	16,242	10,196	0	0	0	0	0	46	0	1,606
1960	0	0	0	0	0	0	0	0	0	0	60	0	0
1961	0	0	0	0	821	0	0	0	0	0	75	0	49
1962	0	0	0	0	5,656	0	0	0	0	0	60	0	339
1963	9,363	0	6,732	2,340	12,345	0	0	0	0	0	0	0	1,847
1964	0	8,478	0	7,615	0	0	0	0	0	0	60	0	966
1965	0	0	19,957	30,729	2,679	0	0	0	0	64	60	0	3,202
1966	0	5,317	1,740	11,108	3,455	496	0	0	0	0	46	0	1,327
1967	0	356	12,744	18,126	8,052	4,098	0	0	5,371	5,467	2,178	87	2,603
1968	738	0	2,686	14,755	12,139	1,425	0	0	0	0	0	0	1,905
1969	0	0	6,184	36,108	32,869	11,112	0	0	2,818	417	1,846	3,535	5,176
1970	313	1,388	20,689	48,182	21,438	4,321	0	0	0	0	0	0	5,780
1971	0	5,499	17,922	13,754	0	1,567	0	0	0	51	46	0	2,324
1972	0	0	3,159	2,100	215	0	0	0	0	0	60	0	328
1973	0	3,472	6,486	19,565	17,114	5,314	0	0	0	0	0	0	3,117
1974	0	14,891	17,861	26,204	8,820	9,919	0	0	0	1,015	2,816	828	4,662
1975	0	0	0	2,822	12,342	9,054	0	0	598	0	1,802	0	1,453
1976	3,475	0	0	0	454	0	0	0	0	0	0	0	236
1977	0	0	0	0	0	0	0	0	0	0	0	0	0
1978	0	0	0	17,771	7,920	6,460	0	0	0	0	0	0	1,929
1979	0	0	0	8,337	9,089	3,895	0	0	0	0	0	0	1,279
1980	0	0	3,219	30,753	32,228	9,507	0	0	0	0	46	0	4,542
1981	0	0	2,540	13,671	3,648	1,352	0	0	0	0	0	0	1,273
1982	0	10,999	16,249	25,857	20,195	12,695	0	0	877	1,625	2,692	4,549	5,160
1983	8,819	18,142	38,390	52,532	47,491	36,495	0	0	11,835	14,121	6,707	11,086	12,112
1984	12,416	37,108	52,339	32,698	8,293	3,082	0	0	0	0	0	0	8,756
1985	0	10,277	5,473	0	640	0	0	0	0	0	60	0	983
1986	0	0	0	4,819	46,285	18,154	0	0	0	0	0	0	4,155
1987	0	0	0	0	806	25	0	0	0	0	60	0	50
1988	0	0	0	7,394	0	0	0	0	0	0	0	0	444
1989	0	0	0	0	0	0	0	0	0	0	60	0	0
1990	0	0	0	1,289	0	0	0	0	0	0	0	0	77
1991	0	0	0	0	0	0	0	0	0	0	0	0	0
1992	0	0	0	0	717	0	0	0	0	0	0	0	43
1993	0	0	0	21,161	6,303	426	0	0	577	0	60	0	1,673
1994	0	0	0	0	1,442	0	0	0	0	0	0	0	86
Avg ('22-'94)	578	1,984	5,945	11,102	8,114	3,437	0	0	495	371	360	284	1,870

Note: See "Notes and Acronyms" at end of tables section.

Table 3-12. Unused CVP and SWP Permitted Pumping Capacity for Delta Wetlands Exports (cfs)

Water Year	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Jun - Sep (TAF)
1922	3,353	3,108	0	0	0	3,052	0	0	0	4,176	1,494	1,558	434
1923	0	0	0	2,693	7,805	4,582	0	0	3,922	0	3,706	1,613	554
1924	3,971	4,570	1,946	660	2,821	7,424	0	0	9,262	9,852	10,098	6,633	2,151
1925	6,899	6,284	1,537	4,155	0	6,047	0	0	6,472	6,160	5,007	2,919	1,234
1926	5,370	5,662	2,506	0	0	4,590	0	0	5,633	5,396	210	5,322	994
1927	4,394	0	0	0	562	3,678	0	0	3,728	1,184	3,397	1,438	585
1928	32	0	0	0	3,324	3,268	0	0	4,992	1,639	1,332	4,028	719
1929	3,581	1,511	547	347	2,292	6,706	0	0	6,774	9,299	9,626	5,003	1,842
1930	6,704	5,427	0	0	4,270	0	0	0	5,951	5,689	470	4,482	995
1931	4,671	4,956	819	1,636	5,283	7,534	0	0	10,959	10,958	6,991	5,171	2,045
1932	8,753	6,872	0	0	1,552	8,138	0	0	8,959	9,120	6,259	5,407	1,785
1933	5,289	6,334	4,956	967	4,699	6,356	0	0	10,774	10,974	8,048	5,339	2,108
1934	8,232	6,838	839	0	5,245	7,052	0	0	6,892	10,730	7,870	5,087	1,835
1935	8,558	3,998	3,934	0	5,954	253	0	0	2,940	598	4,845	3,272	699
1936	2,670	4,402	4,250	0	0	268	0	0	3,939	1,444	5,040	1,558	719
1937	4,020	4,385	1,456	27	0	3,998	0	0	4,153	4,827	6,146	2,180	1,038
1938	1,694	0	0	1,523	6,558	5,114	0	0	0	484	0	0	29
1939	0	0	4,567	5,966	5,321	4,508	0	0	5,239	4,957	1,462	6,112	1,066
1940	5,695	6,553	6,575	0	0	0	0	0	4,134	0	2,129	2,017	497
1941	3,109	1,629	0	0	651	5,428	0	0	0	3,965	0	0	238
1942	0	0	1,658	7,182	6,301	3,979	0	0	0	2,875	0	0	173
1943	0	0	0	6,559	5,856	5,036	0	0	4,633	3,119	2,698	1,340	707
1944	857	2,066	649	2,526	5,295	3,722	0	0	4,045	972	5,349	5,457	949
1945	4,947	0	0	106	790	3,884	0	0	2,998	452	5,007	3,289	705
1946	1,523	0	0	0	6,674	2,271	0	0	3,275	0	3,153	2,348	527
1947	3,435	1,220	0	628	1,052	2,600	0	0	5,669	5,591	0	1,372	758
1948	3,256	2,738	4,254	0	6,791	4,047	0	0	2,351	0	0	892	195
1949	1,369	2,015	0	706	3,570	0	0	0	3,734	0	4,503	2,953	671
1950	3,841	3,713	3,910	0	0	2,214	0	0	3,316	0	0	804	247
1951	2,833	0	0	0	1,746	3,289	0	0	4,563	712	0	695	358
1952	1,483	0	0	0	7,542	5,525	0	0	0	0	0	0	0
1953	0	3,372	6,932	6,710	5,816	3,727	0	0	1,404	2,452	0	0	231
1954	0	0	0	2,547	4,099	2,946	0	0	4,939	582	0	2,079	456
1955	1,662	0	0	0	3,342	5,071	0	0	4,192	3,688	5,446	3,390	1,003
1956	4,768	2,738	0	0	165	4,438	0	0	204	0	0	0	12
1957	0	1,847	624	83	4,235	3,057	0	0	3,598	0	779	957	320
1958	0	0	0	0	3,748	3,933	0	0	0	0	0	0	0
1959	0	1,175	3,363	5,858	5,500	5,482	0	0	5,816	5,754	0	2,181	825
1960	4,134	4,150	860	923	0	2,481	0	0	5,475	4,957	0	2,197	758
1961	3,223	881	0	0	0	3,579	0	0	5,751	5,672	0	4,045	928
1962	3,906	3,595	0	2,871	0	0	0	0	4,228	923	0	1,930	425
1963	0	0	0	0	0	0	0	0	3,116	13	161	116	204
1964	455	0	0	0	4,698	4,581	0	0	5,886	5,689	0	2,028	816
1965	3,630	0	0	0	0	1,254	0	0	4,504	0	0	586	305
1966	1,190	0	0	1,699	5,461	3,379	0	0	5,663	4,957	0	2,936	813
1967	3,532	0	0	0	0	1,380	0	0	0	0	0	0	0
1968	0	1,091	5,420	5,751	5,344	3,578	0	0	5,845	5,672	242	3,289	903
1969	2,573	750	0	0	3,645	7,119	0	0	0	0	0	0	0
1970	0	4,726	7,253	7,088	6,447	3,912	0	0	5,322	3,395	2,389	2,516	817
1971	2,312	0	0	0	4,427	1,318	0	0	1,981	0	0	0	119
1972	0	957	0	0	2,480	2,732	0	0	5,328	4,306	0	2,508	729
1973	1,565	0	0	0	0	903	0	0	3,010	354	2,828	127	379
1974	0	0	0	1,453	5,521	3,582	0	0	1,210	0	0	0	73
1975	0	717	0	2,736	5,186	3,322	0	0	0	403	0	0	24
1976	0	0	0	705	4,265	4,271	0	0	5,186	5,087	3,674	3,423	1,042
1977	3,971	4,670	4,854	5,630	9,172	8,401	0	0	10,068	10,063	7,186	6,785	2,046
1978	10,558	8,065	1,408	0	0	2,349	0	0	3,239	6,063	1,413	0	643
1979	0	1,629	2,147	0	5,704	3,979	0	0	2,675	2,940	5,154	1,978	765
1980	1,079	0	0	0	7,078	7,053	0	0	3,445	5,054	0	0	510
1981	223	4,234	4,899	5,901	4,977	3,605	0	0	5,751	5,542	600	3,827	943
1982	3,126	0	0	0	0	3,098	0	0	0	0	0	0	0
1983	0	0	1,896	9,121	9,233	7,804	0	0	0	656	0	2,418	184
1984	6,552	7,620	8,210	7,620	6,586	4,030	0	0	3,528	1,070	2,584	553	464
1985	1,089	0	0	0	3,703	2,867	0	0	5,804	5,737	0	2,443	839
1986	3,158	2,267	0	0	0	753	0	0	3,551	4,566	5,040	160	799
1987	593	3,494	2,349	1,581	4,026	2,836	0	0	5,263	4,794	0	4,902	898
1988	4,719	6,233	0	0	7,150	6,848	0	0	6,421	6,453	7,821	5,894	1,595
1989	7,744	4,200	3,516	1,652	8,968	0	0	0	6,051	5,819	0	2,214	845
1990	1,516	4,654	673	0	4,996	5,694	0	0	5,816	8,209	7,365	5,659	1,623
1991	8,118	6,368	6,164	6,718	10,217	0	0	0	10,976	11,072	8,000	6,247	2,178
1992	8,265	7,326	6,850	2,768	0	2,984	0	0	8,556	9,559	10,146	6,919	2,111
1993	8,232	7,359	80	0	0	104	0	0	0	5,054	0	804	352
1994	0	1,931	0	0	2,470	4,942	0	0	5,392	5,315	291	3,205	852
Avg ('22-'94)	2,910	2,470	1,533	1,577	3,570	3,671	0	0	4,226	3,658	2,410	2,419	763

Note: See "Notes and Acronyms" at end of tables section.

Table 3-13. Delta Wetlands Diversions (cfs) with Unlimited Demands

Water Year	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Total (TAF)
1922	0	0	0	1,723	2,409	49	0	0	296	0	0	0	270
1923	0	0	3,871	15	0	0	0	0	0	51	0	0	237
1924	0	0	0	0	0	0	0	0	0	0	0	0	0
1925	0	0	0	0	4,000	0	0	0	0	0	0	0	241
1926	0	0	0	0	2,128	0	0	0	0	0	0	0	128
1927	0	0	0	3,576	357	49	0	0	0	0	0	0	240
1928	0	1,218	0	2,719	30	49	0	0	0	0	0	0	242
1929	0	0	0	0	0	0	0	0	0	0	0	0	0
1930	0	0	0	2,238	0	0	0	0	0	0	0	0	135
1931	0	0	0	0	0	0	0	0	0	0	0	0	0
1932	0	0	0	1,786	0	0	0	0	0	0	0	0	108
1933	0	0	0	0	0	0	0	0	0	0	0	0	0
1934	0	0	0	0	0	0	0	0	0	0	0	0	0
1935	0	0	0	0	0	0	0	0	0	0	0	0	0
1936	0	0	0	0	4,000	177	0	0	0	0	0	0	252
1937	0	0	0	0	4,000	307	0	0	0	0	0	0	259
1938	0	0	3,871	15	31	49	0	0	296	0	46	0	259
1939	822	0	37	15	31	0	0	0	0	0	0	0	54
1940	0	0	0	0	4,000	177	0	0	0	64	0	0	256
1941	0	0	0	3,871	31	49	0	0	160	0	924	0	303
1942	943	0	2,179	15	31	49	0	0	296	0	60	0	215
1943	0	1,611	1,676	15	31	49	0	0	0	0	0	0	204
1944	0	0	0	0	4,000	177	0	0	0	0	0	0	252
1945	0	0	0	0	4,000	307	0	0	0	0	0	0	259
1946	0	0	3,871	15	0	422	0	0	0	51	0	0	263
1947	0	0	0	0	0	0	0	0	0	0	75	0	5
1948	0	0	0	0	0	0	0	0	0	51	60	0	7
1949	0	0	0	0	0	913	0	0	0	64	0	0	59
1950	0	0	0	0	1,809	0	0	0	0	39	46	0	114
1951	0	0	3,871	15	31	49	0	0	0	0	46	0	242
1952	0	0	3,871	15	30	49	0	0	296	130	115	87	277
1953	35	0	3,319	15	31	49	0	0	0	0	60	0	211
1954	0	0	0	3,668	255	49	0	0	0	0	46	0	242
1955	0	0	3,000	885	0	0	0	0	0	0	0	0	234
1956	0	0	0	3,871	30	49	0	0	0	51	60	0	245
1957	755	0	0	302	2,087	49	0	0	0	51	0	0	195
1958	0	0	3,000	885	31	49	0	0	296	130	115	0	271
1959	137	0	0	3,871	31	0	0	0	0	0	46	0	246
1960	0	0	0	0	0	0	0	0	0	0	60	0	4
1961	0	0	0	0	821	0	0	0	0	0	75	0	54
1962	0	0	0	0	4,000	0	0	0	0	0	60	0	245
1963	0	0	3,000	885	31	0	0	0	0	0	0	0	236
1964	0	3,533	0	28	0	0	0	0	0	0	60	0	218
1965	0	0	0	3,871	31	0	0	0	0	64	60	0	243
1966	0	0	1,740	2,145	31	49	0	0	0	0	46	0	242
1967	0	0	3,871	15	31	49	0	0	296	130	115	87	277
1968	53	0	1,093	15	30	49	0	0	0	0	0	0	75
1969	0	0	0	3,871	31	49	0	0	296	130	115	87	276
1970	53	25	13	15	31	49	0	0	0	0	0	0	11
1971	0	0	3,871	15	0	1,567	0	0	0	51	46	0	334
1972	0	0	3,000	200	30	0	0	0	0	0	60	0	198
1973	0	0	3,000	885	31	49	0	0	0	0	0	0	239
1974	0	4,000	13	15	31	49	0	0	0	1,015	688	87	355
1975	0	0	0	799	31	49	0	0	296	0	649	0	110
1976	137	0	0	0	265	0	0	0	0	0	0	0	24
1977	0	0	0	0	0	0	0	0	0	0	0	0	0
1978	0	0	0	0	4,000	307	0	0	0	0	0	0	259
1979	0	0	0	3,417	533	49	0	0	0	0	0	0	241
1980	0	0	3,000	885	30	49	0	0	0	0	46	0	242
1981	0	0	0	3,871	31	49	0	0	0	0	0	0	238
1982	0	0	3,871	15	31	49	0	0	296	130	115	87	277
1983	53	25	13	15	31	49	0	0	296	130	115	87	49
1984	53	25	13	15	30	49	0	0	0	0	0	0	11
1985	0	0	3,000	0	640	0	0	0	0	0	60	0	223
1986	0	0	0	2,356	1,708	49	0	0	0	0	0	0	248
1987	0	0	0	0	806	25	0	0	0	0	60	0	54
1988	0	0	0	2,999	0	0	0	0	0	0	0	0	181
1989	0	0	0	0	0	0	0	0	0	0	60	0	4
1990	0	0	0	0	0	0	0	0	0	0	0	0	0
1991	0	0	0	0	0	0	0	0	0	0	0	0	0
1992	0	0	0	0	0	0	0	0	0	0	0	0	0
1993	0	0	0	3,871	31	49	0	0	296	0	60	0	259
1994	0	0	0	0	1,442	0	0	0	0	0	0	0	87
Avg ('22-'94)	42	143	850	818	659	80	0	0	47	32	58	7	165

Note: See "Notes and Acronyms" at end of tables section.

Table 3-14. Delta Wetlands Storage (TAF) with Unlimited Demands

Water Year	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1922	0	0	0	106	238	238	234	227	238	0	0	0
1923	0	0	238	238	125	0	0	0	0	3	0	0
1924	0	0	0	0	0	0	0	0	0	0	0	0
1925	0	0	0	0	222	96	92	86	0	0	0	0
1926	0	0	0	0	118	0	0	0	0	0	0	0
1927	0	0	0	220	238	238	234	227	101	21	0	0
1928	0	72	72	238	238	238	234	227	101	0	0	0
1929	0	0	0	0	0	0	0	0	0	0	0	0
1930	0	0	0	138	25	22	17	11	0	0	0	0
1931	0	0	0	0	0	0	0	0	0	0	0	0
1932	0	0	0	110	108	0	0	0	0	0	0	0
1933	0	0	0	0	0	0	0	0	0	0	0	0
1934	0	0	0	0	0	0	0	0	0	0	0	0
1935	0	0	0	0	0	0	0	0	0	0	0	0
1936	0	0	0	0	230	238	234	227	101	5	0	0
1937	0	0	0	0	222	238	234	227	101	0	0	0
1938	0	0	238	238	238	238	234	227	238	200	196	191
1939	238	237	238	238	238	112	108	101	0	0	0	0
1940	0	0	0	0	230	238	234	227	101	97	0	0
1941	0	0	0	238	238	238	234	227	230	0	57	52
1942	106	105	238	238	238	238	234	227	238	53	50	45
1943	41	136	238	238	238	238	234	227	101	0	0	0
1944	0	0	0	0	230	238	234	227	101	34	0	0
1945	0	0	0	0	222	238	234	227	101	66	0	0
1946	0	0	238	238	125	148	144	138	12	7	0	0
1947	0	0	0	0	0	0	0	0	0	0	5	0
1948	0	0	0	0	0	0	0	0	0	3	4	0
1949	0	0	0	0	0	56	52	46	0	4	0	0
1950	0	0	0	0	100	0	0	0	0	2	3	0
1951	0	0	238	238	238	238	234	227	101	50	45	0
1952	0	0	238	238	238	238	234	227	238	238	238	238
1953	237	35	238	238	238	238	234	227	137	0	4	0
1954	0	0	0	226	238	238	234	227	101	58	53	0
1955	0	0	184	238	125	0	0	0	0	0	0	0
1956	0	0	0	238	238	238	234	227	208	203	200	195
1957	238	127	106	124	238	238	234	227	101	97	42	0
1958	0	0	184	238	238	238	234	227	238	238	238	233
1959	238	167	0	238	238	112	108	101	0	0	3	0
1960	0	0	0	0	0	0	0	0	0	0	4	0
1961	0	0	0	0	46	0	0	0	0	0	5	0
1962	0	0	0	0	222	219	215	209	83	18	14	0
1963	0	0	184	238	238	235	231	224	98	90	73	61
1964	29	238	237	238	121	0	0	0	0	0	4	0
1965	0	0	0	238	238	207	203	197	71	67	63	23
1966	0	0	107	238	238	238	234	227	101	0	3	0
1967	0	0	238	238	238	238	234	227	238	238	238	238
1968	238	172	238	238	238	238	234	227	101	0	0	0
1969	0	0	0	238	238	238	234	227	238	238	238	238
1970	238	238	238	238	238	238	234	227	101	0	0	0
1971	0	0	238	238	125	219	214	208	83	78	74	69
1972	66	43	227	238	238	112	108	101	0	0	4	0
1973	0	0	184	238	238	238	234	227	101	72	0	0
1974	0	238	238	238	238	238	234	227	148	203	238	238
1975	235	191	190	238	238	238	234	227	238	205	238	233
1976	238	237	236	224	238	112	108	101	0	0	0	0
1977	0	0	0	0	0	0	0	0	0	0	0	0
1978	0	0	0	0	222	238	234	227	101	0	0	0
1979	0	0	0	210	238	238	234	227	101	0	0	0
1980	0	0	184	238	238	238	234	227	101	0	3	0
1981	0	0	0	238	238	238	234	227	101	0	0	0
1982	0	0	238	238	238	238	234	227	238	238	238	238
1983	238	238	238	238	238	238	234	227	238	238	238	238
1984	238	238	238	238	238	238	234	227	101	28	0	0
1985	0	0	184	184	217	91	87	81	0	0	4	0
1986	0	0	0	145	238	238	234	227	101	0	0	0
1987	0	0	0	0	45	43	39	33	0	0	4	0
1988	0	0	0	184	68	0	0	0	0	0	0	0
1989	0	0	0	0	0	0	0	0	0	0	4	0
1990	0	0	0	0	0	0	0	0	0	0	0	0
1991	0	0	0	0	0	0	0	0	0	0	0	0
1992	0	0	0	0	0	0	0	0	0	0	0	0
1993	0	0	0	238	238	238	234	227	238	0	4	0
1994	0	0	0	0	80	0	0	0	0	0	0	0
Avg ('22-'94)	36	37	87	136	162	142	139	135	80	42	39	35

Note: See "Notes and Acronyms" at end of tables section.

Table 3-15. Delta Wetlands Discharge for Exports (cfs) with Unlimited Demands

Water Year	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Total (TAF)	Calendar (TAF)
1922	0	0	0	0	0	0	0	0	0	3,741	0	0	225	226
1923	0	0	0	0	2,000	1,988	0	0	0	0	0	0	240	241
1924	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1925	0	0	0	0	0	2,000	0	0	1,320	0	0	0	200	200
1926	0	0	0	0	0	1,873	0	0	0	0	0	0	113	113
1927	0	0	0	0	0	0	0	0	2,000	1,184	220	0	205	205
1928	0	0	0	0	0	0	0	0	2,000	1,519	0	0	212	212
1929	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1930	0	0	0	0	2,000	0	0	0	71	0	0	0	125	125
1931	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1932	0	0	0	0	0	1,709	0	0	0	0	0	0	103	103
1933	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1934	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1935	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1936	0	0	0	0	0	0	0	0	2,000	1,444	0	0	207	208
1937	0	0	0	0	0	0	0	0	2,000	1,519	0	0	212	212
1938	0	0	0	0	0	0	0	0	0	484	0	0	29	29
1939	0	0	0	0	0	2,000	0	0	1,587	0	0	0	216	216
1940	0	0	0	0	0	0	0	0	2,000	0	1,467	0	209	209
1941	0	0	0	0	0	0	0	0	0	3,609	0	0	217	218
1942	0	0	0	0	0	0	0	0	0	2,875	0	0	173	173
1943	0	0	0	0	0	0	0	0	2,000	1,519	0	0	212	212
1944	0	0	0	0	0	0	0	0	2,000	972	431	0	205	205
1945	0	0	0	0	0	0	0	0	2,000	452	952	0	205	205
1946	0	0	0	0	2,000	0	0	0	2,000	0	0	0	241	241
1947	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1948	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1949	0	0	0	0	0	0	0	0	647	0	0	0	39	39
1950	0	0	0	0	0	1,585	0	0	0	0	0	0	95	96
1951	0	0	0	0	0	0	0	0	2,000	712	0	674	204	204
1952	0	0	0	0	0	0	0	0	0	0	0	0	0	203
1953	0	3,372	0	0	0	0	0	0	1,404	2,095	0	0	414	211
1954	0	0	0	0	0	0	0	0	2,000	582	0	809	204	205
1955	0	0	0	0	2,000	1,988	0	0	0	0	0	0	240	241
1956	0	0	0	0	0	0	0	0	204	0	0	0	12	143
1957	0	1,847	319	0	0	0	0	0	2,000	0	779	611	335	205
1958	0	0	0	0	0	0	0	0	0	0	0	0	0	234
1959	0	1,175	2,696	0	0	2,000	0	0	1,587	0	0	0	449	216
1960	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1961	0	0	0	0	0	692	0	0	0	0	0	0	42	42
1962	0	0	0	0	0	0	0	0	2,000	923	0	154	185	186
1963	0	0	0	0	0	0	0	0	2,000	13	161	116	138	166
1964	455	0	0	0	2,000	1,923	0	0	0	0	0	0	264	237
1965	0	0	0	0	0	452	0	0	2,000	0	0	586	183	203
1966	322	0	0	0	0	0	0	0	2,000	1,519	0	0	231	212
1967	0	0	0	0	0	0	0	0	0	0	0	0	0	66
1968	0	1,091	0	0	0	0	0	0	2,000	1,519	0	0	278	212
1969	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1970	0	0	0	0	0	0	0	0	2,000	1,519	0	0	212	212
1971	0	0	0	0	2,000	0	0	0	1,981	0	0	0	240	262
1972	0	354	0	0	0	2,000	0	0	1,587	0	0	0	237	216
1973	0	0	0	0	0	0	0	0	2,000	354	1,049	0	205	205
1974	0	0	0	0	0	0	0	0	1,210	0	0	0	73	116
1975	0	717	0	0	0	0	0	0	0	403	0	0	67	24
1976	0	0	0	168	0	2,000	0	0	1,587	0	0	0	226	227
1977	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1978	0	0	0	0	0	0	0	0	2,000	1,519	0	0	212	212
1979	0	0	0	0	0	0	0	0	2,000	1,519	0	0	212	212
1980	0	0	0	0	0	0	0	0	2,000	1,519	0	0	212	212
1981	0	0	0	0	0	0	0	0	2,000	1,519	0	0	212	212
1982	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1983	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1984	0	0	0	0	0	0	0	0	2,000	1,070	334	0	205	205
1985	0	0	0	0	0	2,000	0	0	1,241	0	0	0	195	196
1986	0	0	0	0	0	0	0	0	2,000	1,519	0	0	212	212
1987	0	0	0	0	0	0	0	0	432	0	0	0	26	26
1988	0	0	0	0	2,000	1,052	0	0	0	0	0	0	184	184
1989	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1991	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1992	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1993	0	0	0	0	0	0	0	0	0	3,741	0	0	225	226
1994	0	0	0	0	0	1,253	0	0	0	0	0	0	76	76
Avg ('22-'94)	11	117	41	2	192	363	0	0	888	567	74	40	138	139

Note: See "Notes and Acronyms" at end of tables section.

Table 3-16. Delta Wetlands Diversions (cfs) Limited by South-of-Delta Delivery Deficits

Water Year	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Total (TAF)
1922	0	0	0	1,723	2,409	49	0	0	296	0	0	0	270
1923	0	0	3,556	15	0	0	0	0	0	51	0	0	218
1924	0	0	0	0	0	0	0	0	0	0	0	0	0
1925	0	0	0	0	4,000	0	0	0	0	0	0	0	241
1926	0	0	0	0	2,128	0	0	0	0	0	0	0	128
1927	0	0	0	3,576	357	49	0	0	0	0	0	0	240
1928	0	1,218	0	2,719	30	49	0	0	0	0	0	0	242
1929	0	0	0	0	0	0	0	0	0	0	0	0	0
1930	0	0	0	2,238	0	0	0	0	0	0	0	0	135
1931	0	0	0	0	0	0	0	0	0	0	0	0	0
1932	0	0	0	1,786	0	0	0	0	0	0	0	0	108
1933	0	0	0	0	0	0	0	0	0	0	0	0	0
1934	0	0	0	0	0	0	0	0	0	0	0	0	0
1935	0	0	0	0	0	0	0	0	0	0	0	0	0
1936	0	0	0	0	4,000	177	0	0	0	0	0	0	252
1937	0	0	0	0	4,000	307	0	0	0	0	0	0	259
1938	0	0	3,871	15	31	49	0	0	296	0	46	0	259
1939	337	0	37	15	31	0	0	0	0	0	0	0	25
1940	0	0	0	0	4,000	177	0	0	0	64	0	0	256
1941	0	0	0	3,871	31	49	0	0	160	0	377	0	270
1942	137	0	37	15	31	49	0	0	296	0	60	0	38
1943	0	359	13	15	31	49	0	0	0	0	0	0	28
1944	0	0	0	0	4,000	177	0	0	0	0	0	0	252
1945	0	0	0	0	4,000	307	0	0	0	0	0	0	259
1946	0	0	3,871	15	0	422	0	0	0	51	0	0	263
1947	0	0	0	0	0	0	0	0	0	0	75	0	5
1948	0	0	0	0	0	0	0	0	0	51	60	0	7
1949	0	0	0	0	0	913	0	0	0	64	0	0	59
1950	0	0	0	0	1,809	0	0	0	0	39	46	0	114
1951	0	0	3,871	15	31	49	0	0	0	0	46	0	242
1952	0	0	3,871	15	30	49	0	0	296	130	115	87	277
1953	35	0	55	15	31	49	0	0	0	0	60	0	15
1954	0	0	0	3,668	255	49	0	0	0	0	46	0	242
1955	0	0	3,000	885	0	0	0	0	0	0	0	0	234
1956	0	0	0	3,871	30	49	0	0	0	51	60	0	245
1957	755	0	0	302	270	49	0	0	0	51	0	0	86
1958	0	0	3,000	885	31	49	0	0	296	130	115	0	271
1959	137	0	0	52	31	0	0	0	0	0	46	0	16
1960	0	0	0	0	0	0	0	0	0	0	60	0	4
1961	0	0	0	0	821	0	0	0	0	0	75	0	54
1962	0	0	0	0	4,000	0	0	0	0	0	60	0	245
1963	0	0	3,000	885	31	0	0	0	0	0	0	0	236
1964	0	1,893	0	28	0	0	0	0	0	0	60	0	119
1965	0	0	0	3,871	31	0	0	0	0	64	60	0	243
1966	0	0	1,740	2,145	31	49	0	0	0	0	46	0	242
1967	0	0	3,871	15	31	49	0	0	296	130	115	87	277
1968	53	0	37	15	30	49	0	0	0	0	0	0	11
1969	0	0	0	3,871	31	49	0	0	296	130	115	87	276
1970	53	25	13	15	31	49	0	0	0	0	0	0	11
1971	0	0	3,871	15	0	485	0	0	0	51	46	0	269
1972	0	0	2,797	15	30	0	0	0	0	0	60	0	175
1973	0	0	3,000	885	31	49	0	0	0	0	0	0	239
1974	0	4,000	13	15	31	49	0	0	0	1,015	688	87	355
1975	0	0	0	332	31	49	0	0	296	0	649	0	82
1976	137	0	0	0	85	0	0	0	0	0	0	0	13
1977	0	0	0	0	0	0	0	0	0	0	0	0	0
1978	0	0	0	0	4,000	307	0	0	0	0	0	0	259
1979	0	0	0	721	31	49	0	0	0	0	0	0	48
1980	0	0	3,000	885	30	49	0	0	0	0	46	0	242
1981	0	0	0	3,871	31	49	0	0	0	0	0	0	238
1982	0	0	3,871	15	31	49	0	0	296	130	115	87	277
1983	53	25	13	15	31	49	0	0	296	130	115	87	49
1984	53	25	13	15	30	49	0	0	0	0	0	0	11
1985	0	0	3,000	0	640	0	0	0	0	0	60	0	223
1986	0	0	0	2,356	1,708	49	0	0	0	0	0	0	248
1987	0	0	0	0	806	25	0	0	0	0	60	0	54
1988	0	0	0	2,999	0	0	0	0	0	0	0	0	181
1989	0	0	0	0	0	0	0	0	0	0	60	0	4
1990	0	0	0	0	0	0	0	0	0	0	0	0	0
1991	0	0	0	0	0	0	0	0	0	0	0	0	0
1992	0	0	0	0	0	0	0	0	0	0	0	0	0
1993	0	0	0	3,871	31	49	0	0	296	0	60	0	259
1994	0	0	0	0	446	0	0	0	0	0	0	0	27
Avg ('22-'94)	24	103	732	720	612	65	0	0	47	32	51	7	144

Note: See "Notes and Acronyms" at end of tables section.

Table 3-17. Delta Wetlands Storage (TAF) Limited by South-of-Delta Delivery Deficits

Water Year	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1922	0	0	0	106	238	238	234	227	238	91	47	25
1923	22	20	238	238	236	233	229	223	97	92	0	0
1924	0	0	0	0	0	0	0	0	0	0	0	0
1925	0	0	0	0	222	96	92	86	0	0	0	0
1926	0	0	0	0	118	10	5	0	0	0	0	0
1927	0	0	0	220	238	238	234	227	101	21	0	0
1928	0	72	72	238	238	238	234	227	101	0	0	0
1929	0	0	0	0	0	0	0	0	0	0	0	0
1930	0	0	0	138	25	22	17	11	0	0	0	0
1931	0	0	0	0	0	0	0	0	0	0	0	0
1932	0	0	0	110	108	0	0	0	0	0	0	0
1933	0	0	0	0	0	0	0	0	0	0	0	0
1934	0	0	0	0	0	0	0	0	0	0	0	0
1935	0	0	0	0	0	0	0	0	0	0	0	0
1936	0	0	0	0	230	238	234	227	101	5	0	0
1937	0	0	0	0	222	238	234	227	101	0	0	0
1938	0	0	238	238	238	238	234	227	238	230	226	221
1939	238	237	238	238	238	180	175	169	43	0	0	0
1940	0	0	0	0	230	238	234	227	101	97	0	0
1941	0	0	0	238	238	238	234	227	230	222	238	233
1942	238	237	238	238	238	238	234	227	238	230	227	221
1943	218	238	238	238	238	238	234	227	101	0	0	0
1944	0	0	0	0	230	238	234	227	101	34	0	0
1945	0	0	0	0	222	238	234	227	101	66	0	0
1946	0	0	238	238	210	233	229	223	97	92	0	0
1947	0	0	0	0	0	0	0	0	0	0	5	0
1948	0	0	0	0	0	0	0	0	0	3	4	0
1949	0	0	0	0	0	56	52	46	0	4	0	0
1950	0	0	0	0	100	0	0	0	0	2	3	0
1951	0	0	238	238	238	238	234	227	101	50	45	0
1952	0	0	238	238	238	238	234	227	238	238	238	238
1953	237	235	238	238	238	238	234	227	137	0	4	0
1954	0	0	0	226	238	238	234	227	101	58	53	0
1955	0	0	184	238	158	68	63	57	0	0	0	0
1956	0	0	0	238	238	238	234	227	208	203	200	195
1957	238	223	207	225	238	238	234	227	101	97	42	0
1958	0	0	184	238	238	238	234	227	238	238	238	233
1959	238	237	236	238	238	201	197	191	65	0	3	0
1960	0	0	0	0	0	0	0	0	0	0	4	0
1961	0	0	0	0	46	0	0	0	0	0	5	0
1962	0	0	0	0	222	219	215	209	83	18	14	0
1963	0	0	184	238	238	235	231	224	189	180	163	151
1964	127	238	237	238	236	233	229	223	97	0	4	0
1965	0	0	0	238	238	207	203	197	71	67	63	23
1966	0	0	107	238	238	238	234	227	101	0	3	0
1967	0	0	238	238	238	238	234	227	238	238	238	238
1968	238	237	238	238	238	238	234	227	101	0	0	0
1969	0	0	0	238	238	238	234	227	238	238	238	238
1970	238	238	238	238	238	238	234	227	101	0	0	0
1971	0	0	238	238	211	238	234	227	103	98	93	88
1972	85	67	238	238	238	235	231	224	98	0	4	0
1973	0	0	184	238	238	238	234	227	101	72	0	0
1974	0	238	238	238	238	238	234	227	148	203	238	238
1975	235	219	218	238	238	238	234	227	238	205	238	233
1976	238	237	236	235	238	140	135	129	3	0	0	0
1977	0	0	0	0	0	0	0	0	0	0	0	0
1978	0	0	0	0	222	238	234	227	220	212	205	200
1979	197	195	195	238	238	238	234	227	220	97	0	0
1980	0	0	184	238	238	238	234	227	101	0	3	0
1981	0	0	0	238	238	238	234	227	101	0	0	0
1982	0	0	238	238	238	238	234	227	238	238	238	238
1983	238	238	238	238	238	238	234	227	238	238	238	238
1984	238	238	238	238	238	238	234	227	101	28	0	0
1985	0	0	184	184	217	210	206	199	73	0	4	0
1986	0	0	0	145	238	238	234	227	101	0	0	0
1987	0	0	0	0	45	43	39	33	0	0	4	0
1988	0	0	0	184	68	0	0	0	0	0	0	0
1989	0	0	0	0	0	0	0	0	0	0	4	0
1990	0	0	0	0	0	0	0	0	0	0	0	0
1991	0	0	0	0	0	0	0	0	0	0	0	0
1992	0	0	0	0	0	0	0	0	0	0	0	0
1993	0	0	0	238	238	238	234	227	238	230	227	221
1994	218	217	216	215	238	235	231	224	154	0	0	0
Avg ('22-'94)	48	53	97	141	170	160	156	152	94	61	52	48

Note: See "Notes and Acronyms" at end of tables section.

Table 3-18. Delta Wetlands Discharges for Export (cfs) Limited by South-of-Delta Delivery Deficits

Water Year	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Total (TAF)	Calendar (TAF)
1922	0	0	0	0	0	0	0	0	0	2,256	602	287	189	190
1923	0	0	0	0	0	0	0	0	2,000	0	1,378	0	204	204
1924	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1925	0	0	0	0	0	2,000	0	0	1,320	0	0	0	200	200
1926	0	0	0	0	0	1,711	0	0	0	0	0	0	103	103
1927	0	0	0	0	0	0	0	0	2,000	1,184	220	0	205	205
1928	0	0	0	0	0	0	0	0	2,000	1,519	0	0	212	212
1929	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1930	0	0	0	0	2,000	0	0	0	71	0	0	0	125	125
1931	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1932	0	0	0	0	0	1,709	0	0	0	0	0	0	103	103
1933	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1934	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1935	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1936	0	0	0	0	0	0	0	0	2,000	1,444	0	0	207	208
1937	0	0	0	0	0	0	0	0	2,000	1,519	0	0	212	212
1938	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1939	0	0	0	0	0	895	0	0	2,000	575	0	0	209	209
1940	0	0	0	0	0	0	0	0	2,000	0	1,467	0	209	209
1941	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1942	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1943	0	0	0	0	0	0	0	0	2,000	1,519	0	0	212	212
1944	0	0	0	0	0	0	0	0	2,000	972	431	0	205	205
1945	0	0	0	0	0	0	0	0	2,000	452	952	0	205	205
1946	0	0	0	0	470	0	0	0	2,000	0	1,376	0	232	232
1947	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1948	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1949	0	0	0	0	0	0	0	0	647	0	0	0	39	39
1950	0	0	0	0	0	1,585	0	0	0	0	0	0	95	96
1951	0	0	0	0	0	0	0	0	2,000	712	0	674	204	204
1952	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1953	0	0	0	0	0	0	0	0	1,404	2,095	0	0	211	211
1954	0	0	0	0	0	0	0	0	2,000	582	0	809	204	205
1955	0	0	0	0	1,414	1,415	0	0	844	0	0	0	221	222
1956	0	0	0	0	0	0	0	0	204	0	0	0	12	41
1957	0	229	244	0	0	0	0	0	2,000	0	779	611	233	205
1958	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1959	0	0	0	0	0	549	0	0	2,000	921	0	0	209	209
1960	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1961	0	0	0	0	0	692	0	0	0	0	0	0	42	42
1962	0	0	0	0	0	0	0	0	2,000	923	0	154	185	186
1963	0	0	0	0	0	0	0	0	483	13	161	116	47	67
1964	337	0	0	0	0	0	0	0	2,000	1,442	0	0	228	208
1965	0	0	0	0	0	452	0	0	2,000	0	0	586	183	203
1966	322	0	0	0	0	0	0	0	2,000	1,519	0	0	231	212
1967	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1968	0	0	0	0	0	0	0	0	2,000	1,519	0	0	212	212
1969	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1970	0	0	0	0	0	0	0	0	2,000	1,519	0	0	212	212
1971	0	0	0	0	452	0	0	0	1,981	0	0	0	147	164
1972	0	280	0	0	0	0	0	0	2,000	1,470	0	0	226	209
1973	0	0	0	0	0	0	0	0	2,000	354	1,049	0	205	205
1974	0	0	0	0	0	0	0	0	1,210	0	0	0	73	87
1975	0	235	0	0	0	0	0	0	0	403	0	0	38	24
1976	0	0	0	0	0	1,545	0	0	2,000	0	0	0	214	214
1977	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1978	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1979	0	0	0	0	0	0	0	0	0	1,881	1,458	0	201	201
1980	0	0	0	0	0	0	0	0	2,000	1,519	0	0	212	212
1981	0	0	0	0	0	0	0	0	2,000	1,519	0	0	212	212
1982	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1983	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1984	0	0	0	0	0	0	0	0	2,000	1,070	334	0	205	205
1985	0	0	0	0	0	72	0	0	2,000	1,064	0	0	189	189
1986	0	0	0	0	0	0	0	0	2,000	1,519	0	0	212	212
1987	0	0	0	0	0	0	0	0	432	0	0	0	26	26
1988	0	0	0	0	2,000	1,052	0	0	0	0	0	0	184	184
1989	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1991	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1992	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1993	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1994	0	0	0	0	0	0	0	0	1,057	2,382	0	0	207	208
Avg ('22-'94)	9	10	3	0	87	187	0	0	927	491	140	44	114	115

Note: See "Notes and Acronyms" at end of tables section.

Table 3-19. Diversion and Discharge Rules from the Final Operations Criteria and Application to the Daily Delta Wetlands Operations Model

Diversion Rules	Discharge Rules
X2 at Chipps Island: The X2 location must be downstream of Chipps Island (74 km) for at least 1 day prior to Delta Wetlands diversions in September through November, and for at least 10 days if the initial Delta Wetlands diversion occurs after November 30. The combined Delta Wetlands diversions are then limited to 5,500 cfs for 5 days. **X2 at Collinsville:** The X2 locations must always be downstream of Collinsville (81 km). This is approximately equivalent to an outflow of 7,100 cfs. **X2 Shift:** The Delta Wetlands diversions cannot cause a cumulative upstream shift in the X2 location of more than 2.5 km. This is generally equivalent to limiting the Delta Wetlands diversions to less than 25% of the outflow. **Diversion Prohibition:** No Delta Wetlands diversions are allowed in the months of April or May. **Surplus Available Water:** Delta Wetlands diversions are limited to a specified fraction of the "surplus" available water for diversions as defined by the required Delta outflow and the E/I ratio. Delta Wetlands may divert 90% of this available water in August through January, 75% in February or July, and 50% in March or June. **Delta Outflows:** Delta Wetlands diversions are limited to a specified fraction of Delta outflow. A maximum of 25% of outflows can be diverted in June through December, and a maximum of 15% of outflows can be diverted in January through March. **DFG Limits:** At the request of DFG, Delta Wetlands diversions can be limited to a specified fraction of the San Joaquin River flow for a maximum of 15 days between December and March. This criterion is a "real-time" adaptive management criterion that was not included in the daily modeling. **Delta Smelt:** A daily monitoring program is required during Delta Wetlands diversion periods. The Delta Wetlands diversion rate must be reduced to 50% if delta smelt are sampled near the Delta Wetlands islands. This was not included in the daily modeling.	**San Joaquin Inflow:** During the period of April through June, Bacon Island discharges for export are limited to 50% of the San Joaquin River inflow at Vernalis. No Delta Wetlands discharges for export are simulated in April or May because the monthly DWRSIM results do not allow an accurate simulation of the "split-month" VAMP pulse flows and exports. There may be some opportunity for discharging stored water from Bacon Island at the allowable 50% of San Joaquin River flow during April and May. Such discharges were not included in the daily results shown in this report. **Webb Tract Discharge Prohibition:** No discharges from Webb Tract are allowed from January through June. **Habitat Island Discharges:** No discharges from Delta Wetlands habitat islands can be exported by Delta Wetlands or rediverted onto the Delta Wetlands reservoir islands. **Export Capacity:** Delta Wetlands discharges are limited to a specified fraction of the unused permitted CVP and SWP export capacity. This fraction is 75% in February and July, and 50% from March through June (but no Delta Wetlands discharges are simulated in April or May). Delta Wetlands discharges can use 100% of the unused permitted export capacity in August through January. **Environmental Water:** Delta Wetlands discharges for export made during December through June will be mitigated by an allocation of 10% of the discharge volume to an "environmental water account" that will be controlled by DFG. The daily modeling assumed that an additional 10% of any Delta Wetlands discharges for export were released to increase Delta outflows during the December-June period. **Discharge Maximum:** A calendar-year maximum of 250 TAF of Delta Wetlands storage can be exported. The daily water-year model specifies the amount of Delta Wetlands export from the previous January-September. Any remaining export volume can be exported during the October-December period. The 250-TAF cumulative export limit is reset on January 1.

Table 3-19. Continued

Diversion Rules	Discharge Rules
DCC Gates and Delta Inflow: During the November-through-January period, Delta Wetlands diversions will be limited to 3,000 cfs if the DCC gates are closed and Delta inflow is less than 30,000 cfs. Delta Wetlands diversions will be limited to 4,000 cfs if the inflow is less than 50,000 cfs and DCC gates are closed.	
Topping Off: The FOC allow some Delta Wetlands diversions for replacement of evaporative losses from the reservoir islands in June through October. This allowance was not included in the daily modeling; Delta Wetlands storage discharge for export generally begins in June from Bacon Island and in July from Webb Tract, so the potential gain in Delta Wetlands storage is limited to about 10 TAF.	

Note: See "Notes and Acronyms" at end of tables section.

Table 3-20. Comparison of Monthly and Daily Operations Model Results for Delta Wetlands Diversions and Exports (1985-1994)

Delta Wetlands Diversions (cfs)

Monthly Model Results

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	(TAF)
85	0	0	3,000	0	640	0	0	0	0	0	60	0	223
86	0	0	0	2,356	1,708	49	0	0	0	0	0	0	248
87	0	0	0	0	806	25	0	0	0	0	60	0	54
88	0	0	0	2,999	0	0	0	0	0	0	0	0	181
89	0	0	0	0	0	0	0	0	0	0	60	0	4
90	0	0	0	0	0	0	0	0	0	0	0	0	0
91	0	0	0	0	0	0	0	0	0	0	0	0	0
92	0	0	0	0	0	0	0	0	0	0	0	0	0
93	0	0	0	3,871	31	49	0	0	296	0	60	0	259
94	0	0	0	0	1,442	0	0	0	0	0	0	0	87

Daily Model Results

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	(TAF)
85	0	1,186	2,356	659	226	49	0	0	0	0	128	0	278
86	0	0	0	0	4,074	260	0	0	0	0	0	295	279
87	0	0	0	0	110	1,777	0	0	0	0	154	0	123
88	0	0	0	269	0	0	0	0	0	0	0	0	16
89	0	0	0	0	0	978	0	0	0	0	750	0	104
90	0	0	0	0	0	0	0	0	0	0	0	0	0
91	0	0	0	0	0	199	0	0	0	0	0	0	12
92	0	0	0	0	86	21	0	0	0	0	0	0	6
93	0	0	0	1,729	2,361	650	0	0	1,036	0	425	17	375
94	0	0	0	0	491	1,187	0	0	0	0	141	0	110

Delta Wetlands Exports (cfs)

Monthly Model Results

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	(TAF)
85	0	0	0	0	0	2,000	0	0	1,241	0	0	0	195
86	0	0	0	0	0	0	0	0	2,000	1,519	0	0	212
87	0	0	0	0	0	0	0	0	432	0	0	0	26
88	0	0	0	0	2,000	1,052	0	0	0	0	0	0	184
89	0	0	0	0	0	0	0	0	0	0	0	0	0
90	0	0	0	0	0	0	0	0	0	0	0	0	0
91	0	0	0	0	0	0	0	0	0	0	0	0	0
92	0	0	0	0	0	0	0	0	0	0	0	0	0
93	0	0	0	0	0	0	0	0	0	3,741	0	0	225
94	0	0	0	0	0	1,253	0	0	0	0	0	0	76

Daily Model Results

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	(TAF)
85	0	0	287	110	0	0	0	0	590	2,839	95	0	237
86	0	0	0	0	0	0	0	0	1,435	1,977	0	0	206
87	259	0	0	0	0	89	0	0	753	706	108	0	115
88	0	0	0	0	259	0	0	0	0	0	0	0	16
89	0	0	0	0	0	0	0	0	750	9	501	191	88
90	0	0	0	0	0	0	0	0	0	0	0	0	0
91	0	0	0	0	0	0	0	0	98	0	0	0	6
92	0	0	0	0	0	89	0	0	0	0	0	0	5
93	0	0	0	0	0	1,184	0	0	157	2,729	0	0	246
94	91	933	0	0	0	0	0	0	757	625	0	126	153

Notes: See "Notes and Acronyms" at end of tables section.

Table 3-21. Delta Wetlands Diversions (cfs) under Cumulative Conditions

Water Year	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Total (TAF)
1922	0	0	0	0	4,000	307	0	0	214	0	0	0	272
1923	0	0	3,871	15	0	0	0	0	0	0	0	0	234
1924	0	0	0	0	0	0	0	0	0	0	0	0	0
1925	0	0	0	0	4,000	0	0	0	0	0	0	0	241
1926	0	0	0	0	15	0	0	0	0	0	0	0	1
1927	0	0	0	3,299	664	49	0	0	0	0	0	0	242
1928	0	0	0	3,375	559	49	0	0	0	0	0	0	240
1929	0	0	0	0	0	0	0	0	0	0	0	0	0
1930	0	0	0	0	0	0	0	0	0	0	0	0	0
1931	0	0	0	0	0	0	0	0	0	0	0	0	0
1932	0	0	0	379	0	0	0	0	0	0	0	0	23
1933	0	0	0	0	0	0	0	0	0	0	0	0	0
1934	0	0	0	0	0	0	0	0	0	0	0	0	0
1935	0	0	0	0	0	0	0	0	0	0	0	0	0
1936	0	0	0	0	4,000	177	0	0	0	0	0	0	252
1937	0	0	0	0	3,050	1,165	0	0	0	0	0	0	254
1938	0	0	3,871	15	31	49	0	0	296	0	0	0	257
1939	2,474	1,468	13	15	31	0	0	0	0	0	0	0	241
1940	0	0	0	0	4,000	177	0	0	0	0	0	0	252
1941	0	0	0	3,871	31	49	0	0	0	0	0	0	238
1942	0	0	3,871	15	31	49	0	0	0	0	0	0	239
1943	0	0	3,871	15	31	49	0	0	0	0	0	0	239
1944	0	0	0	0	4,000	177	0	0	0	0	0	0	252
1945	0	0	0	0	4,000	307	0	0	0	0	0	0	259
1946	0	0	3,871	15	0	1,039	0	0	0	0	0	0	297
1947	0	0	0	0	0	0	0	0	0	0	0	0	0
1948	0	0	0	0	0	0	0	0	0	0	0	0	0
1949	0	0	0	0	0	0	0	0	0	0	0	0	0
1950	0	0	0	0	0	0	0	0	0	0	0	0	0
1951	0	0	3,871	15	31	49	0	0	0	0	0	0	239
1952	0	0	3,871	15	30	49	0	0	296	130	115	87	277
1953	53	25	13	15	31	49	0	0	0	0	0	0	11
1954	0	0	0	3,871	31	49	0	0	0	0	0	0	238
1955	0	0	3,000	885	0	0	0	0	0	0	0	0	234
1956	0	0	0	3,871	30	49	0	0	0	0	0	0	238
1957	0	0	0	1,854	2,263	49	0	0	0	0	0	0	251
1958	0	0	1,913	1,972	31	49	0	0	296	0	0	0	257
1959	1,698	0	762	1,988	31	0	0	0	0	0	0	0	270
1960	0	0	0	0	0	0	0	0	0	0	0	0	0
1961	0	0	0	0	0	0	0	0	0	0	0	0	0
1962	0	0	0	0	4,000	0	0	0	0	0	0	0	241
1963	0	0	3,000	0	1,510	49	0	0	0	0	0	0	275
1964	0	4,000	0	188	30	0	0	0	0	0	0	0	254
1965	0	0	0	3,871	31	49	0	0	0	0	0	0	238
1966	0	0	0	3,871	31	49	0	0	0	0	0	0	238
1967	0	0	3,871	15	31	49	0	0	296	130	0	154	274
1968	1,304	0	2,785	133	30	49	0	0	0	0	0	0	259
1969	0	0	0	3,871	31	49	0	0	296	0	0	3,343	457
1970	688	25	13	15	31	49	0	0	0	0	0	0	49
1971	0	0	3,871	15	31	49	0	0	0	0	0	0	239
1972	0	0	157	2,048	1,429	0	0	0	0	0	0	0	219
1973	0	0	3,000	885	31	49	0	0	0	0	0	0	239
1974	0	4,000	13	15	31	49	0	0	0	0	0	0	247
1975	0	0	3,000	885	31	49	0	0	0	0	0	0	239
1976	217	0	0	1,834	454	0	0	0	0	0	0	0	151
1977	0	0	0	0	0	0	0	0	0	0	0	0	0
1978	0	0	0	0	4,000	307	0	0	0	0	0	0	259
1979	0	0	0	0	4,000	307	0	0	0	0	0	0	259
1980	0	0	259	3,626	30	49	0	0	0	0	0	0	239
1981	0	0	0	3,871	31	49	0	0	0	0	0	0	238
1982	0	0	3,871	15	31	49	0	0	0	0	0	1,291	317
1983	2,674	25	13	15	31	49	0	0	296	130	115	87	207
1984	53	25	13	15	30	49	0	0	0	0	0	0	11
1985	0	0	3,000	885	31	0	0	0	0	0	0	0	236
1986	0	0	0	1,894	2,219	49	0	0	0	0	0	0	251
1987	0	0	0	0	806	25	0	0	0	0	0	0	50
1988	0	0	0	2,516	0	0	0	0	0	0	0	0	152
1989	0	0	0	0	0	0	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0	0	0	0	0	0	0
1991	0	0	0	0	0	0	0	0	0	0	0	0	0
1992	0	0	0	0	0	0	0	0	0	0	0	0	0
1993	0	0	0	3,871	31	49	0	0	0	0	0	0	238
1994	0	0	0	1,316	2,859	0	0	0	0	0	0	0	252
Avg ('22-'94)	126	131	817	838	722	75	0	0	27	5	3	68	169

Note: See "Notes and Acronyms" at end of tables section.

Table 3-22. Delta Wetlands Storage (TAF) under Cumulative Conditions

Water Year	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1922	0	0	0	0	222	238	234	227	233	0	0	0
1923	0	0	238	238	125	0	0	0	0	0	0	0
1924	0	0	0	0	0	0	0	0	0	0	0	0
1925	0	0	0	0	222	96	92	86	0	0	0	0
1926	0	0	0	0	1	0	0	0	0	0	0	0
1927	0	0	0	203	238	238	234	227	101	0	0	0
1928	0	0	0	208	238	238	234	227	101	0	0	0
1929	0	0	0	0	0	0	0	0	0	0	0	0
1930	0	0	0	0	0	0	0	0	0	0	0	0
1931	0	0	0	0	0	0	0	0	0	0	0	0
1932	0	0	0	23	0	0	0	0	0	0	0	0
1933	0	0	0	0	0	0	0	0	0	0	0	0
1934	0	0	0	0	0	0	0	0	0	0	0	0
1935	0	0	0	0	0	0	0	0	0	0	0	0
1936	0	0	0	0	230	238	234	227	101	0	0	0
1937	0	0	0	0	169	238	234	227	101	0	0	0
1938	0	0	238	238	238	238	234	227	238	0	0	0
1939	152	238	238	238	238	112	108	101	0	0	0	0
1940	0	0	0	0	230	238	234	227	101	0	0	0
1941	0	0	0	238	238	238	234	227	101	0	0	0
1942	0	0	238	238	238	238	234	227	127	0	0	0
1943	0	0	238	238	238	238	234	227	101	0	0	0
1944	0	0	0	0	230	238	234	227	101	0	0	0
1945	0	0	0	0	222	238	234	227	101	0	0	0
1946	0	0	238	238	125	186	182	175	49	22	14	9
1947	6	5	4	0	0	0	0	0	0	0	0	0
1948	0	0	0	0	0	0	0	0	0	0	0	0
1949	0	0	0	0	0	0	0	0	0	0	0	0
1950	0	0	0	0	0	0	0	0	0	0	0	0
1951	0	0	238	238	238	238	234	227	101	0	0	0
1952	0	0	238	238	238	238	234	227	238	238	238	238
1953	238	238	238	238	238	238	234	227	101	0	0	0
1954	0	0	0	238	238	238	234	227	101	0	0	0
1955	0	0	184	238	125	0	0	0	0	0	0	0
1956	0	0	0	238	238	238	234	227	101	0	0	0
1957	0	0	0	114	238	238	234	227	101	0	0	0
1958	0	0	118	238	238	238	234	227	238	58	44	0
1959	104	71	117	238	238	112	108	101	0	0	0	0
1960	0	0	0	0	0	0	0	0	0	0	0	0
1961	0	0	0	0	0	0	0	0	0	0	0	0
1962	0	0	0	0	222	96	92	86	0	0	0	0
1963	0	0	184	156	238	238	234	227	101	0	0	0
1964	0	238	227	238	238	112	108	101	0	0	0	0
1965	0	0	0	238	238	238	234	227	101	0	0	0
1966	0	0	0	238	238	238	234	227	101	0	0	0
1967	0	0	238	238	238	238	234	227	238	238	157	161
1968	238	60	231	238	238	238	234	227	101	0	0	0
1969	0	0	0	238	238	238	234	227	238	42	0	199
1970	238	238	238	238	238	238	234	227	101	0	0	0
1971	0	0	238	238	238	238	234	227	101	0	0	0
1972	0	0	10	135	215	89	85	79	0	0	0	0
1973	0	0	184	238	238	238	234	227	101	0	0	0
1974	0	238	238	238	238	238	234	227	101	0	0	0
1975	0	0	184	238	238	238	234	227	101	0	0	0
1976	13	0	0	113	137	11	7	1	0	0	0	0
1977	0	0	0	0	0	0	0	0	0	0	0	0
1978	0	0	0	0	222	238	234	227	101	0	0	0
1979	0	0	0	0	222	238	234	227	101	0	0	0
1980	0	0	16	238	238	238	234	227	101	0	0	0
1981	0	0	0	238	238	238	234	227	101	0	0	0
1982	0	0	238	238	238	238	234	227	109	12	0	77
1983	238	238	238	238	238	238	234	227	238	238	238	238
1984	238	238	238	238	238	238	234	227	101	0	0	0
1985	0	0	184	238	238	112	108	101	0	0	0	0
1986	0	0	0	116	238	238	234	227	101	0	0	0
1987	0	0	0	0	45	43	39	33	0	0	0	0
1988	0	0	0	155	38	0	0	0	0	0	0	0
1989	0	0	0	0	0	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0	0	0	0	0	0
1991	0	0	0	0	0	0	0	0	0	0	0	0
1992	0	0	0	0	0	0	0	0	0	0	0	0
1993	0	0	0	238	238	238	234	227	101	0	0	0
1994	0	0	0	81	238	112	108	101	0	0	0	0
Avg ('22-'94)	20	25	75	125	159	142	139	135	68	12	9	13

Note: See "Notes and Acronyms" at end of tables section.

Table 3-23. Delta Wetlands Discharges for Export (cfs) under Cumulative Conditions

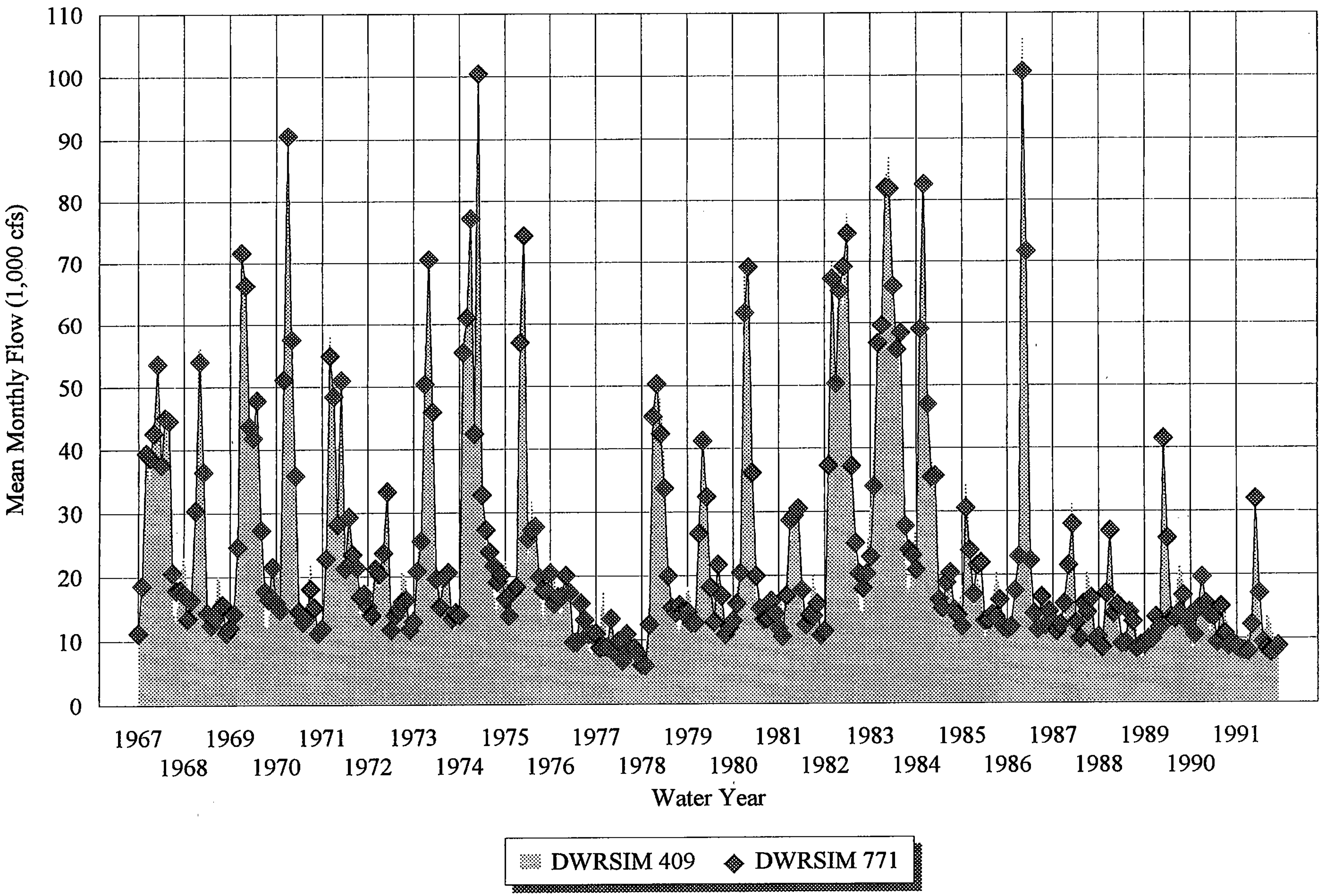
Water Year	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Total (TAF)	Calendar (TAF)
1922	0	0	0	0	0	0	0	0	0	3,661	0	0	221	221
1923	0	0	0	0	2,000	1,988	0	0	0	0	0	0	240	241
1924	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1925	0	0	0	0	0	2,000	0	0	1,320	0	0	0	200	200
1926	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1927	0	0	0	0	0	0	0	0	2,000	1,519	0	0	212	212
1928	0	0	0	0	0	0	0	0	2,000	1,519	0	0	212	212
1929	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1930	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1931	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1932	0	0	0	0	376	0	0	0	0	0	0	0	23	23
1933	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1934	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1935	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1936	0	0	0	0	0	0	0	0	2,000	1,519	0	0	212	212
1937	0	0	0	0	0	0	0	0	2,000	1,519	0	0	212	212
1938	0	0	0	0	0	0	0	0	0	3,741	0	0	225	226
1939	0	0	0	0	0	2,000	0	0	1,587	0	0	0	216	216
1940	0	0	0	0	0	0	0	0	2,000	1,519	0	0	212	212
1941	0	0	0	0	0	0	0	0	2,000	1,519	0	0	212	212
1942	0	0	0	0	0	0	0	0	1,578	1,928	0	0	211	211
1943	0	0	0	0	0	0	0	0	2,000	1,519	0	0	212	212
1944	0	0	0	0	0	0	0	0	2,000	1,519	0	0	212	212
1945	0	0	0	0	0	0	0	0	2,000	1,519	0	0	212	212
1946	0	0	0	0	2,000	0	0	0	2,000	324	0	0	261	261
1947	0	0	0	46	0	0	0	0	0	0	0	0	3	3
1948	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1949	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1950	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1951	0	0	0	0	0	0	0	0	2,000	1,519	0	0	212	212
1952	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1953	0	0	0	0	0	0	0	0	2,000	1,519	0	0	212	212
1954	0	0	0	0	0	0	0	0	2,000	1,519	0	0	212	212
1955	0	0	0	0	2,000	1,988	0	0	0	0	0	0	240	241
1956	0	0	0	0	0	0	0	0	2,000	1,519	0	0	212	212
1957	0	0	0	0	0	0	0	0	2,000	1,519	0	0	212	212
1958	0	0	0	0	0	0	0	0	0	2,803	100	658	215	248
1959	0	543	0	0	0	2,000	0	0	1,587	0	0	0	249	216
1960	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1961	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1962	0	0	0	0	0	2,000	0	0	1,320	0	0	0	200	200
1963	0	0	0	451	0	0	0	0	2,000	1,519	0	0	239	249
1964	0	0	160	0	0	2,000	0	0	1,587	0	0	0	226	216
1965	0	0	0	0	0	0	0	0	2,000	1,519	0	0	212	212
1966	0	0	0	0	0	0	0	0	2,000	1,519	0	0	212	212
1967	0	0	0	0	0	0	0	0	0	0	1,200	0	72	251
1968	0	2,961	0	0	0	0	0	0	2,000	1,519	0	0	390	212
1969	0	0	0	0	0	0	0	0	0	3,064	562	0	218	219
1970	0	0	0	0	0	0	0	0	2,000	1,519	0	0	212	212
1971	0	0	0	0	0	0	0	0	2,000	1,519	0	0	212	212
1972	0	0	0	0	0	2,000	0	0	1,203	0	0	0	193	193
1973	0	0	0	0	0	0	0	0	2,000	1,519	0	0	212	212
1974	0	0	0	0	0	0	0	0	2,000	1,519	0	0	212	212
1975	0	0	0	0	0	0	0	0	2,000	1,519	0	0	212	224
1976	0	199	0	0	0	2,000	0	0	0	0	0	0	132	121
1977	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1978	0	0	0	0	0	0	0	0	2,000	1,519	0	0	212	212
1979	0	0	0	0	0	0	0	0	2,000	1,519	0	0	212	212
1980	0	0	0	0	0	0	0	0	2,000	1,519	0	0	212	212
1981	0	0	0	0	0	0	0	0	2,000	1,519	0	0	212	212
1982	0	0	0	0	0	0	0	0	1,866	1,453	80	0	205	205
1983	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1984	0	0	0	0	0	0	0	0	2,000	1,519	0	0	212	212
1985	0	0	0	0	0	2,000	0	0	1,587	0	0	0	216	216
1986	0	0	0	0	0	0	0	0	2,000	1,519	0	0	212	212
1987	0	0	0	0	0	0	0	0	432	0	0	0	26	26
1988	0	0	0	0	2,000	568	0	0	0	0	0	0	155	155
1989	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1991	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1992	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1993	0	0	0	0	0	0	0	0	2,000	1,519	0	0	212	212
1994	0	0	0	0	0	2,000	0	0	1,587	0	0	0	216	216
Avg ('22-'94)	0	51	2	7	115	309	0	0	1,064	857	27	9	147	147

Note: See "Notes and Acronyms" at end of tables section.

Notes and Acronyms

The following acronyms and terms appear in the tables that accompany Chapter 3, "Water Supply and Operations".

CCWD	Contra Costa Water District
cfs	cubic feet per second
CVP	Central Valley Project
DCC	Delta Cross Channel
DFG	California Department of Fish and Game
E/I ratio	allowable amount of exports as a percentage of inflow
km	kilometer
SJR	San Joaquin River
SWP	State Water Project
TAF	thousand acre-feet
VAMP	Vernalis Adaptive Management Plan
WQCP	Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary



Jones & Stokes

Figure 3-1
DWRSIM-Simulated Mean Monthly Sacramento River Flows: Studies 409 and 771

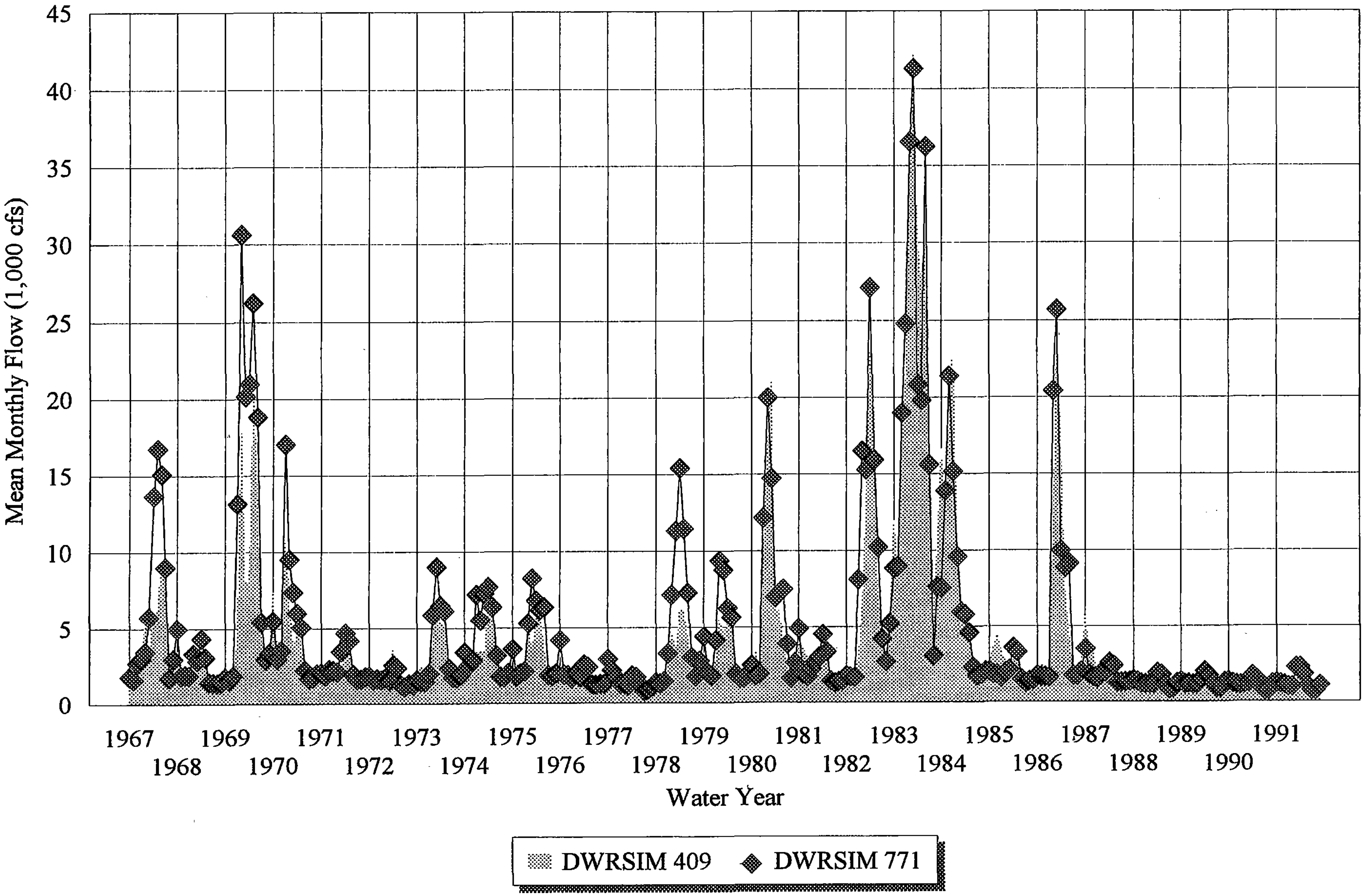


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Figure 3-2
DWRSIM-Simulated Mean Monthly San Joaquin River Flows: Studies 409 and 771

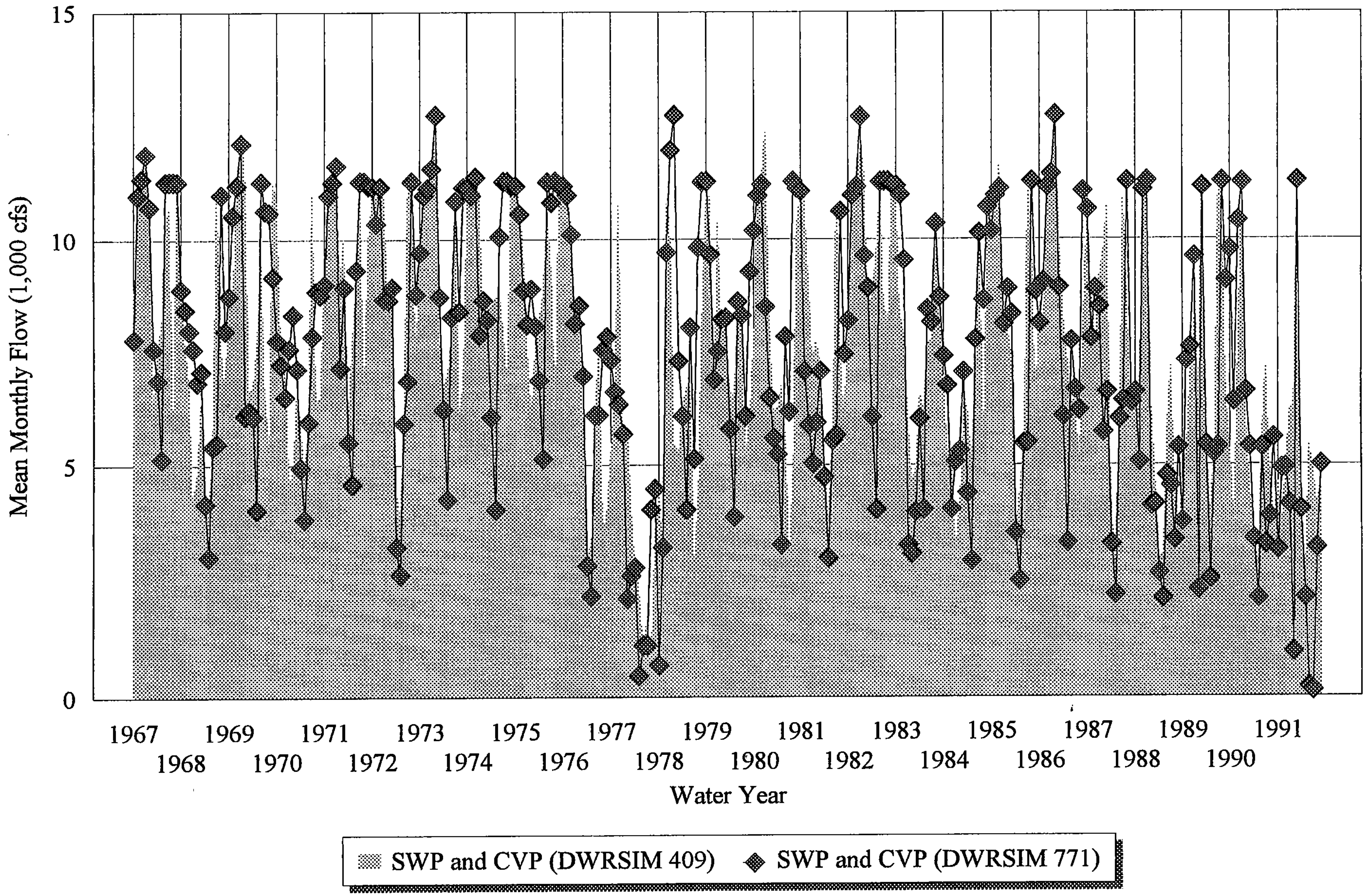

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Figure 3-3
DWRSIM-Simulated Mean Monthly SWP and CVP Exports: Studies 409 and 771

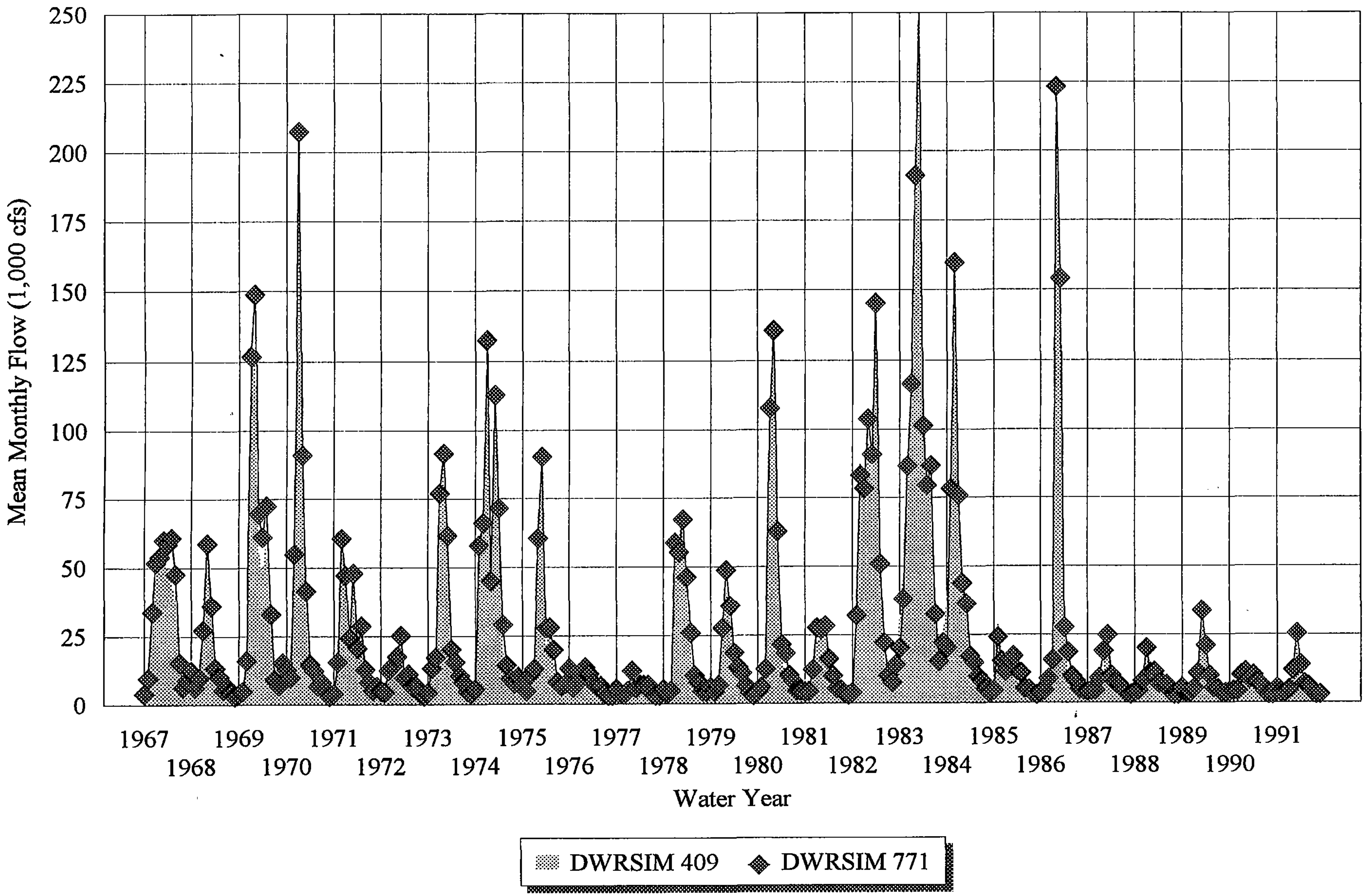

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Figure 3-4
DWRSIM-Simulated Mean Monthly Delta Outflow: Studies 409 and 771

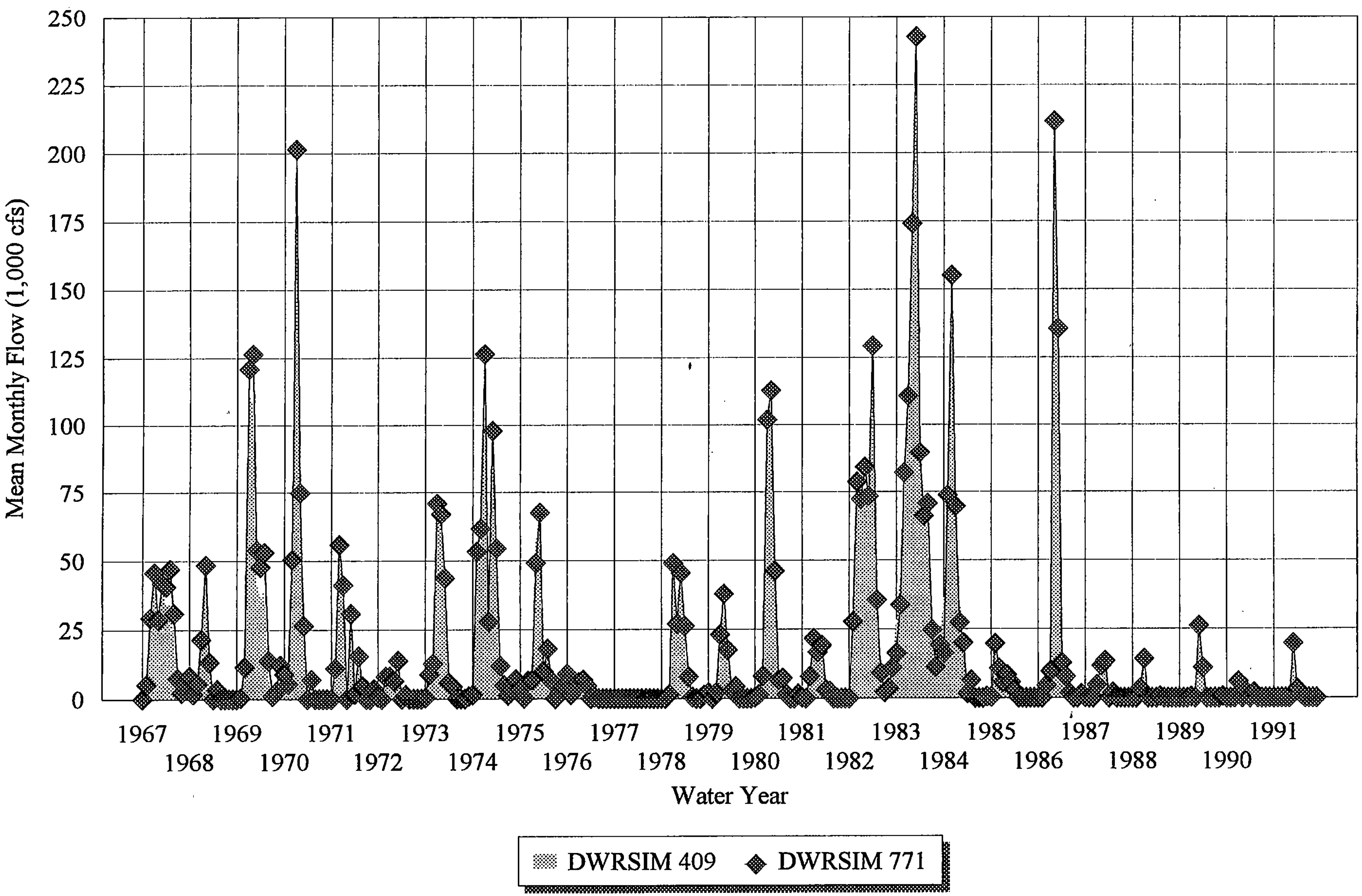

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Figure 3-5
DWRSIM-Simulated Mean Monthly Available Water for Delta Wetlands Diversion: Studies 409 and 771

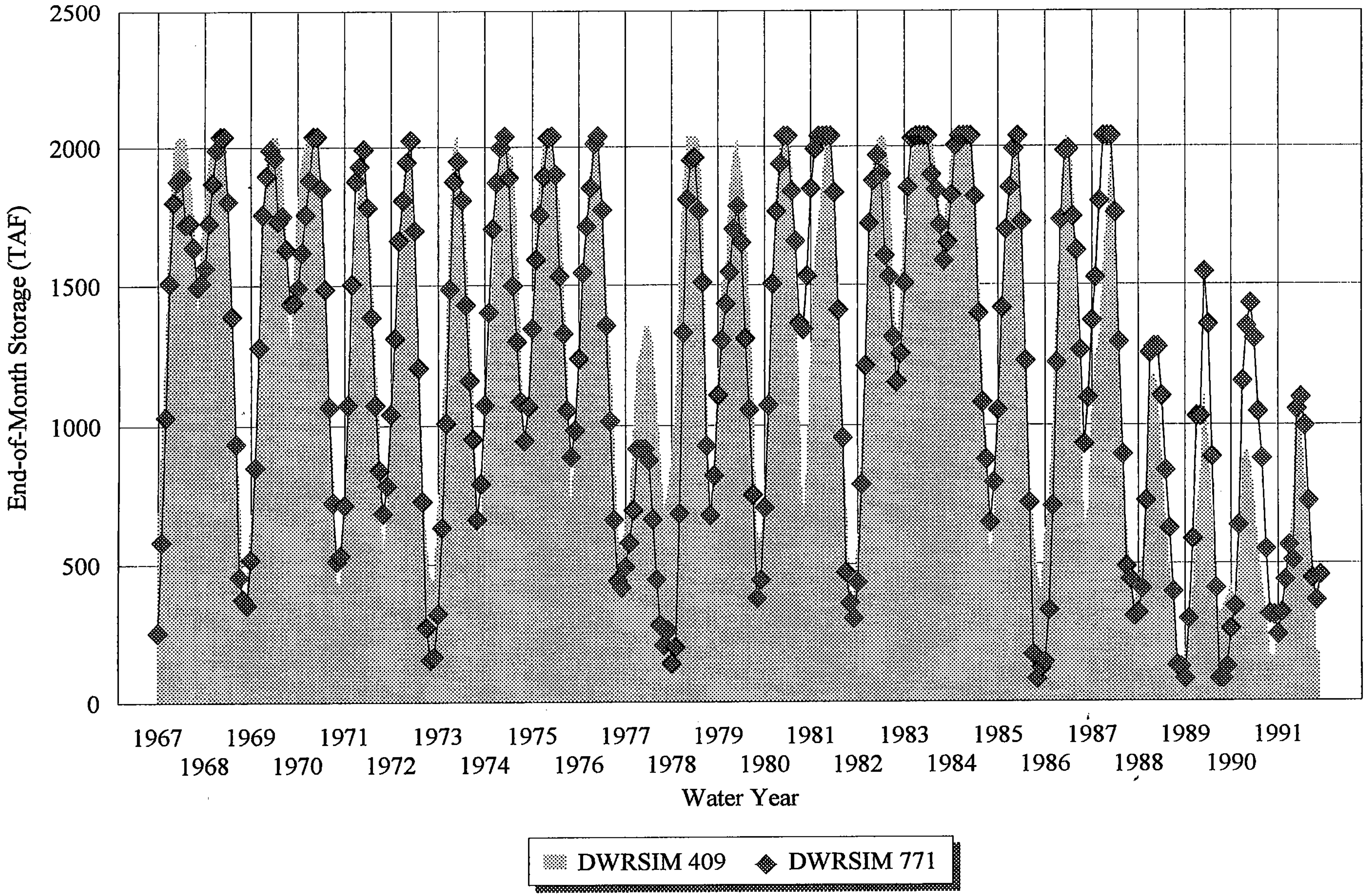

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Figure 3-6
DWRSIM-Simulated Mean Monthly SWP and CVP San Luis Reservoir Storage: Studies 409 and 771

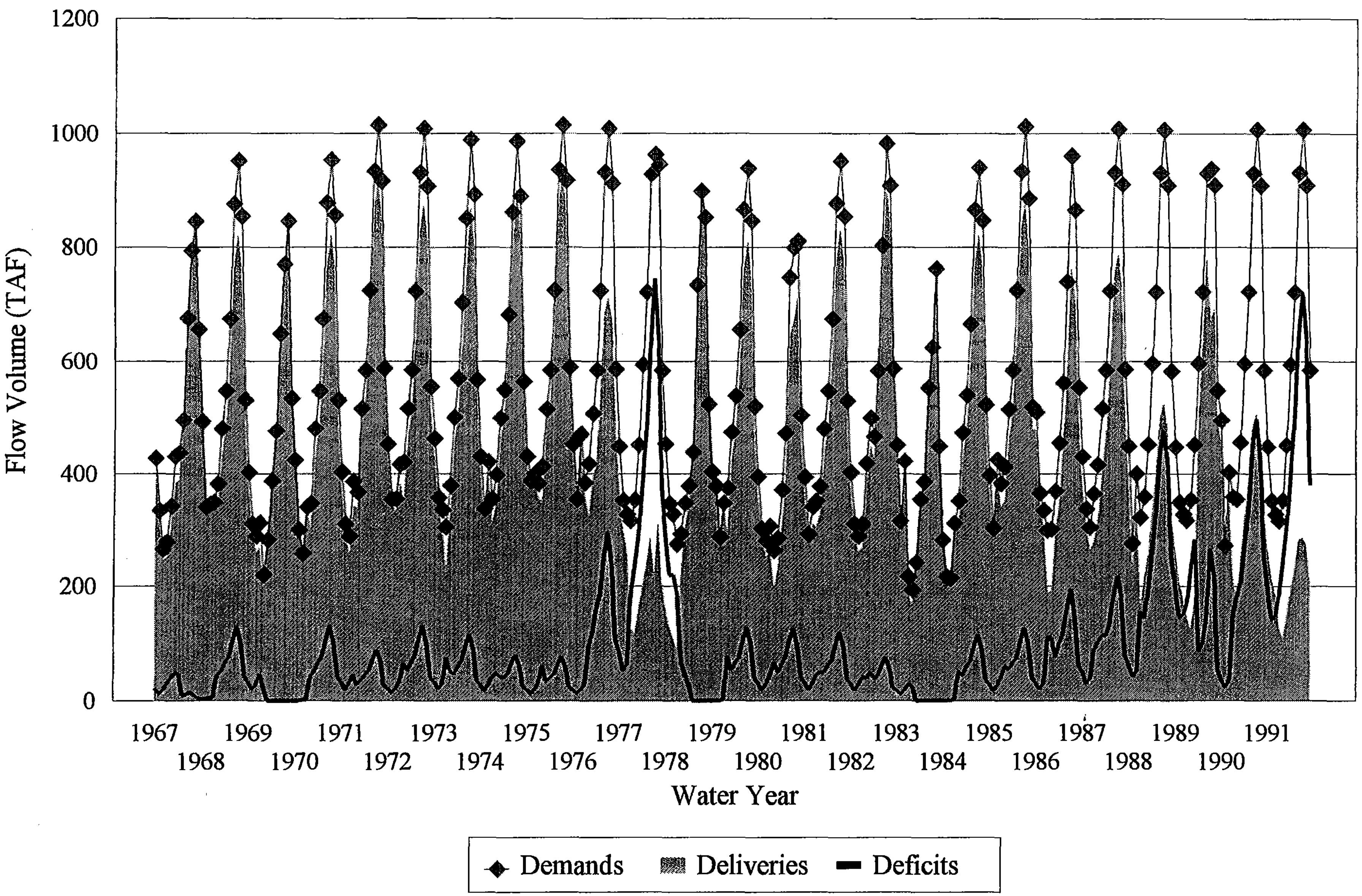

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Figure 3-7
South-of-Delta Demands and Deliveries:
DWRSIM Study 771 with VAMP

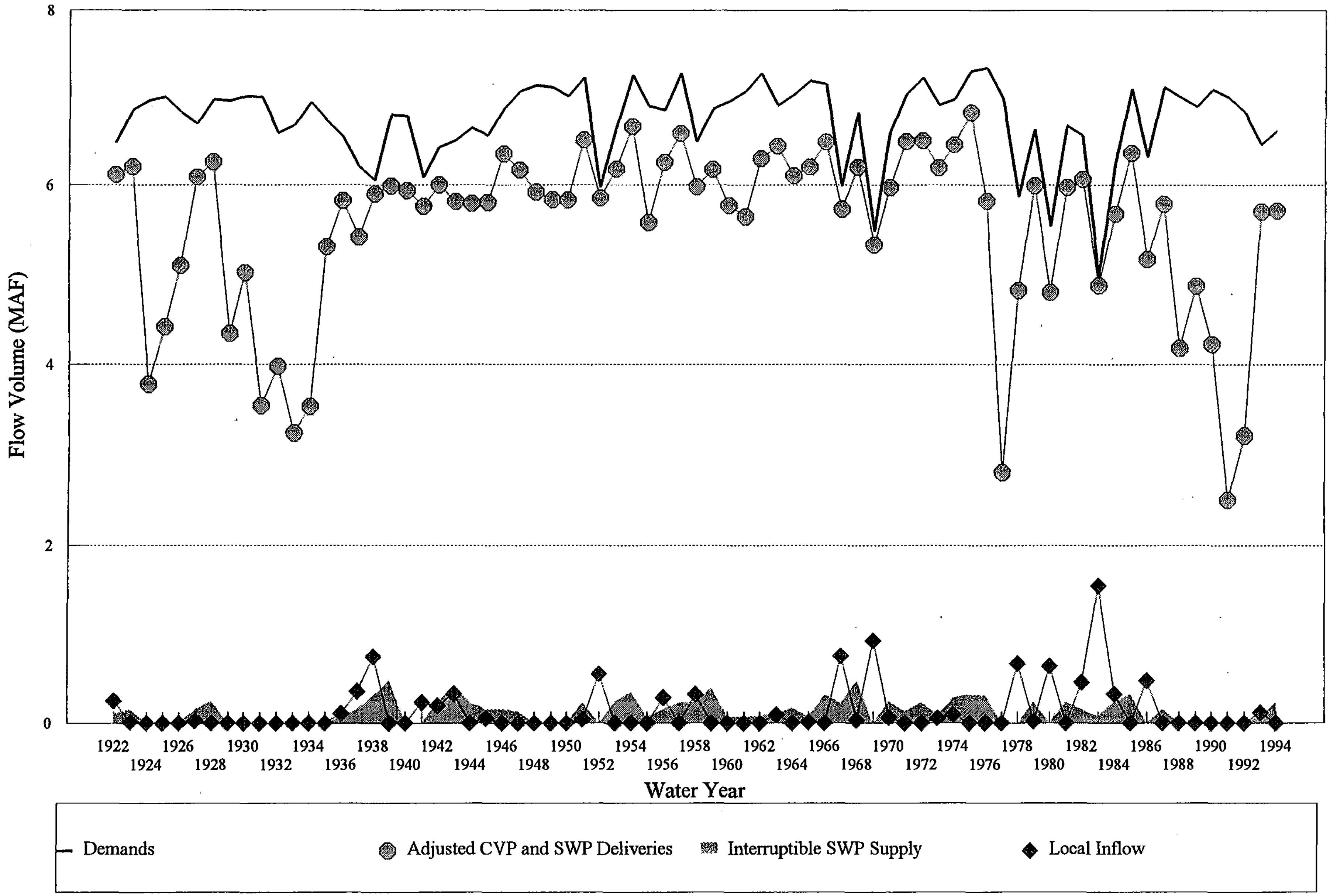

Figure 3-8
Annual Demands and Deliveries for South-of-Delta Water Supply: DWRSIM Study 771 as Adjusted by DeltaSOS for Joint Point of Diversion

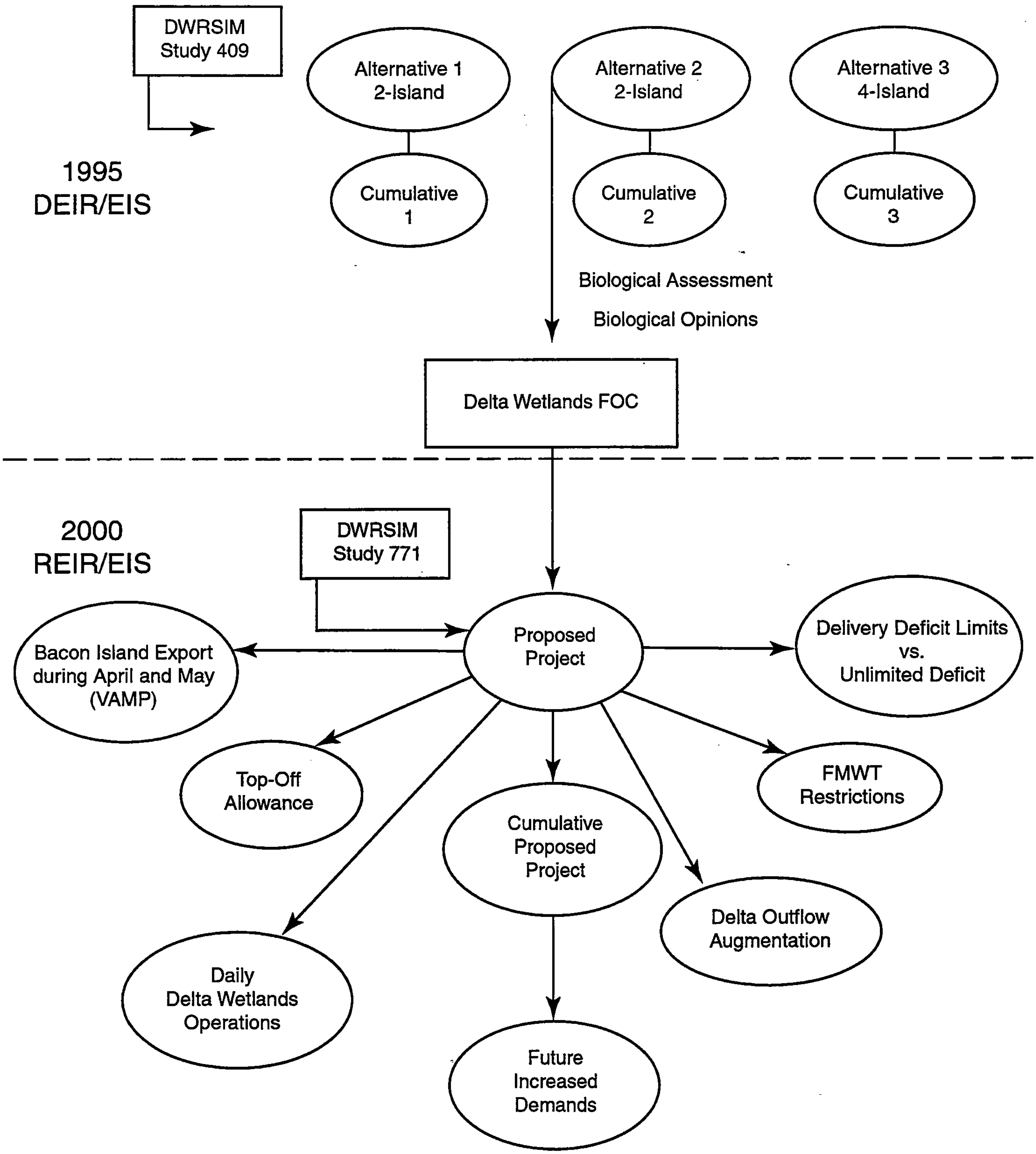

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Figure 3-9
Relationship between 1995 DEIR/EIS Alternatives and 2000 REIR/EIS Simulated Potential Project Operations

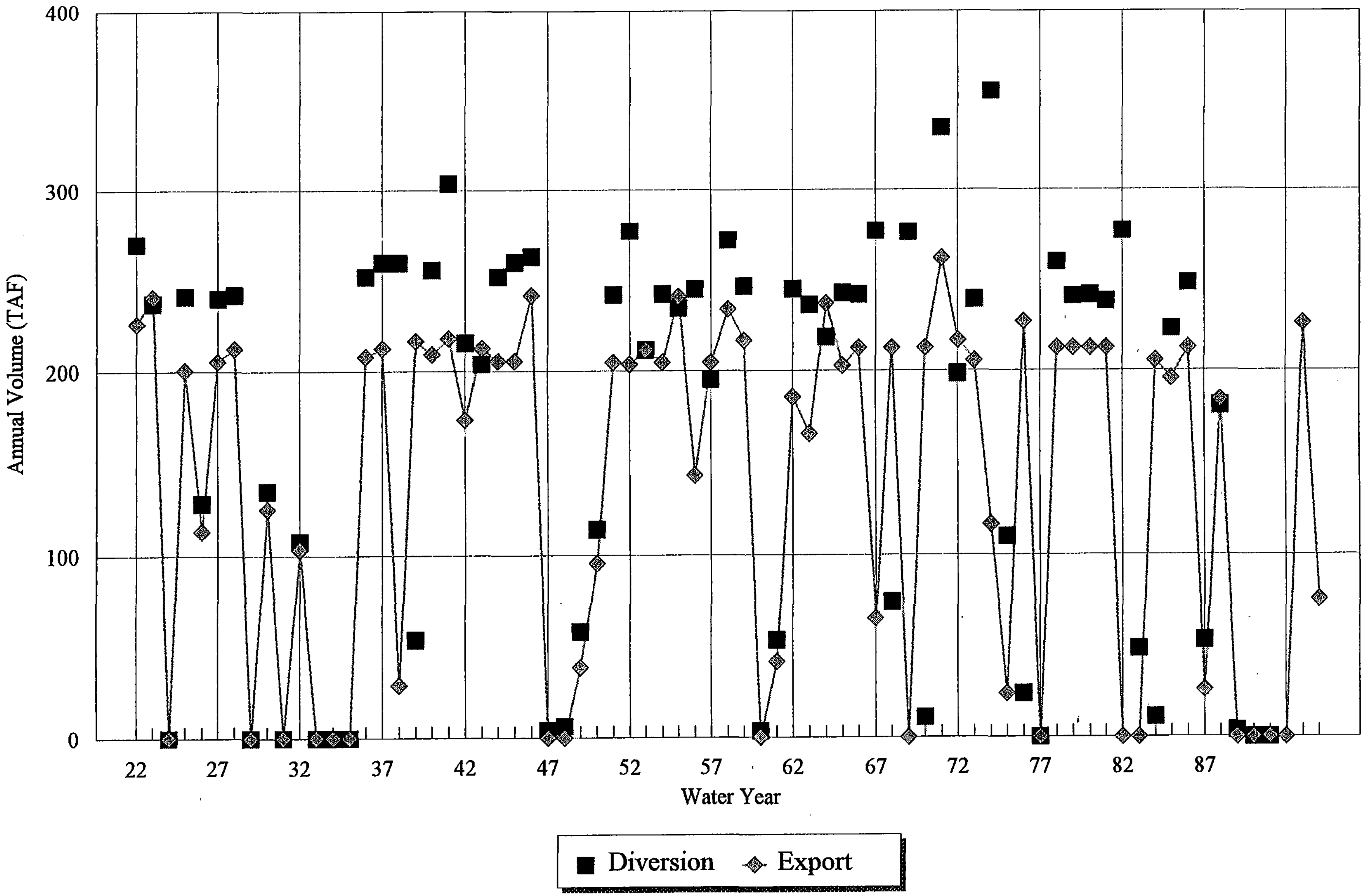

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Figure 3-10
Simulated Annual Delta Wetlands Diversion and Export Volumes Unlimited by South-of-Delta Delivery Deficits

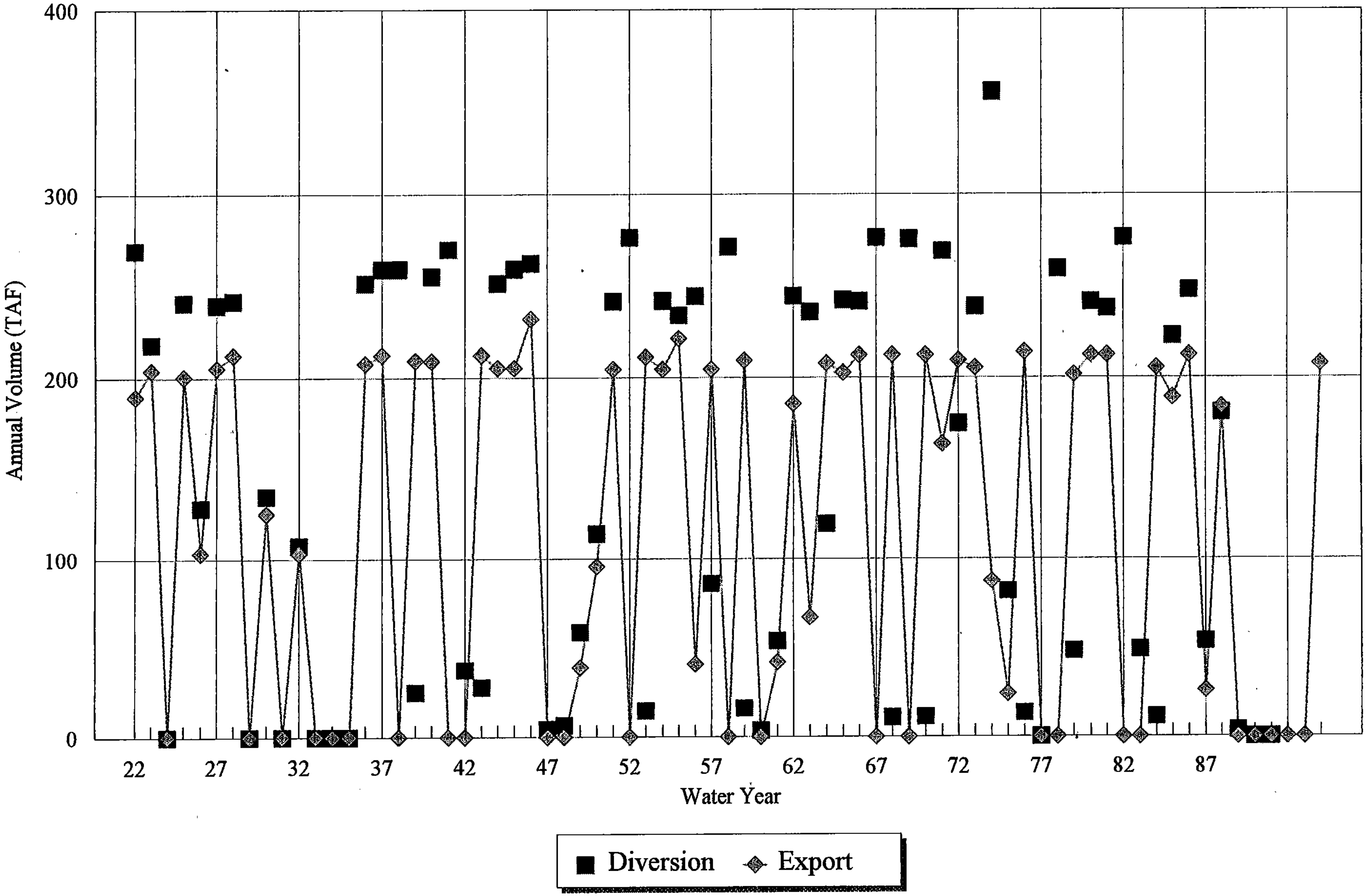
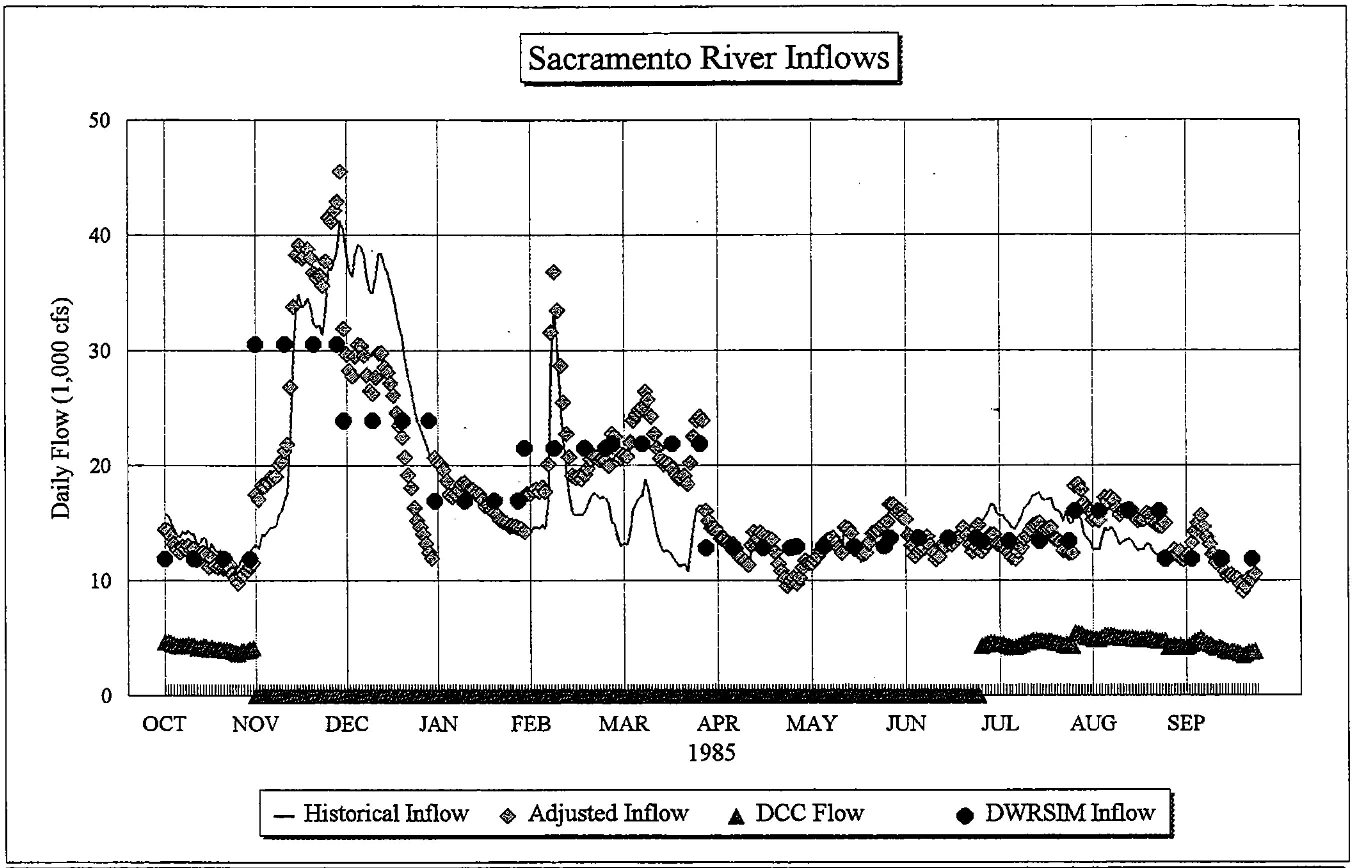


Figure 3-11
Simulated Annual Delta Wetlands Diversion and Export Volumes Limited by South-of-Delta Delivery Deficits



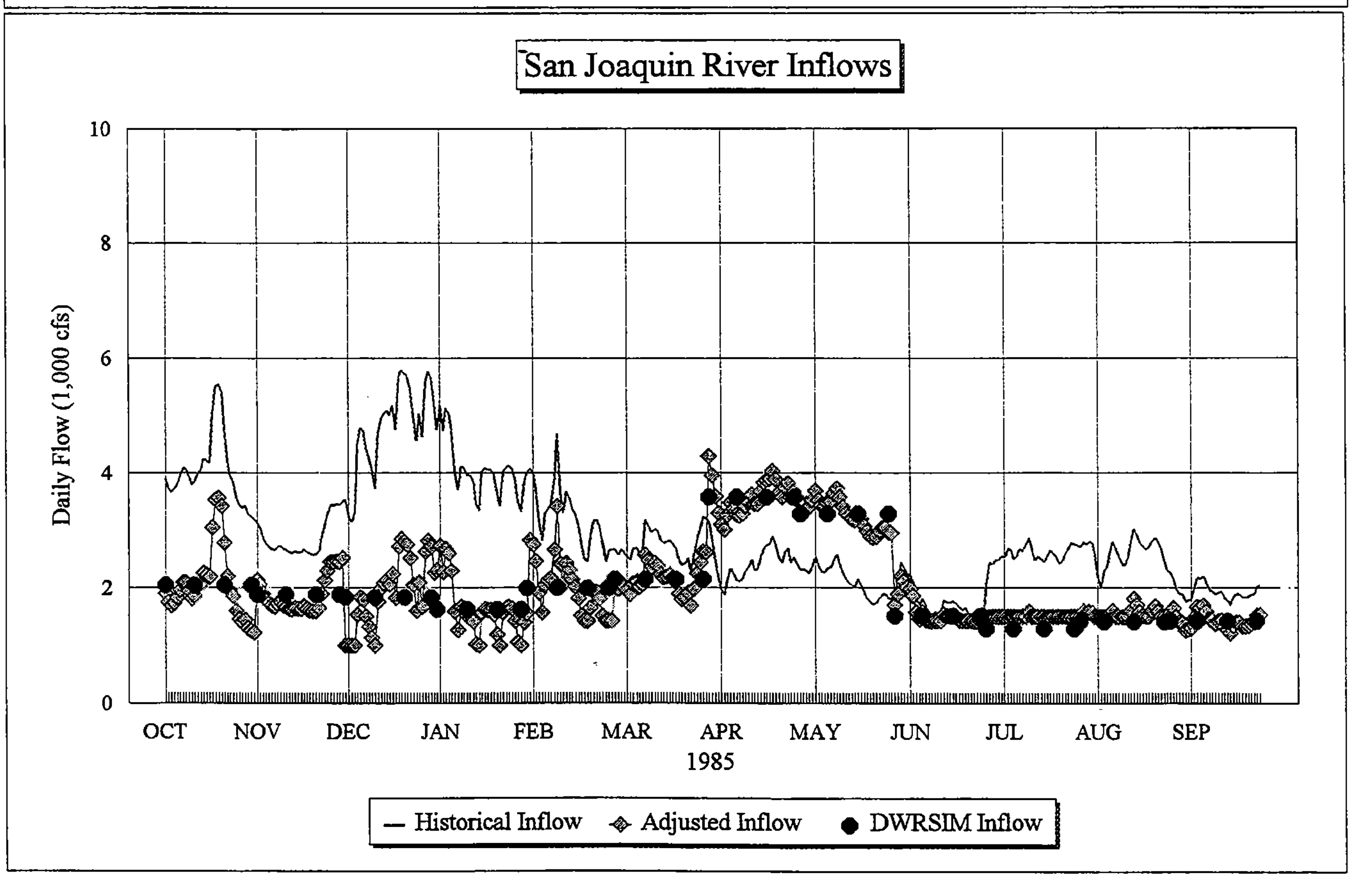


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Figure 3-12
Daily Adjusted Sacramento and San Joaquin River Inflows for Simulating Delta Wetlands Final Operations Criteria for 1985

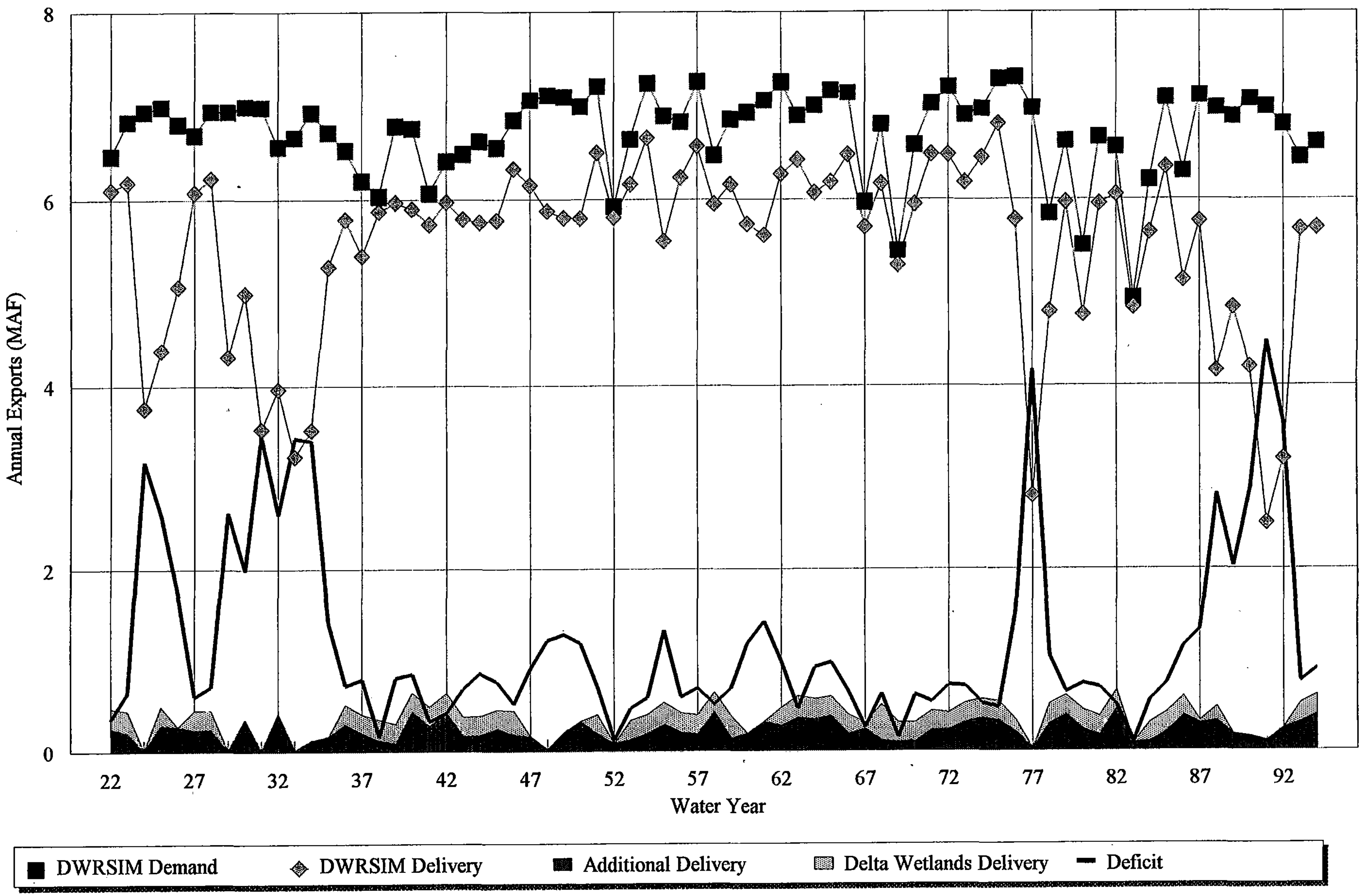

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Figure 3-13
Simulated Annual Delta Demands and Deliveries under Cumulative Conditions

Chapter 4. Water Quality

FOCUS OF THE REVISED DRAFT EIR/EIS ANALYSIS

Issues Raised in Water Right Hearing Testimony and Comments on the 1995 Draft EIR/EIS

As described in the 1995 DEIR/EIS, the Delta Wetlands Project could affect water quality in Delta waters during project diversion and discharge operations. Project effects on salinity and DOC concentrations in Delta channels and exports are a major concern for other Delta water users, especially providers of municipal drinking water. Project effects on other water quality variables (e.g., temperature, suspended sediments, dissolved oxygen, and chlorophyll) were also described qualitatively in the 1995 DEIR/EIS. Project effects on temperature and dissolved oxygen were addressed during the ESA consultation process, and no new information on other variables, such as suspended sediment and chlorophyll, has been presented in testimony or comment letters. Therefore, this REIR/EIS analysis focuses on project effects on DOC and salinity.

The Delta Wetlands Project could affect water quality in the following ways:

- Diverting water onto the project islands would reduce Delta outflows. As a result, brackish water from Suisun Bay would intrude into the central Delta and salinity in Delta channels and exports would increase.
- While water is stored on the reservoir islands, salinity and DOC concentrations would increase because of evaporative losses, and DOC concentrations would increase as a result of peat-soil leaching and algal growth. Therefore, discharges from the Delta Wetlands Project islands would contribute to increased concentrations of salinity and DOC in Delta channel receiving waters and in exports.
- Increases in DOC and salinity could indirectly cause increases in THMs and other disinfection byproducts (DBPs) in treated drinking-water supplies that are diverted or exported from the Delta.

For more information on Delta water quality issues, refer to Chapter 3C of the 1995 DEIR/EIS.

Although commenters on the 1995 DEIR/EIS and parties to the water right hearing generally agreed on the processes through which the Delta Wetlands Project could affect water quality, the methods and assumptions used to determine the magnitude of those impacts were debated at length. The magnitude of the effect of project operations on other water users' water quality depends on several factors:

- quality of water when it is diverted onto the project islands;
- length of time that water is held on the islands;
- rate of peat-soil leaching and other DOC-loading mechanisms;
- quality of receiving waters at the time of project discharges; and
- amount of Delta Wetlands water exported (the portion of total exports), which is determined by the rate of release from the reservoir islands.

The following components of the Delta Wetlands impact analysis for water quality were the focus of many comments:

- the concentrations of constituents in Delta inflow and Delta agricultural drainage, and resulting baseline water quality;
- DOC loading rates from peat-soil leaching, plant material growth and degradation, and interceptor well pumping activities under project operations;
- the question of whether ceasing agricultural activities on the Delta Wetlands Project islands can be considered to benefit water quality and to what degree it may offset the effects of project diversions and discharges; and
- methods of determining how much DBP would form as a result of export salinity (bromide [Br^-]) and DOC concentration.

Several commenters suggested that the lead agencies could obtain a more accurate estimate of the potential range of project effects by using new data on Delta DOC loading and ambient salinity developed through DWR programs. Commenters also suggested that revised methods of predicting the relationship between DOC and salinity levels and the formation of THMs and other DBPs at municipal water treatment plants would yield a better estimate of project effects.

This chapter updates the assessment of Delta Wetlands Project effects on water quality presented in Chapter 3C and Appendices C1 through C5 of the 1995 DEIR/EIS. New information has been reviewed and the previous analysis has been revised as appropriate.

Summary of Issues Addressed in This Chapter

The analysis presented in this chapter addresses the following questions, which represent the concerns expressed by stakeholders at the SWRCB water right hearing on the Delta Wetlands Project and in comments on the 1995 DEIR/EIS:

- What will be the DOC loading on the reservoir islands from short-term and long-term peat-soil leaching, plant material growth and decay, and interceptor well water returns?
- What impact will DOC from reservoir island water have on in-Delta water quality and senior water right holders?
- What impact will Delta Wetlands Project operations have on salinity in the Delta and at diversion points for senior water right holders?
- What impact would the Delta Wetlands Project's incremental change of DOC and salinity (Br^-) have on the formation of DBPs, including THMs and bromate, at municipal treatment plants receiving Delta water?

The analysis addresses these questions by providing new estimates of monthly Delta export water quality using a revised version of the DeltaSOS model. As described in Chapter 3, "Water Supply and Operations", this version incorporates new baseline DWRSIM model input, revised Delta standards and AFRP program measures, and Delta Wetlands Project operating rules. It augments the previously presented information with the most recent DWR data on Delta water quality constituents, and with updated information on the assumed relationship between constituents in raw water and municipal water treatment plant operations.

Definition of Terms

The following are definitions of key terms as they are used in this chapter:

- *Central Delta Water:* Used in the DeltaSOQ model to represent the source of export water from the central Delta, which includes a mixture of water from the Sacramento, Mokelumne, and Cosumnes Rivers; seawater intrusion from the western Delta; and some portion of the San Joaquin River that does not flow directly to the export locations.
- *Delta Drainage Water Quality Model (DeltaDWQ):* A model developed for the 1995 DEIR/EIS analysis to estimate how much the Delta Wetlands islands contribute to EC, DOC, Cl^-, and Br^- levels at Delta channel locations and in Delta diversions and exports under no-project conditions and under project operations.

- *Delta Exports:* The water pumped from the Delta to south-of-Delta users by DWR at Banks Pumping Plant and by Reclamation at the CVP Tracy Pumping Plant, and the amount diverted by CCWD at its Rock Slough and Old River intakes.

- *Delta Standards, Operations, and Quality Model (DeltaSOQ):* A modified version of the DeltaSOS model that incorporates equations that predict the water quality of agricultural drainage and Delta Wetlands reservoir island storage. This model also incorporates equations that predict the effects of agricultural drainage and Delta Wetlands discharges on EC levels and DOC concentrations in Delta channels and exports.

- *Electrical Conductivity (EC):* A general measure of dissolved minerals (i.e., salinity); the most commonly measured variable in Delta waters.

- *Leaching:* The removal of soluble substances from soil by percolating water.

- *Simulated Disinfection System (SDS):* A method of determining THM formation potential. This laboratory analytical method was developed to simulate municipal water treatment facilities' actual disinfection process (and THM concentrations) more closely than other methods; it uses a much lower chlorine (Cl_2) dose and much less contact time.

- *Trihalomethane (THM):* A class of carcinogenic substances, including chloroform ($CHCl_3$) and bromoform ($CHBr_3$), formed from chlorination of drinking-water supplies.

- *Trihalomethane Formation Potential (THMFP):* The potential for creation of THMs during chlorination or other oxidation treatment processes used for disinfection of municipal water supplies; an index of the maximum possible THM concentrations that could be produced by maximum chlorination of Delta water.

- *Ultraviolet Absorbance (UVA):* A physical measurement used in the study of humic acids and THM precursors, often found to be linearly related to DOC concentration. UVA may provide a measure of the humic and fulvic acid portion of total DOC in a water sample; this portion of total DOC is thought to be the precursor for THM.

- *Water Treatment Plant (WTP) Model:* A U.S. Environmental Protection Agency (EPA) model used for the 1995 DEIR/EIS to estimate THM concentrations at a typical water treatment plant that may use Delta exports containing water released from the Delta Wetlands Project islands. The model consists of a series of subroutines that simulate removal of organic THM precursor compounds and formation of THM. A more detailed description of the operation of the WTP model is provided in Appendix C5 of the 1995 DEIR/EIS. The model predicts total THM concentration, then estimates the relative concentrations of each of the four types of THM molecules by using separate regression equations for each type of THM molecule.

Organization of This Chapter

The remainder of this chapter presents information supporting the updated evaluation of water quality effects of Delta Wetlands Project operations in sections that can be divided into two themes. The first half describes new and updated information that has been considered in the analysis of project impacts, and is organized into the following major sections:

- "Overview of Sources of New and Updated Information": Provides an overview of the following four sections.
- "Updated Measurements of Inflow, Export, and Agricultural Drainage Water Quality": Presents Delta water quality data recently collected by the DWR MWQI program and other programs.
- "California Department of Water Resources Special Multipurpose Applied Research Technology Station Studies": Describes DWR's recent peat-soil flooding experiments.
- "Reported Estimates of Dissolved Organic Carbon Loading": Summarizes available estimates of DOC loading under existing and with-project conditions.
- "Changes in Disinfection Byproduct Rules": Discusses changes in rules for TOC removal and THM concentrations for water treatment.

The contents of these sections are described more fully under "Overview of Sources of New and Updated Information".

The second half of this chapter presents the impact analysis for the Delta Wetlands Project and is organized as follows:

- "Impact Assessment Methodology": Describes the methods used to assess project impacts and explains how the new and updated information has been incorporated into the modeling used to determine those impacts. Includes discussions of the updated methods for estimating project effects on DOC and salinity levels and for predicting the formation of THMs and bromate at water treatment plants. These methods are described more fully in Appendix G, "Water Quality Assessment Methods".
- "Criteria for Determining Impact Significance":
  - describes the impact significance thresholds used in the 1995 DEIR/EIS analysis,
  - summarizes comments on these criteria,

- discusses the relationship between the significance thresholds and mitigation triggers of water right terms and conditions, and
- presents the criteria used in this REIR/EIS.

■ "Environmental Consequences":

- presents the results of simulations of Delta water quality conditions for the No-Project Alternative and of effects of the proposed project on Delta salinity, export DOC levels, and THMs produced at water treatment plants,
- compares the impacts of the 1995 DEIR/EIS project alternatives on water quality to those identified for the proposed project using the new information and updated methods presented in this analysis,
- describes options for applying the recommended mitigation and discusses how mitigation measures may be refined in water right permit terms and conditions,
- describes cumulative impacts of the proposed project, and
- discusses the implications of the changes in water quality information and assessment methods with regard to Alternatives 1 and 3 in the section "Impact Evaluation of Project Alternatives from the 1995 Draft EIR/EIS".

OVERVIEW OF SOURCES OF NEW AND UPDATED INFORMATION

A great amount of water quality data is collected in the Delta each year. Data are collected by the Municipal Water Quality Investigations (MWQI) program of the DWR Division of Planning and Local Assistance, the Interagency Ecological Program (IEP), and the U.S. Geological Survey (USGS) Water Resources Division.

DWR's MWQI program has collected data on numerous water quality variables in Delta inflows and exports. The MWQI data include measurements of EC, DOC, THMFP, and related variables; therefore, they are the most relevant source of baseline Delta water quality information for this assessment. Appendices C1 and C2 of the 1995 DEIR/EIS presented MWQI monitoring data collected through water year 1991. This REIR/EIS includes the most recent MWQI data through water year 1998.

The MWQI program has also collected data on Delta agricultural drainage water quality, including measurements from drainage pumps on the four Delta Wetlands Project islands. Delta agricultural drainage data from 1986-1991 were included in Appendix C4 of the 1995 DEIR/EIS; this REIR/EIS includes the MWQI data on agricultural drainage through 1998 (California Department of Water Resources 1999a). However, most of the drainage sampling was discontinued in 1994, so only limited information from drainage sampling is available to augment the information presented in the 1995 DEIR/EIS. The MWQI data are used to estimate the contributions of water quality constituents of concern from Delta sources under no-project conditions and under project operations.

Also evaluated for this assessment of Delta Wetlands Project effects are data from DWR's Special Multipurpose Applied Research Technology Station (SMARTS), which conducts peat-soil flooding experiments at the DWR Bryte facility in West Sacramento (California Department of Water Resources 1999b), and data from flooded-island studies conducted jointly by DWR and the USGS on Twitchell Island. In addition, this chapter summarizes information on potential DOC loading received from water right hearing participants. This information has been used to refine the assumptions used in the 1995 DEIR/EIS regarding the potential loading of DOC from the Delta Wetlands islands under no-project conditions and under project operations.

Since publication of the 1995 DEIR/EIS, standards for total organic carbon (TOC) removal before treatment have been adopted under the Safe Drinking Water Act, and EPA has revised its standard for THM concentrations in drinking water. These newly adopted standards and potential future standards are also described below.

This chapter and the accompanying appendix (Appendix G) describe methods for calculating Delta Wetlands Project contributions to salinity, DOC concentrations, and THMFP in water that could be exported from the Delta and subsequently treated for municipal use. Revised equations used to predict formation of THMs and bromate at treatment plants have been reviewed and incorporated, as appropriate, into the REIR/EIS analysis.

The following sections present the results of this review of new and updated information:

- "Updated Measurements of Inflow, Export, and Agricultural Drainage Water Quality" presents data collected since 1995 on existing inflow, export, and agricultural drainage water quality. These data, reported by the DWR MWQI program and other programs, are used to update assumptions of existing water quality conditions in the Delta for impact analysis.

- "California Department of Water Resources Special Multipurpose Applied Research Technology Station Studies" describes the methods and results from these peat-soil flooding experiments and discusses the applicability of these results to the Delta Wetlands Project.

- "Reported Estimates of Dissolved Organic Carbon Loading" summarizes information from the 1995 DEIR/EIS, estimates from recent in-field and experimental data, and evidence presented at the Delta Wetlands water right hearing and in comments on the 1995 DEIR/EIS regarding DOC loading under existing and with-project conditions.

- "Changes in Disinfection Byproduct Rules" discusses new, revised, and proposed rules for TOC removal and THM concentrations for water treatment.

This information is used to estimate existing Delta conditions (e.g., inflow and export water quality, agricultural drainage operations and water quality) and to provide input toward an estimate of DOC loading under existing (i.e., agricultural) and project conditions. The "Impact Assessment Methodology" section that follows describes how this information is incorporated into the quantitative modeling used to determine impacts of the Delta Wetlands Project.

UPDATED MEASUREMENTS OF INFLOW, EXPORT, AND AGRICULTURAL DRAINAGE WATER QUALITY

Measured data on the quality of water in Sacramento and San Joaquin River inflows, at Delta export locations, and in agricultural drainage in the Delta are presented below. Data on Delta inflow and export EC, Cl^-, Br^-, DOC, and THMFP are taken from the DWR MWQI data collection program. Agricultural drainage data from the MWQI program on the Delta Wetlands islands and from USGS, DWR, and California Urban Water Agencies (CUWA) investigations on Twitchell Island are summarized below; Appendix G includes more detailed information about agricultural drainage from the Delta Wetlands islands.

Measurements of Delta Water Quality Variables in Delta Inflows and Exports

Data on Delta inflow and export water quality constituents, as reported by the DWR MWQI program, are used to describe existing inflow and export water quality conditions and to determine how the concentrations of constituents change as water flows through the Delta. The difference between concentrations of a selected water quality constituent, such as DOC, in Delta inflows and concentrations in exports is used to estimate the net contribution from Delta sources, including agricultural drains. For a discussion of the way that these contributions are estimated for the impact assessment and used in the quantitative modeling, see "Delta Source Contributions of Salinity and Dissolved Organic Carbon" in Appendix G.

This section describes MWQI program measurements of EC values and the concentrations of several constituents in Sacramento and San Joaquin River inflows and at Delta export locations collected during the most recent 15-year period, 1984-1998 (California Department of Water Resources 1999a). The 1995 DEIR/EIS analysis used data from the 10-year period of 1982-1991 (see Appendix C1, "Analysis of Delta Inflow and Export Water Quality Data", in the 1995 DEIR/EIS). The 15-year period used in this REIR/EIS reflects several significant hydrological events. The 1988-1993 water years were a significant period of drought. In addition, flooding events and wet-year-type conditions experienced in 1995, 1997, and 1998 provide recent data that broaden the span of much of the range of potential hydrological conditions (except those of extreme drought, such as the 1976-1977 period). Sacramento River inflows are generally the largest source of Delta water and have lower concentrations of DOC and related constituents than other sources; therefore, the Sacramento River concentrations are used as the baseline for determining Delta source contributions.

The DWR MWQI data collection program has changed each year. Sampling from the Sacramento River and Delta export locations began in 1983. Several assay techniques for THMFP measurement have been used since 1992; major revisions were made in 1994 and 1996. Results from the differing assay methods are not directly comparable. DOC measurements began in 1987, and Br^- and UVA measurements began in 1990. The use of UVA data is explained below.

The number of samples collected at each station each year has also changed. At the SWP Banks Pumping Plant, for example, five samples were collected in water year 1982; nine samples were collected in water year 1983; and 11 or 12 (monthly) samples were collected in water years 1984 through 1989. During water years 1990 through 1994, sampling was generally conducted on a weekly or biweekly schedule. Intensive sampling began in May 1995 and continued through August 1996, averaging 11 samples per month. Recent sampling has returned to a monthly schedule. Intensive sampling was also conducted in the Sacramento River at Greene's Landing from February 1993 through water year 1995. During this period, samples were often collected daily for several consecutive months. Samples from the San Joaquin River at Vernalis, from the Old River near the Rock Slough intake for CCWD's diversion, and at the CVP Tracy Pumping Plant for the DMC have generally been collected on a regular monthly schedule.

A standardized data set of monthly values for the entire 1984-1998 period was created using the first grab sample collected in each calendar month and eliminating any additional samples collected that month. Samples were often, but not always, collected on about the same day at each of the sampling stations. The mean values of the monthly samples did not differ by more than 10% from those of the entire data set. This is the same method used for the data from the 1982-1991 period in the 1995 DEIR/EIS analysis, as summarized in Table C1-1 of Appendix C1 of the 1995 DEIR/EIS.

The MWQI program did not collect data on all these variables for all years of the 1984-1998 period. However, the graphs show all available data plotted against the 1984-1998 time period to provide for easy comparison of water quality conditions for each year. The following sections describe the data for EC, Cl^-, Br^-, DOC, and THMFP.

Delta Electrical Conductivity Values

EC is a general measure of dissolved minerals (i.e., salinity) and is the most commonly measured variable in Delta waters. High levels of dissolved minerals can limit beneficial uses of Delta water for agricultural, municipal, and industrial water supplies. Changes in EC values can be used to interpret the movement of water and the mixing of salt in the Delta (see 1995 DEIR/EIS Appendix B2, "Salt Transport Modeling Methods and Results").

Figure 4-1 and Table 4-1 show 1984-1998 EC measurements for the DWR MWQI samples from Sacramento and San Joaquin River inflows and from the following three export locations:

- the SWP Banks Pumping Plant,
- the CVP Tracy Pumping Plant, and
- Rock Slough for CCWD's pumping plant.

The data show ranges of EC values at these monitoring locations that are consistent with those presented in the 1995 DEIR/EIS for 1982-1991.

The EC values for the Sacramento River are generally in the range of 100 to 200 microsiemens per centimeter (μS/cm), although measurements during the 1986, 1995, and 1997 high-flow periods were less than 100 μS/cm, and 5% of the values exceeded 200 μS/cm. Sacramento River EC measurements, shown in Figure 4-2, generally decrease with higher flows, exhibiting a typical flow-dilution relationship.

The EC values for the San Joaquin River are usually much higher than Sacramento River EC values, fluctuating between 150 and 1,300 μS/cm. Figure 4-3 indicates that San Joaquin River EC measurements also generally decrease with higher flows, exhibiting a flow-dilution relationship.

Several San Joaquin River EC values observed during the winters of 1988-1993 exceeded 1,000 μS/cm and are as much as 500 μS/cm higher than the EC values estimated with the flow-dilution equation. These elevated EC values suggest that an additional load of salt drainage may have been released into the San Joaquin River during these drought years. Values in the recent postdrought years 1995-1998 indicate a lower trend of San Joaquin salt content similar to the pre-drought period. Measurements, when available, are superior to flow-regression estimates of inflow water quality; flow regressions must be used for planning and assessment studies.

Observed EC values at the three export locations have fluctuated between about 200 and 1,000 μS/cm. During months when low EC values were measured, corresponding to periods of high Delta outflow, the export locations each had similar EC values. During months when high EC values were measured, EC values at Rock Slough (CCWD) were generally the highest because effects of salinity intrusion are usually strongest there. Local agricultural drainage may also have different effects at each export location.

The DWR MWQI EC data presented here and in the 1995 DEIR/EIS clearly indicate that EC (representing dissolved salts) usually increases between Sacramento River inflow and the export locations. The net source of elevated EC may differ for each month and each export location, however. San Joaquin River inflows, seawater intrusion, agricultural drainage, and municipal discharges (e.g., from Stockton) may each contribute to elevated EC measurements.

Delta Chloride Data

Cl^- concentration is important in evaluating the quality of the domestic water supply and is a major parameter for judging Delta water quality. The ratio of Cl^- to EC (using units of mg/l for Cl^- and μS/cm for EC) can be used to distinguish between sources of water from different inflows (e.g., Sacramento River, San Joaquin River, and seawater) sampled at different Delta locations. Delta Wetlands Project operations would influence the relative contributions of water from different Delta inflow sources; therefore, they would affect concentrations of minerals (including Cl^-) in the Delta. (See 1995 DEIR/EIS Appendices B2 and C1 for more information.)

For example, seawater has a Cl^- concentration of 19,000 mg/l and an EC value of approximately 55,000 μS/cm, for a Cl^-:EC ratio of about 0.35 (CRC 1989). As described below, Sacramento River water, with a Cl^- concentration of approximately 6 mg/l and an EC value of 150 μS/cm, has a Cl^-:EC value of about 0.04. Therefore, a mixture of 1% seawater and 99% Sacramento River water would have a Cl^- concentration of 196 mg/l and an EC concentration of 699 μS/cm, resulting in a Cl^-:EC ratio of 0.28. A Cl^-:EC ratio of more than 0.20 indicates that seawater intrusion is a dominant source of salinity in the Delta.

Figure 4-4 and Table 4-1 show DWR MWQI data on Cl^- concentrations for water years 1984 through 1998 for the two Delta inflow and three Delta export locations. Cl^- concentration patterns are similar but not identical to the EC patterns because each major water source has a different Cl^-:EC ratio value. Figure 4-5 shows the Cl^-:EC ratios for each of the monthly DWR MWQI samples. These two figures will be described together. The patterns among the different monitoring locations seen in the updated (1984-1998) data are essentially identical to those described in the 1995 DEIR/EIS for 1982-1991.

Sacramento River Cl^- concentrations were less than 10 mg/l in 94% of the monthly measurements (Figure 4-4), and the Cl^-:EC value (mg/l:μS/cm) in this inflow averaged 0.04 (Figure 4-5). Some of the scatter in the Sacramento Cl^-:EC values was caused by low Cl^- concentrations.

San Joaquin River Cl^- concentrations fluctuated between 7 and 183 mg/l (Figure 4-4), and Cl^-:EC ratio values increased from 0.055 at low EC values to 0.16 at high EC values (Figure 4-5). The variability in the Cl^-:EC values of this inflow may be explained by the fact that the inflow represents a mixture of water from the San Joaquin River, Stanislaus River, and especially during wet periods, other tributaries. Nevertheless, the Cl^-:EC value of 0.055 to 0.16, averaging 0.12, for the San Joaquin River inflow is distinct from the lower Cl^-:EC value of about 0.04 for the Sacramento River.

There are only three basic sources of Delta salinity: seawater, San Joaquin River water, and Sacramento River water. The proportion of water from each of these sources in exports can be estimated by evaluating the Cl^-:EC ratio together with the Cl^- concentrations and EC values.

Measurements of Cl^- concentrations from the export locations fluctuated between 11 and 303 mg/l (Figure 4-4). The Cl^- concentrations in CCWD diversions from Rock Slough were the highest, indicating a stronger influence from seawater intrusion or local agricultural drainage at this location.

Cl^-:EC values for the export locations were greater than 0.16 (the maximum San Joaquin River ratio) during periods with the highest Cl^- concentrations (Figure 4-5). These high Cl^-:EC values suggest that seawater intrusion is the dominant source of Cl^- during these periods. CCWD water diverted at Rock Slough usually has a higher Cl^-:EC value than water exported from the other export locations, suggesting a higher seawater contribution at this location.

Delta Bromide Data

Similar to Cl^- concentration, Br^- concentration is important in evaluating domestic water supply quality and influences the potential formation of DBPs, including THM and bromate. Br^- is more difficult to measure than Cl^-, so measurements of Cl^- are often used to calculate Br^- concentrations based on observed ratios of Br^- to Cl^-.

Figure 4-6 shows DWR MWQI Br^-:Cl^- values, based on Br^- measurements that began in January 1990. The Br^-:Cl^- value for concentrations measured from San Joaquin River samples (mostly in the range of 0.0025 to 0.0035) is similar to the Br^-:Cl^- value for seawater (0.0035). Br^-:Cl^- values for Sacramento River inflow were scattered (mostly 0.001 to 0.006) because of low concentrations of Cl^- and Br^-, but they were generally lower than those of seawater or San Joaquin River water. These DWR MWQI data suggest that Br^- concentrations may be adequately estimated from Cl^- measurements. Based on the limited data available during the preparation of the 1995 DEIR/EIS, a single value of 0.0035 was assumed for all source waters for impact assessment purposes. The recent postdrought data (1993-1998) more clearly show an average Br^-:Cl^- ratio that is approximately 0.0030 for San Joaquin River water and 0.0020 for Sacramento River water. Therefore, these revised Br^-:Cl^- ratios are used in this REIR/EIS analysis.

Delta Dissolved Organic Carbon Data

Figure 4-7 shows DWR MWQI measurements of DOC at Delta inflow and export locations since collection began in 1987. DOC is considered to be the major organic precursor of DBPs, including THMs. DOC is therefore one of the most important water quality variables for assessment of potential formation of DBPs in treated drinking water from the Delta.

DOC concentrations in Sacramento River samples are generally the lowest measured in the Delta, with average measured values of 2.3 mg/l (Figure 4-7 and Table 4-1). American River samples have even lower DOC concentrations (California Department of Water Resources 1989a). Sacramento River DOC concentrations sometimes exceed 3 mg/l, with 21 of the 124 measured DOC values above 3 mg/l and two above 5 mg/l. Daily measurements taken periodically between 1993 and 1995 have confirmed that Sacramento River DOC concentrations can be elevated above 2 mg/l when sources of DOC material appear in surface runoff, with 430 of 694 measurements at or above 2 mg/l (California Department of Water Resources 1999a).

DOC concentrations in the San Joaquin River were higher and more variable than Sacramento River DOC concentrations. The average measured DOC value was 3.7 mg/l (Table 4-1); 98 of the 118 measured DOC values (83%) were between 2.5 mg/l and 6 mg/l and four exceeded 8 mg/l during major storm events. The San Joaquin River must therefore be considered a major source of DOC relative to the Sacramento River, which has comparatively low DOC concentrations.

DOC concentrations at the export locations averaged 3.7 mg/l, with 85% of the measured values in the range of 2.5 to 6 mg/l. The DWR MWQI data clearly show that Delta sources or San Joaquin River inflow contribute DOC. The relative influences of the various possible sources cannot be easily identified from these data alone. The patterns seen in the more recent (1992-1998) data shown in Figure 4-7 and Table 4-1 are similar to the 1987-1991 data described in the 1995 DEIR/EIS; however, the newer data also show that DOC concentrations measured in some wet months are considerably higher than the average concentration of DOC.

Figure 4-8 compares DWR MWQI measurements of DOC and Cl^- to EC values for the Sacramento and San Joaquin Rivers for 1984-1998. DOC concentrations in Sacramento and San Joaquin River samples do not demonstrate a clear relationship to concentrations of either EC or Cl^-. Therefore, it is not possible to estimate DOC concentrations in the river inflows as a function of either flow or salinity. Consequently, frequent measurements are the only accurate method for establishing the river-inflow DOC concentrations.

Delta Trihalomethane Precursor Data

To provide a comparative measure of THM precursors in Delta water, the DWR MWQI program has developed assays for determining THMFP, an index of the maximum possible THM concentrations that could be produced by maximum chlorination of Delta water. Starting in 1984, the assay was performed by spiking a water sample with an initial 120-mg/l concentration of Cl_2, holding the sample for 7 days (168 hours) at 25°C, then measuring the THM species with standard EPA procedures (gas chromatograph purge and trap, EPA method 502.2).

In 1994, the original method was discontinued and a buffered variation was implemented in which the pH of the sample was adjusted to a constant value of about 8.2. In 1996, two new methods were implemented, one of them a reactivity method in which the sample is spiked with a Cl_2 dose of 4.5 times the DOC concentration and held for 7 days. However, both the buffered and reactivity methods have been discontinued.

The SDS method is currently used for the MWQI program. This method was developed to simulate the actual disinfection process (and THM concentrations) of municipal water treatment facilities more closely than other methods; it uses a much lower Cl_2 dose and much less contact time. Because the SDS method results in substantially lower values for THMFP and very few SDS data are available, only data generated from the original, buffered, or reactivity methods were plotted for the analysis of data trends presented below.

The four types of THM molecules are chloroform ($CHCl_3$), dichlorobromomethane ($CHCl_2Br$), dibromochloromethane ($CHClBr_2$), and bromoform ($CHBr_3$). The carbon-fraction concentrations of the four types of THM molecules are added together to calculate the carbon equivalent of the total THM concentration, called the C-THM concentration. The DWR MWQI program uses the term "total formation potential carbon" (TFPC) for the same variable.

Dividing the C-THM concentration by the initial DOC concentration in a water sample provides a direct estimate of the fraction of the initial DOC concentration that was converted to THM molecules during the THMFP assay. The ratio of C-THM to DOC is called the "THM yield" and is generally in the range of 0.005 to 0.02 for the high chlorination dose used in the THMFP assay.

Delta C-THM Data. Figure 4-9 and Table 4-1 show the C-THM concentrations measured by the DWR MWQI for 1984-1998. The results indicate conditions similar to those analyzed in the 1995 DEIR/EIS for 1982-1991.

The Sacramento River concentrations of C-THM averaged 28 μg/l, with 25% of the measured concentrations greater than 30 μg/l. Most (90%) export concentrations of C-THM were between about 30 and 90 μg/l, and were generally higher than Sacramento River concentrations. San Joaquin River C-THM concentrations averaged 47 μg/l, exceeding Sacramento River concentrations but remaining almost the same as export concentrations (Table 4-1). Because the C-THM concentrations for Sacramento River inflow fluctuated, and because the San Joaquin River C-THM concentrations were similar to those measured at the export locations, it is difficult to directly estimate the monthly contributions of C-THM from Delta sources.

Figure 4-10 shows the data for ratios of C-THM to DOC for the two inflow and three export locations for 1984-1998. With allowances made for a certain amount of scatter in both measurements, these ratios for THM yield from DOC range from 0.005 to 0.02, indicating that approximately 0.5% to 2% of DOC became THM molecules during the THMFP assay in most samples. The THM yield has less scatter in the results from 1994-1998; this change may be related to the introduction of the new measurement methods described above, which served to better standardize pH and Cl_2 dose in the samples. This yield relationship shown in Figure 4-10 suggests that DOC measurements can be used to estimate the C-THM concentration in a THMFP assay. This relatively constant C-THM:DOC value might be used to condition Delta Wetlands operations; therefore, frequent DOC measurements may be used to monitor project effects on THM concentration and minimize the need for using the comparatively expensive and time-consuming THMFP assay procedure. This procedure for estimating THMFP is described in Appendix C-3 of the 1995 DEIR/EIS and is illustrated in Figure 4-11.

Delta Ultraviolet Absorbance Data. UVA (254-nanometer [nm] wavelength) was added to the DWR MWQI program as a measurement variable in 1990. UVA is measured with a spectrophotometer and reported in units of 1/cm. UVA may provide a measure of the humic and fulvic acid portion of total DOC in a water sample; this portion of total DOC is thought to be the precursor for THM. The ratio of UVA to DOC may increase with a higher proportion of humic substances. A greater yield of THM molecules may also be expected from samples with higher UVA:DOC values because the humic substances are thought to be the most active THM-precursor component of DOC.

Figure 4-12 and Table 4-1 show data from 1990-1998 and indicate that most Delta inflow and export samples have UVA (1/cm):DOC (mg/l) ratios of between 0.02 and 0.04, with an average slightly above 0.03. The Sacramento and San Joaquin River UVA:DOC values tend to be slightly lower than the UVA:DOC values for the export locations (Table 4-1). The MWQI program calls this ratio the specific UVA (i.e., SUVA). The patterns shown in Figure 4-12 are the same as those indicated in the 1995 DEIR/EIS.

Data on Delta Agricultural Drainage Salinity and Dissolved Organic Carbon

The purpose of the agricultural drainage data analysis is to estimate annual loading of DOC and salinity from existing agricultural operations. Agricultural drainage discharges containing natural decomposition products of peat soil and crop residues are considered dominant sources of DOC in Delta waters. Also, because the objectives specified in the 1995 WQCP substantially protect Delta water supplies from salinity intrusion effects during periods of reduced Delta outflow, agricultural drainage is the major remaining source of concern with regard to elevated salinity in Delta waters. This section of the REIR/EIS updates information about measurements of water quality constituents in agricultural drainage presented in Appendix C2, "Analysis of Delta Agricultural Drainage Water Quality Data", of the 1995 DEIR/EIS.

There are two general ways to estimate the observed DOC loads (expressed as grams per square meter [g/m^2]) from the agricultural islands in the Delta:

- Multiply the annual drainage volume (expressed as water depth in meters [m]) by the average DOC concentration (mg/l) of the drainage water to estimate the DOC load.

- Multiply the DOC increase observed between the Sacramento and San Joaquin River inflows and the export locations by the export flow to estimate the increased mass of DOC. This increased mass (g) of DOC is then divided by the area of the Delta agricultural islands to estimate the average load of DOC (g/m^2).

Both methods have been used to evaluate the DOC load from Delta agricultural islands under existing conditions. The following section summarizes the results of these analyses; Appendix G, "Water Quality Assessment Methods", presents detailed information on agricultural drainage water quality for Bacon Island, Webb Tract, Bouldin Island, Holland Tract, and Twitchell Island.

The 1995 DEIR/EIS presented water quality data collected at a large number of Delta island agricultural drainage pumping stations from 1986 through 1991 to determine annual drainage volumes and DOC concentrations. DWR stopped monitoring drainage water quality at the majority of Delta island drainage pumping locations in July 1994. The data used in this REIR/EIS were updated to include the more recent measurements. The following analysis presents agricultural drainage water quality data collected from the Delta Wetlands Project island locations from 1986 through 1994, with the exception of Bacon Island, where sampling was continued through August 1999, and Twitchell Island (not a project island), the location of several DWR and USGS studies that began in 1994.

Agricultural Drainage Volumes

The 1995 DEIR/EIS presented a detailed analysis of drainage volume calculations for Delta islands based on available data collected by DWR in 1954-1955. Because DWR stopped monitoring drainage water quality at the majority of Delta island drainage pumping locations in July 1994, no comprehensive drainage volume measurements have been collected since preparation of the 1995 DEIR/EIS that would substantially change the results of the analysis.

A study by USGS (U.S. Geological Survey 1997) determined that measuring electrical power usage from Delta pumps might be a reliable method of determining drainage volumes if more calibration of drainage pumps (volume per kilowatt-hour [kwh]) and regular monthly power usage records were available. However, no Delta-wide estimates of drainage flow were attempted. This method was used to estimate the drainage from Twitchell Island for calendar year 1995; the results were determined to be very close to (within 10% of) the flow measured using flow meters in the two Twitchell Island drainage pumps.

Dissolved Organic Carbon and Salt Budgets for Delta Islands

Results presented in the 1995 DEIR/EIS showed that 1986-1991 MWQI measurements of drainage EC from many of the Delta island agricultural drains show a strong seasonal pattern, with the highest EC values in drainage water during winter. EC values generally ranged from low values characteristic of Delta channel water (137 to 568 μS/cm) to much higher values (1,280 to 2,870 μS/cm). This range in drainage EC values is expected because of the variation in Delta precipitation and irrigation, leaching, and drainage practices. Higher EC values indicate that the salt has become concentrated in the agricultural soils through ET. Cl^- concentrations in agricultural drainage samples follow the seasonal EC patterns. DOC concentrations in these samples have a similar seasonal pattern; however, the variation in DOC concentrations is greater because the agricultural soils can be a source of DOC, and because evaporation of soil water during the growing season can increase DOC concentrations.

Agricultural drainage from Delta islands will have a Cl^-:EC ratio that reflects that of the original applied water because Cl^- and the dissolved solids that contribute most of the EC in water are conservative in water and not removed by biological or other physical and chemical processes. The concentrations of dissolved substances in drainage will vary because of dilution by rainwater or increases from evaporation losses.

Table 4-2 summarizes the average DWR MWQI drainage data available for the Delta Wetlands islands and Twitchell Island. A detailed description of these results for each island is provided in Appendix G.

CALIFORNIA DEPARTMENT OF WATER RESOURCES SPECIAL MULTIPURPOSE APPLIED RESEARCH TECHNOLOGY STATION STUDIES

SMARTS is a new test facility located in West Sacramento that began operating in 1998 and is managed under DWR's MWQI program. The facility consists of a series of large tanks specifically designed for conducting a variety of water quality studies under controlled static or continuous water-flow conditions. The first studies at SMARTS were designed to measure DOC loads from peat soils. Two reports from SMARTS studies have been prepared (California Department of Water Resources 1999b, 1999c) and are referred to below as SMARTS 1 and SMARTS 2. For the purpose of this analysis of Delta Wetlands Project effects on water quality, results of the SMARTS studies were evaluated for information on potential DOC loading rates from peat soils and are summarized below. The following summary and interpretation of the SMARTS reports were reviewed by MWQI's consultant Marvin Jung, who confirmed that the loading calculations described below are appropriate (Jung pers. comm.).

Summary of Methods

The SMARTS experiments measured DOC loading from peat soils by partially filling tanks with peat soil taken from Twitchell Island and measuring changes in EC and DOC concentrations in the peat-soil pore water and surface water. EC values were used to track evaporation and salt loading from the peat soil; DOC concentrations were measured to track DOC loading from the peat soil.

The SMARTS 1 report presents results of a 12-week experiment and SMARTS 2, results of a 27-week experiment. The SMARTS facility tanks have a diameter of 5 feet, with a surface area (for peat-water interface) of 1.8 square meters (m^2). The control tank (tank 9) was filled with 11 feet of water (volume of 1,616 gallons) with no peat soil. The following conditions varied for the eight experimental tanks:

- water flow,
- depth of peat soil,
- depth of water, and
- initial peat-soil composition.

These conditions are described below.

Water-Flow Conditions

The experiment used two water-flow conditions: "static" and "flushing". Four of the tanks (1, 3, 5, and 7) held static water depths above the peat soil. The static tanks were refilled as needed to compensate for evaporation losses, so the water level was held constant. However, the term "static" does not mean that there was no movement of water in the tanks. The surface water in the static tanks was mixed with submersible pumps that circulated about 1,680 gallons per day (gpd) in SMARTS 1; the mixing increased with larger 2,880-gpd pumps in SMARTS 2. Because the water depth was held constant in the static tanks, the load (g/m^2) for a static tank can be estimated as the change in DOC concentration (mg/l [equivalent to g/m^3]) times the depth of water (m).

Other tanks (2, 4, 6, and 8) were flushed repeatedly during the experiment. The total water volume in each tank was replaced weekly as water was added continuously while being removed from the top of the tank. The load of the flushing tanks can be estimated as the weekly flushing depths times the difference between the weekly inflow and outflow concentration. However, the volume of outflow from the tanks and DOC concentrations in the outflow were not directly measured. The pumps were set at the beginning of the experiment to flush a certain volume. Weekly measurements were not conducted to verify the assumed volume of water being pumped from the flushing tanks, and for the SMARTS 1 experiment, it was reported, when the output was checked, that the observed flushing volumes appeared to be as much as 50% more than anticipated. DOC concentration in the tank water was measured weekly; this measurement was assumed to represent the outflow DOC concentration. Because the cumulative depth of water for the flushing tanks was large (either 26 feet [8 meters] or 138 feet [42 meters]), very small changes in the measured tank DOC concentrations result in large changes in the load estimate (where DOC load = flushing depth • outflow concentration). The loading estimates were sensitive to even very low concentrations of DOC. Because the flushing volumes (i.e., depths) and changes in outflow DOC concentration are uncertain for the flushing tanks, DOC load estimates obtained from the flushing tanks are questionable and are not applied to the Delta Wetlands Project. Therefore, the results reported below focus on DOC loading from the static tanks (1, 3, 5, and 7).

Water and Peat Depth

The water and peat depth for the four static tanks varied; the water depth was either 2 feet (0.6 meters) or 7 feet (2.1 meters), and the peat depth was either 1.5 feet or 4 feet.

Initial Peat-Soil Composition

The initial peat-soil composition (e.g., pore-water DOC and EC concentrations, peat-soil density, soil salt content) also varied in each tank and for each experiment. Oxidized peat soils were taken from the top 2 feet of Twitchell Island to use in the experiments. The intent was for each tank to have similar soil characteristics. However, in SMARTS 1, although all the peat soil was mixed together before the tanks were filled, peat-soil pore-water EC measurements in the eight tanks ranged widely (842 to 2,140 μS/cm) at the start of the experiment. In SMARTS 2, two different peat-soil sources were used. Initial peat-soil pore-water EC concentrations had an even greater range, with one peat-soil source resulting in initial pore-water EC concentrations of 578 to 1,232 μS/cm (tanks 5–8) and the other source resulting in initial pore-water EC concentrations of 3,640 to 4,800 μS/cm (tanks 1–4).

Dissolved Organic Carbon and Salinity Measurements

The SMARTS static tank results can be evaluated by considering that two pools of EC or DOC are being measured:

- EC or DOC in the peat-soil pore-water volume, measured by the bottom sampling spigot (0.5 foot from the bottom of the tank), and
- surface-water EC or DOC.

The amount of salt (EC) or DOC observed in the surface water is directly influenced by the concentration in the peat-soil pore water and the exchange rate caused by mixing processes. There may be a gradient of pore-water EC and DOC concentrations as EC and DOC are transferred from the soil into the surface water, but the average pore-water EC and DOC concentrations are assumed to be characterized by the measurements made from the bottom port. The peat-soil pore-water volume was not directly measured in the SMARTS studies but can be approximated from previous peat-soil measurements, which reported 40% to 60% solids (Table C3-8 in Appendix C3 of the 1995 DEIR/EIS). Because the percentage of solids averages 50%, the porosity of peat soil is assumed to be 50%, and the pore-water volume is assumed to be half the peat-soil volume.

Summary of Results

SMARTS 1 Pore-Water EC and DOC Concentrations

Table 4-3 summarizes the results of the SMARTS 1 (12-week) experiment, and Table 4-4 summarizes the results of the SMARTS 2 (27-week) experiment.

The peat-soil pore-water measurements of EC for the SMARTS 1 experiment ranged from 842 to 2,140 μS/cm at the start of the experiment. The range of measurements from the eight tanks indicates that although all the peat soil was mixed together before the tanks were filled, the peat-soil salt content in each tank varied.

The initial peat-soil pore-water DOC concentrations (week 1) for SMARTS 1 ranged from 143 to 226 mg/l (Table 4-3). This range is higher than any soil DOC values measured by the USGS at Twitchell Island (U.S. Geological Survey 1998), which were generally in the range of 40 to 100 mg/l. They are also greater than the DOC in surface saturated soil samples collected from Holland Tract, which were in the range of 25 to 75 mg/l (as shown in Table C3-8 in Appendix C3 of the 1995 DEIR/EIS).

By the fifth week, approximate peat-soil pore-water DOC concentrations had increased to between 271 and 341 mg/l. By week 9, the peat-soil pore-water DOC concentrations were 58 to 386 mg/l, and in the final sampling at week 12, they were 74 to 358 mg/l (Table 4-3). Pore-water DOC did not increase between weeks 9 and 12 in most of the peat-soil pore-water measurements.

Therefore, although the flooded peat-soil DOC concentration is high, these results may indicate that the peat soil does not contain an unlimited supply of DOC, at least in the limited depth samples used in the experiment.

SMARTS 2 Pore-Water EC and DOC Concentrations

The SMARTS 2 peat-soil pore-water EC values on week 1 (January 21, 1999) ranged from 3,640 to 4,800 μS/cm in tanks 1–4 and from 578 to 1,232 μS/cm in tanks 5–8 (Table 4-4). By week 15, the pore-water EC values were 2,383 to 3,280 μS/cm in tanks 1–4 and 455 to 998 μS/cm in tanks 5–8. As described above, these two groups of tanks were filled with different peat-soil sources from different locations on Twitchell Island. The peat soil used to fill tanks 1–4 is extremely high in soil EC (dissolved minerals apparently had not been leached by rainfall or field-flooding operations).

SMARTS 2 DOC concentrations in the peat-soil pore water were very high in tanks 1–4, but were relatively low in tanks 5–8. Again, the soils for these tanks came from different locations on Twitchell Island. The differences illustrate the wide range of peat-soil conditions in the Delta. On January 21 (week 1), the peat-soil pore-water DOC ranged from 82 to 96 mg/l in tanks 1–4 and from 11 to 28 mg/l in tanks 5–8. By April 28 (week 15), the peat-soil pore-water DOC concentration had increased to between 342 and 561 mg/l in tanks 1–4 and between 30 and 84 mg/l in tanks 5–8. On July 21 (week 27), the DOC concentration of peat-soil pore water in tanks 1–4 ranged from 368 to 590 mg/l and from 40 to 100 mg/l in tanks 5–8. The DOC concentrations in the peat-soil pore water increased substantially during the first months but did not continue to increase from week 15 to week 27, even though the temperature was higher. The experimental design called for the same peat-soil content in all eight tanks. However, because the peat-soil composition differed between tanks 1–4 and tanks 5–8, peat-soil composition is another factor to consider in the interpretation of the SMARTS 2 results.

DOC Loading Estimates

The DOC load that was transferred from the peat-soil pore water into the surface water through the various possible exchange processes (including the submersible pumps) can be calculated from the final water DOC concentration and surface water depth in the static tanks. These calculations result in loading estimates of 24 to 32 g/m^2 for the static tanks with 1.5 feet of peat (tanks 1 and 7) and 53 to 54 g/m^2 for the static tanks with 4 feet of peat in SMARTS 1 (tanks 3 and 5) (Table 4-3). The SMARTS 2 experiment resulted in a wide range of load estimates because the tanks' peat-soil pore-water DOC concentrations varied considerably. The SMARTS 2 experiment data for week 27 indicated that the DOC load from the high-DOC static peat tanks (tanks 1 and 3) was 73 to 121 g/m^2, and from the low-DOC static peat tanks (tanks 5 and 7), 23 to 42 g/m^2 (Table 4-4).

Application to the Delta Wetlands Project

The peat-soil DOC loads measured in the SMARTS tanks are higher than the estimates obtained from agricultural drainage samples, and the peat-soil pore-water DOC concentrations were considerably higher than any DOC concentrations that have been measured in Delta peat soils. DOC loads in the static tanks are higher than the DOC load estimates from the Delta agricultural drains, but the peat-soil pore-water DOC concentrations in the SMARTS experiments were probably higher than would be experienced in undisturbed Delta agricultural peat soils that are flooded, based on USGS measurements at Twitchell Island. To determine the applicability of the SMARTS results to the Delta Wetlands Project, the experimental variables (i.e., water-flow condition, depth of peat, depth of water, and initial peat-soil composition) were evaluated for their consistency with proposed Delta Wetlands Project operations.

As discussed above, results from the static tanks were used to determine DOC loading estimates. The submersible pumps may mimic wave-induced mixing that would occur on the Delta Wetlands islands. The observed SMARTS loads were proportional to the depth of the peat soil and the DOC concentration of the peat-soil pore water. Likewise, DOC loading of flooded agricultural peat soils on the Delta Wetlands islands would be proportional to the depth of oxidized peat soil on the islands. Release of DOC is generally much greater for oxidized soil than for anaerobic (reduced) soils. Under existing agricultural practices, depth of oxidized soil on the Delta Wetlands islands has been assumed to be 2 feet based on DWR's Delta depletion analysis. Therefore, it is unlikely that Delta soils will have 4 feet of recently oxidized (aerobic) peat. The tanks with a 1.5-foot peat layer are perhaps the most realistic representation of Delta agricultural peat soils; however, loading estimates from both the 1.5-foot and 4-foot peat-soil depths were considered.

Peat soil composition on Delta islands is variable. However, the initial peat-soil pore-water EC and DOC concentrations reported for tanks 1–4 in the SMARTS 2 report exceed measured results from most other Delta soils. Initial pore-water EC values in tanks 1–4 were 3,640 to 4,800 μS/cm and pore-water DOC reached 374 to 590 mg/l by week 27. In comparison, samples of soil water (i.e., pore water extracted from soil samples) collected at the soil surface and at a depth of 2 feet from the demonstration wetland site on Holland Tract in 1992 yielded EC values between 612 and 1,990 μS/cm and DOC concentrations between 24 and 71 mg/l with an average of 55 mg/l (n=9). Soil-water samples collected from an agricultural field on Holland Tract in 1992 included measured EC values between 455 and 11,500 μS/cm and DOC concentrations between 41 and 240 mg/l with an average of 141 mg/l (n=9) (see Tables C3-8 and C3-9 in Appendix C3 of the 1995 DEIR/EIS). The SMARTS 2 pore-water DOC measurements are considerably higher than those of the surface or 2-foot-deep peat samples collected on Holland Tract.

The SMARTS 1 surface-water load estimates for static tanks with 1.5 feet of peat soil (tanks 1 and 7) were 24 to 32 g/m^2, and for static tanks with 4 feet of peat soil (tanks 3 and 5) were 53 to 54 g/m^2. For the SMARTS 2 tanks filled with peat soil that produced pore-water DOC concentrations of 40 to 100 mg/l (tanks 5–8), the DOC load estimates were 23 to 42 g/m^2 for static tanks with 1.5 and 4.0 feet of peat, respectively. These values suggest that submerged peat soil with a previous history of agricultural use may produce a DOC load of 2 to 5 times the measured agricultural drainage DOC loads (of about 12 g/m^2).

CCWD sent a letter to the SWRCB (Shum pers. comm.) suggesting that the 12-week load estimates from the SMARTS 1 experiment should be multiplied by 52/12 to estimate the annual loads. However, it seems clear from the measurements that the DOC concentrations in the water and in the peat-soil pore-water samples were approaching loading limits after week 9 (SMARTS 1); it would not be reasonable to expect 4 times these observed 12-week loads to originate from the peat soil during a year of submergence. The SMARTS 2 experiments confirm that the peat-soil pore-water DOC and the surface-water DOC concentrations do not continue to increase during longer submergence as rapidly as during the initial 3 months of submergence. The SMARTS 2 results indicate that surface-water DOC did continue to increase for the life of the experiment (27 weeks) in the static tanks, but average weekly peat-soil pore-water DOC concentrations increased at a slower rate after week 11 in all static tanks.

In conclusion, loading estimates from static tanks were considered in the context of estimates from other studies and expert testimony (described in the next section) to develop assumptions about Delta Wetlands reservoir islands under initial-fill operations. The loading observed in the SMARTS experiments may correspond to the first year of flooding of agricultural soils, but it is unlikely that the high initial level of peat-soil pore-water DOC would be produced in subsequent years from moist peat soils (U.S. Geological Survey 1998). The SMARTS experiments have not tested the DOC load from a second year of peat-soil submergence. It is likely that the DOC loads in subsequent years will be less than those measured for the first year of peat-soil submergence.

It should be noted that the SMARTS experiments do not represent the proposed conditions on the Delta Wetlands islands, and the experimental design and sampling methods may not be applicable to in-situ conditions. However, the SMARTS experiments provide the best source of experimental or laboratory data on DOC release from peat soils.

See "Impact Assessment Methodology" below and Appendix G for more information about how results of the SMARTS studies were used in the impact analysis.

REPORTED ESTIMATES OF DISSOLVED ORGANIC CARBON LOADING

DOC loading is a function of many variables, including peat-soil depth, pore-water concentration, pore-water and water column mixing, and plant material growth and degradation. Agricultural production, wetland habitat, and flooded island conditions may result in different DOC loadings. For example, DOC loading from plant material growth and decay (including algal blooms) is expected to be greater under agricultural production or wetland habitat conditions than under flooded reservoir conditions.

During the Delta Wetlands Project water right hearing and in comments on the 1995 DEIR/EIS, the estimates of DOC loading on the Delta Wetlands islands under agricultural, reservoir, and wetland habitat conditions were debated at length. The lead agencies have received a wide range of estimates of potential DOC loading rates. Table 4-5 summarizes the loading estimates for agricultural drainage, seasonal wetland, and flooded island conditions that were presented in the 1995 DEIR/EIS, obtained from the Twitchell Island and SMARTS experiments, and presented at the

SWRCB water right hearing for Delta Wetlands by expert witnesses. For purposes of comparison, these estimates are presented in similar units; all estimates have been reported as grams of DOC per square meter per year ($g/m^2/yr$). Units of $g/m^2/yr$ can be converted to pounds per acre per year (lbs/ac/yr) by multiplying the value by 8.9. For example, 10 $g/m^2/yr$ is equivalent to 89 lbs/ac/yr.

Source loading estimates represent attempts to characterize DOC loading from individual DOC loading components, such as vegetation residue, primary production, and peat soil, or from all components and factors expressed as a total DOC load. Some estimates are based on actual field data collection and experiments; others are based only on general theory calculations (e.g., organic carbon production and hydrodynamics). Some of the DOC load estimates vary considerably; the estimates range over several orders of magnitude from less than 5 to more than 1,800 $g/m^2/yr$.

The following text describes the estimates of DOC loading rates presented in Table 4-5 and summarizes DOC loading estimates and criticisms of the 1995 estimates presented at the water right hearing. Consult the sources listed in the notes for Table 4-5 for more detail about how these estimates were derived. The use of DOC loading estimates for the impact analysis is described under "Impact Assessment Methodology".

Dissolved Organic Carbon Loading in Existing Agricultural Drainage

Estimates of DOC loading from agricultural operations in the Delta provide a baseline DOC loading level for the impact analysis. The 1995 DEIR/EIS used information from DWR MWQI agricultural measurements to establish existing DOC budgets and loading estimates. Those estimates have been updated based on DWR MWQI measurements of DOC concentrations and annual drainage volume (see Appendix G). That fraction of the average DOC concentrations not accounted for in applied-water DOC was multiplied by estimated annual drainage depth to provide a calculated load. A similar method of load calculation was conducted for Twitchell Island records. These estimates are described further in Appendix G.

Assumed agricultural loads from two modeling studies are also included in the list of agricultural drainage estimates. Using the Delta Wetlands island drainage load values as a reasonable range of likely DOC loads, an average of 12 $g/m^2/yr$ was used in the DeltaDWQ model in the 1995 DEIR/EIS. This average value for the project islands was supported further when the model was calibrated to export DOC concentration data; the loading estimate of 12 $g/m^2/yr$ correlated well with DOC concentrations measured at the SWP and CVP pumping plants (see Appendices C2 and C4 of the 1995 DEIR/EIS).

Estimates of drainage flows and drainage DOC concentrations presented in an MWQI report titled "Candidate Delta Regions for Treatment to Reduce Organic Carbon Loads, MWQI-CR #2" (Jung and Tran 1999) were used to calculate the average DOC load for Delta lowlands islands. These estimates were based on DOC concentrations and drainage volumes from DWR Delta lowlands modeling. The calculated load was 8 $g/m^2/yr$.

Dissolved Organic Carbon Loading under Project Conditions

Estimates from the 1995 DEIR/EIS

Several experiments were conducted for the Delta Wetlands Project to assess DOC loading under seasonal wetland and reservoir operations (see Appendix C3 of the 1995 DEIR/EIS). The methods and results of these experiments were challenged at the water right hearing and in comments on the 1995 DEIR/EIS. A brief summary of the experiment results and a discussion of challenges to those results follows.

In the wetland demonstration experiment, a portion of Holland Tract was flooded and a shallow flooded wetland habitat (0.5 meter deep) was created. Water samples were collected for approximately 3 months, and a DOC load was estimated. The wetland demonstration project estimated a total DOC load of 7 to 17 $g/m^2/yr$. In addition, a second experiment was conducted to ascertain the DOC load generated from the decay of wetland plants. Wetland plant decay experiments suggested a load of 5.1 to 7.5 $g/m^2/yr$. Compared to agricultural conditions, wetlands may provide lower DOC loads because the peat soil of wetlands generally will be more moist and less aerobic than that of agricultural soils. However, a seasonal wetland loading of 12 $g/m^2/yr$ was assumed in DeltaDWQ, equivalent to the assumed agricultural drainage load.

Additional experiments were conducted to assess DOC loading under Delta Wetlands Project reservoir operations. At the demonstration wetland on Holland Tract, loading was estimated for an extended period of time when a seasonal wetland was deep-flooded (to approximately 0.8 m) to characterize possible reservoir operations. In this experiment, the overall DOC load was estimated from the combined flooded wetland and water storage periods at the Holland Tract wetland demonstration project. The result was an estimated DOC load of 21 $g/m^2/yr$.

In 1991, as part of DWR's emergency water bank, Tyler Island was flooded for approximately one month. DOC loading was estimated based on collected water samples. The Tyler Island experiment resulted in an estimated total DOC load of 30 to 36 $g/m^2/yr$. Much of the DOC loading was probably the result of the rapid decay of cornfield vegetation residue and oxidized surface peat soil.

Parties to the water right hearing questioned the validity of these experimental results. CUWA, CCWD, and others argued that the Holland Tract flooded wetland experiment was stopped too soon; they said that it was unclear whether the level of DOC had started to level off or not, and that the reported DOC loading was therefore underestimated. Additionally, for all the experiments, CUWA stated that the testing procedure for THMFP was inaccurate in waters containing more than 10 mg/l of DOC and that the laboratory used for water quality testing did not maintain good laboratory practices (Krasner testimony 1997).

Estimates from the Special Multipurpose Applied Research Technology Station Studies

The SMARTS experiments provided estimates of DOC loading from flooded peat soils obtained from a field on Twitchell Island that had been in agricultural conditions during the previous year. The results of the SMARTS experiments are discussed above in detail; Table 4-5 includes loading results from the static tanks.

Estimates from Water Right Hearing Participants

Table 4-5 summarizes the range of estimated DOC loads provided in testimony. A wide range of DOC estimates was provided; the estimates were based on physical/chemical process theory, including molecular diffusion, advection, and bioturbation (i.e., mixing by benthic organisms). Estimates from Stuart Krasner and Richard Losee for CUWA, K. T. Shum for CCWD, and Michael Kavanaugh for Delta Wetlands are briefly discussed below. Refer to the hearing exhibits for more information on how these values were developed. The estimates of DOC loading provided in testimony are theoretical; no direct in-field or experimental results on DOC loading under project conditions were presented.

Stuart Krasner of CUWA estimated the potential impact of the Delta Wetlands Project on THM formation and water treatment operations using estimated DOC concentrations from the Delta Wetlands reservoirs of 8, 16, and 32 mg/l. Assuming a reservoir depth of 6 meters and an initial applied-water DOC concentration of 3 mg/l, the resulting DOC loading estimates would be 30, 78, and 174 g/m^2/yr, respectively (Krasner testimony 1997).

Richard Losee of CUWA provided independent estimates of DOC from primary production (i.e., algae biomass) and from peat soil. Losee identifies the following sources of primary production on the reservoir islands:

- planktonic algae or phytoplankton,
- benthic or attached algae,
- submersed macrophytes,
- floating vegetation,
- emergent macrophytes, and
- terrestrial vegetation.

Based on *Cladophora* production rates in a shallow MWD reservoir reported by Losee and assuming a Delta Wetlands reservoir depth of 6 meters, DOC loading from primary production is calculated as 50 to 1,250 g/m^2/yr. Losee also estimated peat soil as a source of DOC by determining the amount of organic carbon that is potentially available from mass estimates of the organic carbon in the sediment pools. This analysis resulted in an estimated DOC concentration of 300 mg/l in water 6 meters deep, which translates into a DOC loading estimate of 1,830 g/m^2/yr. Losee's DOC loading estimates were the highest estimates presented at the hearing and more than 10 times greater than measurements from the SMARTS experiments. (Losee testimony 1997.)

K. T. Shum of CCWD and Losee provided an estimate of DOC loading from seepage control pump operations (see Chapter 6). They estimated groundwater DOC concentrations of 20 to 40 mg/l (loading of 9.2 to 18.4 $g/m^2/yr$) based on an assumption that 8,100 af of water would be pumped through the wells on Bacon Island during a 9-month storage period. (Losee and Shum testimony 1997.)

Shum also testified about the magnitude of the flux of TOC from the peat sediments when molecular diffusion is the only transport process present. This estimate is based on an assumed peat-soil pore-water DOC concentration of 70 mg/l from the top 0.3 meter of the soil and a water column DOC concentration of 10 or 40 mg/l. Based on a 5- to 25-fold increase in the DOC diffusion loading rate as a result of various transport mechanisms such as bioturbation, wave pumping, and seepage, the resulting loading values were 16 to 160 $g/m^2/yr$. (Shum testimony 1997.)

Michael Kavanaugh for Delta Wetlands estimated DOC loading on habitat and reservoir islands based on diffusion from sediments, vegetative biomass, and algae production. Results for the reservoir islands were 3.5 to 11.9 $g/m^2/yr$ for Bacon Island and 3.5 to 12.7 $g/m^2/yr$ for Webb Tract; results for the habitat islands were 7.3 to 20.6 $g/m^2/yr$ for Bouldin Island and 3.7 to 10.3 $g/m^2/yr$ for Holland Tract. (Kavanaugh testimony 1997.)

See "Impact Assessment Methodology" below and Appendix G for information about how estimates presented in testimony were considered in the impact analysis.

CHANGES IN DISINFECTION BYPRODUCT RULES

Since release of the 1995 DEIR/EIS, new or revised standards have been adopted or proposed regarding DBPs in treated drinking water. The following sections describe new rules for TOC removal before treatment and revised and proposed THM standards.

Total Organic Carbon Removal Requirements

Since release of the 1995 DEIR/EIS, standards for TOC removal before treatment have been adopted under the Safe Drinking Water Act (SDWA). TOC consists of both DOC and particulate organic carbon (POC). DOC represents more than 90% of the TOC present in Delta waters (California Department of Water Resources 1994). The SDWA rules specify requirements for the removal of TOC. Municipal water treatment plants may remove this substance by enhanced coagulation (e.g., using alum); water systems that obtain their water supplies from surface-water or groundwater sources and use conventional filtration processes may use enhanced softening to remove TOC.

The following table shows the percentage of TOC that must be removed based on the alkalinity and TOC concentrations in source water. Removal of TOC before chlorination will generally reduce the THM concentrations. Because Delta water generally has an alkalinity between

60 and 120 mg/l as calcium carbonate ($CaCO_3$), removal of 25% or 35% of the raw-water TOC will be required. This TOC would be removed before the water is chlorinated to reduce the necessary Cl_2 dose and to reduce the subsequent formation of THMs.

Requirements for Percentage of Total Organic Carbon to be Removed
for Systems Using Conventional Treatment

	Alkalinity (mg/l as $CaCO_3$)		
Source Water TOC (mg/l)	0-60	60-120	>120
2–4	35%	25%	15%
4–8	45%	35%	25%
>8	50%	40%	30%

Revised Trihalomethane Standards

The EPA maximum contaminant level (MCL) for THM concentrations in drinking water has been revised from 100 to 80 μg/l since release of the 1995 DEIR/EIS. Because THM concentrations vary seasonally, the THM standard is applied to a moving annual average based on quarterly or monthly samples at the treatment plants. Many water treatment plants have responded to the regulatory change by using enhanced coagulation with Cl_2 as the primary disinfectant or by changing treatment technology (e.g., ozone [O_3]).

EPA has also proposed future ("Stage 2") THM rules. The proposed rule, which is expected to go into effect in 2002, would lower the MCL for THMs to 40 μg/l. To respond to this regulatory change, treatment plants will likely need to install treatment systems using O_3, granular activated carbon (GAC), and/or membranes. These changes will increase water treatment costs.

IMPACT ASSESSMENT METHODOLOGY

This section provides an overview of the assessment methods used to evaluate water quality impacts of the proposed Delta Wetlands Project and explains how the new or updated information described above has been incorporated into the assumptions and methods used. The section focuses on the quantitative models used to estimate Delta drainage and export water quality (i.e., DOC and salinity) and DBP concentrations (i.e., THMs and bromate) at the treatment plants under baseline and with-project conditions. Additional information about these methods can also be found in Appendix G of this REIR/EIS and Chapter 3C and Appendix C4 of the 1995 DEIR/EIS.

Modeling Delta Wetlands Project Effects on Salinity and Dissolved Organic Carbon

Water quality at Delta export locations is a function of the quality of water coming into the Delta, the ways in which that quality may change as a result of in-Delta activities, the volume of Delta inflows and exports, and the proportion of the export water coming from each source. Export water is a mixture of water from the central Delta, San Joaquin River water, and Delta agricultural drainage. Under Delta Wetlands Project operations, Delta Wetlands discharges would be another source of export water and would therefore affect Delta export water quality. Quantitative modeling is used to estimate the contribution of the Delta Wetlands islands to levels of water quality constituents at Delta channel locations and in Delta diversions and exports.

Modeling Used for the 1995 Draft EIR/EIS Impact Assessment

Before the 1995 DEIR/EIS was prepared, no model existed for estimating the relationship between the water budget for Delta agricultural islands (diversions, ET, and drainage) and the salinity (EC) and DOC concentration patterns in agricultural drainage. The Delta drainage water quality model DeltaDWQ was developed to estimate the contribution of the Delta Wetlands islands to levels of EC, DOC, Cl^-, and Br^- at Delta channel locations and in Delta diversions and exports under no-project conditions and under project operations. DeltaDWQ combined all of the following:

- DeltaSOS simulations of monthly channel flows;
- DeltaSOS estimates of monthly diversion, storage, and discharge volumes for the Delta Wetlands Project islands; and
- simulations of water quality constituent concentrations in monthly agricultural drainage flows and Delta Wetlands Project discharges.

DeltaDWQ simulated Delta agricultural drainage water quality by simultaneously accounting for water, salt, and DOC budgets. Refer to Appendix C4 in the 1995 DEIR/EIS for a detailed description of the DeltaDWQ model.

Modeling Used for This Revised Draft EIR/EIS Impact Assessment

For this REIR/EIS, the DeltaSOS model was modified to incorporate the equations for predicting the water quality of agricultural drainage and Delta Wetlands reservoir island storage. The revised model also incorporated equations that would predict the effects of agricultural drainage and Delta Wetlands discharges on constituent concentrations in Delta channels and exports. Simplified water budget and DOC and salt loading functions were included in the model. This modification of DeltaSOS with water quality calculations is called the DeltaSOQ model. Use of the DeltaSOQ model eliminates the need for a separate DeltaDWQ model. This section provides a summary of the assessment method; Appendix G describes the method in detail by:

- describing the methods included in DeltaSOQ for estimating Delta source contributions of DOC and salt concentrations,

- explaining the assumptions and methods used for calculating DOC loading from agricultural drainage and Delta Wetlands discharges, and

- demonstrating the calibration of the model using historical water quality measurements of Delta inflows and exports.

Estimating Changes in Salinity. The salinity (EC and Cl^-) of water from the central Delta, the San Joaquin River, agricultural drainage, and the Delta Wetlands Project islands and the proportions in which water from these sources is present in the exports determine export salinity. The volume of Delta flows and exports and salinity intrusion from Suisun Bay are used in calculations of Delta salinity. Methods used to simulate project effects on salinity in this REIR/EIS are similar to the methods described in the 1995 DEIR/EIS, but the equations have been updated to reflect updated salinity measurements from MWQI and other sources. Appendix G provides more detail on the equations used to calculate salinity in DeltaSOQ.

Estimating Changes in Dissolved Organic Carbon. Project effects on DOC concentrations in Delta exports are a function of the following:

- the DOC concentrations in water diverted onto the Delta Wetlands islands;

- evaporative losses;

- DOC loading from peat soils and plant growth;

- residence time (i.e., the length of time water is stored on the islands before being discharged);

- DOC concentrations in Delta receiving waters at the time of Delta Wetlands discharges; and

- the relative amount of Delta Wetlands water in exports.

The methods used to estimate DOC under existing conditions (i.e., DOC in Delta inflows and Delta agricultural drainage) are based on DOC measurements and mass balance estimates, similar to the methods used for salinity (see Appendix G). Although Delta Wetlands would cease farming operations on the islands under project conditions, the contribution of Delta Wetlands islands to agricultural drainage DOC (estimated as 1 g/m^2/month or 12 g/m^2/yr, as shown in Appendix C4 of the 1995 DEIR/EIS) is simulated as a constant under no-project and with-project conditions in response to comments on the 1995 DEIR/EIS. To determine project effects on DOC concentrations in the exports, the model includes an estimate of DOC loading under project operations in addition to the no-project estimate, as described below.

An additional load of DOC could result from inundation of the peat soils during reservoir operations under the proposed project. Reservoir operations might cause more DOC to be mixed from the pore water into the water column than when the peat soils are drained under agricultural practices. Measured data on DOC loading under flooded peat-soil conditions similar to conditions proposed by Delta Wetlands are not available; therefore, an estimated range of possible DOC loading from reservoir operations is based on experimental results.

For purposes of impact analysis, a range of potential DOC loads on the reservoir islands was assumed. In the long term, repeated filling and emptying of the Delta Wetlands reservoir islands might leach out most of the soluble organic material, and DOC loading from peat soils might decline over time. However, the first fillings of the islands would likely result in high DOC loading. The analysis presents three simulations of potential project effects on DOC in Delta exports: an assumption for long-term DOC loading (1 g/m^2/month of storage), an assumption for initial-filling DOC loading (4 g/m^2/month of storage), and an assumption for high initial-filling DOC loading (9 g/m^2/month of storage). The initial-fill assumptions include potential DOC loads from interceptor well operations. The loading estimates are summarized in Table 4-6 and are discussed in more detail in Appendix G.

Modeling Delta Wetlands Project Effects on Disinfection Byproducts

The potential effects of Delta Wetlands Project operations on treated-drinking-water DBPs (i.e., THM and bromate) are evaluated as an additional level of water quality impact assessment. DBP concentrations are determined by the raw water quality parameters (DOC and Br^-) as well as the treatment process parameters (chlorination dose, pH, temperature); therefore, only representative estimates of the incremental effects of increased DOC and Br^- concentrations on these DBP concentrations can be calculated. The latest Malcolm Pirnie equation for use in predicting THM concentrations and the Ozekin predictive equation for bromate formation in treating drinking water were evaluated for use in the impact analysis. The review of these assessment methods and the equations used in the DeltaSOQ model are described in Appendix G. Potential effects of Delta Wetlands Project operations on THM concentrations are calculated in the model; the effects on bromate concentration are not calculated because no reliable relationship between bromate and DOC or Br^- could be identified.

CRITERIA FOR DETERMINING IMPACT SIGNIFICANCE

The State CEQA Guidelines encourage each public agency to develop and publish thresholds of significance. The SWRCB has not published specific significance criteria for projects affecting Delta water quality; however, the SWRCB and EPA have established regulatory objectives and numerical standards, such as those contained in the 1995 WQCP, to protect beneficial uses of Delta waters. The criteria used to determine the significance of effects of Delta Wetlands Project operations on water quality have been set to conform with these existing objectives and standards. For Delta water quality variables for which no regulatory objectives or numerical standards have been set, the selected significance threshold is a percentage change from existing measured values that encompasses natural variability in water quality constituents.

Since release of the 1995 DEIR/EIS, numerical requirements for TOC removal before water treatment have been established under the Safe Drinking Water Act, and EPA has revised its standard for THM concentrations in drinking water. Also, during the Delta Wetlands water right hearing, some protestants raised concerns about the adequacy of the 1995 DEIR/EIS significance criteria in protecting Delta water quality. As discussed below, these factors were considered when significance criteria were established for this REIR/EIS impact analysis for water quality.

Significance Criteria Used in the 1995 Draft EIR/EIS

For the 1995 DEIR/EIS analysis, it was assumed that there are benefits to maintaining water quality better than that specified by the numerical water quality criteria. Therefore, significance thresholds for variables with numerical water quality criteria were established at 90% of the specified water quality standards. If simulated project operations caused the value for a water quality variable to exceed 90% of the numerical standard for that variable, the effect was considered in the 1995 DEIR/EIS to be a significant water quality impact. Maximum significance criteria were not set for constituents that do not have numerical regulatory standards.

A second significance criterion was based on the assumption that some changes may be substantial compared with the natural variability of the water quality variable under no-project conditions and could be considered significant impacts. Natural variability caused by tidal flows, river inflows, agricultural drainage, and biological processes in the Delta channels is sometimes quite large relative to the numerical standards or mean values of water quality variables. Natural variability was assumed to be 10% of the specified numerical limit for variables with numerical limits or 10% of the mean value for variables without numerical limits. Measurement errors and modeling uncertainties were likewise assumed to be about 10% of the measured or modeled values. Therefore, simulated changes that were less than 10% of either the numerical limit or the measured or simulated mean value of the variable were not considered to be changes. In other words, these changes are not greater than natural variability and model uncertainty. Based on professional experience, the second (i.e., incremental) significance criterion adds 10%, adding up to 20% of the numerical limits for water quality variables with numerical limits or 20% of the mean value for variables without numerical limits.

Comments on Significance Criteria

Several parties to the water right hearing and commenters on the 1995 DEIR/EIS have questioned the adequacy of the significance thresholds used in the impact analysis for water quality, arguing that these thresholds would not ensure the protection of all beneficial uses, most notably municipal water uses. The challenges are based on the concern that natural variability differs among water quality constituents and that any change for some constituents may unacceptably degrade resources that are already impaired. In addition, some parties have argued that economic effects on treatment plant operators (increases in treatment costs) that could result from project-related increases in salinity and DOC concentrations should be considered significant impacts.

The determination of impact significance and proposed mitigation described in the 1995 DEIR/EIS and in this REIR/EIS are intended to ensure that the project complies with CEQA and NEPA requirements. A lead agency is directed by CEQA to assess the significant environmental effects of a proposed project and has discretion regarding the most appropriate methodology for determining the significance of effects. The lead agency may adopt thresholds of significance for general use developed through a public review process, or may use other methods for determining impact significance for each particular project, based on substantial evidence. In addition, the State CEQA Guidelines state that a change in the environment is not significant if it complies with a "standard". A standard is defined as, among other things, a quantitative requirement adopted by a public agency through a public review process. (State CEQA Guidelines Sections 15126, 15064.7, and 15064.) NEPA requires that an EIS disclose the direct, indirect, and cumulative effects of the proposed action but does not require significance determinations for individual project effects (40 CFR 1502.16). Also, the State CEQA Guidelines state that economic changes resulting from a project "shall not be treated as significant effects on the environment"; similarly, NEPA requires discussion of economic effects to the extent that they are interrelated with environmental impacts (State CEQA Guidelines Section 15064; 40 CFR 1508.14). Therefore, economic effects will be considered by the SWRCB and USACE in their project approval processes, but no significance thresholds are required for such effects.

Normally, significance thresholds are based on established regulatory standards. The 1995 WQCP established numerical objectives for some of the Delta water quality variables assessed in this analysis (i.e., Cl^-, EC). In this EIR/EIS, significance thresholds for these variables are set to be more stringent than the adopted standards based on the following assumptions:

- It would be beneficial to maintain water quality that is better than that specified by the water quality objectives.
- Measurement errors and modeling uncertainties account for 10% of measured or modeled values.

The significance thresholds of a change of 20% of the numerical limit and a change to a value that is more than 90% of the allowed limit for these variables therefore exceed the expectations of CEQA and NEPA.

Established standards do not exist for project effects on DOC concentrations in Delta waters. In the absence of recognized standards, this analysis proposes 20% of average measured DOC values as the significance threshold for the assessment of project effects. This criterion was selected to detect changes that exceed the range of natural variability and that can therefore be attributed to project operations. It would be unreasonable to establish a significance threshold that does not allow for project effects that are within the natural variability of the constituents in question because project effects would be impossible to differentiate from no-project conditions.

In addition, EPA has set numerical limits for THM levels at municipal water treatment plants. Although the Delta Wetlands Project would not directly produce THMs, project contributions to DOC and Br^- concentrations in Delta waters could affect the subsequent formation of THMs at treatment plants. Therefore, the 20% and 90% significance thresholds described above have also been applied to the THM limits, with potential THM increases calculated based on estimated increases in DOC concentrations under unmitigated project operations. The potential effects of DOC loading under project operations are thus covered under two significance determinations, one for increases in DOC concentrations and one for estimated effects on treatment plant production of THMs.

The impact assessment for Delta Wetlands Project effects on water quality is performed using the available monthly average measurements and simulations of monthly average Delta conditions and project operations. Use of monthly data allows for a preliminary estimate of the number of months in which unmitigated project operations could substantially affect water quality; it also provides the basis for a comparison of relative effects of the project alternatives, consistent with CEQA and NEPA requirements. However, Delta Wetlands would be required to adjust actual operations daily in response to daily monitoring of actual Delta conditions and the quality of water stored on the Delta Wetlands islands. The significance criteria and estimates of the potential for project operations to cause exceedances of specified parameters presented in this impact assessment are used to develop mitigation measures under CEQA and NEPA on a monthly time step (see "Recommended Mitigation and Application to Delta Wetlands Project Operations" below). However, significance criteria for CEQA/NEPA analysis may differ from the requirements in water right terms and conditions that may be used to trigger changes in project operations.

During the water right decision process, the SWRCB will consider project effects on present and anticipated beneficial uses of Delta water. For example, some beneficial uses are more sensitive to changes in specific water quality variables than to changes in other variables; in these cases, the lead agencies may apply a mitigation trigger other than 90% of a specified limit or 20% change. In other words, the SWRCB may apply different performance standards for triggering mitigation, based on substantial evidence, in the terms and conditions of the water right permits. Possible mitigation approaches and the relationship between CEQA/NEPA mitigation measures and the terms and conditions of water right permits are discussed in "Recommended Mitigation and Application to Delta Wetlands Project Operations" below.

Summary of Significance Criteria Used in This Revised Draft EIR/EIS Analysis

The significance criteria used in this analysis are identical to those used in the 1995 DEIR/EIS except that the THM criterion has been updated in response to changes in the federal Disinfection Byproducts Rule. The selected water quality impact assessment variables and the significance criteria used in this REIR/EIS for each variable are summarized in Table 4-7.

The EPA standard for THM concentrations in drinking water has been revised from 100 to 80 μg/l since preparation of the 1995 DEIR/EIS. For the REIR/EIS analysis, the significance criterion was lowered to exceedance of 72 μg/l (90% of 80 μg/l) or changes greater than 16 μg/l

(20% of 80 μg/l) to reflect the new THM standard. Because the THM standard is based on an annual running average of THM measurements, the significance criterion may be applied more appropriately to the annual average THM values. However, the monthly criterion has been used for both the 1995 DEIR/EIS and REIR/EIS analyses to provide a more conservative approach to THM impact analysis.

Changes in export DOC concentrations caused by Delta Wetlands Project operations could affect TOC removal requirements at treatment plants (see "Changes in Disinfection Byproduct Rules" above). An increase in export DOC might cause the TOC removal requirement to change from 25% to 35%. Although the project-related changes in export DOC are within existing variations in DOC, the Delta Wetlands Project could affect the frequency with which treatment plants would need to meet higher TOC removal requirements and, as a result, could affect the cost of treatment operations. As discussed above, changes in treatment costs are not considered an environmental impact (State CEQA Guidelines Section 15064[e]). No new significance criteria are needed for this water quality variable.

ENVIRONMENTAL CONSEQUENCES

Water quality impacts of Delta Wetlands Project operations were assessed by comparing conditions under simulated project operations with conditions under the simulated No-Project Alternative. The simulated No-Project Alternative represents Delta water quality conditions that are likely to exist in the absence of Delta Wetlands Project operations (i.e., continued and intensified farming operations on the four Delta Wetlands Project islands), with a repeat of the historical hydrologic conditions, but with existing facilities, water demands, and Delta standards. See Chapter 3 for a description of the DeltaSOS modeling assumptions.

The 25-year period of 1967-1991 was used in the 1995 DEIR/EIS assessment of water quality effects for several reasons:

- The range of hydrologic conditions during this period is similar to that of the full 73-year period of the hydrologic record (1922-1994) (see Appendix A1 of the 1995 DEIR/EIS).
- Most reservoirs and diversion facilities were operational during this 25-year period.
- Historical EC and water quality data are available for this period.

The full 1922-1994 period is used in this REIR/EIS assessment. The results from the most recent 23-year period of the hydrologic record (1972-1994) are shown graphically to illustrate the model calculations and results.

As described in the 1995 DEIR/EIS, four locations in the Delta (Chipps Island, Emmaton, Jersey Point, and Delta exports) were selected for assessment of impacts related to Delta salinity conditions. A representative Delta export location was used because the impact assessment methods cannot distinguish reliably between water quality conditions at the major export or diversion locations (CVP exports at Tracy, SWP exports at Banks, and CCWD diversions at Rock Slough or Old River intakes).

Impacts related to DOC and THM concentrations were assessed for Delta exports only. Export DOC concentrations were evaluated with the DeltaSOQ model for a range of estimates of DOC loading from the Delta Wetlands reservoir islands. THM concentrations in treated drinking water were evaluated using the revised THM equation (Appendix G).

Simulated Delta Water Quality for the No-Project Alternative

As noted above, the No-Project Alternative is simulated to represent likely Delta conditions that would result from a repeat of the historical hydrologic sequence, but with existing water project facilities (reservoirs, diversions, and canals) and current levels of demand for upstream diversions and Delta exports. Delta conditions under the No-Project Alternative are assumed to be controlled by objectives of the 1995 WQCP and other applicable water rights, agreements, and requirements. The results of simulations of the No-Project Alternative are compared with historical data to confirm the reliability of the DeltaSOQ model in predicting general trends. Water quality conditions were simulated for 1922 through 1994 (73 years) based on the results of baseline water supply and operations modeling (i.e., DWRSIM results; see Chapter 3, "Water Supply and Operations"). Results for the entire 73-year study period are presented in tables, and a series of figures compares simulation results and available historical data for 1972 to 1994.

Because of the differences in facilities, levels of demand, and regulatory requirements between the No-Project Alternative and historical conditions, however, the No-Project Alternative simulation results should not be expected to correspond in all details to historical Delta operations and should not be confused with actual Delta operating conditions for the years compared. Once the reliability of DeltaSOQ in predicting trends is established, the simulated No-Project Alternative serves as the baseline condition with which simulated Delta Wetlands Project operations are compared for impact assessment purposes, as described below.

Simulated Electrical Conductivity at Delta Channel Locations and Chloride in Delta Exports

As reported in the 1995 DEIR/EIS, the simulated maximum EC values at all four Delta locations and the export Cl^- concentrations were generally lower than measured historical values because Delta outflow, as simulated by DeltaSOS, satisfies the 1995 WQCP objectives and therefore is generally higher than historical flows.

Figure 4-13 shows simulated patterns of EC at Chipps Island for 1972-1994 for the No-Project Alternative. Table 4-8 lists the simulated no-project EC values at Chipps Island for the entire 1922-1994 study period. During periods of high Delta inflow, salts at Chipps Island are flushed and salinity becomes similar to river-inflow EC (assumed to be 150 μS/cm). During periods of low Delta inflow, outflow is often controlled by required minimum outflow objectives or salinity standards. The maximum monthly EC value for Chipps Island was 12,355 μS/cm for the simulated No-Project Alternative.

Figure 4-14 shows simulated patterns of EC at Emmaton for 1972-1994 for the No-Project Alternative. Table 4-9 lists the simulated no-project EC values at Emmaton for the entire 1922-1994 study period. The simulated maximum EC value for Emmaton for the No-Project Alternative was 3,115 μS/cm.

Figure 4-15 shows simulated patterns of EC at Jersey Point for 1972-1994 for the No-Project Alternative outflows. Table 4-10 lists the simulated no-project EC values at Jersey Point for the entire 1922-1994 study period. The simulated maximum EC value for the No-Project Alternative at Jersey Point was 2,522 μS/cm.

Seawater intrusion effects are much less pronounced in central Delta exports than at Jersey Point; Sacramento River diversions through the DCC and Georgiana and Threemile Sloughs into the central Delta mix with tidal flows from the lower San Joaquin River to produce relatively freshwater conditions in Delta exports. In addition to seawater intrusion episodes, other fluctuations in simulated EC and Cl^- concentrations in Delta exports are caused by variations in San Joaquin River inflow and agricultural drainage effects. These effects are included in the DeltaSOQ estimates of Delta export EC and Cl^- concentrations.

Figures 4-16 and 4-17 show the simulated patterns of EC and Cl^- concentration, respectively, in Delta exports for 1972-1994 for the No-Project Alternative. Simulated monthly EC values reach a maximum of about 1,000 μS/cm during low-outflow periods when seawater intrusion is greatest. Maximum simulated monthly Cl^- concentrations are about 230 mg/l, which is less than the maximum allowable (i.e., WQCP objective) concentration of 250 mg/l. Table 4-11 lists the simulated export EC values for the No-Project Alternative for the entire 1922-1994 study period and the flow-weighted average export EC values for each water year. Table 4-12 lists the simulated export Cl^- concentrations for the No-Project Alternative for the entire study period. The flow-weighted average export Cl^- concentrations range from 38 to 171 mg/l, with an overall average export Cl^- concentration of 87 mg/l.

Simulated Dissolved Organic Carbon in Delta Exports

Figure 4-18 shows simulated monthly values of DOC concentrations in Delta exports for 1972-1994 for the No-Project Alternative. Historical DOC data from the export locations was available only after 1986; however, the graph shows the data plotted against the 1972-1994 time period to provide for easy comparison with Cl^- data in Figures 4-13 through 4-17. Table 4-13 lists the simulated export DOC concentrations for the No-Project Alternative for the entire 1922-1994 study period. The simulated monthly values ranged from 2.4 to 11.4 mg/l but were generally between about 3 and 6 mg/l, with occasional DOC concentrations of greater than 10 mg/l that correspond to periods when Delta agricultural drainage returns are highest (i.e., December–March) (see Table G-2 in Appendix G) account for a high portion of the exported water. The simulated

DOC concentrations were highest in the winter months (January–March) because of rainfall, drainage, and leaching of salt from the agricultural islands. The simulated flow-weighted average export DOC concentrations for the No-Project Alternative ranged from 3.2 to 6.2 mg/l, with an average export DOC concentration of 4.3 mg/l.

Estimated Trihalomethane Concentrations for a Typical Treatment Plant

Figure 4-19 shows the estimated THM concentrations in chlorinated drinking water from Delta exports for the No-Project Alternative for 1972-1994. Table 4-14 lists the simulated THM concentrations for the No-Project Alternative for the entire 1922-1994 study period. The concentrations were estimated using the revised THM equation described in Appendix G. The monthly values ranged from 32 to 171 μg/l, but were generally between about 30 and 80 μg/l, with occasional THM concentrations of greater than 100 μg/l that corresponded to high DOC or Cl^- concentrations at the export locations. Because the THM drinking-water MCL standard (80 μg/l) is based on an annual moving average, the flow-weighted annual average THM concentrations may be more relevant for regulatory compliance purposes than the monthly concentrations. The average flow-weighted THM concentration for the No-Project Alternative was 55.7 μg/l.

Impacts of the Proposed Project

The proposed project represents Delta Wetlands Project operations with two reservoir islands (Bacon Island and Webb Tract) and two habitat islands (Bouldin Island and most of Holland Tract). As described in Chapter 3, the proposed project in this REIR/EIS analysis is represented by Alternative 2 of the 1995 DEIR/EIS with the revisions described in Chapter 2 of this REIR/EIS. The most consequential of these changes is the addition of the FOC terms. Under the proposed project, discharges from the Delta Wetlands Project islands would be exported in any month when combined CVP and SWP delivery deficits exist, there is unused pumping capacity within the permitted pumping rate at the SWP and CVP pumps, and the FOC and other operating rules are met.

Significant water quality impacts of Delta Wetlands Project operations may occur during months for which Delta Wetlands diversions or discharges are simulated. Project diversions could occur during months with relatively high Delta outflows, when EC values in the Delta are low. Most diversions would occur from November through February, the only months with simulated diversions of more than 500 cfs. Most project discharges would occur from June through August.

Operational Scenarios and Maximum Water Quality Effects

Chapter 3 presents DeltaSOS simulation results for the proposed project under two operational scenarios for discharge to export. To establish the maximum potential effects from Delta Wetlands Project operations, all project discharges are assumed to reach the exports under both scenarios. In one scenario, project discharges are assumed to be exported if pumping capacity exists within the permitted pumping limits at the SWP and CVP pumping plants and if the FOC terms and other operating rules are met. In the other scenario, project discharges for export are subject to these same limits and are limited to periods when there are simulated south-of-Delta delivery deficits.

The salinity impacts of the proposed project are expected to be substantially less than shown in the 1995 DEIR/EIS because of the restrictions on project diversions incorporated into the project description for this REIR/EIS (see Chapter 3). Because of evaporation, the Delta Wetlands discharge salinity would be only slightly higher with the delivery-deficit restriction than it would be without such a restriction.

DOC loading from the reservoir islands is anticipated to increase with the period of storage; as a result, the proposed project operations defined by the second scenario (with discharges limited by south-of-Delta delivery deficits) represent the worst-case DOC loading. The simulations of project operations show that Delta Wetlands discharges under the second scenario are sometimes delayed by a few months compared with discharges under the first scenario; additionally, carryover storage on the reservoir islands is more likely under the delivery-deficit restriction (see Tables 3-15 and 3-18). Therefore, the DOC loading and Delta Wetlands discharge DOC concentrations are highest under the simulated conditions of the second scenario. For this reason, the second scenario has been used in the REIR/EIS DeltaSOQ simulations.

Table 4-24 compares the impact conclusions of the 1995 DEIR/EIS and this REIR/EIS and summarizes recommended mitigation measures.

Delta Salinity Impacts (Electrical Conductivity, Chloride)

Water quality impacts of salinity increases were assessed for four selected locations in the Delta: Chipps Island, Emmaton, Jersey Point, and Delta exports. To simulate maximum project effects, it is assumed in DeltaSOQ that all Delta Wetlands discharges go to the export facilities. Therefore, when Delta Wetlands is discharging for exports, Delta outflow would not change, so Delta Wetlands discharges would not affect EC values at Chipps Island, Emmaton, or Jersey Point. Delta Wetlands discharges would change the export EC and Cl^- concentration if the Delta Wetlands discharge salinity were different from the central Delta salinity.

Delta Wetlands diversions are allowable only when Delta outflow is relatively large, so the simulated effects of the diversions are generally small at any of the Delta locations. The diversions may reduce the export fractions from the San Joaquin River or from agricultural drainage, causing a slight change in export salinity. Depending on the magnitude of Delta flows and exports and the timing of Delta Wetlands discharges, the EC values and Cl^- concentrations of these discharges may be less than or greater than export salinity. DWRSIM results used in the DeltaSOS simulations include required Delta outflows that are designed to satisfy applicable 1995 WQCP objectives for EC at all Delta locations. Therefore, simulated Delta Wetlands diversions are not allowed to prevent the Delta salinity objectives from being met.

The applicable 1995 WQCP EC objective changes with month, water-year type, or runoff conditions, or with the applicable minimum required outflow. Significance criteria may therefore differ for each month at each Delta location. Once the monthly effective EC objective is determined, the significance criteria are established as 90% and 20% of the maximum EC limit under the applicable conditions. For example, the applicable estuarine salinity (X2) objective for Chipps Island for February to June of some years requires an effective outflow of 11,400 cfs and is equivalent to an EC value of about 2,600 μS/cm. However, for some months with lower runoff, the X2 objective is at Collinsville (requiring an effective outflow of 7,100 cfs), and the Chipps Island EC value would be approximately 5,000 μS/cm. During most other months, the required Delta outflow is between 3,000 and 4,500 cfs, corresponding to EC values of between 10,000 and 14,000 μS/cm.

Chipps Island. Table 4-15 compares the monthly changes in simulated EC values for the proposed project at Chipps Island with the EC values for the No-Project Alternative. In the table, positive values represent increases in EC and negative values represent decreases in EC under the proposed project when compared to the simulated No-Project Alternative.

The project effects on Chipps Island EC shown in Table 4-15 are less than those reported in the 1995 DEIR/EIS because the FOC terms now limit Delta Wetlands Project operations. The average changes in EC at Chipps Island in months with major Delta Wetlands diversions (December through February) are relatively small percentages (0.8 to 2.8%) of the No-Project Alternative values (shown in Table 4-8). The largest simulated project increase in EC at Chipps Island during February through June, when the significance criterion would be 520 μS/cm, is 140 μS/cm. Therefore, as a result of incorporating the FOC terms into proposed project operations, none of the simulated changes in EC at Chipps Island exceed the significance criterion. This impact is considered less than significant. Although no mitigation is required, the lead agencies likely will require that Delta Wetlands monitor salinity effects of the project to demonstrate compliance with the FOC terms and Delta salinity standards.

Emmaton. Table 4-16 compares the monthly changes in simulated EC values for the proposed project at Emmaton with the EC values for the No-Project Alternative. EC objectives for Emmaton, applicable from April to August, range from 450 to 2,780 μS/cm, depending on water-year type. It is unlikely that Delta Wetlands would divert during these months, except to compensate for evaporative losses (if permitted to do so). The changes in Emmaton EC values under simulated project operations are less than those predicted in the 1995 DEIR/EIS because the FOC terms now limit Delta Wetlands diversions. As shown in the table, the largest simulated project increases in EC at Emmaton occur in August 1974 and August 1975 (120 and 103 μS/cm, respectively). These are wet years and the applicable EC standard during these years is a 14-day moving average of 450 μS/cm, with an associated 20% change significance criterion of 90 μS/cm. Therefore, monthly simulated project operations indicate that the significance criterion would be exceeded in these two months. As reported in the 1995 DEIR/EIS, this impact is considered significant and mitigation is recommended (see Table 4-24).

Jersey Point. Table 4-17 compares the monthly changes in simulated EC values for the proposed project at Jersey Point with the EC values for the No-Project Alternative. EC objectives for Jersey Point, applicable from April to August, range from 450 to 2,200 μS/cm, depending on water-year type. The results for Jersey Point are less than those predicted in the 1995 DEIR/EIS because the FOC terms limit Delta Wetlands diversions in these months. As shown in the table, the largest simulated project increases in EC at Jersey Point occur in August 1974 and August 1975

(96 and 82 μS/cm, respectively). These are wet years and the applicable EC standard is a 14-day moving average of 450 μS/cm, with an associated 20% change significance criterion of 90 μS/cm. Therefore, monthly simulated project operations indicate that the significance criterion would be exceeded in one month. As reported in the 1995 DEIR/EIS, this impact is considered significant and mitigation is recommended (see Table 4-24).

Delta Exports. Table 4-18 compares the monthly changes in simulated export EC values for the proposed project with the export EC values for the No-Project Alternative. The results reflect changes caused by both diversion and discharge operations of Delta Wetlands. The applicable EC standard is 1,000 μS/cm and the 20% change criterion is 200 μS/cm. None of the simulated monthly EC changes was greater than the criterion, so these impacts on export EC values are considered less than significant, and no mitigation is recommended. Changes in export EC values are less than those presented in the 1995 DEIR/EIS because the FOC terms limit Delta Wetlands diversions and simulated delivery deficits limit Delta Wetlands discharges.

Commenters on the 1995 DEIR/EIS raised the concern that salinity in water diverted onto the reservoir islands might be very high because Delta Wetlands would divert water during an initial winter stormflow, which may be higher in salinity because of the proportion of agricultural drainage in Delta channels at that time. However, as described in Chapter 3 (see "Restrictions for Fish Protection" in the section "Revisions to DeltaSOS"), for monthly modeling purposes, diversions are restricted until the previous month's Cl^- concentration is less than 150 mg/l. Although this restriction on diversions is not specified in the FOC, it is used in DeltaSOQ to approximate the daily restrictions on project operations that would be applied in response to daily changes in Delta water quality that cannot be directly modeled in the monthly model. The FOC restriction against diverting until the X2 location has been downstream of Chipps Island for 1 or 10 days will generally result in Cl^- concentration decreasing to less than the concentration of 150 mg/l simulated in DeltaSOQ.

Table 4-19 compares the monthly changes in simulated export Cl^- concentrations for the proposed project with the Cl^- concentrations for the No-Project Alternative. The simulated export Br^- changes would be directly proportional to the export Cl^- changes. The maximum simulated increase in Cl^- is 24 mg/l, which is equivalent to less than 0.1 mg/l of Br^-. The applicable Cl^- objective for all Delta exports is 250 mg/l, with some periods of 150 mg/l required for CCWD diversions (depending on water-year type). The impacts on export Cl^- concentrations shown in Table 4-19 are less than those presented in the 1995 DEIR/EIS because the FOC terms limit Delta Wetlands diversions and the assumed delivery deficits limit Delta Wetlands discharges. DeltaSOQ also limits diversions until the central-Delta Cl^- concentration is reduced to less than 150 mg/l. This lowers the Delta Wetlands discharge Cl^- concentrations compared with those in the 1995 DEIR/EIS simulations.

As a result of incorporating the FOC terms into proposed project operations, none of the simulated changes in export Cl^- concentrations exceed the 20% change criterion (Table 4-19). Therefore, this impact is considered less than significant and no mitigation is recommended.

Export Concentrations of Dissolved Organic Carbon

An additional load of DOC could result from inundation of the peat soils during reservoir operations under the proposed project. In the long term, repeated filling and emptying of the Delta Wetlands reservoir islands might leach out most of the soluble organic material, and DOC loading from peat soils should therefore decline over time. At least the first few fillings, however, might result in high DOC loading. Therefore, the tables and discussion presented below show export DOC concentrations under three assumptions for DOC loading to stored water: an assumed initial-filling DOC loading of 4 g/m^2/month of storage, an assumed high DOC loading of 9 g/m^2/month of storage, and an assumed long-term DOC loading of 1 g/m^2/month of storage. Total Delta agricultural drainage DOC contributions (12 g/m^2/year) are assumed to remain the same under no-project and proposed project conditions, resulting in an additional 1 g/m^2/month of DOC loading on the project islands.

The simulated effects of proposed project operations on export DOC concentrations during months with Delta Wetlands discharges for export depend on the difference between the estimated DOC concentration in the discharges under project conditions and the export DOC simulated for the No-Project Alternative. The selected significance criterion for a change in export DOC concentration is 0.8 mg/l, which is 20% of the mean measured export DOC concentration (4 mg/l).

Export Concentrations of Dissolved Organic Carbon under Long-Term Reservoir Operations. Figure 4-20 shows the simulated export DOC concentrations and the simulated Delta Wetlands reservoir storage DOC concentrations for 1972-1994 using the long-term reservoir island loading assumption of 1 g/m^2 per month during periods of flooding. Periods when Delta Wetlands DOC concentration is shown as 0 mg/l are those periods when the reservoirs are empty. The DOC concentration in stored water increases during the storage period as follows:

$$\frac{\text{Monthly DOC loading rate } (g/m^2)}{\text{Storage depth (m)}} =$$

$$\text{Monthly increase in storage DOC concentration } (g/m^3, \text{or } mg/l)$$

For a given loading rate, as depth of stored water increases, the DOC will be diluted more and DOC concentration will be reduced. Concentration will be higher with less water depth for the same loading rate. Under the assumed long-term loading rate of 1 g/m^2/month, when the reservoir is full (i.e., storage depth is 6 meters), the Delta Wetlands DOC concentration increases during the storage period by 0.167 mg/l per month (1 $g/m^2 \div 6$ m). This corresponds to an increase of approximately 2.0 mg/l per year.

For example, as shown in Table 3-14, the simulated Delta Wetlands reservoir filled in November 1974 and remained full until March of water-year 1976. The initial Delta Wetlands DOC concentration was assumed to equal the export DOC concentration of 3 mg/l. With an increase of 2 mg/l per year, the DOC concentration increased to about 5 mg/l in water-year 1974, and further increased to about 7 mg/l in 1975 (Figure 4-20). About half of the Delta Wetlands storage water was discharged in March 1976. With the average depth of Delta Wetlands storage reduced, the subsequent increase in Delta Wetlands DOC concentration was more rapid until June 1976, when all but 3 TAF of Delta Wetlands storage water was discharged, with a DOC concentration of 10 mg/l. The very high Delta Wetlands DOC concentration of 20 mg/l shown in July 1976 corresponds to the very small remaining volume, which was discharged in July. A similar rapid increase in Delta Wetlands DOC concentration was simulated in 1987, when a Delta Wetlands storage volume of 40 TAF was simulated. Periods with the greatest effect on export DOC resulting from Delta Wetlands discharges can be identified by comparing the simulated export DOC for the long-term loading and for the no-project conditions (Figures 4-20 and 4-18). Because Delta Wetlands discharges are a small proportion of total exports, Delta Wetlands discharges with high DOC concentrations do not result in dramatic changes in export DOC concentrations, as illustrated in the figure.

Table 4-20 compares the resulting monthly changes in simulated export DOC concentrations for the proposed project with DOC concentrations for the No-Project Alternative. The simulation results indicate that the proposed project would increase average export DOC concentrations during months when Delta Wetlands discharges occur. Simulated export DOC concentrations decreased slightly during months with Delta Wetlands diversions because the diversions reduced the fraction of agricultural drainage and San Joaquin River inflow in exports. The DeltaSOQ model assumes that the Delta Wetlands habitat islands, and the reservoir islands during periods of no storage, would contribute the same DOC load as agricultural drainage. As shown in the table, some of the simulated monthly changes (20 out of 876) were greater than or equal to 0.8 mg/l. This occurred in 15 of the 73 simulated water-years. These results are higher than those predicted in the 1995 DEIR/EIS, which showed a change greater than 0.8 mg/l in one of 300 months. Therefore, project effects on export DOC are considered significant and mitigation is recommended (see Table 4-24).

Export Concentrations of Dissolved Organic Carbon under Initial-Filling Operations. To simulate DOC loading under initial-filling operations, an assumed DOC load of 4 g/m^2/month during storage periods was simulated. Figure 4-21 shows the simulated DOC concentrations in the Delta Wetlands storage water and exports using the initial-fill DOC-loading assumption. Table 4-21 compares the monthly changes in simulated export DOC concentrations for the proposed project under the initial-filling DOC-loading assumption with the simulated DOC concentrations under the No-Project Alternative. As shown in the table, increases in export DOC concentrations greater than or equal to 0.8 mg/l were simulated in at least one month of approximately half (37) of the years. As described above under the long-term load assumption, project impacts on export DOC are considered significant and mitigation is recommended (see Table 4-24).

Export Concentrations of Dissolved Organic Carbon under High Initial-Filling Operations. Figure 4-22 shows the simulated DOC concentrations in Delta Wetlands storage water and exports using the high initial-filling DOC loading assumption of 9 g/m^2/month during the flooded period. Table 4-22 compares the resulting monthly changes in simulated export DOC concentrations for the proposed project with DOC concentrations for the No-Project Alternative. As shown in the table, simulated monthly changes were greater than or equal to 0.8 mg/l in 41 of the simulated water-years when discharges from the project are simulated (48 of the 73 simulated water-years). The following section describes how the recommended mitigation (Table 4-24) would affect Delta Wetlands operations.

Example of Discharge of Delta Wetlands Storage Water with High Dissolved Organic Carbon Concentrations under Mitigation Recommended in the 1995 Draft EIR/EIS. As described in the 1995 DEIR/EIS, the recommended mitigation for high DOC concentrations in water stored on the Delta Wetlands islands is to restrict Delta Wetlands discharges to prevent DOC increases of more than 0.8 mg/l in Delta exports on a monthly basis. High DOC concentrations in Delta Wetlands storage water are anticipated particularly during the first several fill operations. Changes in export DOC under the assumed initial-fill or high initial-fill DOC load rates are shown in Tables 4-21 and 4-22. Implementation of the recommended mitigation measure would affect Delta Wetlands' ability to export water.

An example of how Delta Wetlands discharges would be restricted to prevent significant increases in DOC at the export pumps is presented here. Channel DOC concentration is assumed to be 4 mg/l. The highest observed DOC load from the SMARTS 2 experiment (121 g/m^2 from tank 3) is used in this example to represent worst-case DOC loading in the first year of Delta Wetlands storage operation. With DOC loading at a given rate (g/m^2) during the first year of storage, the DOC concentration (g/m^3, or mg/l) depends on the depth of water (m) in which the DOC is diluted. If the depth of stored water were 20 feet (6 meters), the DOC concentration of the stored water would increase by the end of the first year of storage by 20 mg/l (121 $g/m^2 \div 6$ meters = 20 g/m^3). If the depth of water were only 10 feet (3 meters), representing a half-filled reservoir island, the DOC concentration of the stored water would increase by the end of the first year of storage by 40 mg/l (121 $g/m^2 \div 3$ meters = 40 g/m^3). The worst-case DOC concentrations for Delta Wetlands storage water, therefore, would be 24 to 44 mg/l.

A mass balance equation for export DOC is used to determine the applicable Delta Wetlands discharge rate when the DOC concentration in stored water is high. The allowable increment of export DOC concentration will be specified by the SWRCB as one of the terms and conditions of the water right permits. Consistent with the 1995 DEIR/EIS mitigation measure, the significance threshold of 0.8 mg/l of DOC is used in this example as the allowable increment. A relatively low export flow of 5,000 cfs is assumed for this example, to limit the Delta Wetlands discharge during dry summer conditions. The following mass balance for export DOC would apply to the discharge of DOC from the Delta Wetlands islands:

Delta Wetlands DOC (mg/l) • Delta Wetlands discharge (cfs) + Export DOC (mg/l) • Export flow (cfs) =
(Export DOC + Allowed DOC increment [mg/l]) •
(Delta Wetlands discharge + Export flow)

The DOC mass balance equation can be rearranged to solve for the allowable Delta Wetlands discharge:

$$\text{Delta Wetlands discharge} = \frac{\text{DOC increment} \bullet \text{Export}}{(\text{Delta Wetlands DOC} - \text{DOC increment})}$$

For an export DOC of 4 mg/l, with an assumed Delta Wetlands DOC of 24 mg/l and an allowable DOC increment of 0.8 mg/l, the Delta Wetlands discharge would be limited to 208 cfs. This would require 240 days (8 months) to empty one Delta Wetlands reservoir island (100 TAF). If both Delta Wetlands reservoir islands were filled, more than a year (16 months) would be required to discharge the Delta Wetlands storage (200 TAF). DOC concentrations may continue to increase during the discharge period. Assuming Delta Wetlands DOC concentrations were 44 mg/l with exports at 5,000 cfs, a Delta Wetlands discharge of only 104 cfs would be allowed.

The Delta Wetlands discharge rate could be twice as high as the rates reported above if the export pumping were increased to 10,000 cfs, and more Delta Wetlands discharge could occur during high-flow periods when the entire Delta Wetlands discharge would not be transported to the exports (i.e., Webb discharge during periods of high QWEST and Delta outflow). In comparison to the worst-case assumptions presented above, a Delta Wetlands discharge of 2,000 cfs would be allowed when the export pumping was 10,000 cfs and the Delta Wetlands DOC concentration was no greater than 5 mg/l more than the export DOC. If the SWRCB adopts a more stringent allowable DOC increment (i.e., less than 0.8 mg/l), the Delta Wetlands discharge rate would be lower. In conclusion, Delta Wetlands discharges could be limited substantially if initial storage of Delta Wetlands water results in DOC concentrations in the stored water corresponding to the high initial-fill loading illustrated above.

Trihalomethane Concentrations in Treated Drinking Water

Table 4-23 compares the monthly changes in simulated treated-drinking-water THM concentrations for the proposed project with THM concentrations for the No-Project Alternative. The DeltaSOQ calculations of THM for typical treatment conditions indicated that the monthly increases in THM concentrations under the proposed project were almost always less than the criterion of 16 μg/l. As shown in Table 4-23, the 20% change threshold would be exceeded in 6 out of 876 months. This is considered a significant impact, as in the 1995 DEIR/EIS. The mitigation measure has been revised to reflect the new standards for THM (see Table 4-24).

If the THM MCL is reduced to 40 μg/l as proposed by EPA, water treatment plant operations will need to be modified to provide acceptable THM concentrations for the range of DOC and Br^- that is observed in Delta diversions and exports, even without Delta Wetlands Project operations (see "Changes in Disinfection Byproduct Rules" above). Because the linear relationship between treated THM concentrations and Delta DOC and Br^- concentrations under improved treatment conditions will likely remain similar to the relationship under existing treatment conditions (i.e., a 10% increase in DOC or Br^- will increase THM concentration by 10%), the mitigation measures adopted to limit project-related increases in DOC or Br^- are still appropriate methods for controlling changes in THM concentrations as a result of project operations. If new THM regulations take effect, the allowable project-related increase in DOC at the exports could be reduced and the mitigation requirement for Delta Wetlands operations could be changed if needed.

The effect of project-related changes in THM concentrations at the treatment plant is primarily an economic one. The project-related changes in export DOC are within existing seasonal variations in DOC, so operators would have to be prepared to treat those levels under existing or future standards. However, the Delta Wetlands Project could affect the frequency with which higher DOC levels reach the treatment plants, as well as the time (i.e., season) that these DOC levels reach the plants; as a result, the project could affect the cost of treatment operations. Although CEQA and NEPA do not require a significance determination of the economic impacts on treatment plant operators, the lead agencies acknowledge this potential effect of the project. Incremental increases in the cost of water treatment with the proposed project will be considered by the SWRCB and USACE in their project approval processes.

Because of substantial monthly variations in THM concentrations, the current EPA monitoring requirements allow averaging of monthly or quarterly THM samples. The THM MCL is an annual moving average of 80 μg/l. Because Delta Wetlands Project discharges would occur for a limited period each year, the possible effects on annual average THM concentrations would be less than the increases in these concentrations attributable to increased DOC or Br^- concentrations during the discharge period. The flow-weighted annual increase in THM concentrations might be a closer approximation of the actual regulatory requirements (Table 4-23). As described below, mitigation requirements could consider both a maximum monthly and an annual average acceptable change in DOC or expected THM concentrations.

Recommended Mitigation and Application to Delta Wetlands Project Operations

CEQA requires that, for each significant impact identified, an EIR discuss feasible measures to avoid or substantially reduce the project's significant environmental effect; mitigation measures are not required for effects that are not found to be significant (State CEQA Guidelines Section 15126.4[a]). NEPA, on the other hand, does not require federal agencies preparing an EIS to avoid or mitigate impacts even if mitigation is feasible (*Robertson v. Methow Valley Citizens Council* (1989) 490 U.S. 332). In practice, however, most individual federal agency regulations require that adverse effects of a project on protected resources be mitigated.

In the 1995 DEIR/EIS, proposed mitigation measures to offset significant impacts on water quality were based on limiting Delta Wetlands Project operations (i.e., diversions and discharges) so that the levels of water quality variables would remain below the 90% and 20% significance thresholds. This basic mitigation requirement remains the recommended method to prevent significant water quality impacts of Delta Wetlands Project operations. As explained in the description of the 1995 DEIR/EIS mitigation measures, Delta Wetlands Project operations would be regulated based on information from real-time monitoring of actual daily Delta flows, Delta Wetlands Project operating capacities, CVP and SWP operations, Delta water quality, quality of water stored on the Delta Wetlands Project islands, and fisheries. The effects of Delta Wetlands Project operations on Delta flows, water quality, and fish entrainment patterns would be reported in monthly operating reports.

The lead agencies will adopt final mitigation requirements that would be used to trigger adjustments to Delta Wetlands' operations in response to project monitoring. Those mitigation requirements may differ from the significance criteria proposed above to meet CEQA/NEPA requirements (see discussion under "Comments on Significance Criteria" above). The adopted mitigation requirements will specify monitoring and averaging periods for determining Delta Wetlands Project effects; therefore, they may differ from the mitigation requirements that are based on the monthly simulations used in the 1995 DEIR/EIS and this REIR/EIS, which provide a reasonable analysis of the potential for significant project impacts. The lead agencies could specify annual averages, daily maximums, or monthly averages as mitigation triggers, with different criteria used for different variables. The application of different averaging periods for water quality variables is consistent with other water quality standards (e.g., objectives in the WQCP and EPA standards for quality of drinking water). For example, EPA's THM standard is applied to a moving annual average based on quarterly or monthly sampling at treatment plants (see "Changes in Disinfection Byproduct Rules" above). The lead agencies will make a final determination of the mitigation requirements to be applied to the Delta Wetlands Project in the terms and conditions of the water right permits and in the mitigation and monitoring plan they adopt.

The effects of Delta Wetlands diversions on salinity and X2 location could be easily determined with daily calculations and comparison with daily measurements at the established Delta monitoring locations (i.e., Chipps, Collinsville, Emmaton, Jersey Point, and export and diversion locations).

The effects of anticipated Delta Wetlands discharges on salinity and DOC concentrations at the Delta export and diversion locations would be estimated from measurements of Delta Wetlands storage water quality and the measured water quality at the export and diversion locations. The allowable Delta Wetlands discharge flow could then be calculated; the flow would be restricted to preclude Delta Wetlands discharge from causing salinity and DOC concentrations to exceed the allowable increases established by the SWRCB in water right terms and conditions. For example, if the monthly maximum increase in DOC concentration were established as 0.8 mg/l (corresponding to 20% of the average export DOC value, which was used as the significance criterion) and if the measured Delta Wetlands DOC concentration were 8 mg/l, then the Delta Wetlands Project discharge would be limited to 10% of the export pumping (including Delta Wetlands discharge). Such suggested permit conditions would be used to prevent Delta Wetlands Project operations from exceeding acceptable increases in DOC or Cl^- concentrations based on the averaging period (e.g., monthly, annual) adopted by the lead agencies for each variable.

For salinity increases, the 1995 WQCP objectives are generally expressed as monthly average values. The allowable salinity increases from the Delta Wetlands Project could be specified as similar monthly average values, which might be different in each month at each location. An annual limit on the salinity increase resulting from Delta Wetlands discharges might also be specified. Some method for tracking salinity credits from Delta Wetlands operations (i.e., credits for Delta Wetlands discharge salinity being lower than export salinity) might also be allowed.

For DOC, there is no applicable adopted standard, but setting a moving annual average for DOC increases similar to that used for the EPA THM standards may be an appropriate condition for the Delta Wetlands Project. Alternately, the lead agencies could specify a set of monthly and/or annual acceptable increases similar to those described above for salinity.

Potential effects on water treatment costs for downstream water users caused by Delta Wetlands operations are an economic issue outside the scope of this environmental analysis. However, the SWRCB may choose to establish a monitoring and compensation plan for these potential effects in the water right terms and conditions. A procedure for establishing Delta Wetlands' contribution to increased water treatment costs (e.g., for TOC removal) would need to be determined and agreed to by Delta Wetlands and the water treatment operators.

The lead agencies would incorporate into the water right permit terms and conditions and the project mitigation monitoring plan selected mitigation triggers for each water quality variable of concern. These triggers would consist of the suggested significance thresholds (or other adopted criteria) combined with averaging periods deemed most appropriate for each respective water quality variable. In this way, the lead agencies could adopt mitigation measures other than those recommended in this REIR/EIS and could address potential effects on beneficial uses and economic considerations that are beyond the scope of this REIR/EIS.

Cumulative Impacts

Cumulative water supply effects were evaluated using DeltaSOS simulations of the Delta Wetlands Project, as described above, but under the assumption that SWP pumping is permitted at full capacity of Banks Pumping Plant. This scenario represents reasonably foreseeable future Delta conditions and regulatory standards (refer to Chapter 3).

As described in Chapter 3, the proposed project would be operated in fewer years under cumulative conditions than under existing conditions because of limited availability of water for Delta Wetlands diversions. However, because of greater assumed export pumping capacity at Banks Pumping Plant, simulated Delta Wetlands export volumes under cumulative conditions were greater in several of the years than under existing conditions. The average annual simulated Delta Wetlands diversion under cumulative future conditions was 169 TAF/yr, with discharges for export of 147 TAF/yr. These simulated operations are not limited by south-of-Delta delivery deficits and represent the greatest possible DOC-loading impacts at export and diversion locations. Because DOC loads are proportional to the period of storage, loads under cumulative conditions could be somewhat less than for the proposed project, even if simulated exports are slightly higher.

Changes in water quality conditions (levels of EC, Cl^-, DOC, and THM) between the cumulative future no-project conditions and the cumulative with-project conditions would be similar to the changes simulated between no-project and proposed project conditions described above. Results of the revised analyses indicate that Delta Wetlands discharges to export under the proposed project would be less than previously reported for the 1995 DEIR/EIS (refer to Chapter 3). Consequently, impacts on most water quality constituents would be reduced. Similarly, water quality impacts under cumulative conditions would be less than those presented in the 1995 DEIR/EIS analysis for cumulative conditions. However, there remains the likelihood that project operations under future cumulative conditions could exceed applicable significance criteria and would therefore require mitigation.

As described in the 1995 DEIR/EIS, cumulative impacts of the project on water quality concentrations are considered significant and mitigation measures are recommended (see Table 4-24).

Impact Evaluation of Project Alternatives from the 1995 Draft EIR/EIS

As described in Chapter 2, project operations under Alternative 1 in the 1995 DEIR/EIS were assumed to be the same as project operations under Alternative 2, except that discharges to export were assumed to be more restricted (i.e., by strict interpretation of the E/I ratio, the maximum allowed exports as a percentage of inflow). As shown in the 1995 DEIR/EIS analysis and described in Chapter 3 of this REIR/EIS, operations under Alternative 1 provide fewer opportunities for Delta Wetlands discharges to export than Alternative 2 operations. Changes in simulated Alternative 1 project operations between the 1995 DEIR/EIS analysis and this REIR/EIS analysis are similar in magnitude and direction to the changes described above for the proposed project (i.e., Alternative 2). Therefore, Delta Wetlands discharges to exports under Alternative 1 would be less than previously reported in the 1995 DEIR/EIS. The resulting impacts of Alternative 1 on salinity, DOC levels, and potential formation of THMs are less than those estimated for Alternative 1 in the 1995 DEIR/EIS, but remain significant.

Alternative 3, the four-reservoir-island alternative, has not changed since the 1995 DEIR/EIS was published. The FOC and biological opinion terms were developed for the two-reservoir-island operations represented by Alternative 2 in the 1995 DEIR/EIS and are not applicable to a four-reservoir-island alternative. New simulations of Alternative 3, which are based on the Delta water budget developed from DWRSIM study 771 and include AFRP actions, result in minor changes in project diversion, storage, and discharge operations. There are no changes to the conclusions of the environmental impact analysis presented in the 1995 DEIR/EIS for Alternative 3.

Table 4-1. Summary of Average DWR MWQI Data on Water Quality at Delta Channel and Export Locations

Drainage Location	Samples (#)		EC (µS/cm)	Cl^- (mg/l)	DOC (mg/l)	Cl^-:EC Ratio	Br^-:Cl^- Ratio	C-THM (µg/l)	C-THM:DOC Ratio	UVA:DOC Ratio
Sacramento River - Greene's Landing	164	AVG	159	6.8	2.3	0.041	0.0032	28	0.0116	0.0275
		MIN	70	1.0	1.3	0.009	0.0010	7	0.0039	0.0070
		MAX	253	19.0	5.5	0.080	0.0267	122	0.0358	0.0538
San Joaquin River - Vernalis	162	AVG	647	86.0	3.7	0.124	0.0030	47	0.0125	0.0277
		MIN	117	7.0	1.4	0.055	0.0002	21	0.0051	0.0160
		MAX	1320	183.0	11.4	0.161	0.0056	160	0.0226	0.0394
SWP Banks Pumping Plant	172	AVG	439	69.8	3.8	0.143	0.0031	52	0.0134	0.0333
		MIN	143	14.0	1.6	0.083	0.0021	12	0.0043	0.0277
		MAX	877	185.0	10.5	0.225	0.0041	204	0.0272	0.0474
CVP Tracy Pumping Plant	172	AVG	485	71.2	3.8	0.138	0.0030	50	0.0135	0.0317
		MIN	151	12.0	1.9	0.077	0.0021	19	0.0057	0.0200
		MAX	1150	181.0	11.0	0.217	0.0052	154	0.0251	0.0463
CCWD Rock Slough	175	AVG	514	93.7	3.6	0.154	0.0030	51	0.0145	0.0326
		MIN	146	9.0	1.1	0.056	0.0019	24	0.0070	0.0242
		MAX	1250	303.0	9.1	0.254	0.0044	735	0.1008	0.0426

Sources: 1995 DEIR/EIS and California Department of Water Resources 1999a.

Table 4-2. Summary of Average DWR MWQI Data on Water Quality of Delta Island Drainage

Drainage Location	Sampling Dates	Grab Samples (#)		EC (µS/cm)	Cl^- (mg/l)	Br^- (mg/l)	Cl^-:EC Ratio	Br^-:Cl^- Ratio
Bacon Island	JAN '90 - AUG '99	111	AVG	589	102	0.24	0.17	0.0029
			MIN	200	18	0.05	0.04	0.0005
			MAX	1280	211	0.70	0.42	0.0045
Bouldin Island	MAR '87 - JUL '94	121	AVG	426	32	0.19	0.07	0.0061
			MIN	137	8	0.02	0.04	0.0025
			MAX	1300	94	0.56	0.13	0.0150
Holland Tract	JAN '90 - JUL '94	87	AVG	1177	211	0.65	0.18	0.0032
			MIN	559	64	0.18	0.11	0.0020
			MAX	2870	542	1.18	0.22	0.0052
Webb Tract	JAN '90 - APR '93	33	AVG	1143	183	0.61	0.16	0.0037
			MIN	568	97	0.41	0.11	0.0017
			MAX	2530	378	0.90	0.23	0.0065
Twitchell Island	JAN '94 - JAN '98	476	AVG	937	174	0.45	0.18	0.0028
			MIN	337	49	0.15	0.14	0.0008
			MAX	1980	328	0.72	0.24	0.0050

Drainage Location	Sampling Dates	Grab Samples (#)		DOC (mg/l)	UVA (1/cm)	C-THM (µg/l)	TTHMFP (µg/l)
Bacon Island	JAN '90 - AUG '99	111	AVG	11.4	0.52	129	1236
			MIN	3.4	0.15	18	178
			MAX	29.5	1.27	333	3080
Bouldin Island	MAR '87 - JUL '94	121	AVG	33.7	1.41	271	2511
			MIN	3.5	0.13	45	415
			MAX	96.0	3.48	691	6350
Holland Tract	JAN '90 - JUL '94	87	AVG	18.2	0.83	207	2044
			MIN	5.8	0.34	77	814
			MAX	37.0	1.55	549	6165
Webb Tract	JAN '90 - APR '93	33	AVG	29.7	1.32	258	2487
			MIN	10.0	0.47	102	1075
			MAX	57.0	2.54	483	4551
Twitchell Island	JAN '94 - JAN '98	476	AVG	20.1	0.93	213	2041
			MIN	1.1	0.13	33	360
			MAX	58.9	2.62	519	4840

Sources: 1995 DEIR/EIS and California Department of Water Resources 1999a.

Table 4-3. Results of SMARTS 1 Flooded Peat Soil DOC and Salt (EC) Load Experiments

TANK	Peat Depth (feet)	Water Depth (feet)	Initial Surface Water DOC (mg/l)	Surface Water DOC (mg/l) Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Water Load of DOC (g/m²)
1 static	1.5	2.0	1	8	11	15	20	23	25	30	32	35	39	40	40	24
2 flushing	1.5	2.0	1	10	10	11	10	9	8	7	8	7	5	4	4	55
3 static	4.0	2.0	1	23	31	43	59	73	83	99	114	135	108	92	88	53
4 flushing	4.0	2.0	1	18	15	19	18	15	12	14	11	9	8	6	7	92
5 static	4.0	7.0	1	6	8	10	13	16	18	20	19	24	26	27	26	54
6 flushing	1.5	7.0	1	8	5	4	5	4	3	3	3	3	3	2	2	143
7 static	1.5	7.0	1	5	6	7	9	11	11	12	14	15	17	19	16	32
8 flushing	4.0	7.0	1	4	3	2	2	2	2	2	2	2	2	2	2	90
9 control	0.0	11.0	1	2	2	1	2	2	2	2	2	2	2	3	2	4
Water Supply			1					1	1	1	1	1	1	1	1	

TANK	Peat Water DOC (mg/l) Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12
1 static	158				287				58			74
2 flushing	205				301				301			279
3 static	222				273				283			270
4 flushing	145				282				324			301
5 static	143				271							323
6 flushing	226				338				339			341
7 static	155				336				386			341
8 flushing	208				341				374			358

TANK	Peat Depth (feet)	Water Depth (feet)	Initial Surface Water EC (µS/cm)	Surface Water EC (µS/cm) Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Water Load of Salt (g/m²)
1 static	1.5	2.0	135	148	160	167	178	193	204	216	220	236	245	248	256	49
2 flushing	1.5	2.0	135	153	158	160	159	163	165	173	175	179	174	161	152	96
3 static	4.0	2.0	135	157	190	228	228	267	304	203	383	483	532	340	354	89
4 flushing	4.0	2.0	135	180	188	188	188	193	185	208	187	206	201	167	171	214
5 static	4.0	7.0	135	138	149	160	167	180	185	193	212	218	225	229	226	130
6 flushing	1.5	7.0	135	135	135	156	158	155	150	153	164	159	174	177	148	272
7 static	1.5	7.0	135	136	136	146	147	152	152	157	168	169	174	177	177	60
8 flushing	4.0	7.0	135	142	147	154	156	155	152	154	163	160	172	165	154	294
9 control	0.0	11.0	135	135	137	140	141	145	144	146	150	151	150	154	153	40
Water Supply			135	135	135	135	135	135	135	158	158	150	182	134	145	

TANK	Peat Water EC (µS/cm) Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12
1 static	842				1017				345			395
2 flushing	986				1044				1138			1141
3 static	1480				1094				1181			1226
4 flushing	2060				1434				1388			1446
5 static	1931				2000							1852
6 flushing	1830				1516				1535			1830
7 static	1890				1762				1637			1590
8 flushing	2140				1730				1765			1563

Table 4-4. Results of SMARTS 2 Flooded Peat Soil DOC and Salt (EC) Load Experiments

TANK	Peat Depth (feet)	Water Depth (feet)	Surface Water DOC (mg/l) Initial	Week 1 Jan 21	Week 3 Feb 3	Week 5 Feb 18	Week 7 Mar 4	Week 9 Mar 17	Week 11 Mar 31	Week 13 Apr 13	Week 15 Apr 28	Week 17 May 12	Week 19 May 26	Week 21 Jun 9	Week 23 Jun 23	Week 25 Jul 7	Week 27 Jul 21	Water Load of DOC (g/m²)
1 static	1.5	2.0	1.3	10.7	16.0	19.7	23.0	28.0	33.4	39.3	51.8	65.2	76.9	88.3	99.6	106.5	121	73
2 flushing	1.5	2.0	1.3	16.8	9.6	4.5	4.6	5.4	5.6	4.2	6.6	12	9.9	7.4	7.3	8.05	5	65
3 static	4.0	2.0	1.3	8.6	10.7	13.4	16.8	27.2	39.4	45.1	66.1	88.7	109.0	134.0	146.0	170.1	200	121
4 flushing	4.0	2.0	1.3	11.3	4.7	3.5	4.2	4.4	4.8	4.6	7.5	13.6	11.1	8.2	8.3	8.28	7	62
5 static	4.0	7.0	1.3	1.9	2.3	2.5	2.9	3.5	4.0	4.3	5.4	6	6.9	7.6	8.9	10.3	12.2	23
6 flushing	1.5	7.0	1.3	1.8	1.4	1.2	1.0	1.0	1.3	1.0	1.2	1.2	1.4	1.3	1.4	1.39	1.4	38
7 static	1.5	7.0	1.3	2.2	4.8	3.6	3.8	5.0	6.3	6.9	10.3	13.0	15.7	17.2	18.6	19.54	20.8	42
8 flushing	4.0	7.0	1.3	2.8	1.8	1.4	1.6	1.4	1.7	1.5	2.8	2.7	3.5	3.2	4.0	3.66	3.3	75
9 control	0.0	11.0	1.3	1.1	1.3	1.3	1.1	1.1	1.1	1.0	1.0	1.2	1.1	1.0	1.2	1.07	1.3	0
Water Supply				1.3	1.1	1.0	0.9	0.8	1.0	0.8	0.8	0.9	0.8	1.0	1.1	1.1	0.9	

TANK	Peat Water DOC (mg/l) Initial	Week 1	Week 3	Week 5	Week 7	Week 9	Week 11	Week 13	Week 15	Week 17	Week 19	Week 21	Week 23	Week 25	Week 27
1 static		82.1	126		233		441.7		561		600		544		590
2 flushing		96	109		214		295.6		426		429		413		392
3 static		85.5	114		161		229.5		342		381		380		374
4 flushing		94.6	118		170		259.8		416		453		411		368
5 static		14.1	16.7		21.1		28.2		35.1		42.2		45.3		46.8
6 flushing		11.3	16.7		20		26.6		29.7		35.6		36.4		40.1
7 static		27.5	32.4		45.6		47.0		52.8		54.2		55.8		57.8
8 flushing		27.9	33.6		47.1		63.0		83.5		97.4		106.0		99.5

TANK	Peat Depth (feet)	Water Depth (feet)	Surface Water EC (µS/cm) Initial	Week 1	Week 3	Week 5	Week 7	Week 9	Week 11	Week 13	Week 15	Week 17	Week 19	Week 21	Week 23	Week 25	Week 27	Water Load of Salt (g/m²)
1 static	1.5	2.0	116	312	244	386	411	432	461	465	428	574	632	664	717	780	851	300
2 flushing	1.5	2.0	116	483	276	166	166	167	186	142	145	206	219	211	209	177	162	335
3 static	4.0	2.0	116	248	276	302	348	424	500	410	563	825	1029	1177	1378	1513	1597	605
4 flushing	4.0	2.0	116	621	187	172	175	178	198	149	203	249	251	232	234	195	192	466
5 static	4.0	7.0	116	177	182	186	191	191	199	195	171	222	236	243	253	254	260	206
6 flushing	1.5	7.0	116	170	148	139	142	143	163	127	119	152	179	181	177	139	146	43
7 static	1.5	7.0	116	184	188	191	193	195	204	157	206	222	234	238	246	246	251	193
8 flushing	4.0	7.0	116	194	152	142	145	146	166	161	124	159	187	185	180	144	150	202
9 control	0.0	11.0	116	170	173	172	171	170	129	133	143	175	180	182	185	183	185	155
Water Supply				116	154	141	142	152	170	151	122	147	161	176	165	149	149	

TANK	Peat Water EC (µS/cm) Initial	Week 1	Week 3	Week 5	Week 7	Week 9	Week 11	Week 13	Week 15	Week 17	Week 19	Week 21	Week 23	Week 25	Week 27
1 static		3640	3960		2730		3770		3159		3310		3260		3260
2 flushing		3740	3680		2430		2110		2383		2620		2530		2320
3 static		4000	4450		3400		3100		3115		3310		3140		3010
4 flushing		4800	4790		3290		3130		3280		3360		3300		2880
5 static		708	797		761		790		550		676		714		663
6 flushing		578	604		619		635		454.8		673		658		675
7 static		936	985		915		924		702		990		1021		1021
8 flushing		1232	1321		1308		1250		998		1265		1291		1249

Table 4-5. Comparative Estimates of DOC Loading Rates (g/m²/yr)

Source Estimates	Vegetation Residue	Primary Production	Peat Soil	Total DOC Load	Notes
Existing Agricultural Drainage Conditions					
Bacon Island				9.3	a
Webb Tract				10.4	b
Bouldin Island				22.4	c
Holland Tract				2.5	d
Twitchell Island				10	e
Twitchell Island, flow weighted				19	e
DeltaDWQ Model for Agricultural Conditions (1995 DEIR/EIS)				12	f
MWQI-CR#2				8	g
Seasonal Wetland and Flooded Island Conditions (1995 DEIR/EIS)					
Wetland Demonstration				7-17	h
Vegetation Decay Experiment	5.4-7.5				i
Flooded Wetland Demonstration				21	j
Tyler Island Flooding				30-36	k
DeltaDWQ Model for Seasonal Wetlands				12	l
DeltaDWQ Model for Flooded Islands				14-20	m
SMARTS Experiments—Peat Soil Flooding Conditions					
SMARTS 1—1.5 feet of peat (tanks 1 and 7)				24-32	n
SMARTS 1—4.0 feet of peat (tanks 3 and 5)				53-54	n
SMARTS 1—control (tank 9)		4			o
SMARTS 2—1.5 feet of peat (tanks 1 and 7)				42-73	p
SMARTS 2—4.0 feet of peat (tanks 3 and 5)				23-121	p
Water Right Hearing Testimony on Delta Wetlands Project Conditions					
Stuart Krasner, 8 mg/l DOC discharge				30	q
Stuart Krasner, 16 mg/l DOC discharge				78	q
Stuart Krasner, 32 mg/l DOC discharge				174	q
Richard Losee, algal biomass and peat soil		50-1,250	1,830		r
Richard Losee and K.T. Shum, groundwater seepage control pumping				9.2-18.4	s
K.T. Shum, molecular diffusion			16-160		t
Michael Kavanaugh, reservoir islands				3.5-12.7	u
Michael Kavanaugh, habitat islands				3.7-20.6	u

To obtain lb/acre, multiply g/m² value by 8.9.

Notes:

a. Calculated based on mean drainage depth of 1.73 m and mean excess DOC concentration of 5.4 mg/l. Source: Appendix G.
b. Calculated based on mean drainage depth of 0.5 m and mean excess DOC concentration of 20.7 mg/l. Source: Appendix G.
c. Calculated based on mean drainage depth of 0.83 m and mean excess DOC concentration of 27.1 mg/l. Source: Appendix G.
d. Calculated based on mean drainage depth of 0.4 m and mean excess DOC concentration of 6.2 mg/l. Source: Appendix G.
e. Calculated based on metered drainage volume from Twitchell Island in 1995 (11,232 af), Twitchell Island acreage of 3,580 acres, and mean DOC drainage concentration of 22.6 mg/l (n=231). Applied water DOC concentration assumed to be 3 mg/l (Sacramento River source). Flow-weighted average estimated from weekly flow-weighted DOC measurements from 1995. Sources: USGS 97-350; DWR's "Estimation of Delta Island Diversion and Return Flows", February 1995; MWQI.
f. DeltaDWQ assumed an agricultural drainage DOC loading for Delta lowlands of 12 g/m^2 per year, or 1 g/m^2 per month for 12 months. Source: 1995 DEIR/EIS, Appendix C4.
g. Loadings calculated from data presented in "Candidate Delta Regions for Treatment to Reduce Organic Carbon Loads, MWQI-CR#2" (Marvin Jung Associates in association with Limit to Infinity Enterprises, January 1999). Calculations based on DOC concentrations and volumes of drainage water presented in MWQI-CR#2 converted to mass loadings per square meter for an assumed 420,000-acre Delta lowland area. Loading factor does not account for initial DOC concentration of applied water.
h. Based on measurements of Holland Tract demonstration wetland. Source: 1995 DEIR/EIS, Appendix C3.
i. Based on bench-scale vegetation decay experiments utilizing Holland Tract demonstration wetland vegetation. Source: 1995 DEIR/EIS, Appendix C3.
j. Source: 1995 DEIR/EIS, Appendix C3.
k. DWR sponsored flooding of Tyler Island for a period of 1 month. Depth of stored water estimated based on acre-feet stored divided by Tyler Island acreage. Estimated depth multiplied by DOC concentration of discharge water provided for estimated DOC loading. Source: 1995 DEIR/EIS, Appendix C3.
l. DeltaDWQ assumed habitat island operation would provide a total of 12 g/m^2 per year of DOC between the months of October and March, or 1 g/m^2 per month for the months of October, February, and March and 3 g/m^2 per month for the months of November through January.
m. DeltaDWQ assumed wetland vegetation decay would provide a maximum of 8 g/m^2 per year of DOC if the islands were dry from May through August, based on wetland vegetation decay experiments. Dry reservoir islands were assumed to provide a total of 12 g/m^2 per year of DOC, or 1 g/m^2 per month for dry-period months. For periods when islands were flooded, DOC loads were assumed to be 0.5 g/m^2 per month for those months with flooded conditions to simulate lower DOC release conditions as suggested in flooded wetland/water storage experiments. Depending on monthly conditions, DeltaDWQ modeled a hydrologic year at a possible maximum load of 20 g/m^2 per year (12 dry months with wetland vegetation decay) or a possible minimum load of 6 g/m^2 per year (year-round wet period with no vegetation decay).
n. Loading estimate calculated from data provided in "A Trial Experiment on Studying Short-Term Water Quality Changes in Flooded Peat Soil Environments" (Marvin Jung Associates in association with MWQI, July 1999). Trial experiment used the top 2 feet of soil scraped from Twitchell Island agricultural fields with large clumps of vegetation and roots removed by hand.
o. Primary production DOC load calculated from data provided in "A Trial Experiment on Studying Short-Term Water Quality Changes in Flooded Peat Soil Environments" (Marvin Jung Associates in association with MWQI, July 1999). Primary production was measured in a control tank containing no peat.
p. Loading estimate calculated from data provided in "First Progress Report on Experiment #2: Seasonal Water Quality Changes in Flooded Peat Soil Environments Due to Peat Soil, Water Depth, and Water Exchange Rate" (Marvin Jung Associates, October 1999). This is the second experiment using the SMARTS test facility, and is to continue for at least one year. Data collected span January 21, 1999, through July 21, 1999.
q. Estimates provided by Stuart Krasner for CUWA. Krasner provides discussion of potential water quality effects based on assumed DOC discharge concentrations of 8 mg/l, 16 mg/l, and 32 mg/l. Source: Krasner testimony 1997, page 28. Loading factor in table was calculated by Jones & Stokes based on assumed reservoir depth of 6 m, minus an initial applied water DOC concentration of 3 mg/l.
r. Estimates provided by Richard Losee for CUWA. Algal biomass loading estimate was based on *Cladophora* production rates in a shallow MWD reservoir. Source: Losee testimony 1997, page 6. Peat soil DOC contributions were estimated based on conversion of peat soil to DOC. Testimony presented assumed DOC concentrations in 6-meter-deep storage reservoir water column of 300 mg/l. Source: Losee testimony 1997, page 11. Loading factor in table calculated by Jones & Stokes based on assumed reservoir depth of 6 m.
s. Estimates calculated based on rebuttal testimony provided by Richard Losee and K. T. Shum. Groundwater seepage loading based on 8,100-af perimeter well pumping estimate for Bacon Island during a period of nine months. Seepage water DOC concentration assumed to be 20-40 mg/l. Source: Losee and Shum testimony 1997, page 3.
t. Estimates calculated based on rebuttal testimony provided by K. T. Shum. Molecular diffusion DOC flux based on an assumed peat-soil pore-water DOC concentration of 70 mg/l (top 0.3 m of peat soil) and water column DOC concentration of 40 mg/l (3.1 g/m^2 per year) and a scenario in which the water column DOC concentration is 10 mg/l (6.2 g/m^2 per year). Loading value was estimated based on a 5- to 25-fold increase in DOC diffusion (misquoted from Kavanaugh testimony – Kavanaugh assumed 10-fold increase resulting in diffusion ranging from 5 to 25 mg/m^2 per day) as a result of external force, including advective currents, bioturbation, etc. Source: Shum testimony 1997, page 3.
u. Estimates based on testimony from Michael Kavanaugh. Source: Kavanaugh testimony 1997, Table V.

Table 4-6. Estimates of Dissolved Organic Carbon Loading
Using the DeltaSOQ Impact Analysis

	Assumed DOC Loading		Supporting Information
	(g/m^2/month)	(g/m^2/year)	
Agricultural Operations	1	12	MWQI agricultural drainage data for the Delta Wetlands Islands
			Twitchell Island drainage data
			MWQI-CR#2 Delta region organic carbon study
Wetland Habitat Operations	1	12	Holland Tract wetland demonstration
			Vegetation decay experiment
			MWQI agricultural drainage data
Long-Term Reservoir Operations	1[a]	12	DeltaDWQ Model—1995 DEIR/EIS
			Tyler Island flooding
			Holland Tract flooded wetland demonstration
Initial-Fill Reservoir Operations	4[a]	48	SMARTS 1 static tanks 1, 3, 5, and 7
			SMARTS 2 static tanks 5 and 7
High Initial-Fill Reservoir Operations	9[a]	108	SMARTS 2 static tanks 1 and 3

[a] For the impact analysis, the agricultural DOC loading estimate (1 g/m^2/month) is assumed under both no-project and with-project conditions. Therefore, the reservoir operation DOC loading assumptions are added to the agricultural loading (i.e., Total monthly reservoir operations DOC loading = Reservoir operations loading + agricultural operations loading).

Table 4-7. Water Quality Impact Assessment Variables and Significance Criteria

Variable	Significance Threshold	Location of Assessment	Discussion of Criteria and Changes Since the 1995 DEIR/EIS
Electrical conductivity and chloride	a. Increase of 20% of applicable standards or b. 90% of applicable standard	Chipps Island, Emmaton, Jersey Point, and representative export location (CCWD, SWP, and CVP) for EC; representative export location for Cl^-[a]	The 1995 WQCP objectives for EC and Cl^- have not changed since the 1995 DEIR/EIS was published. These objectives only apply in some months and at some locations. Therefore, significance criteria for EC and Cl^- are different for each month at each Delta location. For example, the applicable objectives for Cl^- are either 150 mg/l or 250 mg/l at the export locations. The same criteria used in the 1995 DEIR/EIS are used in the REIR/EIS analysis.
Bromide	Increase of 20% equivalent of Cl^- standards, using the Br^-:Cl^- ratio	Representative export location[a]	There are no numerical standards for Br^-. Because the ratio of Br^- to Cl^- is relatively uniform (0.0035) in the Delta, a change of 0.1 mg/l Br^- (equivalent to about 28 mg/l Cl^- or 20% of the most restrictive Cl^- objective of 150 mg/l) is used as the 20% significance criterion. The same criteria used in the 1995 DEIR/EIS are used in the REIR/EIS analysis.
Dissolved organic carbon	Increase of 0.8 mg/l (or 20% of mean value)	Representative export location[a]	There are no numerical standards for DOC. Increases in export DOC of more than 20% of the mean DOC concentration (5 mg/l), or about 1 mg/l, are considered to be significant water quality impacts. This criterion is the same as that used in the 1995 DEIR/EIS.

Table 4-7. Continued

Variable	Significance Threshold	Location of Assessment	Discussion of Criteria and Changes Since the 1995 DEIR/EIS
Trihalomethanes	a. Increase of 20% of standard (16 μg/l) or b. 90% of applicable standard (72 μg/l)	Treated water from representative export location[a]	The EPA standard for THM concentrations in drinking water has been revised from 100 μg/l to 80 μg/l since preparation of the 1995 DEIR/EIS. For REIR/EIS analysis, the significance criterion was lowered to exceedances of 72 μg/l (90% of 80 μg/l) or changes greater than 16 μg/l (20% of 80 μg/l) to reflect the new THM standard.

Notes:

[a] As described in the 1995 DEIR/EIS, a representative Delta export location was used for the impact assessment because the impact assessment methods cannot reliably distinguish between water quality conditions of CVP exports at Tracy Pumping Plant, SWP exports at Banks Pumping Plant, and CCWD diversions at Rock Slough or Old River.

Table 4-8. Simulated No-Project Chipps Island EC (μS/cm)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Flow Weighted Average
1922	11185	10558	4956	2361	153	161	202	150	175	2507	6878	9988	4131
1923	6886	5489	158	161	235	1459	226	731	2155	4589	7916	10086	3774
1924	10598	10248	10066	8453	3736	2193	5268	5419	5477	8337	10925	12295	8118
1925	9989	11172	9758	8084	150	182	253	767	2155	5794	9049	11279	5908
1926	11236	10585	10240	5175	164	1485	413	1656	5274	7203	9744	11649	6311
1927	11440	2976	4471	257	150	151	150	194	1865	3484	6224	9409	3406
1928	9118	3851	3947	509	231	150	179	673	3474	3990	6706	10070	3833
1929	10590	10244	9227	7617	3150	2098	3903	4702	5880	8528	11025	12351	7810
1930	9840	11093	8656	1509	1157	254	1249	2129	5281	7206	9745	11650	5797
1931	11441	10695	10298	8701	5986	6284	5530	5525	5514	8355	10934	12300	9469
1932	9972	11163	4057	2042	916	1693	1912	2028	2057	5745	9025	11266	4510
1933	11229	10581	10238	7652	5315	4173	2701	4246	5913	8544	11033	12355	8357
1934	9822	11083	10033	5031	1807	1871	2277	5456	5446	8323	10918	12291	7045
1935	10007	11181	11818	380	1534	310	151	177	1607	4353	7803	10630	4448
1936	10885	10399	10144	220	150	167	232	580	2266	4634	7937	10587	4501
1937	10862	10387	10138	6884	151	150	198	413	2049	4545	7895	10677	5551
1938	10910	1917	150	161	150	150	150	150	152	2350	6399	5618	2619
1939	2210	4114	1475	801	722	1409	2164	3623	5268	7200	9742	11648	4259
1940	11440	10695	10297	349	150	150	150	485	2730	3759	6759	10061	3915
1941	10585	10241	152	150	150	150	150	150	459	2864	5468	8338	3370
1942	3867	6203	150	150	150	163	150	152	259	2677	6336	8731	2963
1943	5188	2726	317	150	150	150	160	279	2715	3758	6194	9663	3056
1944	10258	10073	9761	2761	161	257	1529	2774	3047	6222	9259	11390	6123
1945	11297	8817	4910	5808	150	157	571	1003	1997	4523	7884	10672	4977
1946	10685	7582	150	150	228	365	1158	1257	2140	4583	7913	10686	4140
1947	10915	10345	5653	6370	1869	839	1635	3423	5526	7312	9771	11663	6771
1948	11448	10699	10300	7886	3148	1585	245	185	1120	4116	7682	9887	6295
1949	10495	10195	8863	7821	4103	153	1072	1697	2690	6049	9174	11345	6659
1950	11272	10605	10250	2753	176	595	458	1015	2075	4556	7900	9741	5254
1951	10419	152	150	150	150	161	747	683	2993	3844	6735	9394	3035
1952	10232	7437	152	150	150	150	150	150	152	1118	3460	2975	2451
1953	3197	3814	151	150	172	276	562	220	841	3083	6276	7948	2864
1954	6724	4257	5383	245	150	150	151	304	2990	3843	6734	10084	3974
1955	10597	7506	1086	610	1614	2226	2720	2357	3148	6268	9282	11402	5025
1956	11304	10621	150	150	150	151	238	152	594	2952	6305	7692	3263
1957	2376	6340	8160	4358	182	151	384	518	2127	3571	6813	9401	4239
1958	5341	6206	1403	163	150	150	150	150	154	2092	3410	3676	2208
1959	3184	6741	5122	163	150	322	2450	2026	5421	5817	8073	9869	4762
1960	10485	10190	10036	8210	431	752	1649	1814	4990	7080	9675	11612	6900
1961	11420	10202	6142	5134	261	982	2060	2350	5492	7298	9764	11660	6445
1962	11446	10698	7216	6994	150	277	1293	1628	3198	4997	8103	10785	5643
1963	221	3920	736	1500	150	198	150	166	1504	3356	6243	8576	2397
1964	9077	560	4255	416	1377	1791	3469	3337	5282	7206	9738	11645	5083
1965	11438	9506	150	150	157	404	151	246	2461	3675	6197	8855	3640
1966	9969	1646	2003	207	189	241	1583	1830	4862	5611	8119	10793	4135
1967	10972	5161	158	150	150	150	150	150	150	657	3891	3416	2001
1968	2874	6591	2372	174	150	154	938	2114	5492	5843	8068	10766	4298
1969	10958	10099	1310	150	150	150	150	150	158	2230	4973	1783	2903
1970	2723	2379	150	150	150	151	727	1402	4178	4199	6155	9790	3134
1971	10444	1573	150	150	214	150	309	174	1057	3180	6268	6089	2688
1972	7876	8903	2505	2023	642	203	1872	1972	4599	5515	8137	10802	5008
1973	10661	2648	658	150	150	150	312	717	1956	3514	6818	9007	3121
1974	8480	150	150	150	150	150	150	170	837	2466	3971	2961	1914
1975	4036	7050	4701	2043	150	150	177	178	354	2780	4709	4916	2955
1976	1788	5158	5653	4817	1239	1860	3605	4993	5479	8338	10926	12295	5472
1977	9969	11161	11807	10609	3128	5682	5395	5450	5488	8342	10928	12297	9747
1978	9990	11172	10156	150	150	150	150	195	1718	3433	6843	8763	3762
1979	7548	8749	9319	337	150	153	399	1090	1800	4439	7844	10651	4705
1980	10479	8829	2459	150	150	150	269	442	1881	3489	6838	8498	4463
1981	9424	9652	3021	194	194	180	590	1997	5448	7279	9781	11669	5704
1982	11451	167	150	150	150	150	150	150	260	1861	3748	1309	1541
1983	376	152	150	150	150	150	150	150	150	165	810	287	270
1984	251	150	150	150	151	154	495	845	2221	3602	6231	9271	2878
1985	9741	297	763	2969	723	584	1487	1944	5365	7242	9756	11655	4596
1986	11444	10697	5455	1047	150	150	178	415	2067	3552	6224	8316	4203
1987	9530	9705	9791	6288	819	254	1897	3954	5169	7157	9713	11632	6881
1988	11431	10690	6480	479	1689	1850	3987	5064	5511	8353	10934	12300	6298
1989	9972	11163	11808	10104	3785	158	301	1929	5415	7264	9766	10877	7412
1990	11018	10469	10180	4097	2111	3114	2614	4015	5458	8328	10920	12293	7414
1991	9988	11171	11812	10612	3150	218	917	3666	5610	8400	10958	12313	6911
1992	9939	11145	11798	10645	231	740	1927	3955	5535	8365	10940	12303	6055
1993	9973	11164	8668	150	150	154	151	165	323	2750	7000	9691	3615
1994	6665	8340	6189	4665	275	1597	3062	3748	5475	8336	10925	12295	6414
Average	8810	7538	5218	2767	854	769	1162	1646	3043	5055	7853	9629	4460

Table 4-9. Simulated No-Project Emmaton EC (μS/cm)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Flow Weighted Average
1922	2673	2448	817	343	150	150	150	150	150	364	1293	2250	904
1923	1295	940	150	150	151	233	151	173	315	738	1588	2283	759
1924	2462	2339	2277	1751	568	320	888	923	937	1715	2579	3091	1757
1925	2250	2668	2172	1638	150	150	151	175	315	1013	1939	2708	1333
1926	2692	2457	2337	867	150	236	156	254	889	1383	2167	2845	1385
1927	2767	435	713	152	150	150	150	150	278	522	1121	2056	704
1928	1961	589	608	161	151	150	150	169	520	616	1247	2278	757
1929	2459	2338	1996	1501	464	307	599	762	1034	1774	2615	3113	1676
1930	2199	2639	1814	238	205	151	213	311	891	1384	2167	2845	1264
1931	2767	2496	2356	1828	1061	1136	949	948	946	1720	2582	3093	2127
1932	2244	2665	629	300	185	258	284	298	302	1001	1931	2703	915
1933	2689	2456	2336	1511	899	652	392	667	1042	1779	2618	3115	1825
1934	2193	2636	2265	834	271	279	331	932	930	1711	2576	3090	1513
1935	2256	2672	2909	155	241	153	150	150	249	688	1555	2473	1010
1936	2564	2392	2303	151	150	150	151	164	330	747	1595	2458	1028
1937	2556	2388	2301	1295	150	150	150	156	301	728	1582	2490	1232
1938	2574	285	150	150	150	150	150	150	150	341	1166	970	571
1939	322	640	235	177	172	228	316	547	888	1382	2167	2845	835
1940	2767	2496	2356	154	150	150	150	159	397	572	1261	2275	877
1941	2457	2337	150	150	150	150	150	150	158	418	935	1715	766
1942	592	1115	150	150	150	150	150	150	152	389	1149	1837	603
1943	870	396	153	150	150	150	150	152	394	572	1113	2140	605
1944	2343	2279	2173	401	150	152	241	403	447	1120	2006	2749	1317
1945	2714	1864	807	1016	150	150	164	192	295	724	1579	2488	1025
1946	2493	1490	150	150	151	155	205	214	313	736	1587	2493	899
1947	2575	2373	979	1158	279	180	252	511	948	1414	2176	2851	1436
1948	2770	2498	2357	1579	464	246	151	150	202	641	1519	2215	1349
1949	2425	2321	1879	1560	638	150	198	259	391	1076	1979	2732	1420
1950	2705	2464	2340	400	150	165	158	193	304	731	1584	2166	1127
1951	2399	150	150	150	150	150	174	170	438	588	1255	2051	673
1952	2334	1449	150	150	150	150	150	150	150	201	518	435	538
1953	472	582	150	150	150	152	163	151	180	453	1134	1598	547
1954	1252	669	915	151	150	150	150	153	438	588	1254	2283	770
1955	2462	1469	199	166	250	324	395	342	464	1132	2014	2753	1045
1956	2717	2470	150	150	150	150	151	150	165	432	1141	1523	736
1957	345	1150	1661	690	150	150	155	161	311	537	1276	2053	812
1958	905	1116	228	150	150	150	150	150	150	307	509	557	414
1959	470	1256	855	150	150	153	355	298	924	1019	1635	2209	928
1960	2422	2319	2266	1676	157	174	253	272	825	1349	2144	2831	1523
1961	2760	2323	1100	857	152	190	303	341	940	1409	2174	2849	1383
1962	2769	2497	1387	1325	150	152	217	251	472	827	1644	2528	1206
1963	151	602	173	238	150	150	150	150	238	499	1125	1789	478
1964	1947	163	669	157	225	270	519	496	891	1384	2165	2844	1069
1965	2767	2087	150	150	150	156	150	151	357	556	1114	1876	805
1966	2243	253	295	151	150	151	246	274	797	969	1649	2531	869
1967	2596	863	150	150	150	150	150	150	150	168	597	510	448
1968	419	1216	344	150	150	150	187	309	940	1025	1633	2522	860
1969	2591	2288	219	150	150	150	150	150	150	325	821	269	645
1970	396	345	150	150	150	150	172	228	653	657	1103	2182	609
1971	2408	245	150	150	151	150	153	150	196	469	1132	1086	564
1972	1576	1892	363	298	167	150	279	291	740	946	1654	2535	1007
1973	2484	384	168	150	150	150	153	172	289	527	1277	1925	667
1974	1759	150	150	150	150	150	150	150	180	357	612	433	405
1975	625	1340	762	300	150	150	150	150	154	404	763	809	528
1976	269	863	979	787	212	278	544	826	937	1715	2579	3092	1083
1977	2243	2665	2905	2466	460	986	917	930	939	1717	2580	3092	2243
1978	2250	2669	2308	150	150	150	150	150	261	513	1284	1847	841
1979	1481	1843	2026	154	150	150	156	199	271	706	1567	2481	1004
1980	2420	1868	357	150	150	150	152	158	280	523	1282	1764	936
1981	2060	2136	443	150	150	150	165	294	930	1404	2180	2853	1259
1982	2771	150	150	150	150	150	150	150	152	278	570	219	387
1983	155	150	150	150	150	150	150	150	150	150	178	152	154
1984	151	150	150	150	150	150	160	180	324	543	1123	2010	599
1985	2166	153	175	434	172	164	236	288	911	1394	2171	2847	998
1986	2768	2497	932	195	150	150	150	156	303	534	1121	1708	905
1987	2096	2154	2183	1137	178	151	282	609	865	1370	2157	2839	1478
1988	2764	2495	1187	159	258	277	615	842	945	1720	2582	3093	1368
1989	2244	2665	2905	2289	577	150	153	286	922	1400	2175	2562	1691
1990	2612	2416	2316	637	309	458	379	621	932	1712	2577	3090	1604
1991	2250	2668	2907	2467	464	151	185	555	968	1734	2591	3099	1657
1992	2233	2659	2901	2479	151	173	286	609	951	1724	2584	3095	1416
1993	2245	2665	1818	150	150	150	150	150	153	400	1327	2149	824
1994	1236	1716	1112	754	152	248	449	570	936	1715	2579	3091	1328
Average	1991	1657	1133	592	222	210	248	312	518	909	1629	2225	954

Table 4-10. Simulated No-Project Jersey Point EC (µS/cm)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Flow Weighted Average
1922	2169	1988	684	304	150	150	150	150	150	321	1065	1830	753
1923	1066	782	150	150	151	217	151	168	282	620	1301	1857	637
1924	2000	1902	1851	1430	484	286	740	769	779	1402	2093	2503	1436
1925	1830	2165	1767	1341	150	150	151	170	282	841	1581	2196	1096
1926	2184	1996	1899	723	150	219	155	233	741	1136	1764	2306	1138
1927	2244	378	600	151	150	150	150	150	253	447	927	1675	593
1928	1599	501	516	158	151	150	150	165	446	523	1027	1852	635
1929	1997	1900	1627	1231	401	276	509	639	857	1449	2122	2520	1370
1930	1789	2142	1481	221	194	151	200	279	743	1137	1764	2306	1041
1931	2244	2027	1915	1492	878	939	789	789	787	1406	2096	2505	1731
1932	1825	2162	533	270	178	237	257	269	272	831	1575	2192	762
1933	2181	1995	1899	1239	749	552	344	563	864	1453	2124	2522	1490
1934	1785	2139	1842	697	247	253	295	776	774	1399	2091	2502	1240
1935	1835	2167	2357	154	223	152	150	150	229	581	1274	2008	838
1936	2082	1943	1873	151	150	150	151	161	294	628	1306	1996	853
1937	2075	1940	1871	1066	150	150	150	155	271	613	1296	2022	1015
1938	2089	258	150	150	150	150	150	150	150	303	963	806	486
1939	288	542	218	172	168	213	283	468	740	1136	1763	2306	698
1940	2244	2027	1915	153	150	150	150	158	347	488	1039	1850	731
1941	1996	1900	150	150	150	150	150	150	157	364	778	1402	643
1942	504	922	150	150	150	150	150	150	151	341	950	1500	512
1943	726	347	152	150	150	150	150	152	345	488	920	1742	514
1944	1904	1853	1768	351	150	151	222	353	388	926	1635	2229	1084
1945	2201	1522	676	843	150	150	161	184	266	609	1293	2020	850
1946	2024	1222	150	150	151	154	194	201	280	619	1300	2025	749
1947	2090	1929	813	957	253	174	232	439	789	1161	1771	2310	1179
1948	2246	2028	1916	1293	401	227	151	150	191	543	1246	1802	1109
1949	1970	1887	1533	1278	541	150	188	237	342	891	1613	2216	1166
1950	2194	2001	1902	350	150	162	157	184	274	615	1297	1763	931
1951	1949	150	150	150	150	150	169	166	380	500	1034	1670	568
1952	1897	1189	150	150	150	150	150	150	150	191	444	378	460
1953	408	496	150	150	150	152	160	151	174	392	937	1308	468
1954	1031	565	762	151	150	150	150	152	380	500	1034	1856	646
1955	1999	1205	189	163	230	289	346	304	401	936	1641	2232	866
1956	2203	2006	150	150	150	150	151	150	162	375	943	1248	619
1957	306	950	1359	582	150	150	154	159	279	460	1051	1672	679
1958	754	923	212	150	150	150	150	150	150	275	437	475	361
1959	406	1035	714	150	150	153	314	268	769	845	1338	1797	772
1960	1968	1885	1843	1371	156	169	233	248	690	1109	1745	2295	1249
1961	2238	1889	910	716	151	182	272	303	782	1158	1769	2309	1136
1962	2246	2028	1139	1090	150	152	204	231	408	691	1345	2053	995
1963	151	512	168	220	150	150	150	150	220	429	930	1461	413
1964	1588	160	565	155	210	246	445	427	743	1137	1762	2305	886
1965	2243	1700	150	150	150	155	150	151	315	475	921	1531	674
1966	1824	233	266	150	150	151	227	249	667	805	1349	2055	725
1967	2107	721	150	150	150	150	150	150	150	165	508	438	389
1968	365	1003	305	150	150	150	180	277	782	850	1337	2047	718
1969	2103	1860	205	150	150	150	150	150	150	290	687	245	546
1970	346	306	150	150	150	150	168	212	552	556	912	1776	518
1971	1956	226	150	150	151	150	152	150	187	405	935	899	481
1972	1291	1543	321	268	164	150	253	263	622	787	1353	2058	836
1973	2018	337	165	150	150	150	152	167	262	452	1052	1570	564
1974	1437	150	150	150	150	150	150	150	174	316	520	376	354
1975	530	1102	639	270	150	150	150	150	153	353	641	677	453
1976	245	720	813	659	200	252	465	690	780	1402	2093	2503	896
1977	1825	2162	2354	2003	398	819	764	774	781	1403	2094	2504	1824
1978	1830	2165	1876	150	150	150	150	150	239	440	1057	1508	703
1979	1215	1504	1651	153	150	150	155	189	247	595	1284	2015	833
1980	1966	1525	315	150	150	150	151	156	254	448	1056	1442	779
1981	1678	1739	384	150	150	150	162	266	774	1153	1774	2312	1037
1982	2247	150	150	150	150	150	150	150	151	252	486	205	339
1983	154	150	150	150	150	150	150	150	150	150	172	152	153
1984	151	150	150	150	150	150	158	174	289	464	928	1638	509
1985	1763	152	170	377	168	161	219	260	758	1145	1767	2308	829
1986	2245	2028	775	186	150	150	150	155	273	457	927	1397	754
1987	1707	1753	1776	940	173	151	256	517	722	1126	1755	2301	1212
1988	2241	2026	980	157	236	251	522	703	786	1406	2095	2505	1125
1989	1825	2162	2354	1862	492	150	152	259	768	1150	1770	2079	1382
1990	2120	1963	1883	540	277	396	333	527	776	1400	2092	2502	1313
1991	1830	2165	2355	2004	401	151	178	474	805	1417	2103	2509	1356
1992	1816	2157	2351	2013	151	169	259	517	791	1409	2097	2506	1163
1993	1826	2162	1484	150	150	150	150	150	153	350	1091	1749	689
1994	1019	1403	919	633	152	228	390	486	779	1402	2093	2503	1092
Average	1623	1356	936	503	208	198	228	279	444	757	1333	1810	794

Table 4-11. Simulated No-Project Export EC (µS/cm)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Flow Weighted Average
1922	759	726	374	274	265	303	367	424	272	302	493	705	426
1923	484	419	287	308	433	334	360	435	307	363	576	722	419
1924	752	751	731	626	395	478	561	588	532	713	920	965	656
1925	786	873	739	693	325	386	382	506	346	483	673	830	586
1926	834	799	761	451	321	346	402	498	445	554	717	885	576
1927	865	326	386	311	302	319	375	435	293	322	477	675	410
1928	608	347	355	288	317	298	341	429	354	346	494	737	407
1929	779	751	672	579	364	443	530	557	499	699	907	958	638
1930	771	862	645	350	395	279	442	508	453	559	720	888	558
1931	869	820	770	689	565	652	575	800	646	775	892	979	766
1932	833	912	467	376	364	540	468	491	413	546	693	842	532
1933	796	819	787	623	515	526	528	585	646	771	895	974	707
1934	805	896	761	471	501	495	448	608	481	752	886	964	657
1935	816	865	914	390	452	327	386	407	311	366	591	776	517
1936	757	777	758	329	324	292	359	427	305	375	590	764	485
1937	766	767	735	535	334	363	395	400	312	397	592	768	535
1938	754	280	284	340	272	239	297	262	295	291	459	421	359
1939	308	354	321	377	360	350	453	493	436	546	711	878	452
1940	853	817	797	372	311	310	356	423	322	326	497	718	461
1941	755	740	308	294	320	356	375	372	284	319	409	587	424
1942	355	457	288	419	395	345	373	401	275	312	460	611	395
1943	407	317	267	361	365	298	397	436	349	349	470	688	393
1944	703	727	702	375	388	332	467	465	337	463	687	838	549
1945	829	640	406	477	322	386	446	470	302	371	596	775	488
1946	729	553	298	306	421	330	436	448	309	372	584	775	458
1947	797	754	445	509	333	318	433	513	466	571	719	879	574
1948	865	808	790	615	534	388	386	426	280	354	560	722	568
1949	774	757	652	609	440	299	451	503	325	453	685	842	572
1950	843	799	777	377	298	315	386	470	299	370	573	710	507
1951	769	274	320	314	314	334	421	415	338	335	489	672	410
1952	733	540	283	287	427	358	364	311	294	266	325	315	371
1953	332	372	406	398	367	326	408	396	251	310	458	567	384
1954	491	359	415	298	302	296	346	422	340	335	491	729	409
1955	771	548	258	305	320	363	494	489	335	478	696	848	483
1956	843	790	341	280	306	354	398	448	283	298	460	549	423
1957	314	476	585	384	335	309	393	461	302	320	498	676	425
1958	418	464	263	300	303	370	321	330	293	263	309	327	330
1959	328	487	418	352	358	363	478	478	446	473	583	725	465
1960	776	761	740	632	301	307	446	480	432	546	711	875	598
1961	865	760	474	471	270	324	436	464	460	565	720	886	566
1962	868	813	541	588	338	289	441	466	339	393	584	790	528
1963	250	346	247	314	275	268	364	387	285	309	455	607	340
1964	641	253	359	280	333	335	488	498	445	550	711	873	481
1965	855	694	289	314	301	308	368	400	328	327	458	635	433
1966	663	295	315	334	376	329	444	439	426	459	586	793	453
1967	808	415	287	294	261	297	333	307	304	285	330	327	344
1968	322	481	356	355	337	306	419	447	449	472	582	795	451
1969	803	739	271	323	241	285	280	256	293	294	386	280	378
1970	321	358	417	305	384	349	408	426	387	367	466	702	411
1971	750	271	273	269	315	282	372	387	256	301	458	452	360
1972	564	641	293	298	291	281	443	447	404	443	588	804	462
1973	784	320	256	269	270	306	363	413	285	314	500	638	387
1974	585	253	265	305	355	345	396	439	262	278	339	305	336
1975	360	511	381	332	360	354	361	387	276	292	374	389	364
1976	295	402	428	403	335	336	498	539	451	628	819	937	487
1977	710	819	886	857	673	719	588	791	591	751	896	998	805
1978	916	944	776	367	313	363	317	357	330	384	500	614	465
1979	523	629	675	330	392	373	388	442	279	376	586	770	485
1980	743	636	301	322	286	323	415	428	337	377	492	596	458
1981	616	699	375	390	352	329	404	463	452	559	714	877	543
1982	848	257	258	316	314	318	253	313	291	279	332	286	331
1983	299	310	292	262	224	214	281	287	225	308	247	316	278
1984	422	331	278	319	383	338	431	463	302	326	470	659	408
1985	695	256	252	325	312	304	442	477	447	556	709	870	466
1986	846	790	433	322	283	258	377	396	342	347	483	589	450
1987	650	700	709	497	345	306	441	520	435	548	710	881	576
1988	865	826	493	319	465	444	529	574	475	649	868	957	593
1989	793	864	912	795	702	295	352	475	476	579	728	824	658
1990	833	810	767	419	430	451	457	571	468	678	875	963	649
1991	809	890	942	946	902	332	428	572	688	788	905	989	706
1992	819	911	962	870	377	351	454	542	503	709	936	984	644
1993	800	894	658	330	278	269	337	396	268	325	498	685	437
1994	476	600	458	396	309	332	482	542	449	623	812	931	538
Average	677	610	498	413	365	347	411	456	373	445	598	728	470

Table 4-12. Simulated No-Project Export Chloride Concentrations (mg/l)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Flow Weighted Average
1922	181	171	66	36	32	38	51	62	32	40	100	163	79
1923	95	77	33	38	62	43	49	63	40	62	121	167	72
1924	171	170	169	134	61	67	92	96	92	143	192	225	137
1925	170	195	167	137	38	49	51	73	46	88	146	197	115
1926	191	179	176	79	38	44	54	72	79	113	169	208	116
1927	203	46	64	35	36	39	52	63	36	48	92	153	69
1928	131	54	56	32	37	35	44	60	53	55	100	168	69
1929	181	175	152	119	53	61	81	87	91	144	198	230	134
1930	167	197	143	43	51	30	61	73	80	114	169	211	110
1931	203	188	181	146	100	112	96	123	107	149	202	232	168
1932	169	199	73	50	49	81	69	72	56	95	147	192	93
1933	175	180	176	124	88	82	77	90	108	151	200	231	145
1934	167	197	176	81	69	69	63	100	86	146	199	229	131
1935	167	201	215	49	62	39	54	58	39	61	121	179	95
1936	171	176	170	38	46	35	49	62	40	64	123	180	91
1937	173	174	169	103	48	54	58	60	40	66	121	180	106
1938	174	34	33	44	41	36	45	39	41	38	91	77	59
1939	41	57	40	49	47	46	66	74	77	111	164	203	80
1940	194	179	171	47	39	42	49	61	45	51	100	165	83
1941	174	172	36	35	47	53	56	56	36	45	76	129	76
1942	55	88	34	63	59	46	53	58	33	43	91	135	66
1943	70	44	29	54	55	45	58	65	49	54	90	157	65
1944	159	167	161	53	50	41	69	68	48	91	150	192	109
1945	189	142	71	88	41	55	66	70	38	63	123	179	91
1946	164	115	35	37	59	41	64	65	40	63	123	180	82
1947	184	175	82	96	43	37	60	77	84	115	168	213	117
1948	204	189	179	129	79	50	51	58	31	57	119	166	114
1949	181	175	146	126	70	34	63	73	44	88	150	199	117
1950	197	184	177	53	33	37	51	66	38	63	123	163	97
1951	177	30	42	42	41	44	61	58	48	53	99	153	70
1952	169	113	31	35	62	54	55	47	39	31	49	45	60
1953	49	58	54	55	50	40	57	54	26	44	90	122	61
1954	99	59	76	33	34	34	44	58	48	53	99	168	71
1955	181	115	27	35	40	49	72	71	48	93	155	202	91
1956	196	184	47	42	43	48	57	67	35	42	91	116	76
1957	42	93	127	63	41	37	54	66	39	49	101	154	75
1958	76	90	29	34	37	55	48	50	39	32	46	50	49
1959	48	97	73	44	47	47	70	69	80	87	127	167	85
1960	178	173	173	133	34	35	62	68	75	110	166	211	125
1961	206	177	92	82	28	38	60	65	83	116	169	211	115
1962	205	188	112	114	43	34	64	67	49	70	128	186	104
1963	25	55	25	39	31	29	50	54	34	46	89	134	51
1964	143	26	59	31	42	43	73	74	79	112	167	212	92
1965	202	159	33	41	38	38	51	56	44	50	89	142	77
1966	146	36	41	42	51	41	64	62	73	84	128	186	81
1967	188	74	32	34	28	37	50	46	44	36	52	49	53
1968	46	96	48	44	42	36	59	64	81	87	127	187	81
1969	189	172	30	46	36	43	42	38	44	39	68	34	66
1970	45	49	57	46	58	48	59	61	62	60	90	160	69
1971	173	31	29	29	37	32	50	52	28	43	90	87	57
1972	121	143	39	37	33	30	62	63	68	81	129	191	87
1973	184	43	26	30	32	41	50	60	35	47	100	144	65
1974	125	26	28	39	48	47	58	65	29	36	54	43	49
1975	57	105	65	43	48	50	50	54	32	40	65	68	57
1976	37	72	80	69	42	43	75	86	82	135	193	228	92
1977	154	185	205	183	100	117	97	119	100	148	201	230	171
1978	152	195	178	46	39	54	48	54	45	57	101	135	84
1979	105	138	151	40	59	54	55	65	33	63	121	181	91
1980	172	142	40	45	43	48	61	64	47	57	101	130	86
1981	133	154	54	50	44	40	56	66	81	113	166	209	106
1982	200	26	26	41	47	48	38	47	38	35	52	35	50
1983	39	41	44	39	34	32	42	43	34	45	26	42	38
1984	63	50	42	48	57	45	63	67	39	50	91	149	69
1985	159	26	26	46	37	36	63	69	80	112	165	210	87
1986	200	184	79	38	42	39	57	59	49	53	92	129	85
1987	144	157	162	94	42	35	62	79	77	111	165	208	118
1988	202	183	98	36	63	60	81	92	85	139	196	226	116
1989	168	201	217	178	106	32	42	66	85	117	170	194	139
1990	198	184	179	67	58	66	65	88	84	141	199	228	134
1991	170	200	216	192	135	38	57	86	112	151	203	232	141
1992	170	196	215	194	46	42	63	83	90	145	200	229	124
1993	165	192	143	42	33	31	44	55	30	45	103	157	77
1994	92	130	90	67	36	42	71	82	81	134	197	227	108
Average	146	128	96	66	50	46	59	67	57	80	127	166	87

Table 4-13. Simulated No-Project Export DOC Concentrations (mg/l)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Flow Weighted Average
1922	2.4	2.5	2.6	3.4	3.6	3.6	3.9	4.1	3.4	3.3	3.2	3.3	3.2
1923	3.5	3.3	4.7	4.9	5.1	5.0	4.0	4.8	3.5	3.1	3.8	3.6	4.0
1924	4.2	4.3	3.8	4.9	5.2	7.8	6.2	6.6	4.8	5.6	6.9	5.4	5.0
1925	5.1	5.6	4.3	7.8	5.7	5.3	4.1	5.1	3.9	4.2	4.3	3.9	5.0
1926	4.6	4.9	4.0	5.2	5.9	5.4	4.4	5.4	4.0	4.0	3.3	4.5	4.6
1927	4.4	3.6	3.6	5.7	4.6	4.2	4.0	4.6	3.5	3.3	3.7	3.6	4.1
1928	3.8	3.5	3.6	5.2	5.4	3.9	4.0	5.0	3.9	3.5	3.5	4.2	4.1
1929	4.2	3.8	3.7	5.3	5.2	7.5	5.9	6.3	4.5	5.4	6.3	4.7	4.8
1930	4.9	5.1	3.7	6.1	7.1	4.5	5.1	5.8	4.3	4.2	3.4	4.4	4.8
1931	4.6	4.7	3.7	6.1	6.9	9.1	6.3	8.0	5.5	6.2	5.4	4.9	5.4
1932	5.8	6.2	6.3	5.7	5.6	6.5	5.0	5.3	4.2	4.9	4.7	4.7	5.6
1933	4.9	5.4	4.8	6.2	6.1	7.5	5.7	6.3	5.5	6.0	5.6	4.8	5.7
1934	5.4	5.9	3.9	5.3	8.7	7.9	5.6	6.8	4.5	6.0	5.6	4.8	5.6
1935	5.6	4.6	4.7	6.9	6.6	5.3	4.4	4.6	3.7	3.3	4.2	4.0	4.8
1936	4.2	4.5	4.5	6.0	4.9	4.0	4.1	4.6	3.4	3.2	4.0	3.5	4.3
1937	4.2	4.2	3.7	5.5	5.2	4.0	4.4	4.0	3.4	3.6	4.1	3.6	4.3
1938	3.7	3.4	3.6	5.6	4.0	4.0	4.0	4.0	3.9	3.2	3.1	3.4	3.8
1939	3.6	3.4	4.3	6.6	5.8	5.9	5.2	5.7	4.1	4.1	3.6	5.0	4.5
1940	5.0	5.6	5.8	6.9	5.0	4.1	3.9	4.5	3.4	3.1	3.4	3.6	4.5
1941	3.9	3.6	4.9	4.8	4.7	4.0	4.0	4.0	3.5	3.5	3.1	3.2	4.0
1942	3.6	3.4	3.5	4.0	4.0	4.5	4.2	4.3	3.6	3.5	3.2	3.4	3.7
1943	3.7	3.7	3.7	4.0	4.0	4.0	4.5	4.0	3.8	3.6	3.6	3.6	3.8
1944	3.8	3.8	3.6	5.7	6.4	5.0	5.1	5.2	3.8	3.4	4.4	4.7	4.4
1945	4.7	3.6	3.7	5.2	4.9	5.3	5.0	4.0	3.6	3.3	4.3	4.1	4.3
1946	4.1	3.7	4.1	4.8	5.8	5.2	5.0	5.2	3.8	3.4	4.0	4.0	4.3
1947	4.3	3.9	3.8	5.2	5.2	5.4	5.4	6.2	4.4	4.4	3.5	3.8	4.4
1948	4.3	4.2	4.7	5.0	8.8	6.3	4.5	4.8	3.8	3.4	3.5	3.8	4.5
1949	3.9	4.0	3.7	5.5	6.1	5.0	5.2	5.7	3.9	3.4	4.3	4.1	4.4
1950	4.4	4.4	4.5	6.0	4.9	5.1	4.5	5.2	3.7	3.3	3.4	3.7	4.4
1951	4.1	3.5	4.4	4.8	4.3	4.4	4.7	4.7	3.7	3.3	3.3	3.5	4.0
1952	3.7	3.5	4.5	4.5	4.5	4.0	4.0	4.0	3.8	3.3	3.3	3.5	3.9
1953	3.7	4.1	5.0	5.2	5.0	5.1	4.6	4.5	3.4	3.5	3.3	3.4	4.1
1954	3.5	3.5	3.6	5.7	4.7	4.6	4.1	5.0	4.1	3.4	3.5	3.9	4.0
1955	3.9	3.6	3.7	6.5	5.3	6.0	5.4	5.6	3.9	3.8	4.4	4.1	4.6
1956	4.6	4.1	5.2	4.0	4.1	4.4	4.3	4.6	3.5	3.1	3.2	3.3	4.0
1957	3.6	3.7	3.5	4.7	5.6	4.6	4.6	5.0	3.8	3.3	3.5	3.6	4.0
1958	3.6	3.6	3.6	6.6	4.6	4.5	4.0	4.0	3.8	3.0	3.1	3.2	3.9
1959	3.6	3.5	3.9	5.7	5.1	5.4	5.2	5.4	4.1	4.2	3.3	3.8	4.2
1960	4.3	4.3	3.7	5.6	5.2	4.9	5.2	5.6	4.1	4.1	3.4	3.8	4.4
1961	4.1	3.7	3.6	6.1	4.4	5.4	5.5	6.0	4.2	4.2	3.4	4.3	4.4
1962	4.3	4.3	3.6	6.1	5.7	4.1	4.7	5.0	3.6	3.2	3.2	3.6	4.2
1963	3.5	3.4	3.5	6.0	4.3	4.4	4.2	4.2	3.4	3.2	3.2	3.4	3.9
1964	3.5	3.5	3.5	5.5	5.7	5.7	5.5	5.7	4.2	4.2	3.3	3.8	4.2
1965	4.2	3.6	4.0	4.5	4.4	4.7	4.2	4.5	3.7	3.3	3.4	3.5	4.0
1966	4.0	3.8	4.1	6.1	5.5	5.3	5.1	5.4	4.2	4.2	3.4	4.0	4.5
1967	4.3	3.6	4.5	5.5	3.7	4.0	4.0	4.0	4.2	3.6	3.1	3.4	4.0
1968	3.6	3.5	4.7	6.6	4.6	4.7	4.9	5.4	4.2	4.2	3.4	4.0	4.3
1969	4.0	3.7	3.7	5.0	4.0	4.0	4.0	4.0	4.0	3.4	3.3	3.4	3.9
1970	3.7	4.5	4.3	4.0	4.0	4.4	4.5	4.7	3.8	3.5	3.5	3.7	4.0
1971	3.8	3.5	4.4	4.7	5.2	4.2	4.3	4.4	3.4	3.2	3.3	3.4	3.9
1972	3.5	3.6	3.6	4.9	5.2	5.1	5.4	5.7	4.2	4.0	3.5	4.0	4.2
1973	3.9	4.5	4.0	5.2	3.7	3.9	4.0	4.5	3.3	3.0	3.4	3.2	3.9
1974	3.5	3.3	3.8	4.3	4.6	4.1	4.4	4.7	3.4	3.2	3.3	3.4	3.7
1975	3.7	3.6	3.6	5.6	5.2	4.7	4.2	4.4	3.7	3.3	3.3	3.4	3.9
1976	3.7	3.5	3.6	4.9	6.0	5.8	5.9	6.4	4.2	4.3	4.2	4.2	4.4
1977	4.5	4.9	5.0	8.1	10.0	11.4	6.6	6.1	5.4	6.1	5.7	5.8	6.2
1978	8.0	7.8	4.2	6.3	4.5	4.9	4.0	4.0	3.8	3.9	3.3	3.4	4.5
1979	3.7	3.7	3.8	6.0	4.5	4.6	4.3	4.8	3.4	3.5	4.1	3.6	4.2
1980	3.7	3.5	3.5	4.9	4.0	4.0	4.5	4.0	3.9	3.8	3.2	3.4	3.8
1981	3.8	4.2	4.5	6.5	5.6	5.1	4.7	5.4	4.2	4.2	3.5	4.2	4.5
1982	4.2	3.6	3.7	5.0	4.5	4.0	4.0	4.0	3.8	3.3	3.2	3.5	3.9
1983	3.8	4.4	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.3	3.1	3.7	3.9
1984	4.0	4.0	4.0	4.0	4.0	4.5	4.7	5.0	3.6	3.3	3.7	3.5	3.9
1985	3.7	3.9	3.6	5.0	5.6	5.6	5.1	5.6	4.3	4.3	3.4	3.9	4.3
1986	4.2	4.0	3.7	6.1	4.0	4.0	4.0	4.0	4.0	3.5	3.7	3.3	4.1
1987	3.6	3.9	3.7	4.9	5.9	5.1	5.3	6.0	4.0	4.0	3.4	4.4	4.3
1988	4.5	5.3	3.6	6.1	8.2	7.8	6.1	6.5	4.4	4.5	5.5	5.0	5.4
1989	5.2	4.6	4.4	5.6	9.9	4.8	4.8	6.2	4.6	4.5	3.5	4.0	4.8
1990	3.9	4.8	3.8	5.5	7.3	7.0	5.8	6.8	4.5	5.2	5.5	5.0	5.2
1991	5.5	5.7	5.7	10.2	11.3	5.4	5.5	6.9	6.0	6.5	5.9	5.4	6.2
1992	5.5	6.7	6.4	6.5	6.6	5.5	5.3	6.5	4.7	5.4	6.6	5.4	6.0
1993	5.4	6.4	4.2	5.2	4.1	3.5	3.6	4.1	3.3	3.4	3.1	3.3	4.0
1994	3.5	3.6	3.3	4.7	5.7	5.4	5.3	5.8	4.0	4.0	3.3	3.9	4.2
Average	4.2	4.2	4.1	5.5	5.4	5.1	4.7	5.1	4.0	3.9	3.9	3.9	4.3

Table 4-14. Estimated No-Project Treated Water THM Concentrations (µg/l)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Flow Weighted Average
1922	39.4	40.3	32.0	38.2	40.0	40.4	45.6	50.0	37.5	37.6	42.7	51.8	40.6
1923	46.4	42.0	52.4	55.3	61.9	57.2	47.2	58.4	40.2	38.3	53.7	56.5	49.5
1924	66.7	68.7	60.0	71.9	63.4	96.5	81.9	88.8	63.9	84.6	114.7	96.0	73.0
1925	80.7	94.4	68.4	114.8	64.2	61.6	48.7	63.9	45.1	55.4	64.3	66.1	69.6
1926	77.4	79.5	64.1	66.5	67.0	62.3	52.4	68.2	51.5	56.0	52.7	78.5	64.2
1927	75.0	42.1	44.5	63.8	52.1	47.7	47.1	55.9	39.1	38.3	49.3	54.7	50.3
1928	55.2	41.6	43.1	57.9	60.7	44.1	46.3	60.6	46.5	41.2	47.6	66.4	50.2
1929	67.8	61.1	56.5	75.2	61.4	91.5	76.0	81.6	59.5	81.1	107.3	84.2	69.8
1930	78.4	85.4	55.5	70.8	83.4	49.5	62.4	72.7	54.9	59.4	54.5	76.3	64.9
1931	77.9	77.8	60.8	92.1	93.9	126.1	84.1	114.6	76.2	94.4	92.5	88.4	84.7
1932	92.3	105.3	78.7	67.3	65.8	83.7	62.6	66.5	50.8	65.0	71.0	78.0	73.5
1933	79.4	87.3	77.4	89.4	80.1	95.9	72.6	82.5	76.3	91.6	95.2	87.2	85.1
1934	85.7	100.4	62.6	68.7	108.2	98.2	68.2	91.5	58.2	90.9	94.9	85.7	80.5
1935	88.8	78.3	81.9	80.6	80.2	60.0	52.6	55.5	42.5	40.6	60.0	65.6	63.9
1936	67.3	71.9	71.9	67.5	57.0	44.8	47.5	55.7	39.0	39.7	57.2	57.5	56.1
1937	67.9	68.3	59.4	75.0	60.5	47.6	52.6	48.4	39.1	44.6	57.8	58.0	58.3
1938	60.2	37.9	39.9	64.3	45.7	45.0	46.2	45.5	44.9	36.7	40.6	42.8	45.6
1939	40.9	41.0	48.8	76.8	67.6	68.0	64.5	71.5	51.9	56.9	56.9	85.7	57.3
1940	83.8	91.1	92.7	80.8	56.9	47.1	45.3	55.0	39.6	36.0	45.9	56.1	57.9
1941	62.0	57.7	54.7	54.1	55.2	47.5	47.9	47.8	39.9	40.0	39.7	47.1	49.7
1942	43.3	44.6	39.4	48.8	48.3	52.7	49.4	52.0	40.2	40.7	42.7	50.3	45.3
1943	46.6	42.2	40.4	47.6	47.7	46.3	54.0	49.2	44.6	42.4	48.0	55.5	46.6
1944	58.8	60.5	56.9	67.5	75.1	57.6	63.6	64.9	44.4	44.6	66.7	78.3	60.2
1945	77.4	54.3	45.7	67.3	56.1	62.9	61.4	49.9	41.1	40.7	61.3	66.1	56.2
1946	64.1	51.2	45.7	53.9	70.1	59.7	61.5	63.7	43.0	41.3	56.8	64.9	54.7
1947	70.8	62.6	48.5	69.9	59.7	60.9	65.5	78.4	56.8	62.2	55.6	66.2	61.6
1948	73.9	69.1	75.7	72.7	112.2	74.4	53.0	57.5	41.9	41.3	50.0	59.5	62.4
1949	63.4	64.5	55.9	79.4	76.2	56.1	63.1	71.6	44.8	44.1	66.0	69.5	61.8
1950	73.9	71.9	72.8	71.4	54.2	57.0	52.8	64.3	42.0	40.7	49.4	57.6	58.0
1951	66.5	38.5	51.0	54.5	49.0	51.2	57.1	56.0	43.5	38.9	44.7	54.0	49.6
1952	59.5	49.2	49.9	50.5	54.6	47.5	47.7	46.5	43.4	36.8	38.6	40.0	46.5
1953	43.0	48.7	59.7	62.5	59.0	58.7	55.8	53.8	37.2	40.4	44.1	49.2	49.1
1954	47.2	42.5	45.0	63.8	52.3	51.3	47.2	60.6	47.6	40.5	46.8	61.7	49.6
1955	63.1	50.9	40.3	72.8	60.5	70.7	67.7	70.2	45.3	50.5	67.4	69.6	59.0
1956	77.2	66.9	60.1	45.9	47.5	51.5	51.6	56.8	39.4	36.0	42.2	47.0	50.0
1957	41.8	48.4	51.0	57.0	64.3	51.5	55.0	62.1	42.7	38.6	47.4	55.9	50.2
1958	45.5	47.0	39.9	73.9	52.0	54.1	46.7	46.9	43.1	33.2	35.6	37.7	45.9
1959	41.7	46.9	48.9	66.1	59.8	62.9	65.1	66.8	52.1	54.3	48.3	60.0	53.5
1960	69.2	69.5	59.0	81.6	58.7	55.5	62.9	69.3	51.9	56.3	53.3	66.6	62.6
1961	70.7	60.5	47.8	78.5	48.5	61.7	66.5	73.4	54.5	59.5	54.0	74.4	61.1
1962	74.3	71.6	50.6	85.8	65.7	45.7	57.8	62.1	42.4	40.3	46.9	60.0	57.4
1963	37.5	40.9	37.9	68.5	47.2	48.8	49.0	49.9	38.3	36.6	42.6	49.3	45.4
1964	52.6	38.1	41.9	60.9	65.4	65.1	69.5	71.9	53.5	58.4	53.1	65.6	55.1
1965	72.3	56.1	44.7	52.0	49.3	53.1	49.1	54.4	43.2	38.5	44.2	52.8	50.2
1966	60.5	42.6	47.2	69.4	65.1	60.8	62.8	65.4	53.0	54.0	49.8	66.5	56.9
1967	70.6	45.8	49.8	62.1	40.8	44.6	47.0	46.4	48.0	41.0	37.2	39.8	47.3
1968	42.3	47.0	54.7	76.4	52.6	53.2	58.5	65.6	53.4	54.9	49.6	65.9	54.2
1969	66.0	59.0	40.4	58.1	45.1	46.0	45.9	45.4	46.1	38.8	40.2	37.8	47.4
1970	42.5	52.7	51.3	46.4	48.1	51.2	54.5	57.5	45.7	42.5	46.4	58.0	49.0
1971	60.9	38.8	48.6	51.2	58.6	46.3	50.7	51.5	37.8	37.2	43.9	44.9	46.6
1972	49.8	54.7	40.6	55.6	58.1	56.7	66.3	70.0	52.0	51.6	50.5	66.1	54.1
1973	64.3	52.0	43.2	57.0	41.4	44.4	47.2	54.1	36.7	35.5	46.5	48.9	47.3
1974	50.4	36.3	41.9	49.1	54.0	47.9	52.9	58.3	37.0	36.1	39.1	39.2	43.7
1975	44.1	49.0	43.7	63.9	60.4	54.6	49.5	52.4	41.1	37.6	41.0	42.6	47.2
1976	41.6	44.2	45.5	60.5	68.7	66.6	74.4	83.5	54.4	63.1	70.6	75.8	58.3
1977	69.8	80.9	85.2	133.5	135.0	160.2	88.5	86.4	72.8	93.1	97.4	105.2	98.1
1978	123.0	131.4	67.6	72.9	51.2	58.7	46.7	47.5	44.3	46.5	45.0	50.0	57.7
1979	50.0	54.1	57.3	68.1	54.6	55.3	51.6	58.7	37.6	42.2	58.3	58.9	54.1
1980	58.7	51.7	40.4	56.6	46.0	46.8	54.7	49.0	45.3	45.8	42.9	49.3	49.2
1981	55.1	64.6	53.4	76.1	64.2	58.4	56.7	67.0	53.5	58.8	55.0	72.4	60.6
1982	70.9	39.7	40.9	57.4	52.7	46.7	45.3	46.6	43.0	36.9	38.1	39.0	46.0
1983	43.2	50.0	46.1	45.5	44.7	44.5	45.9	46.0	44.7	49.4	33.7	42.9	44.5
1984	48.9	46.9	45.8	46.7	48.0	52.3	57.9	61.7	40.6	39.0	48.4	53.3	48.2
1985	57.1	42.2	38.8	58.1	62.8	62.9	62.1	69.4	54.4	60.3	54.2	67.8	55.5
1986	70.9	66.3	47.1	69.4	45.9	45.4	47.9	48.3	47.1	40.9	49.4	47.4	52.6
1987	53.6	60.3	58.1	65.4	67.5	56.9	64.0	76.3	51.4	56.2	53.5	76.8	60.1
1988	77.5	87.6	48.6	68.6	100.5	94.9	78.0	86.7	56.7	67.3	91.9	89.7	74.2
1989	83.3	78.0	78.3	91.6	135.5	53.1	55.1	76.6	59.0	63.3	56.0	68.0	70.0
1990	66.4	78.5	62.0	67.7	87.9	86.3	71.8	88.3	57.6	78.2	93.4	90.3	74.4
1991	87.7	96.6	100.2	171.3	166.9	61.6	65.9	89.8	83.7	98.7	100.7	97.4	93.2
1992	88.5	112.3	111.6	109.3	77.0	62.6	64.4	83.4	61.6	81.7	112.5	97.4	86.9
1993	84.9	107.7	62.9	59.6	45.6	39.0	41.0	48.4	36.8	39.9	41.8	50.9	50.5
1994	46.8	51.8	43.6	57.9	64.3	61.8	66.3	74.8	51.2	59.0	56.4	70.4	56.3
Average	63.8	61.5	54.9	68.6	64.4	60.2	57.5	63.6	48.2	51.2	56.8	63.1	55.7

Table 4-15. Differences in Chipps Island EC between Proposed Project and Simulated No-Project (µS/cm)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Flow Weighted Average
1922	0	0	18	897	3	-0	-1	-0	1	5	3	-28	75
1923	-2	10	13	0	0	-19	-1	-8	-24	-23	-11	-36	-8
1924	-19	-10	-5	-19	-20	-3	-42	-66	-23	-11	-6	-3	-19
1925	-2	-1	25	11	0	0	-1	-8	-3	-1	-1	-0	2
1926	-0	-0	-0	-13	10	6	-3	-19	-65	-28	-14	-8	-11
1927	-4	6	18	163	0	-0	-0	-1	-24	-8	-4	-31	10
1928	-3	936	285	352	3	-0	-0	-7	-43	-13	-6	-3	125
1929	-2	-1	25	-5	-15	-2	-34	-57	-22	-10	-5	-3	-11
1930	-2	-1	24	883	86	-1	-12	-27	-68	-29	-15	-8	69
1931	-4	-2	-1	-17	-6	-2	-45	-68	-24	-11	-6	-3	-16
1932	-2	-1	16	820	52	12	-16	-26	-5	-3	-1	-1	71
1933	-0	-0	-0	-16	-26	-59	-37	-55	-22	-10	-5	-3	-19
1934	-2	-1	25	-4	-9	-2	-22	-60	-21	-10	-5	-3	-9
1935	-2	-1	-0	-1	-0	-3	-0	-0	-19	-9	-4	-2	-3
1936	-1	-1	-0	-0	0	0	-1	-6	-30	-12	-6	-34	-8
1937	-18	-9	-5	-17	2	0	-1	-4	-2	-1	-0	-0	-5
1938	-0	5	0	0	0	-0	-0	-0	0	3	-3	-23	-2
1939	151	63	24	2	1	-19	-25	-45	-68	-29	-15	-8	3
1940	-4	-2	-1	-1	0	0	-0	-4	-33	-20	-9	-34	-9
1941	-18	-9	0	0	0	-0	-0	-0	6	4	271	101	30
1942	131	66	0	-0	0	-0	-0	-0	6	8	4	-26	16
1943	-0	197	4	-0	0	-0	-0	-2	-34	-11	-4	-32	10
1944	-4	-2	24	-3	20	5	-10	-33	-41	-19	-9	-5	-6
1945	-3	12	22	-5	0	0	-4	-12	-23	-10	-5	-2	-2
1946	11	18	0	0	0	18	-5	-15	-28	-24	-12	-6	-4
1947	-3	13	24	9	-8	-12	-18	-42	-75	-33	1	-19	-14
1948	-11	-6	-3	-18	-4	-23	-1	-1	-14	-19	-9	-34	-12
1949	-18	-9	20	-7	-19	1	-5	-20	-38	-31	-15	-8	-13
1950	-4	-2	-1	-8	16	-1	-4	-12	-29	-22	-16	-38	-10
1951	-19	0	0	0	0	-0	-7	-8	-39	-12	-10	-34	-11
1952	-9	9	5	0	0	-0	-0	-0	0	11	37	42	8
1953	37	19	0	-0	0	-1	-5	-1	-11	-5	-2	-28	0
1954	-1	8	21	155	0	-0	-0	-2	-34	-11	-10	-5	10
1955	-3	12	947	161	44	-20	-30	-32	-47	-22	-11	-6	83
1956	-3	-2	0	0	0	-0	-1	-0	-7	-13	-6	-29	-5
1957	380	193	111	256	3	-0	-3	-5	-28	-20	-9	-34	70
1958	-3	10	1171	4	0	-0	-0	-0	0	21	39	-5	103
1959	84	40	40	0	0	0	-21	-27	-67	-25	-17	-38	-3
1960	-20	-10	-5	-19	-2	-10	-18	-24	-65	-28	-14	-7	-19
1961	-4	12	25	-4	26	-4	-20	-30	-71	-31	2	1	-8
1962	1	0	23	9	0	-1	-12	-21	-45	-17	-8	-6	-6
1963	0	8	603	409	0	-1	-0	-0	-19	-7	-3	-29	80
1964	-3	263	222	5	-4	-1	-30	-43	-73	-32	-16	-29	22
1965	-16	6	0	0	0	-4	-0	-1	-29	-18	-8	-32	-9
1966	-16	1401	728	2	0	-1	-15	-23	-60	-22	-16	-8	164
1967	-4	9	14	0	0	-0	-0	-0	0	6	39	47	9
1968	44	22	36	0	0	-0	-8	-26	-64	-24	-11	-6	-3
1969	-3	13	7	0	0	-0	-0	-0	0	23	53	29	10
1970	39	24	0	0	0	-0	-6	-17	-48	-14	-6	-3	-3
1971	-2	4	0	0	0	0	-2	-0	-13	-15	-11	-28	-6
1972	-2	-1	1764	293	13	-1	-18	-26	-59	-22	-10	-17	160
1973	3	7	519	0	0	-0	-2	-8	-26	-9	-4	-31	37
1974	-3	0	0	-0	0	-0	-0	-0	-10	437	595	165	99
1975	59	39	29	135	0	-0	-0	-0	11	10	464	133	73
1976	70	44	35	-1	16	-22	-39	-62	-81	-38	-20	-11	-9
1977	-6	-3	-2	-1	-0	-0	-43	-67	-23	-11	-6	-3	-14
1978	-2	-1	25	-0	0	0	-0	-1	-22	-8	-4	-30	-3
1979	-2	-1	-1	-1	0	-0	-3	-13	-26	-11	-5	-3	-5
1980	11	19	1898	0	0	-0	-1	-4	-25	-9	-9	-32	154
1981	-4	-2	12	76	1	-0	-5	-24	-68	-30	-15	-8	-6
1982	-4	0	0	0	0	-0	-0	-0	6	22	43	20	7
1983	4	0	0	-0	0	0	-0	-0	0	0	8	2	1
1984	2	0	0	-0	0	-0	-4	-10	-29	-9	-4	-31	-7
1985	-4	0	556	228	102	-1	-14	-25	-68	-30	-15	-22	59
1986	-12	-6	17	640	0	-0	-0	-4	-27	-9	-4	-29	47
1987	-3	-1	-1	-15	140	0	-17	-46	-72	-31	-16	-8	-6
1988	-5	-3	20	374	116	21	-25	-57	-21	-10	-5	-3	34
1989	-2	-1	-0	-18	-5	-0	-2	-22	-52	-22	-11	-37	-14
1990	-20	-11	-5	-12	-11	-43	-33	-51	-19	-9	-5	-3	-19
1991	-1	-1	-0	-0	-0	-1	-9	-41	-16	-8	-4	-2	-7
1992	-1	-1	-0	-0	-1	-10	-21	-47	-18	-9	-4	-2	-10
1993	-1	-1	24	0	0	-0	-0	-0	9	9	5	-27	2
1994	-1	-0	20	-5	14	-12	-31	-48	-77	-36	-19	-10	-17
Minimum	-20	-11	-5	-19	-26	-59	-45	-68	-81	-38	-20	-38	-19
Average	10	46	129	78	7	-3	-10	-19	-30	-6	15	-7	17
Maximum	380	1401	1898	897	140	21	-0	-0	11	437	595	165	164

Note: Difference is Proposed Project minus No-Project.

Table 4-16. Differences in Emmaton EC between Proposed Project and Simulated No-Project (µS/cm)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Flow Weighted Average
1922	0	0	4	140	0	-0	-0	-0	0	1	1	-10	11
1923	-0	2	0	0	0	-2	-0	-0	-3	-5	-3	-12	-2
1924	-7	-3	-2	-6	-4	-0	-10	-15	-5	-3	-2	-1	-5
1925	-1	-0	8	3	0	0	-0	-1	-0	-0	-0	-0	1
1926	-0	-0	-0	-3	0	1	-0	-2	-15	-8	-5	-3	-3
1927	-2	1	4	5	0	-0	-0	-0	-3	-1	-1	-10	-1
1928	-1	191	56	21	0	-0	-0	-0	-8	-2	-2	-1	21
1929	-1	-0	8	-1	-3	-0	-6	-12	-5	-3	-2	-1	-2
1930	-1	-0	8	109	8	-0	-1	-3	-16	-8	-5	-3	7
1931	-2	-1	-0	-5	-2	-1	-11	-16	-6	-3	-2	-1	-4
1932	-1	-0	3	117	4	1	-2	-3	-1	-1	-0	-0	10
1933	-0	-0	-0	-5	-6	-12	-6	-11	-5	-3	-2	-1	-4
1934	-1	-0	9	-1	-1	-0	-3	-14	-5	-3	-2	-1	-2
1935	-1	-0	-0	-0	-0	-0	-0	-0	-2	-2	-1	-1	-1
1936	-0	-0	-0	-0	0	0	-0	-0	-4	-3	-2	-12	-2
1937	-6	-3	-2	-5	0	0	-0	-0	-0	-0	-0	-0	-1
1938	-0	1	0	0	0	0	-0	-0	0	0	-1	-6	-0
1939	21	13	2	0	0	-2	-3	-8	-16	-8	-5	-3	-1
1940	-2	-1	-0	-0	0	0	-0	-0	-5	-4	-2	-12	-2
1941	-6	-3	0	0	0	-0	-0	-0	0	1	65	31	7
1942	25	17	0	-0	0	-0	-0	-0	0	1	1	-8	3
1943	-0	31	0	-0	0	-0	-0	-0	-5	-2	-1	-11	1
1944	-1	-1	8	-1	0	0	-1	-5	-7	-5	-3	-2	-1
1945	-1	4	5	-1	0	0	-0	-1	-3	-2	-1	-1	-0
1946	4	5	0	0	0	1	-0	-1	-4	-5	-3	-2	-1
1947	-1	4	6	2	-1	-1	-2	-7	-18	-9	0	-7	-3
1948	-4	-2	-1	-5	-1	-2	-0	-0	-1	-4	-3	-12	-3
1949	-6	-3	6	-2	-4	0	-0	-2	-6	-8	-5	-3	-3
1950	-2	-1	-0	-1	0	-0	-0	-1	-4	-5	-5	-13	-3
1951	-7	0	0	0	0	-0	-0	-0	-6	-2	-3	-11	-3
1952	-3	3	0	0	0	-0	-0	-0	0	1	7	7	1
1953	6	4	0	0	0	-0	-0	-0	-1	-1	-1	-8	-0
1954	-0	2	5	5	0	-0	-0	-0	-6	-2	-3	-2	-0
1955	-1	3	100	10	5	-3	-5	-4	-8	-6	-3	-2	7
1956	-1	-1	0	0	0	-0	-0	-0	-0	-2	-2	-9	-1
1957	56	50	34	53	0	-0	-0	-0	-4	-4	-2	-11	14
1958	-1	3	146	0	0	0	-0	-0	0	3	7	-1	13
1959	14	11	9	0	0	0	-3	-3	-16	-6	-5	-13	-1
1960	-7	-4	-2	-6	-0	-1	-2	-3	-14	-8	-5	-3	-4
1961	-2	4	6	-1	1	-0	-3	-4	-17	-9	1	0	-2
1962	0	0	6	3	0	-0	-1	-2	-8	-4	-2	-2	-1
1963	0	1	48	46	0	-0	-0	-0	-2	-1	-1	-9	7
1964	-1	16	46	0	-0	-0	-5	-7	-17	-9	-5	-11	0
1965	-6	2	0	0	0	-0	-0	-0	-4	-3	-2	-10	-2
1966	-5	194	101	0	0	-0	-2	-3	-13	-5	-5	-3	22
1967	-2	2	0	0	0	-0	-0	-0	0	0	8	8	1
1968	7	6	5	0	0	-0	-1	-3	-15	-6	-3	-2	-1
1969	-1	4	1	0	0	-0	-0	-0	0	3	12	3	2
1970	6	3	0	0	0	-0	-0	-2	-10	-3	-1	-1	-1
1971	-1	0	0	0	0	0	-0	-0	-1	-3	-3	-7	-1
1972	-1	-0	308	39	1	-0	-2	-3	-12	-5	-3	-6	26
1973	1	1	38	0	0	-0	-0	-0	-3	-2	-1	-10	2
1974	-1	0	0	0	0	0	-0	-0	-1	66	120	27	18
1975	12	11	6	18	0	-0	-0	-0	0	2	103	30	15
1976	8	10	8	-0	1	-3	-7	-14	-19	-12	-7	-4	-3
1977	-2	-1	-1	-0	-0	-0	-10	-16	-6	-3	-2	-1	-4
1978	-1	-0	9	-0	0	0	-0	-0	-2	-1	-1	-9	-1
1979	-1	-0	-0	-0	0	-0	-0	-1	-3	-2	-2	-1	-1
1980	4	6	333	0	0	-0	-0	-0	-3	-2	-2	-10	27
1981	-1	-1	2	1	0	-0	-0	-3	-16	-8	-5	-3	-3
1982	-2	0	0	0	0	-0	0	-0	0	3	8	2	1
1983	0	0	0	0	0	0	-0	-0	0	0	1	0	0
1984	0	0	0	-0	0	-0	-0	-1	-4	-2	-1	-10	-1
1985	-1	0	45	38	7	-0	-1	-3	-16	-8	-5	-8	4
1986	-4	-2	4	62	0	0	-0	-0	-3	-2	-1	-9	4
1987	-1	-0	-0	-4	10	0	-2	-9	-16	-9	-5	-3	-3
1988	-2	-1	5	22	13	3	-5	-13	-5	-3	-2	-1	1
1989	-1	-0	-0	-6	-1	-0	-0	-3	-12	-6	-4	-13	-4
1990	-7	-4	-2	-2	-1	-7	-5	-10	-5	-3	-2	-1	-4
1991	-0	-0	-0	-0	-0	-0	-1	-8	-4	-2	-1	-1	-1
1992	-0	-0	-0	-0	-0	-1	-3	-9	-4	-3	-2	-1	-2
1993	-0	-0	8	0	0	-0	-0	-0	0	1	1	-9	0
1994	-0	-0	5	-1	0	-1	-5	-9	-18	-11	-7	-4	-4
Minimum	-7	-4	-2	-6	-6	-12	-11	-16	-19	-12	-7	-13	-5
Average	1	8	19	9	0	-0	-2	-3	-6	-2	2	-3	2
Maximum	56	194	333	140	13	3	0	-0	0	66	120	31	27

Note: Difference is Proposed Project minus No-Project.

Table 4-17. Differences in Jersey Point EC between Proposed Project and Simulated No-Project (µS/cm)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Flow Weighted Average
1922	0	0	3	112	0	-0	-0	-0	0	1	1	-8	9
1923	-0	2	0	0	0	-2	-0	-0	-3	-4	-3	-10	-2
1924	-5	-3	-1	-5	-3	-0	-8	-12	-4	-3	-2	-1	-4
1925	-0	-0	7	3	0	0	-0	-0	-0	-0	-0	-0	1
1926	-0	-0	-0	-2	0	0	-0	-2	-12	-6	-4	-2	-2
1927	-1	1	3	4	0	-0	-0	-0	-2	-1	-1	-8	-0
1928	-1	153	45	17	0	-0	-0	-0	-6	-2	-1	-1	17
1929	-0	-0	6	-1	-2	-0	-5	-10	-4	-3	-2	-1	-2
1930	-0	-0	6	87	6	-0	-1	-3	-13	-7	-4	-2	6
1931	-1	-1	-0	-4	-1	-1	-9	-13	-5	-3	-2	-1	-3
1932	-0	-0	2	94	3	1	-2	-3	-1	-0	-0	-0	8
1933	-0	-0	-0	-4	-5	-9	-4	-9	-4	-3	-2	-1	-3
1934	-0	-0	7	-1	-1	-0	-2	-11	-4	-2	-1	-1	-1
1935	-0	-0	-0	-0	-0	-0	-0	-0	-2	-1	-1	-1	-0
1936	-0	-0	-0	-0	0	0	-0	-0	-3	-2	-1	-9	-1
1937	-5	-3	-1	-4	0	0	-0	-0	-0	-0	-0	-0	-1
1938	-0	0	0	0	0	0	-0	-0	0	0	-1	-4	-0
1939	17	10	2	0	0	-1	-3	-7	-12	-7	-4	-2	-1
1940	-1	-1	-0	-0	0	0	-0	-0	-4	-3	-2	-9	-2
1941	-5	-3	0	0	0	-0	-0	-0	0	1	52	25	6
1942	20	13	0	-0	0	-0	-0	-0	0	1	1	-7	2
1943	-0	25	0	-0	0	-0	-0	-0	-4	-2	-1	-8	1
1944	-1	-1	7	-0	0	0	-1	-4	-5	-4	-2	-1	-1
1945	-1	3	4	-1	0	0	-0	-1	-2	-2	-1	-1	-0
1946	3	4	0	0	0	1	-0	-1	-3	-4	-3	-2	-0
1947	-1	4	5	2	-1	-1	-2	-6	-14	-7	0	-6	-2
1948	-3	-2	-1	-4	-0	-2	-0	-0	-1	-3	-2	-9	-2
1949	-5	-3	5	-2	-3	0	-0	-2	-5	-6	-4	-2	-2
1950	-1	-1	-0	-1	0	-0	-0	-1	-3	-4	-4	-10	-2
1951	-5	0	0	0	0	-0	-0	-0	-5	-2	-2	-9	-2
1952	-2	2	0	0	0	-0	-0	-0	0	1	5	6	1
1953	5	3	0	0	0	-0	-0	-0	-1	-1	-0	-7	-0
1954	-0	1	4	4	0	-0	-0	-0	-4	-2	-2	-1	-0
1955	-1	3	80	8	4	-2	-4	-4	-6	-4	-3	-2	6
1956	-1	-0	0	0	0	-0	-0	-0	-0	-2	-1	-7	-1
1957	45	40	27	43	0	-0	-0	-0	-3	-3	-2	-9	11
1958	-1	2	116	0	0	0	-0	-0	0	2	6	-1	10
1959	11	9	7	0	0	0	-2	-3	-13	-5	-4	-10	-1
1960	-6	-3	-1	-5	-0	-1	-2	-2	-11	-6	-4	-2	-4
1961	-1	3	5	-1	1	-0	-2	-3	-13	-7	0	0	-2
1962	0	0	5	2	0	-0	-1	-2	-6	-3	-2	-2	-1
1963	0	1	39	37	0	-0	-0	-0	-2	-1	-1	-7	6
1964	-1	13	36	0	-0	-0	-4	-6	-13	-7	-4	-9	0
1965	-5	2	0	0	0	-0	-0	-0	-3	-3	-2	-8	-2
1966	-4	155	81	0	0	-0	-1	-2	-11	-4	-4	-2	17
1967	-1	2	0	0	0	-0	-0	-0	0	0	6	7	1
1968	6	5	4	0	0	-0	-1	-3	-12	-5	-3	-2	-1
1969	-1	4	1	0	0	-0	-0	-0	0	2	10	3	1
1970	5	3	3	0	0	-0	-0	-1	-8	-2	-1	-1	-1
1971	-0	0	0	0	0	0	-0	-0	-1	-2	-2	-6	-1
1972	-0	-0	247	31	1	-0	-2	-3	-10	-4	-2	-5	21
1973	1	1	31	0	0	-0	-0	-0	-3	-1	-1	-8	2
1974	-1	0	0	0	0	0	-0	-0	-1	53	96	22	14
1975	9	9	5	14	0	-0	-0	-0	0	1	82	24	12
1976	7	8	7	-0	1	-2	-6	-11	-15	-9	-6	-3	-3
1977	-2	-1	-1	-0	-0	-0	-8	-13	-4	-3	-2	-1	-3
1978	-0	-0	7	-0	0	0	-0	-0	-2	-1	-1	-8	-0
1979	-1	-0	-0	-0	0	-0	-0	-1	-2	-2	-1	-1	-1
1980	3	5	266	0	0	-0	-0	-0	-2	-1	-2	-8	22
1981	-1	-1	2	1	0	-0	-0	-2	-13	-7	-4	-2	-2
1982	-1	0	0	0	0	-0	0	-0	0	2	6	2	1
1983	0	0	0	0	0	0	-0	-0	0	0	0	0	0
1984	0	0	0	-0	0	-0	-0	-1	-3	-1	-1	-8	-1
1985	-1	0	36	30	5	-0	-1	-2	-13	-7	-4	-6	3
1986	-4	-2	3	50	0	0	-0	-0	-3	-1	-1	-7	3
1987	-1	-0	-0	-3	8	0	-2	-7	-13	-7	-4	-2	-3
1988	-1	-1	4	17	11	2	-4	-10	-4	-2	-1	-1	1
1989	-0	-0	-0	-5	-1	-0	-0	-2	-10	-5	-3	-11	-3
1990	-6	-3	-2	-2	-1	-6	-4	-8	-4	-2	-1	-1	-3
1991	-0	-0	-0	-0	-0	-0	-1	-6	-3	-2	-1	-1	-1
1992	-0	-0	-0	-0	-0	-0	-2	-7	-3	-2	-1	-1	-2
1993	-0	-0	6	0	0	-0	-0	-0	0	1	1	-7	0
1994	-0	-0	4	-1	0	-1	-4	-7	-14	-9	-5	-3	-3
Minimum	-6	-3	-2	-5	-5	-9	-9	-13	-15	-9	-6	-11	-4
Average	1	6	15	7	0	-0	-1	-3	-5	-2	2	-3	1
Maximum	45	155	266	112	11	2	0	-0	0	53	96	25	22

Note: Difference is Proposed Project minus No-Project.

Table 4-18. Differences in Export EC between Proposed Project and Simulated No-Project (µS/cm)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Flow Weighted Average
1922	-0	-0	1	18	-18	-0	1	1	-2	15	-7	-10	-1
1923	-0	0	-24	-1	-1	0	0	1	33	-1	-9	-2	-1
1924	-1	-0	-0	-1	-0	-2	-1	-1	-3	-3	-2	-0	-1
1925	-0	-0	1	1	-26	83	1	2	95	2	2	2	8
1926	2	2	1	2	-24	23	1	2	-2	-2	-1	-0	-1
1927	-0	0	1	-36	-4	-1	0	1	22	9	-1	-2	-2
1928	0	36	12	-20	-0	-0	0	1	27	19	0	1	6
1929	1	1	2	1	0	-1	1	0	-2	-2	-1	-0	0
1930	0	0	2	-4	57	2	1	1	10	-2	-1	-0	5
1931	-0	0	0	-1	-0	-3	-2	3	-6	-4	-1	-1	-1
1932	-0	-0	-0	-1	0	-24	0	1	-2	-2	-1	-0	-2
1933	-0	-0	-0	-1	-1	-1	0	0	-5	-4	-2	-1	-1
1934	-0	-0	2	-0	-1	-4	-1	-2	-2	-4	-2	-1	-1
1935	-0	-0	-0	-0	-1	1	0	0	-1	-1	-1	-1	-0
1936	-0	-0	-0	-0	-34	-2	0	1	8	-3	-1	-3	-5
1937	-1	-1	-1	-1	-35	0	0	0	51	32	1	1	1
1938	1	1	-28	1	0	0	0	0	-3	-0	-0	-1	-3
1939	1	3	-1	-0	-1	1	1	0	-16	-15	-2	-1	-2
1940	-1	-1	-1	-1	-28	-2	0	1	13	-1	-10	-3	-4
1941	-1	-1	-1	-24	-1	0	0	0	-1	-1	13	7	-1
1942	3	4	-1	0	0	-1	0	1	-3	-0	0	-2	0
1943	-0	3	-0	0	0	0	1	0	34	25	0	-2	5
1944	0	0	2	1	-58	-3	1	0	12	-6	-17	-1	-5
1945	-1	1	1	-0	-32	-8	0	0	36	5	-6	0	-1
1946	1	1	-28	0	9	-6	1	1	53	-1	8	1	2
1947	1	2	2	2	1	1	1	1	-3	-2	0	-2	0
1948	-1	-0	0	-1	-1	1	1	1	-0	-1	-1	-3	-1
1949	-1	-1	1	-0	-0	-6	0	1	16	-2	-1	-1	0
1950	-0	-0	-0	-0	-19	9	0	1	-1	-1	-1	-3	-2
1951	-2	-0	-35	-0	-1	-1	1	1	-11	-3	-1	-20	-7
1952	-1	0	-29	-1	-2	0	0	0	-3	-1	1	1	-3
1953	1	0	-3	-1	-1	-1	1	1	49	68	1	-1	11
1954	1	2	2	-40	-3	1	1	2	22	6	-0	-15	-2
1955	0	1	4	-8	25	25	2	2	26	-1	0	0	6
1956	1	1	1	11	-0	-0	1	1	2	-0	-0	-2	1
1957	5	10	4	10	-4	-0	1	2	38	-0	3	-7	5
1958	0	1	15	-9	-0	-1	0	0	-3	-0	1	-0	0
1959	2	2	2	-1	-1	9	1	1	19	9	-1	-2	3
1960	-1	-0	-0	-0	1	1	1	1	-3	-2	-1	-1	-0
1961	-0	1	1	0	-8	13	0	0	-3	-3	-0	-0	-0
1962	-0	-0	1	1	-26	-0	0	1	63	21	0	4	4
1963	1	1	-7	1	1	1	0	1	3	-0	-1	-4	-0
1964	-7	-10	10	-0	0	-1	0	0	28	4	-1	-2	1
1965	-1	1	0	-30	-0	-0	1	1	-4	-1	-1	-14	-5
1966	-8	16	8	-0	-1	-1	1	0	45	31	-0	0	6
1967	1	1	-34	0	-0	-0	0	0	-3	-1	1	1	-3
1968	1	1	-1	-1	-1	-1	1	1	14	10	-1	-0	2
1969	0	1	0	-33	0	0	0	0	0	-0	2	0	-3
1970	0	-0	-1	0	0	-1	1	1	-10	-1	-1	-0	-1
1971	-0	-0	-21	-0	-3	-5	0	1	7	-1	-1	-2	-2
1972	-0	-7	55	9	0	1	1	1	49	32	0	0	12
1973	2	2	-12	-4	0	-0	1	1	7	0	-15	-2	-2
1974	-0	-25	-0	-0	-1	-1	1	1	38	11	25	6	5
1975	3	4	2	0	0	-1	1	1	-2	10	21	7	4
1976	1	3	2	1	-1	46	1	1	45	-1	-0	0	7
1977	1	1	1	3	1	-2	-0	-10	-3	-3	-1	-0	0
1978	1	0	2	-0	-28	-6	0	0	-0	-1	-1	-2	-5
1979	-0	-0	-0	-0	2	-1	1	1	-1	16	-20	-0	0
1980	1	1	56	-9	0	0	1	0	55	49	1	-1	13
1981	1	1	2	-70	-0	0	1	1	-16	-32	-2	-2	-8
1982	-1	-1	-21	-1	-1	0	0	0	-3	-0	1	-1	-2
1983	-1	-1	0	0	0	0	0	0	0	-1	-1	-1	-0
1984	0	0	0	0	0	-1	1	2	20	8	-1	-2	3
1985	0	0	-9	9	-10	1	1	1	-44	-44	-2	-3	-6
1986	-2	-2	-0	-15	0	0	0	0	13	13	-0	-2	-0
1987	-0	0	0	-0	-16	1	-0	-1	14	-2	-1	-1	-1
1988	-0	-0	1	-30	9	9	-0	-1	-2	-1	-1	-0	-4
1989	-0	-0	-0	-1	-3	1	-0	-0	-3	-2	-1	-3	-1
1990	-2	-1	-1	-1	-0	-1	-1	-1	-2	-2	-1	-1	-1
1991	-0	-0	-0	-1	-6	2	-1	-1	-7	-5	-2	-1	-0
1992	-1	-1	-1	-1	-1	2	-1	-3	-3	-3	-3	-1	-1
1993	-1	-1	1	-26	-1	-1	0	1	-3	-1	-0	-2	-4
1994	-0	-0	1	-0	-7	-0	-0	1	48	52	-0	1	6
Minimum	-8	-25	-35	-70	-58	-24	-2	-10	-44	-44	-20	-20	-8
Average	-0	1	-1	-4	-4	2	0	0	11	4	-1	-1	0
Maximum	5	36	56	18	57	83	2	3	95	68	25	7	13

Note: Difference is Proposed Project minus No-Project.

Table 4-19. Differences in Export Chloride Concentrations between Proposed Project and Simulated No-Project (mg/l)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Flow Weighted Average
1922	-0.0	-0.0	0.3	6.6	-3.6	-0.1	0.1	0.3	-0.5	4.3	-2.3	-3.4	0.05
1923	-0.0	0.1	-4.4	-0.1	-0.2	-0.0	0.1	0.2	9.3	-0.3	-4.5	-0.8	-0.26
1924	-0.3	-0.2	-0.1	-0.3	-0.2	-0.4	-0.3	-0.5	-0.5	-0.3	0.0	-0.0	-0.24
1925	-0.1	-0.1	0.5	0.2	-4.6	23.9	0.1	0.4	23.6	0.3	0.3	0.3	2.59
1926	0.3	0.3	0.2	0.2	-4.3	7.6	0.2	0.3	-0.9	-0.5	-0.3	-0.1	-0.04
1927	-0.1	0.1	0.3	-6.1	-0.7	-0.1	0.1	0.2	6.0	1.9	-0.5	-0.6	-0.19
1928	-0.0	12.0	3.7	-3.0	-0.0	-0.0	0.1	0.2	7.7	4.5	-0.0	0.1	2.23
1929	0.1	0.1	0.6	0.0	-0.0	-0.2	0.0	-0.2	-0.4	-0.2	0.0	-0.0	0.06
1930	-0.0	-0.0	0.5	2.6	20.9	0.4	0.1	0.2	2.2	-0.6	-0.3	-0.1	2.26
1931	-0.1	-0.0	-0.0	-0.3	-0.1	-0.3	-0.5	0.2	-0.9	-0.4	-0.2	-0.1	-0.16
1932	-0.1	-0.1	0.0	2.9	0.1	-2.5	0.1	0.1	-0.4	-0.3	-0.1	-0.0	0.39
1933	-0.1	-0.1	-0.1	-0.4	-0.4	-0.4	-0.0	-0.2	-0.7	-0.4	-0.2	-0.1	-0.22
1934	-0.1	-0.1	0.6	-0.1	-0.2	-0.6	-0.2	-0.7	-0.5	-0.4	-0.2	-0.1	-0.08
1935	-0.1	-0.1	-0.1	-0.0	-0.2	0.2	0.1	0.1	-0.1	-0.2	-0.2	-0.1	-0.06
1936	-0.1	-0.1	-0.1	-0.0	-7.7	-0.4	0.0	0.2	-0.0	-3.0	-0.2	-0.8	-1.40
1937	-0.4	-0.3	-0.2	-0.3	-7.9	0.0	0.1	0.0	13.7	7.8	0.2	0.2	0.42
1938	0.1	0.1	-5.4	0.1	0.0	0.0	0.0	0.0	-0.6	-0.0	-0.1	-0.3	-0.63
1939	0.6	0.8	-0.0	-0.1	-0.1	0.1	0.1	-0.0	-7.6	-5.5	-0.4	-0.2	-0.86
1940	-0.2	-0.2	-0.2	-0.1	-5.5	-0.5	0.1	0.2	0.7	-0.3	-6.4	-0.8	-1.43
1941	-0.4	-0.2	-0.1	-4.5	-0.1	0.0	0.0	0.0	-0.3	-0.1	4.3	2.1	0.03
1942	1.2	1.1	-0.1	0.0	0.0	-0.1	0.1	0.2	-0.5	-0.0	0.0	-0.6	0.13
1943	-0.0	1.3	-0.0	0.0	0.0	0.0	0.1	0.0	3.7	2.1	0.0	-0.6	0.53
1944	0.0	0.0	0.6	0.2	-10.6	-0.6	0.1	-0.0	1.2	-3.2	-6.1	-0.1	-1.40
1945	-0.1	0.2	0.3	-0.1	-6.4	-1.5	0.1	0.0	9.6	1.0	-3.1	0.0	-0.14
1946	0.2	0.4	-5.5	0.0	4.1	-1.0	0.2	0.2	15.3	-0.3	0.9	0.0	0.81
1947	0.1	0.4	0.5	0.3	0.2	0.2	0.1	-0.0	-1.1	-0.6	0.1	-0.5	0.04
1948	-0.2	-0.1	-0.1	-0.3	-0.1	0.0	0.1	0.2	-0.1	-0.3	-0.2	-0.8	-0.21
1949	-0.4	-0.2	0.4	-0.1	-0.2	-1.0	0.1	0.1	2.9	-0.6	-0.3	-0.2	-0.03
1950	-0.1	-0.1	-0.0	-0.0	-3.4	2.4	0.1	0.2	-0.3	-0.4	-0.3	-0.9	-0.37
1951	-0.5	-0.0	-7.5	-0.1	-0.1	-0.1	0.1	0.1	-3.9	-1.4	-0.2	-7.3	-1.93
1952	-0.3	0.1	-5.2	-0.2	-0.3	0.0	0.0	0.0	-0.6	-0.1	0.3	0.3	-0.57
1953	0.3	0.2	-0.6	-0.1	-0.2	-0.1	0.1	0.2	12.8	17.1	0.2	-0.4	2.89
1954	0.2	0.3	0.5	-6.8	-0.5	0.1	0.1	0.3	6.9	1.3	-0.1	-5.7	-0.44
1955	0.0	0.3	3.9	-1.1	8.7	9.3	0.2	0.3	7.0	-0.3	-0.0	0.0	2.29
1956	0.1	0.1	0.1	1.7	-0.0	-0.1	0.2	0.3	0.3	-0.1	-0.1	-0.6	0.17
1957	2.1	2.7	1.0	3.2	-0.7	-0.1	0.1	0.3	8.2	-0.2	-1.1	-4.0	0.95
1958	0.0	0.2	7.2	-1.6	-0.0	-0.3	0.0	0.0	-0.6	0.1	0.4	-0.1	0.51
1959	0.6	0.7	0.5	-0.2	-0.1	3.1	0.1	0.2	3.1	1.2	-0.3	-0.8	0.56
1960	-0.4	-0.2	-0.1	-0.3	0.1	0.1	0.1	0.1	-0.9	-0.6	-0.3	-0.2	-0.20
1961	-0.1	0.3	0.4	-0.0	-1.3	3.7	-0.0	-0.1	-1.1	-0.7	0.0	0.0	0.11
1962	-0.0	-0.0	0.4	0.2	-5.2	-0.0	0.1	0.1	15.7	4.4	-0.0	0.1	0.94
1963	0.1	0.2	0.4	1.4	0.1	0.2	0.1	0.2	0.9	-0.1	-0.5	-1.4	0.11
1964	-2.6	-1.4	3.1	-0.0	-0.0	-0.2	-0.0	-0.1	6.7	-0.9	-0.3	-0.7	0.12
1965	-0.3	0.2	-0.0	-6.5	-0.1	-0.1	0.1	0.2	-2.2	-0.3	-0.2	-5.6	-1.38
1966	-3.3	8.1	3.7	-0.0	-0.1	-0.1	0.1	0.0	13.1	8.5	-0.2	-0.0	2.29
1967	0.1	0.2	-6.0	0.0	-0.0	-0.1	0.0	0.0	-0.7	-0.2	0.4	0.4	-0.55
1968	0.3	0.4	0.0	-0.1	-0.1	-0.1	0.1	0.1	1.4	0.6	-0.2	-0.1	0.17
1969	-0.0	0.3	0.1	-7.7	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.1	-0.75
1970	0.2	0.0	-0.2	0.0	0.0	-0.1	0.1	0.2	-5.4	-2.8	-0.2	-0.1	-0.66
1971	-0.1	-0.0	-3.7	-0.1	-0.5	-0.9	0.1	0.1	1.1	-0.2	-0.2	-0.5	-0.47
1972	-0.0	-2.6	19.0	2.6	0.1	0.2	0.1	0.1	13.1	7.6	-0.0	-0.2	3.45
1973	0.3	0.3	-0.9	-0.7	-0.0	-0.1	0.1	0.2	1.2	-0.2	-5.9	-0.7	-0.53
1974	-0.1	-4.4	-0.1	-0.0	-0.1	-0.2	0.1	0.2	11.1	3.9	8.0	1.9	1.87
1975	0.8	0.8	0.5	0.4	-0.0	-0.1	0.1	0.2	-0.5	2.5	6.8	2.1	1.31
1976	0.3	0.7	0.6	0.1	-0.1	11.8	0.1	-0.2	8.1	-0.5	-0.2	-0.1	1.58
1977	0.1	0.1	0.1	0.4	0.1	-0.1	-0.3	-1.5	-0.6	-0.3	-0.1	-0.0	0.02
1978	-0.1	-0.0	0.6	-0.0	-5.6	-1.3	0.0	0.0	-0.1	-0.3	-0.1	-0.6	-0.97
1979	-0.1	-0.1	-0.1	-0.1	-0.2	-0.1	0.1	0.2	-0.2	-1.0	-11.7	-0.1	-0.86
1980	0.2	0.4	19.9	-2.0	0.0	0.0	0.2	0.0	17.0	15.3	0.0	-0.5	4.25
1981	0.1	0.2	0.3	-12.5	-0.0	0.1	0.1	0.1	-7.0	-11.8	-0.4	-0.3	-2.18
1982	-0.2	-0.1	-3.6	-0.2	-0.1	0.0	0.0	0.0	-0.6	-0.0	0.4	-0.1	-0.41
1983	-0.2	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.3	-0.1	-0.3	-0.10
1984	0.0	0.0	0.0	0.0	0.0	-0.1	0.2	0.3	1.2	-0.3	-1.5	-0.6	-0.16
1985	-0.0	0.0	-0.3	2.5	-1.6	0.2	0.1	0.2	-13.4	-13.3	-0.5	-0.7	-1.47
1986	-0.5	-0.3	0.1	-0.8	0.0	0.0	0.0	0.0	3.6	2.8	-0.1	-0.6	0.24
1987	-0.0	-0.0	-0.0	-0.2	-2.4	0.1	-0.0	-0.3	2.6	-0.6	-0.4	-0.2	-0.16
1988	-0.1	-0.1	0.4	-4.3	11.5	7.4	-0.1	-0.5	-0.4	-0.3	-0.1	-0.1	0.41
1989	-0.1	-0.0	-0.0	-0.4	-0.4	0.1	-0.0	-0.1	-0.9	-0.5	-0.3	-1.0	-0.31
1990	-0.5	-0.3	-0.2	-0.2	-0.0	-0.4	-0.3	-0.4	-0.4	-0.3	-0.2	-0.1	-0.26
1991	-0.1	-0.1	-0.1	-0.1	-1.0	0.3	-0.1	-0.4	-1.0	-0.5	-0.3	-0.2	-0.05
1992	-0.2	-0.2	-0.2	-0.1	-0.1	0.3	-0.2	-0.6	-0.6	-0.4	-0.3	-0.2	-0.13
1993	-0.2	-0.2	0.4	-5.0	-0.2	-0.1	0.0	0.2	-0.5	-0.1	0.1	-0.6	-0.71
1994	-0.0	-0.0	0.3	-0.1	-1.2	-0.1	-0.1	-0.0	11.9	10.1	-0.3	-0.0	1.23
Minimum	-3.3	-4.4	-7.5	-12.5	-10.6	-2.5	-0.5	-1.5	-13.4	-13.3	-11.7	-7.3	-2.2
Average	-0.1	0.3	0.4	-0.6	-0.5	0.8	0.0	0.0	2.5	0.6	-0.4	-0.5	0.17
Maximum	2.1	12.0	19.9	6.6	20.9	23.9	0.2	0.4	23.6	17.1	8.0	2.1	4.2

Note: Difference is Proposed Project minus No-Project.

Table 4-20. Differences in Export DOC (mg/l) between Proposed Project and Simulated No-Project (mg/l) Assuming Long-Term DOC Load (1 g/m²/month)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Flow Weighted Average
1922	0.0	0.0	-0.0	-0.2	-0.1	-0.0	0.0	0.0	-0.0	0.2	0.1	0.1	-0.0
1923	0.0	0.0	-0.1	0.0	-0.0	0.0	0.0	0.0	0.4	0.0	0.4	0.0	0.0
1924	0.0	0.0	0.0	0.0	0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	0.0
1925	0.0	0.0	-0.0	0.0	-0.3	0.7	-0.0	0.0	1.3	0.0	0.0	0.0	0.1
1926	0.0	0.0	0.0	0.0	-0.6	0.0	-0.0	-0.0	0.0	-0.0	-0.0	-0.0	-0.1
1927	-0.0	-0.0	-0.0	-0.9	-0.0	-0.0	-0.0	-0.0	0.3	0.2	0.1	0.0	-0.1
1928	0.0	-0.1	-0.0	-0.6	-0.0	0.0	-0.0	-0.0	0.2	0.3	-0.0	-0.0	-0.0
1929	0.0	0.0	-0.0	0.0	-0.0	-0.1	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0
1930	-0.0	-0.0	-0.0	-0.7	-0.7	0.0	-0.0	-0.0	0.2	-0.0	-0.0	-0.0	-0.1
1931	-0.0	-0.0	-0.0	-0.0	-0.0	-0.1	-0.0	-0.1	-0.0	-0.1	-0.0	-0.0	-0.0
1932	-0.0	-0.0	-0.0	-0.5	-0.0	0.1	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.1
1933	-0.0	-0.0	-0.0	0.0	-0.0	0.0	-0.0	-0.0	-0.0	-0.1	-0.0	-0.0	-0.0
1934	-0.0	-0.0	-0.0	0.0	-0.0	-0.1	-0.0	-0.0	-0.0	-0.1	-0.0	-0.0	-0.0
1935	-0.0	-0.0	-0.0	-0.0	-0.0	0.0	0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0
1936	-0.0	-0.0	-0.0	-0.0	-0.4	-0.0	-0.0	-0.0	0.7	0.5	0.0	0.0	0.1
1937	0.0	0.0	0.0	0.0	-0.4	0.0	-0.0	0.0	0.6	0.6	0.0	0.0	0.1
1938	0.0	0.0	-0.2	0.0	0.0	0.0	0.0	0.0	-0.0	-0.0	-0.0	-0.0	-0.0
1939	-0.0	-0.0	-0.0	0.0	-0.0	0.1	-0.0	-0.0	0.8	0.4	0.0	0.0	0.1
1940	0.0	0.0	0.0	0.0	-0.2	-0.0	-0.0	-0.0	1.0	0.0	0.8	0.0	0.1
1941	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	-0.0	-0.0	-0.0	-0.0	-0.0
1942	-0.0	-0.0	-0.0	0.0	0.0	-0.0	0.0	0.0	-0.0	-0.0	-0.0	-0.0	-0.0
1943	-0.0	-0.1	-0.0	0.0	0.0	0.0	-0.0	0.0	1.6	1.3	0.0	0.0	0.2
1944	0.0	0.0	0.0	0.1	-0.2	-0.0	0.0	0.0	0.6	0.3	0.3	0.0	0.1
1945	0.0	0.0	0.0	0.0	-0.2	-0.0	-0.0	0.0	0.5	0.1	0.4	0.0	0.1
1946	0.0	0.0	-0.2	0.0	-0.1	-0.1	0.0	0.0	0.2	0.0	0.3	0.0	0.0
1947	0.0	0.0	0.0	0.0	0.0	0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	0.0
1948	0.0	0.0	0.0	0.0	-0.0	0.0	-0.0	-0.0	-0.0	-0.0	-0.0	0.0	-0.0
1949	0.0	0.0	-0.0	0.0	0.0	0.0	-0.0	-0.0	0.5	-0.0	-0.0	-0.0	0.0
1950	0.0	0.0	0.0	0.0	-0.4	0.2	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0
1951	-0.0	-0.0	-0.3	-0.0	0.0	-0.0	-0.0	-0.0	0.2	0.1	-0.0	0.3	0.0
1952	0.0	0.0	-0.4	-0.0	-0.0	0.0	0.0	0.0	-0.0	-0.0	-0.0	-0.0	-0.0
1953	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	0.5	0.8	0.0	0.0	0.1
1954	0.0	0.0	0.0	-1.0	-0.0	0.0	-0.0	-0.0	0.1	0.1	-0.0	0.3	-0.0
1955	0.0	0.0	-0.3	-0.3	-0.2	-0.4	-0.0	-0.0	0.3	-0.0	-0.0	-0.0	-0.1
1956	-0.0	-0.0	-0.0	0.8	0.0	-0.0	0.0	0.0	0.1	-0.0	-0.0	0.0	0.1
1957	-0.0	0.1	0.1	-0.1	-0.0	-0.0	-0.0	0.0	0.9	0.0	0.4	0.4	0.2
1958	0.0	0.0	-0.3	-0.3	-0.0	-0.0	0.0	0.0	-0.0	-0.0	-0.0	-0.0	-0.1
1959	-0.0	-0.0	-0.0	-0.0	-0.0	0.1	-0.0	-0.0	0.9	0.6	0.0	0.0	0.1
1960	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.0	0.0	-0.0	-0.0	-0.0	0.0
1961	0.0	0.0	0.0	0.0	-0.2	0.1	-0.0	-0.0	0.0	-0.0	-0.0	-0.0	-0.0
1962	0.0	0.0	-0.0	0.0	-0.2	-0.0	-0.0	-0.0	0.8	0.4	0.0	0.2	0.1
1963	0.0	0.0	-0.3	-0.3	0.0	0.0	0.0	-0.0	0.1	-0.0	0.0	0.0	-0.0
1964	0.1	-0.2	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	0.6	0.6	0.0	0.0	0.0
1965	0.0	0.0	-0.0	-0.2	0.0	-0.0	0.0	0.0	0.3	0.0	0.0	0.2	0.0
1966	0.2	-0.4	-0.2	0.0	0.0	-0.0	-0.0	-0.0	0.3	0.3	0.0	0.0	-0.0
1967	0.0	0.0	-0.6	-0.0	-0.0	0.0	0.0	0.0	-0.0	-0.0	-0.0	-0.0	-0.1
1968	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	0.9	0.8	0.0	0.0	0.1
1969	0.0	0.0	0.0	-0.3	0.0	0.0	0.0	0.0	0.0	-0.0	-0.0	-0.0	-0.0
1970	-0.0	-0.0	-0.0	0.0	0.0	-0.0	-0.0	-0.0	0.9	0.7	0.0	0.0	0.1
1971	0.0	0.0	-0.1	0.0	-0.1	-0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0
1972	0.0	0.1	-0.3	0.0	-0.0	0.0	-0.0	-0.0	0.6	0.5	0.0	0.0	0.1
1973	0.0	0.0	-0.4	-0.0	0.0	0.0	-0.0	0.0	0.4	0.1	0.4	0.0	0.0
1974	0.0	-0.2	-0.0	0.0	-0.0	0.0	0.0	0.0	0.2	-0.1	-0.1	-0.0	-0.0
1975	-0.0	0.0	-0.0	-0.1	-0.0	0.0	-0.0	-0.0	-0.0	0.1	-0.1	-0.0	-0.0
1976	-0.0	-0.0	-0.0	-0.0	-0.1	0.4	-0.0	-0.0	1.3	0.0	0.0	0.0	0.1
1977	0.0	0.0	0.0	0.1	0.0	-0.1	-0.0	-0.7	-0.0	-0.1	-0.0	-0.0	0.0
1978	-0.0	-0.0	-0.0	-0.0	-0.2	-0.1	0.0	0.0	-0.0	-0.0	-0.0	-0.0	-0.0
1979	-0.0	-0.0	-0.0	-0.0	1.0	-0.0	0.0	0.0	0.0	1.3	1.4	0.0	0.3
1980	0.0	0.0	-0.3	-0.1	0.0	0.0	0.0	0.0	0.1	0.2	0.0	0.0	-0.0
1981	0.0	0.0	0.0	-0.7	-0.0	0.0	-0.0	-0.0	0.4	0.4	-0.0	-0.0	0.0
1982	0.0	0.0	-0.2	0.0	-0.0	0.0	0.0	0.0	-0.0	-0.0	-0.0	-0.0	-0.0
1983	-0.0	-0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.0	-0.0	-0.0	-0.0
1984	0.0	0.0	0.0	0.0	0.0	-0.0	0.0	0.0	1.3	0.7	0.4	0.0	0.3
1985	0.0	0.0	-0.3	0.0	-0.2	0.1	-0.0	-0.0	0.3	0.3	0.0	0.0	-0.0
1986	0.0	0.0	0.0	-0.7	0.0	0.0	0.0	0.0	0.3	0.4	-0.0	0.0	-0.0
1987	0.0	0.0	0.0	0.0	-0.3	0.1	-0.0	-0.0	0.5	-0.0	-0.0	-0.0	0.0
1988	0.0	0.0	-0.0	-0.8	-1.5	-0.8	-0.1	-0.1	-0.0	-0.1	-0.1	-0.0	-0.3
1989	-0.0	-0.0	-0.0	-0.0	-0.1	0.0	-0.0	-0.1	-0.0	-0.0	-0.0	-0.0	-0.0
1990	-0.0	-0.0	-0.0	0.0	0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0
1991	-0.0	-0.0	-0.0	-0.0	-0.1	0.1	-0.0	-0.1	-0.1	-0.1	-0.1	-0.0	-0.0
1992	-0.0	-0.0	-0.0	-0.0	-0.0	0.1	-0.0	-0.1	-0.0	-0.1	-0.1	-0.0	-0.0
1993	-0.0	-0.0	-0.0	-0.2	-0.0	0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0
1994	-0.0	-0.0	-0.0	0.0	-0.2	-0.0	-0.0	-0.0	0.6	1.2	0.0	0.0	0.1
Minimum	-0.03	-0.36	-0.64	-1.05	-1.48	-0.82	-0.08	-0.67	-0.07	-0.08	-0.08	-0.04	-0.31
Average	0.01	-0.01	-0.06	-0.09	-0.08	0.01	-0.01	-0.02	0.29	0.17	0.06	0.02	0.02
Maximum	0.19	0.13	0.08	0.84	0.97	0.72	0.02	0.01	1.65	1.29	1.39	0.44	0.27

Note: Difference is Proposed Project minus No-Project

Table 4-21. Differences in Export DOC (mg/l) between Proposed Project and Simulated No-Project (mg/l) Assuming Initial-Filling DOC Load (4 g/m²/month)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Flow Weighted Average
1922	0.0	0.0	-0.0	-0.2	-0.1	-0.0	0.0	0.0	-0.0	0.8	0.3	0.3	0.1
1923	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	1.4	0.0	1.6	0.0	0.3
1924	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	-0.0	-0.0	-0.0	0.0	0.0
1925	0.0	0.0	-0.0	0.0	-0.3	0.8	0.0	0.0	2.2	0.0	0.0	0.0	0.2
1926	0.0	0.1	0.0	0.1	-0.6	0.2	0.0	0.0	0.0	-0.0	-0.0	-0.0	-0.0
1927	0.0	0.0	0.0	-0.9	-0.0	-0.0	-0.0	-0.0	0.7	0.5	0.3	0.0	0.0
1928	0.0	-0.1	0.0	-0.6	-0.0	0.0	-0.0	-0.0	1.0	0.8	0.0	0.0	0.1
1929	0.0	0.0	0.0	0.0	0.0	-0.0	0.0	-0.0	-0.0	-0.0	-0.0	0.0	0.0
1930	0.0	0.0	0.0	-0.7	-0.5	0.0	-0.0	-0.0	0.7	-0.0	-0.0	-0.0	-0.1
1931	-0.0	0.0	0.0	0.0	0.0	-0.1	-0.0	-0.0	-0.0	-0.1	-0.0	-0.0	-0.0
1932	-0.0	-0.0	-0.0	-0.5	-0.0	0.7	0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0
1933	0.0	0.0	0.0	0.0	-0.0	0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	0.0
1934	-0.0	0.0	-0.0	0.0	-0.0	-0.1	-0.0	-0.0	-0.0	-0.1	-0.0	-0.0	-0.0
1935	-0.0	-0.0	-0.0	-0.0	-0.0	0.0	0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0
1936	-0.0	-0.0	-0.0	-0.0	-0.4	-0.0	-0.0	-0.0	1.1	0.9	0.0	0.0	0.1
1937	0.0	0.0	0.0	0.0	-0.3	0.0	0.0	0.0	1.0	1.2	0.0	0.0	0.2
1938	0.0	0.0	-0.2	0.0	0.0	0.0	0.0	0.0	-0.0	-0.0	-0.0	-0.0	-0.0
1939	-0.0	-0.0	-0.0	0.0	-0.0	0.8	0.0	0.0	2.9	1.3	0.1	0.1	0.5
1940	0.1	0.1	0.1	0.1	-0.1	0.0	0.0	0.0	1.4	0.0	1.4	0.0	0.3
1941	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	-0.0	-0.0	-0.0	-0.0	-0.0
1942	-0.0	-0.0	-0.0	0.0	0.0	-0.0	0.0	0.0	-0.0	-0.0	-0.0	-0.0	-0.0
1943	-0.0	-0.1	-0.0	0.0	0.0	0.0	-0.0	0.0	4.5	3.5	0.1	0.1	0.7
1944	0.1	0.1	0.1	0.2	-0.1	0.1	0.0	0.0	1.0	0.6	0.8	0.1	0.3
1945	0.1	0.0	0.0	0.1	-0.2	-0.0	0.0	0.0	0.8	0.3	1.0	0.0	0.2
1946	0.0	0.0	-0.2	0.0	-0.1	-0.0	0.0	0.0	0.8	0.0	1.1	0.0	0.2
1947	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	-0.0	-0.0	0.0	0.0
1948	0.0	0.0	0.0	0.0	-0.0	0.0	0.0	0.0	-0.0	-0.0	-0.0	0.0	0.0
1949	0.0	0.0	-0.0	0.0	0.0	0.0	-0.0	-0.0	1.0	0.0	-0.0	0.0	0.1
1950	0.0	0.0	0.0	0.0	-0.4	0.3	-0.0	-0.0	-0.0	-0.0	-0.0	0.0	-0.0
1951	0.0	0.0	-0.3	0.0	0.0	-0.0	-0.0	-0.0	0.8	0.3	0.0	0.8	0.1
1952	0.0	0.0	-0.4	0.0	-0.0	0.0	0.0	0.0	-0.0	-0.0	-0.0	-0.0	-0.0
1953	-0.0	-0.0	-0.0	0.0	-0.0	-0.0	-0.0	-0.0	1.4	2.5	0.0	0.0	0.4
1954	0.0	0.0	0.0	-1.0	0.0	0.0	0.0	0.0	0.6	0.3	0.0	0.9	0.1
1955	0.0	0.0	-0.3	-0.3	-0.1	-0.1	0.0	-0.0	1.0	0.0	0.0	0.0	0.0
1956	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1
1957	-0.0	0.2	0.2	-0.0	0.0	-0.0	-0.0	0.0	2.3	0.0	1.1	1.2	0.5
1958	0.0	0.0	-0.3	-0.2	0.0	-0.0	0.0	0.0	-0.0	-0.0	-0.0	-0.0	-0.0
1959	-0.0	-0.0	-0.0	0.0	-0.0	0.6	0.0	-0.0	3.1	2.0	0.1	0.1	0.5
1960	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1
1961	0.0	0.0	0.0	0.0	-0.1	0.3	0.0	-0.0	0.0	-0.0	-0.0	0.0	0.0
1962	0.0	0.0	0.0	0.0	-0.2	-0.0	-0.0	-0.0	1.2	0.6	0.0	0.5	0.2
1963	0.0	0.0	-0.3	-0.2	0.0	0.1	0.0	-0.0	0.2	0.0	0.1	0.1	-0.0
1964	0.2	-0.2	-0.0	0.0	-0.0	-0.0	-0.0	-0.0	2.5	2.3	0.0	0.1	0.4
1965	0.1	0.0	0.0	-0.2	0.0	0.1	0.0	0.0	0.9	0.0	0.0	0.6	0.1
1966	0.6	-0.3	-0.2	0.1	0.0	0.0	0.0	0.0	1.2	1.2	0.0	0.0	0.2
1967	0.0	0.0	-0.6	0.0	0.0	0.0	0.0	0.0	-0.0	-0.0	-0.0	-0.0	-0.1
1968	-0.0	-0.0	-0.0	-0.0	0.0	-0.0	-0.0	-0.0	2.9	2.7	0.1	0.1	0.5
1969	0.1	0.1	0.0	-0.3	0.0	0.0	0.0	0.0	0.0	-0.0	-0.0	-0.0	-0.0
1970	-0.0	-0.0	-0.0	0.0	0.0	-0.0	0.0	-0.0	2.7	2.1	0.1	0.1	0.5
1971	0.1	0.1	-0.0	0.1	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.1
1972	0.0	0.4	-0.3	0.0	0.0	0.0	0.0	0.0	2.1	1.8	0.0	0.1	0.3
1973	0.1	0.1	-0.4	0.0	0.0	0.0	0.0	0.0	0.9	0.2	1.0	0.0	0.2
1974	0.0	-0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.5	-0.1	-0.1	-0.0	0.0
1975	0.0	0.1	0.0	-0.1	0.0	0.0	-0.0	-0.0	-0.0	0.4	-0.1	-0.0	0.0
1976	-0.0	-0.0	-0.0	-0.0	-0.0	2.2	0.0	0.0	4.5	0.1	0.1	0.1	0.6
1977	0.1	0.1	0.1	0.2	0.2	0.1	0.1	-0.6	0.0	-0.0	0.0	0.0	0.1
1978	0.0	0.0	0.0	0.0	-0.2	-0.0	0.0	0.0	-0.0	-0.0	-0.0	-0.0	-0.0
1979	-0.0	-0.0	-0.0	-0.0	1.0	-0.0	0.0	0.0	0.0	2.7	3.1	0.1	0.6
1980	0.1	0.0	-0.3	-0.0	0.0	0.0	0.0	0.0	0.7	1.0	0.0	0.0	0.1
1981	0.0	0.0	0.0	-0.7	0.0	0.1	-0.0	-0.0	0.9	1.1	0.0	0.0	0.1
1982	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	-0.0	-0.0	-0.0	-0.0	-0.0
1983	-0.0	-0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.0	-0.0	-0.0	-0.0
1984	0.0	0.0	0.0	0.0	0.0	-0.0	0.0	0.0	3.9	2.1	1.1	0.1	0.9
1985	0.1	0.1	-0.3	0.1	-0.2	0.2	0.0	0.0	1.1	1.0	0.0	0.0	0.2
1986	0.1	0.0	0.0	-0.6	0.0	0.0	0.0	0.0	0.7	1.0	0.0	0.0	0.1
1987	0.0	0.0	0.0	0.0	-0.3	0.1	-0.0	-0.0	1.3	0.0	0.0	0.0	0.1
1988	0.0	0.0	0.0	-0.8	-1.3	-0.4	-0.1	-0.1	-0.0	-0.0	-0.0	-0.0	-0.3
1989	-0.0	-0.0	-0.0	0.0	-0.1	0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0
1990	-0.0	-0.0	-0.0	0.0	0.0	0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0
1991	-0.0	-0.0	-0.0	-0.0	-0.1	0.1	-0.0	-0.1	-0.1	-0.1	-0.0	-0.0	-0.0
1992	-0.0	-0.0	-0.0	-0.0	-0.0	0.1	-0.0	-0.1	-0.0	-0.1	-0.1	-0.0	-0.0
1993	-0.0	-0.0	-0.0	-0.2	-0.0	0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0
1994	-0.0	-0.0	-0.0	0.0	-0.2	-0.0	-0.0	-0.0	1.7	3.6	0.1	0.1	0.4
Minimum	-0.03	-0.34	-0.62	-1.01	-1.28	-0.39	-0.06	-0.64	-0.06	-0.08	-0.08	-0.03	-0.29
Average	0.03	0.01	-0.05	-0.07	-0.06	0.09	0.00	-0.01	0.82	0.53	0.18	0.08	0.14
Maximum	0.60	0.38	0.19	0.85	0.97	2.18	0.07	0.04	4.53	3.60	3.11	1.15	0.92

Note: Difference is Proposed Project minus No-Project.

Table 4-22. Differences in Export DOC (mg/l) between Proposed Project and Simulated No-Project (mg/l) Assuming High Initial-Filling DOC Load (9 g/m²/month)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Flow Weighted Average
1922	0.0	0.0	-0.0	-0.2	-0.1	-0.0	0.0	0.0	-0.0	1.8	0.7	0.6	0.2
1923	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	3.1	0.0	3.5	0.1	0.6
1924	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.1
1925	0.0	0.0	-0.0	0.1	-0.2	1.1	0.0	0.0	3.6	0.1	0.1	0.1	0.4
1926	0.1	0.1	0.1	0.1	-0.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1927	0.0	0.0	0.0	-0.8	-0.0	-0.0	-0.0	0.0	1.5	1.1	0.7	0.0	0.2
1928	0.0	-0.1	0.0	-0.5	0.0	0.0	0.0	0.0	2.2	1.8	0.0	0.1	0.3
1929	0.1	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1930	0.0	0.0	0.0	-0.6	-0.3	0.1	-0.0	-0.0	1.5	0.0	0.0	0.0	-0.0
1931	0.0	0.0	0.0	0.0	0.0	-0.1	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	0.0
1932	0.0	0.0	-0.0	-0.5	-0.0	1.7	0.0	0.0	-0.0	-0.0	-0.0	0.0	0.0
1933	0.0	0.0	0.0	0.0	0.0	0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	0.0
1934	0.0	0.0	-0.0	0.0	-0.0	-0.1	-0.0	-0.0	-0.0	-0.1	-0.0	-0.0	-0.0
1935	-0.0	-0.0	-0.0	-0.0	-0.0	0.0	0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0
1936	-0.0	-0.0	-0.0	-0.0	-0.4	-0.0	-0.0	-0.0	1.7	1.5	0.0	0.0	0.3
1937	0.0	0.0	0.0	0.1	-0.3	0.0	0.0	0.0	1.7	2.0	0.1	0.0	0.3
1938	0.0	0.0	-0.2	0.1	0.0	0.0	0.0	0.0	-0.0	-0.0	-0.0	0.0	-0.0
1939	-0.0	-0.0	-0.0	0.0	-0.0	2.0	0.0	0.0	6.4	2.9	0.1	0.2	1.0
1940	0.2	0.3	0.2	0.3	-0.1	0.0	0.0	0.0	2.0	0.0	2.3	0.1	0.5
1941	0.1	0.1	0.1	-0.1	0.0	0.0	0.0	0.0	-0.0	-0.0	-0.0	0.0	0.0
1942	-0.0	0.0	-0.0	0.0	0.0	-0.0	0.0	0.0	-0.0	-0.0	-0.0	-0.0	-0.0
1943	-0.0	-0.1	-0.0	0.0	0.0	0.0	-0.0	0.0	9.3	7.2	0.2	0.2	1.5
1944	0.2	0.2	0.2	0.4	0.1	0.2	0.1	0.1	1.7	1.1	1.5	0.2	0.5
1945	0.1	0.1	0.1	0.2	-0.1	0.0	0.0	0.0	1.4	0.5	2.1	0.1	0.4
1946	0.1	0.0	-0.1	0.1	0.1	-0.0	0.0	0.0	1.6	0.0	2.3	0.1	0.4
1947	0.1	0.1	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1948	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1949	0.0	0.0	0.0	0.0	0.0	0.0	-0.0	-0.0	1.8	0.0	0.0	0.0	0.2
1950	0.0	0.0	0.0	0.0	-0.3	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1951	0.0	0.0	-0.3	0.0	0.0	-0.0	0.0	-0.0	1.8	0.7	0.0	1.7	0.3
1952	0.0	0.0	-0.4	0.0	0.0	0.0	0.0	0.0	-0.0	-0.0	-0.0	-0.0	-0.0
1953	-0.0	-0.0	-0.0	0.0	-0.0	-0.0	0.0	0.0	3.0	5.3	0.1	0.1	1.0
1954	0.1	0.1	0.1	-0.9	0.1	0.1	0.0	0.0	1.5	0.6	0.0	1.9	0.3
1955	0.1	0.1	-0.3	-0.2	0.2	0.4	0.0	0.0	2.3	0.1	0.1	0.1	0.2
1956	0.1	0.0	0.0	0.9	-0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.1
1957	-0.0	0.3	0.4	-0.0	0.0	-0.0	0.0	0.0	4.6	0.1	2.2	2.3	0.9
1958	0.1	0.1	-0.3	-0.1	0.1	0.0	0.0	0.0	-0.0	-0.0	-0.0	0.0	-0.0
1959	-0.0	0.0	-0.0	0.0	0.0	1.4	0.0	0.0	6.7	4.5	0.1	0.2	1.0
1960	0.2	0.2	0.1	0.3	0.2	0.2	0.1	0.1	0.1	0.1	0.0	0.0	0.1
1961	0.1	0.0	0.0	0.1	-0.1	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.1
1962	0.0	0.0	0.0	0.0	-0.2	0.0	0.0	-0.0	1.9	1.1	0.0	1.0	0.4
1963	0.0	0.0	-0.3	-0.2	0.0	0.1	0.0	0.0	0.4	0.0	0.2	0.2	0.0
1964	0.5	-0.2	0.0	0.0	0.0	-0.0	-0.0	-0.0	5.5	5.1	0.1	0.1	0.8
1965	0.2	0.1	0.1	-0.2	0.1	0.2	0.0	0.0	1.8	0.0	0.0	1.3	0.3
1966	1.3	-0.3	-0.1	0.1	0.1	0.0	0.0	0.0	2.6	2.6	0.1	0.1	0.5
1967	0.1	0.1	-0.6	0.1	0.0	0.0	0.0	0.0	-0.0	-0.0	-0.0	-0.0	-0.0
1968	-0.0	0.0	-0.0	0.0	0.0	-0.0	-0.0	-0.0	6.4	6.0	0.1	0.2	1.1
1969	0.2	0.1	0.1	-0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1970	0.0	0.0	0.0	0.0	0.0	-0.0	0.0	0.0	5.8	4.4	0.1	0.1	1.1
1971	0.1	0.1	0.1	0.2	0.2	0.1	0.1	0.0	1.5	0.0	0.0	0.0	0.2
1972	0.0	0.8	-0.3	0.1	0.1	0.1	0.0	0.0	4.6	3.9	0.1	0.1	0.8
1973	0.1	0.1	-0.3	0.1	0.0	0.0	0.0	0.0	1.8	0.4	2.0	0.0	0.4
1974	0.0	-0.2	0.0	0.0	0.0	0.0	0.0	0.0	1.0	-0.1	-0.0	0.0	0.1
1975	0.0	0.3	0.0	-0.1	0.0	0.0	0.0	0.0	-0.0	0.8	-0.1	0.0	0.1
1976	-0.0	0.0	0.0	0.0	-0.0	5.1	0.1	0.1	9.8	0.3	0.2	0.2	1.4
1977	0.2	0.2	0.2	0.5	0.5	0.4	0.2	-0.6	0.1	0.1	0.1	0.1	0.2
1978	0.1	0.1	0.0	0.1	-0.2	-0.0	0.0	0.0	0.0	-0.0	-0.0	0.0	-0.0
1979	-0.0	0.0	0.0	0.0	1.0	-0.0	0.0	0.0	0.0	5.0	6.0	0.1	1.0
1980	0.1	0.1	-0.3	-0.0	0.0	0.0	0.0	0.0	1.6	2.2	0.0	0.1	0.3
1981	0.0	0.1	0.1	-0.6	0.1	0.1	0.0	0.0	1.9	2.2	0.1	0.1	0.4
1982	0.1	0.0	-0.1	0.1	0.0	0.0	0.0	0.0	-0.0	-0.0	-0.0	-0.0	0.0
1983	-0.0	-0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.0	-0.0	-0.0	-0.0
1984	0.0	0.0	0.0	0.0	0.0	-0.0	0.0	0.0	8.3	4.4	2.4	0.2	2.0
1985	0.2	0.2	-0.2	0.3	-0.0	0.3	0.1	0.1	2.5	2.3	0.1	0.1	0.4
1986	0.1	0.1	0.1	-0.5	0.0	0.0	0.0	0.0	1.5	2.1	0.1	0.0	0.3
1987	0.0	0.1	0.0	0.1	-0.3	0.1	0.0	0.0	2.6	0.1	0.0	0.1	0.2
1988	0.1	0.1	0.0	-0.8	-0.9	0.3	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.2
1989	0.0	0.0	0.0	0.0	-0.0	0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	0.0
1990	-0.0	-0.0	-0.0	0.0	0.0	0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0
1991	-0.0	-0.0	0.0	-0.0	-0.1	0.1	-0.0	-0.1	-0.1	-0.1	-0.0	-0.0	-0.0
1992	-0.0	-0.0	-0.0	-0.0	-0.0	0.1	-0.0	-0.1	-0.0	-0.1	-0.1	-0.0	-0.0
1993	-0.0	-0.0	-0.0	-0.2	-0.0	0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0
1994	-0.0	-0.0	-0.0	0.0	-0.2	-0.0	-0.0	-0.0	3.6	7.6	0.1	0.2	0.9
Minimum	-0.03	-0.32	-0.58	-0.94	-0.94	-0.07	-0.04	-0.60	-0.06	-0.07	-0.08	-0.03	-0.18
Average	0.07	0.05	-0.02	-0.03	-0.02	0.22	0.01	0.00	1.70	1.11	0.38	0.17	0.33
Maximum	1.26	0.79	0.36	0.86	0.97	5.14	0.19	0.11	9.83	7.56	5.98	2.35	1.96

Note: Difference is Proposed Project minus No-Project.

Table 4-23. Differences in Estimated THM Concentrations between Proposed Project and No-Project (µg/l)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Flow Weighted Average
1922	0.0	0.0	0.0	-1.2	-1.9	-0.1	0.0	0.1	-0.3	2.8	0.9	0.7	-0.06
1923	0.0	0.0	-2.3	0.0	-0.1	0.1	0.0	0.1	5.5	-0.0	5.5	0.1	0.57
1924	0.1	0.2	0.1	0.3	0.1	-0.6	-0.3	-0.5	-0.3	-0.6	-0.8	-0.2	0.02
1925	0.0	0.1	-0.5	0.3	-3.8	13.4	0.0	0.1	19.9	0.3	0.3	0.3	1.64
1926	0.5	0.5	0.3	0.5	-7.3	1.8	-0.0	-0.0	-0.1	-0.3	-0.1	-0.2	-0.73
1927	-0.0	-0.0	0.0	-10.7	-0.5	-0.3	-0.0	0.0	3.6	2.5	1.1	-0.0	-0.67
1928	0.0	-0.3	0.5	-7.1	-0.2	0.2	-0.1	-0.2	3.9	3.7	-0.1	-0.1	-0.22
1929	0.0	0.0	0.0	0.2	-0.0	-0.7	-0.2	-0.3	-0.3	-0.6	-0.7	-0.2	-0.09
1930	-0.0	-0.0	0.0	-7.2	-3.5	0.5	-0.5	-0.6	2.6	-0.5	-0.3	-0.4	-1.15
1931	-0.2	-0.2	-0.1	-0.1	-0.1	-1.7	-0.8	-0.7	-0.9	-1.1	-0.7	-0.4	-0.35
1932	-0.2	-0.2	-0.4	-5.0	-0.1	0.6	-0.1	-0.1	-0.3	-0.5	-0.3	-0.2	-1.05
1933	-0.1	-0.1	-0.0	-0.0	-0.2	0.1	-0.2	-0.3	-0.7	-0.9	-0.6	-0.2	-0.12
1934	-0.1	-0.0	0.0	0.1	-0.2	-1.1	-0.4	-0.8	-0.4	-0.9	-0.7	-0.3	-0.23
1935	-0.1	-0.1	-0.0	-0.0	-0.3	0.5	0.3	-0.1	-0.2	-0.2	-0.4	-0.3	-0.05
1936	-0.2	-0.2	-0.1	-0.1	-5.3	-0.4	-0.1	-0.0	8.2	6.0	0.1	0.1	0.43
1937	0.2	0.2	0.2	0.3	-5.5	0.0	0.0	0.0	9.2	8.9	0.2	0.2	0.68
1938	0.2	0.1	-2.8	0.2	0.0	0.0	0.0	0.0	-0.5	-0.1	-0.1	-0.1	-0.30
1939	-0.2	0.1	-0.2	0.0	-0.2	0.7	-0.0	-0.1	9.0	4.2	0.1	0.3	1.01
1940	0.4	0.5	0.5	0.4	-2.9	-0.2	0.0	0.0	11.3	0.1	10.1	0.2	1.49
1941	0.3	0.2	0.1	-1.9	-0.0	0.0	0.0	0.0	-0.2	-0.1	0.0	0.2	-0.17
1942	0.0	0.1	-0.2	0.0	0.0	-0.2	0.2	0.0	-0.5	-0.1	-0.1	-0.1	-0.08
1943	-0.0	-0.4	-0.1	0.0	0.0	0.0	-0.0	0.0	20.0	15.5	0.4	0.4	2.69
1944	0.4	0.5	0.4	0.9	-4.8	-0.2	0.2	0.1	7.6	4.1	3.8	0.4	1.23
1945	0.5	0.3	0.2	0.5	-3.4	-0.5	0.0	0.0	6.6	1.7	5.7	0.1	0.79
1946	0.2	0.1	-2.7	0.2	-0.8	-0.9	0.1	0.1	4.9	-0.0	4.9	0.1	0.39
1947	0.2	0.2	0.1	0.4	0.4	0.2	-0.1	-0.2	-0.3	-0.3	-0.1	-0.1	0.08
1948	-0.0	0.0	0.1	-0.0	-0.3	0.2	-0.0	0.0	-0.1	-0.1	-0.1	-0.1	-0.03
1949	-0.0	-0.0	0.0	0.2	0.3	-0.1	-0.2	-0.3	5.7	-0.1	-0.2	-0.1	0.41
1950	-0.0	0.0	0.0	0.1	-4.6	2.6	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.34
1951	-0.1	-0.0	-4.6	-0.0	-0.0	-0.2	-0.0	-0.0	1.8	1.1	-0.0	2.9	-0.02
1952	0.0	0.0	-5.3	-0.1	-0.1	0.0	0.0	0.0	-0.4	-0.1	-0.1	-0.1	-0.61
1953	-0.0	-0.1	-0.5	-0.0	-0.1	-0.2	-0.0	0.0	6.9	11.8	0.1	0.2	1.79
1954	0.2	0.2	0.2	-12.8	-0.2	0.3	-0.0	-0.1	2.4	1.1	-0.1	3.6	-0.47
1955	0.0	0.0	-3.4	-3.8	-1.1	-2.5	-0.2	-0.2	4.3	-0.2	-0.2	-0.1	-0.86
1956	-0.0	0.0	-0.1	10.0	0.1	-0.0	0.1	0.2	0.6	-0.0	-0.0	-0.0	1.18
1957	-0.1	1.5	1.3	-0.1	-0.2	-0.1	-0.0	0.1	11.5	0.1	5.7	6.2	2.20
1958	0.2	0.2	-2.7	-3.6	-0.1	-0.1	0.0	0.0	-0.4	-0.1	-0.1	-0.0	-0.66
1959	-0.1	0.0	-0.0	-0.1	-0.1	1.2	-0.1	-0.1	11.8	7.7	0.1	0.2	1.36
1960	0.3	0.3	0.2	0.6	0.4	0.2	0.0	-0.0	0.0	-0.2	-0.1	-0.0	0.19
1961	0.1	0.1	0.1	0.2	-2.0	2.2	-0.2	-0.3	-0.1	-0.3	-0.1	-0.1	-0.07
1962	0.0	0.0	0.0	0.2	-3.0	-0.0	-0.0	-0.1	11.6	5.3	0.1	3.5	1.29
1963	0.1	0.1	-3.3	-2.7	0.1	0.5	0.1	-0.0	0.7	-0.1	0.2	0.1	-0.39
1964	0.8	-2.5	0.3	-0.1	-0.1	-0.4	-0.2	-0.3	9.0	8.0	0.1	0.1	0.77
1965	0.2	0.2	-0.0	-3.8	0.0	-0.1	0.1	0.1	3.2	0.0	0.0	2.8	0.06
1966	2.5	-3.1	-1.5	0.2	0.1	-0.2	0.0	-0.1	5.6	5.4	0.0	0.1	0.41
1967	0.2	0.1	-7.9	-0.1	-0.1	0.1	0.0	0.0	-0.6	-0.2	-0.1	-0.1	-0.81
1968	-0.1	-0.0	-0.4	-0.1	-0.0	-0.3	-0.1	-0.2	11.2	10.4	0.1	0.2	1.36
1969	0.3	0.2	0.1	-5.3	0.0	0.0	0.0	0.0	0.0	-0.1	-0.0	-0.0	-0.56
1970	-0.0	-0.1	-0.1	0.0	0.0	-0.1	0.0	0.0	9.5	7.9	0.2	0.3	1.46
1971	0.3	0.2	-1.2	0.4	-0.8	-0.3	0.1	0.1	2.8	0.0	0.0	0.0	0.12
1972	0.1	1.5	-1.3	0.7	-0.0	0.2	-0.1	-0.1	9.2	7.8	0.1	0.2	1.22
1973	0.3	0.1	-4.7	-0.2	0.0	0.1	0.0	0.0	4.9	1.0	4.4	0.0	0.33
1974	0.1	-3.1	-0.1	0.1	-0.0	0.1	0.0	0.1	3.0	-0.5	0.1	0.1	-0.04
1975	0.1	0.6	0.0	-1.2	-0.0	0.0	-0.1	-0.0	-0.5	1.6	-0.1	0.2	0.08
1976	-0.1	0.0	0.0	-0.1	-0.6	7.2	-0.1	-0.3	18.4	0.1	0.2	0.3	1.75
1977	0.4	0.5	0.5	1.2	0.2	-1.0	-0.2	-9.8	-0.6	-0.9	-0.6	-0.4	0.05
1978	-0.1	-0.1	-0.0	-0.2	-3.1	-0.9	0.0	0.0	-0.1	-0.3	-0.2	-0.1	-0.60
1979	-0.1	-0.1	-0.1	-0.1	11.6	-0.1	0.1	0.1	0.0	15.6	17.5	0.4	3.23
1980	0.4	0.4	-1.2	-1.2	0.0	0.0	0.1	0.0	4.0	4.9	0.0	0.0	0.42
1981	0.1	0.2	0.1	-11.1	-0.2	0.4	-0.1	-0.3	3.5	3.3	-0.1	-0.0	-0.29
1982	0.0	0.0	-2.1	-0.0	-0.0	0.0	0.0	0.0	-0.4	-0.2	-0.1	-0.1	-0.27
1983	-0.1	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.2	-0.1	-0.2	-0.08
1984	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.1	14.8	8.1	4.4	0.3	3.16
1985	0.4	0.2	-3.4	1.0	-2.9	1.1	0.0	-0.0	1.7	1.6	-0.0	0.0	-0.16
1986	0.1	0.1	0.1	-7.8	0.0	0.0	0.0	0.0	3.8	5.6	-0.0	0.0	-0.19
1987	0.0	0.1	0.1	0.2	-4.4	0.7	-0.3	-0.5	6.3	-0.2	-0.1	-0.1	0.10
1988	0.0	0.0	0.0	-10.3	-15.4	-8.1	-1.1	-1.4	-0.7	-0.8	-1.1	-0.8	-3.58
1989	-0.5	-0.4	-0.3	-0.3	-1.5	0.1	-0.4	-0.7	-0.5	-0.5	-0.3	-0.3	-0.33
1990	-0.2	-0.2	-0.1	-0.0	0.1	-0.1	-0.5	-0.7	-0.4	-0.6	-0.7	-0.3	-0.23
1991	-0.1	-0.1	-0.1	-0.7	-1.3	0.8	-0.4	-0.9	-1.1	-1.3	-0.9	-0.5	-0.14
1992	-0.2	-0.3	-0.2	-0.1	-0.1	0.8	-0.5	-1.0	-0.6	-1.0	-1.4	-0.6	-0.17
1993	-0.3	-0.3	-0.5	-2.8	-0.2	0.1	-0.0	0.0	-0.4	-0.2	-0.1	-0.1	-0.51
1994	-0.1	-0.1	-0.0	0.0	-2.0	-0.1	-0.3	-0.3	9.4	19.8	0.2	0.3	1.65
Minimum	-0.5	-3.1	-7.9	-12.8	-15.4	-8.1	-1.1	-9.8	-1.1	-1.3	-1.4	-0.8	-3.6
Average	0.1	-0.0	-0.7	-1.1	-1.0	0.2	-0.1	-0.3	3.8	2.2	0.8	0.3	0.28
Maximum	2.5	1.5	1.3	10.0	11.6	13.4	0.3	0.2	20.0	19.8	17.5	6.2	3.2

Note: Difference is Proposed Project minus No-Project.

Table 4-24. Comparison between Delta Wetlands Project Impacts on Water Quality in the 1995 DEIR/EIS and the 2000 REIR/EIS

Impacts and Mitigation Measures of 1995 DEIR/EIS Alternatives 1 and 2	Comparison between 1995 DEIR/EIS and 2000 REIR/EIS
CHAPTER 3C. WATER QUALITY	
Impact C-1: Salinity (EC) Increase at Chipps Island during Months with Applicable EC Objectives (S) • **Mitigation Measure C-1:** Restrict DW Diversions to Limit EC Increases at Chipps Island (LTS)	**Salinity Increase at Chipps Island.** As a result of incorporating the FOC terms into proposed project operations, estimated project effects on EC concentrations at Chipps Island are less than those reported in the 1995 DEIR/EIS. Simulated changes in EC concentrations do not exceed the significance criteria. Therefore, this impact is considered less than significant, and no mitigation is required. (LTS)
Impact C-2: Salinity (EC) Increase at Emmaton during April-August (S) • **Mitigation Measure C-2:** Restrict DW Diversions to Limit EC Increases at Emmaton (LTS) **Impact C-3:** Salinity (EC) Increase at Jersey Point during April-August (S) • **Mitigation Measure C-3:** Restrict DW Diversions to Limit EC Increases at Jersey Point (LTS)	**Salinity Increase at Emmaton and Jersey Point.** Estimated effects of project diversions on EC at these locations are less than those reported in the 1995 DEIR/EIS. The EC significance criterion of a 20% change from No-Project Alternative conditions would still be exceeded; such exceedances would be infrequent. As reported in the 1995 DEIR/EIS, this impact is considered significant. (S) The same mitigation is recommended to reduce this impact to a less-than-significant level. (LTS)
Impact C-4: Salinity (Chloride) Increase in Delta Exports (S) • **Mitigation Measure C-4:** Restrict DW Diversions or Discharges to Limit Chloride Concentrations in Delta Exports (LTS)	**Salinity Increase in Delta Exports.** As a result of incorporating the FOC terms into proposed project operations, estimated project effects on EC concentrations at these locations are less than those reported in the 1995 DEIR/EIS. Simulated changes in EC concentrations do not exceed the significance criteria. Therefore, this impact is considered less than significant, and no mitigation is required. (LTS)

Note: S = Significant; SU = Significant and unavoidable; LTS = Less than significant; B = Beneficial.

Table 4-24. Continued

Impacts and Mitigation Measures of 1995 DEIR/EIS Alternatives 1 and 2	Comparison between 1995 DEIR/EIS and 2000 REIR/EIS
Impact C-5: Elevated DOC Concentrations in Delta Exports (CCWD Rock Slough, SWP Banks, CVP Tracy) (S) • **Mitigation Measure C-5:** Restrict DW Discharges to Prevent DOC Increases of Greater Than 0.8 mg/l in Delta Exports (LTS)	**Increases in DOC Concentrations in Delta Exports.** Changes in DOC concentrations of greater than 0.8 mg/l were simulated under the initial-fill and long-term DOC loading assumptions. As reported in the 1995 DEIR/EIS, this impact is considered significant. (S) The same mitigation is recommended to reduce the impact to a less-than-significant level. (LTS)
Impact C-6: Elevated THM Concentrations in Treated Drinking Water from Delta Exports (CCWD Rock Slough, SWP Banks, CVP Tracy) (S) • **Mitigation Measure C-6:** Restrict DW Discharges to Prevent Increases of More Than 20 μg/l in THM Concentrations or THM Concentrations of Greater than 90 μg/l in Treated Delta Export Water (LTS)	**Increase in THM Concentrations in Treated Drinking Water.** Where project operations were simulated to result in monthly increases of THM concentrations in treated water, the increases were almost always less than the criterion of 16 μg/l. These results are similar to those predicted in the 1995 DEIR/EIS in which the largest monthly increase was less than the previous criterion of 20 μg/l. Effects on THM concentrations are considered a significant impact because the 20% change threshold would be exceeded in some months. (S) The mitigation measure has been revised to reflect the new standards for THM. Implementation would be the same as described in the 1995 DEIR/EIS except for the difference in the numerical thresholds: • Restrict Delta Wetlands Discharges to Prevent Increases of More Than 16 μg/l in THM Concentrations or THM Concentrations of Greater than 72 μg/l in Treated Delta Export Water (LTS)
Impact C-7: Changes in Other Water Quality Variables in Delta Channel Receiving Waters (S) • **Mitigation Measure C-7:** Restrict DW Discharges to Prevent Adverse Changes in Delta Channel Water Quality (LTS)	These effects were not reassessed in the REIR/EIS. Project effects on temperature and dissolved oxygen have been addressed through the Endangered Species Act consultation process, and no new information on other variables (e.g., suspended sediment and chlorophyll) has been presented.

Note: S = Significant; SU = Significant and unavoidable; LTS = Less than significant; B = Beneficial.

Table 4-24. Continued

Impacts and Mitigation Measures of 1995 DEIR/EIS Alternatives 1 and 2	Comparison between 1995 DEIR/EIS and 2000 REIR/EIS
Impact C-8: Potential Contamination of Stored Water by Pollutant Residues (S) • **Mitigation Measure C-8:** Conduct Assessments of Potential Contamination Sites and Rededicate as Necessary (LTS)	This potential project effect was not reassessed in the REIR/EIS. The impact and mitigation remain the same as presented in the 1995 DEIR/EIS.
Cumulative Impacts	
Impact C-17: Salinity (EC) Increase at Chipps Island during Months with Applicable EC Objectives under Cumulative Conditions (S) • **Mitigation Measure C-1:** Restrict DW Diversions to Limit EC Increases at Chipps Island (LTS) **Impact C-18:** Salinity (EC) Increase at Emmaton during April-August under Cumulative Conditions (S) • **Mitigation Measure C-2:** Restrict DW Diversions to Limit EC Increases at Emmaton (LTS) **Impact C-19:** Salinity (EC) Increase at Jersey Point during April-August under Cumulative Conditions (S) • **Mitigation Measure C-3:** Restrict DW Diversions to Limit EC Increases at Jersey Point (LTS) **Impact C-20:** Salinity (Chloride) Increase in Delta Exports under Cumulative Conditions (S) • **Mitigation Measure C-4:** Restrict DW Diversions or Discharges to Limit Chloride Concentrations in Delta Exports (LTS)	**Increase in Salinity under Cumulative Conditions.** The proposed project would be operated in fewer years under cumulative conditions than under existing conditions because of limited availability of water for Delta Wetlands diversions. However, it is assumed under the cumulative future scenario that export pumping capacity at Banks Pumping Plant would be greater. Therefore, simulated exports are greater in several years than under the proposed project. Changes in water quality conditions under cumulative future conditions would be similar to those described for the proposed project and therefore would be smaller than the changes described for cumulative conditions in the 1995 DEIR/EIS. Changes in project operations resulting from the FOC terms reduce the impact on salinity at Chipps Island and in Delta exports to less-than-significant levels. (LTS) Effects on EC at Emmaton and Jersey Point are still considered a significant impact. (S) The same mitigation is recommended to reduce these impacts to less-than-significant levels. (LTS)

Note: S = Significant; SU = Significant and unavoidable; LTS = Less than significant; B = Beneficial.

Table 4-24. Continued

Impacts and Mitigation Measures of 1995 DEIR/EIS Alternatives 1 and 2	Comparison between 1995 DEIR/EIS and 2000 REIR/EIS
Impact C-21: Elevated DOC Concentrations in Delta Exports (CCWD Rock Slough, SWP Banks, CVP Tracy) under Cumulative Conditions (S)	**Increase in DOC Concentrations in Delta Exports under Cumulative Conditions.** Because DOC loads are proportional to period of storage, it is possible that DOC loads under cumulative conditions could be somewhat less than for the proposed project because greater export pumping capacity would provide more frequent opportunities for discharge of Delta Wetlands Project water. However, as reported in the 1995 DEIR/EIS, the significance criteria would be exceeded in some years, so the impact is considered significant. (S)
• **Mitigation Measure C-5:** Restrict DW Discharges to Prevent DOC Increases of Greater Than 0.8 mg/l in Delta Exports (LTS)	The same mitigation is recommended to reduce the impact to a less-than-significant level. (LTS)
Impact C-22: Elevated THM Concentrations in Treated Drinking Water from Delta Exports (CCWD Rock Slough, SWP Banks, CVP Tracy) under Cumulative Conditions (S) • **Mitigation Measure C-6:** Restrict DW Discharges to Prevent Increases of More Than 20 μg/l in THM Concentrations or THM Concentrations of Greater than 90 μg/l in Treated Delta Export Water (LTS)	**Increase in THM Concentrations in Treated Drinking Water under Cumulative Conditions.** Changes would be similar to those described for the proposed project. Because DOC loads are proportional to period of storage, it is possible that DOC loads under cumulative conditions could be somewhat less than for the proposed project and that changes in THM concentrations in treated water would be less than for the proposed project. However, the impact is significant. (S) • Restrict Delta Wetlands Discharges to Prevent Increases of More Than 16 μg/l in THM Concentrations or THM Concentrations of Greater than 72 μg/l in Treated Delta Export Water (LTS)
Impact C-23: Changes in Other Water Quality Variables in Delta Channel Receiving Waters under Cumulative Conditions (S) • **Mitigation Measure C-7:** Restrict DW Discharges to Prevent Adverse Changes in Delta Channel Water Quality (LTS)	See discussion of Impact C-7 above.

Note: S = Significant; SU = Significant and unavoidable; LTS = Less than significant; B = Beneficial.

Impacts and Mitigation Measures of 1995 DEIR/EIS Alternatives 1 and 2	Comparison between 1995 DEIR/EIS and 2000 REIR/EIS
Impact C-24: Increase in Pollutant Loading in Delta Channels (SU) • **Mitigation Measure C-9:** Clearly Post Waste Discharge Requirements, Provide Waste Collection Facilities, and Educate Recreationists regarding Illegal Discharges of Waste (SU)	No change from 1995 DEIR/EIS.

Notes:

Impacts C-9 through C-16 of the 1995 DEIR/EIS describe impacts of Alternative 3, the four-reservoir-island alternative. There is no change to the assessment of Alternative 3; therefore, the impacts and mitigation measures have not changed.

S = Significant; SU = Significant and unavoidable; LTS = Less than significant; B = Beneficial.

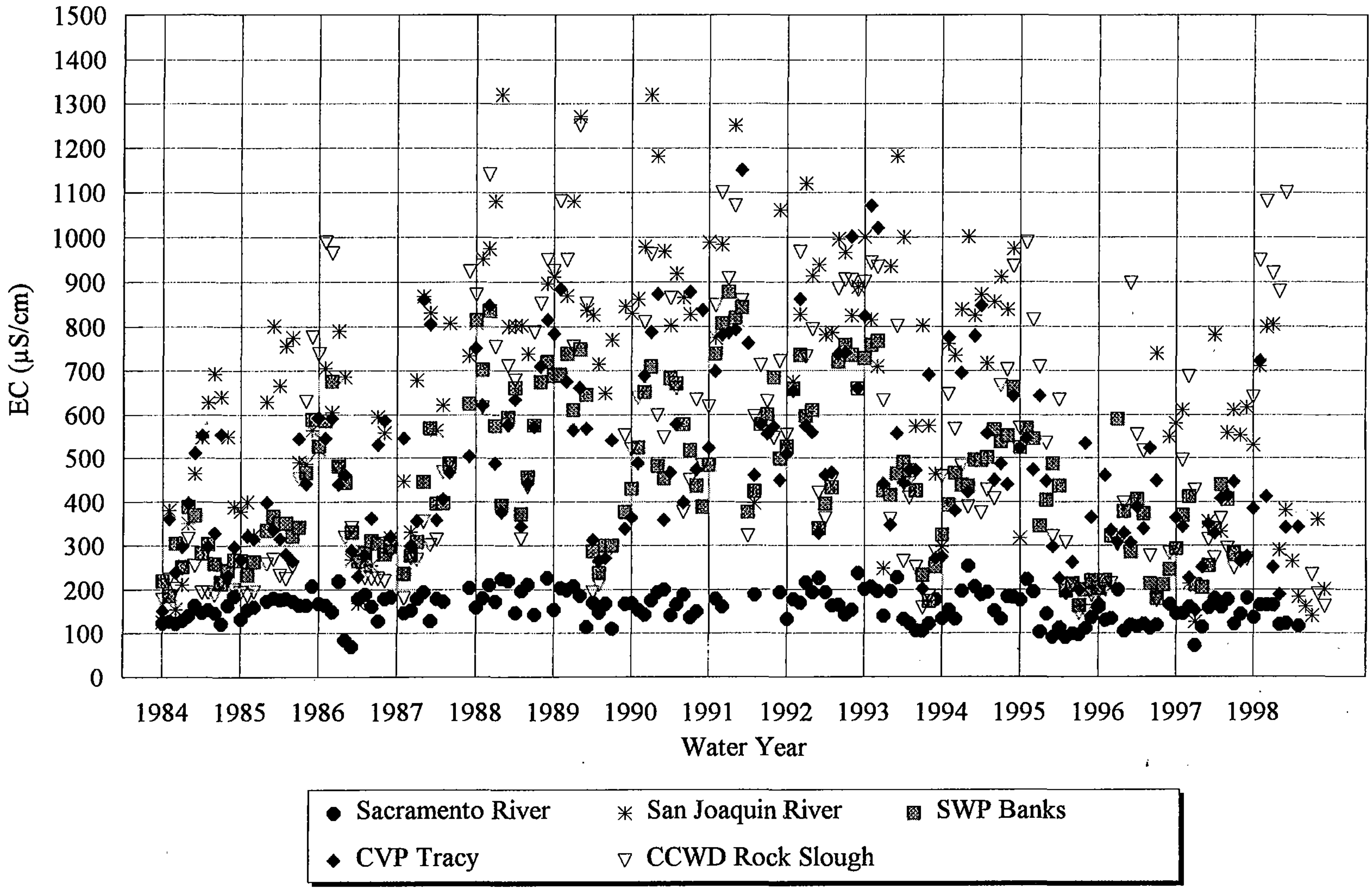

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Figure 4-1
1984-1998 MWQI Monthly EC Values from the Sacramento and San Joaquin Rivers and at Delta Export Locations

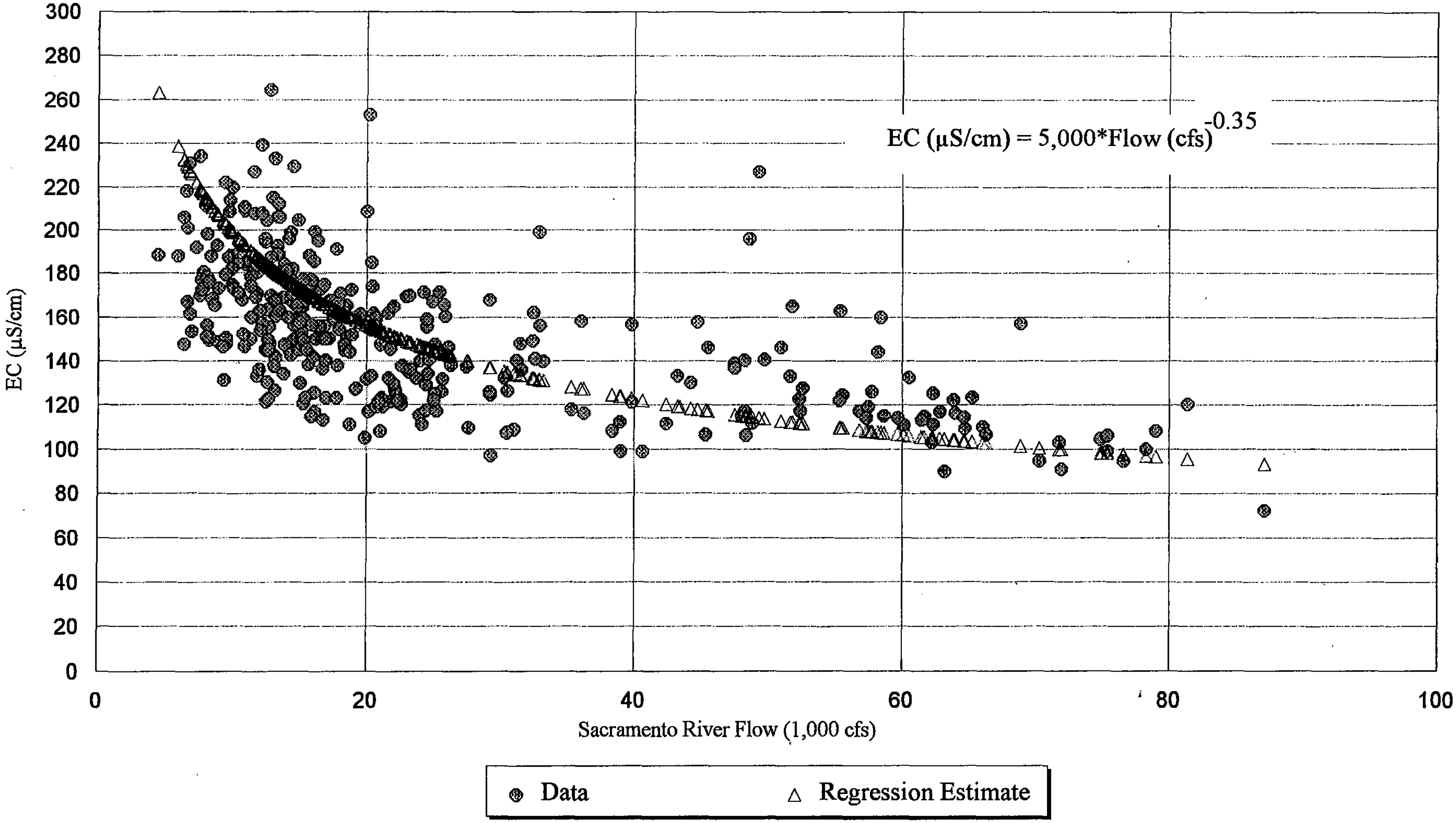

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Figure 4-2
Relationship between Measured Mean Monthly EC at Greene's Landing and Sacramento River Flow for 1968-1998

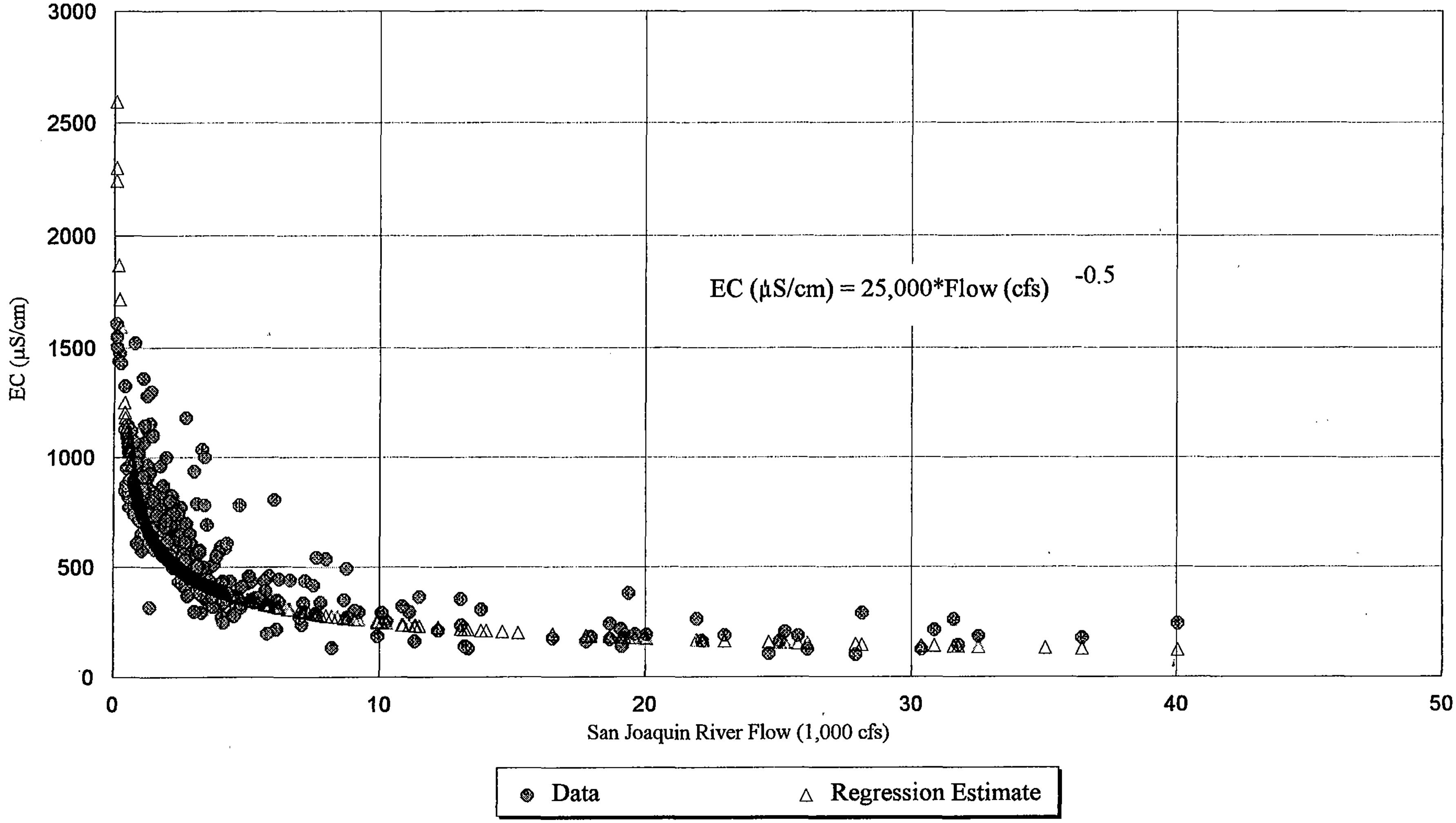

Figure 4-3
Relationship between Measured Mean Monthly EC at Vernalis and San Joaquin River Flow for 1968-1998

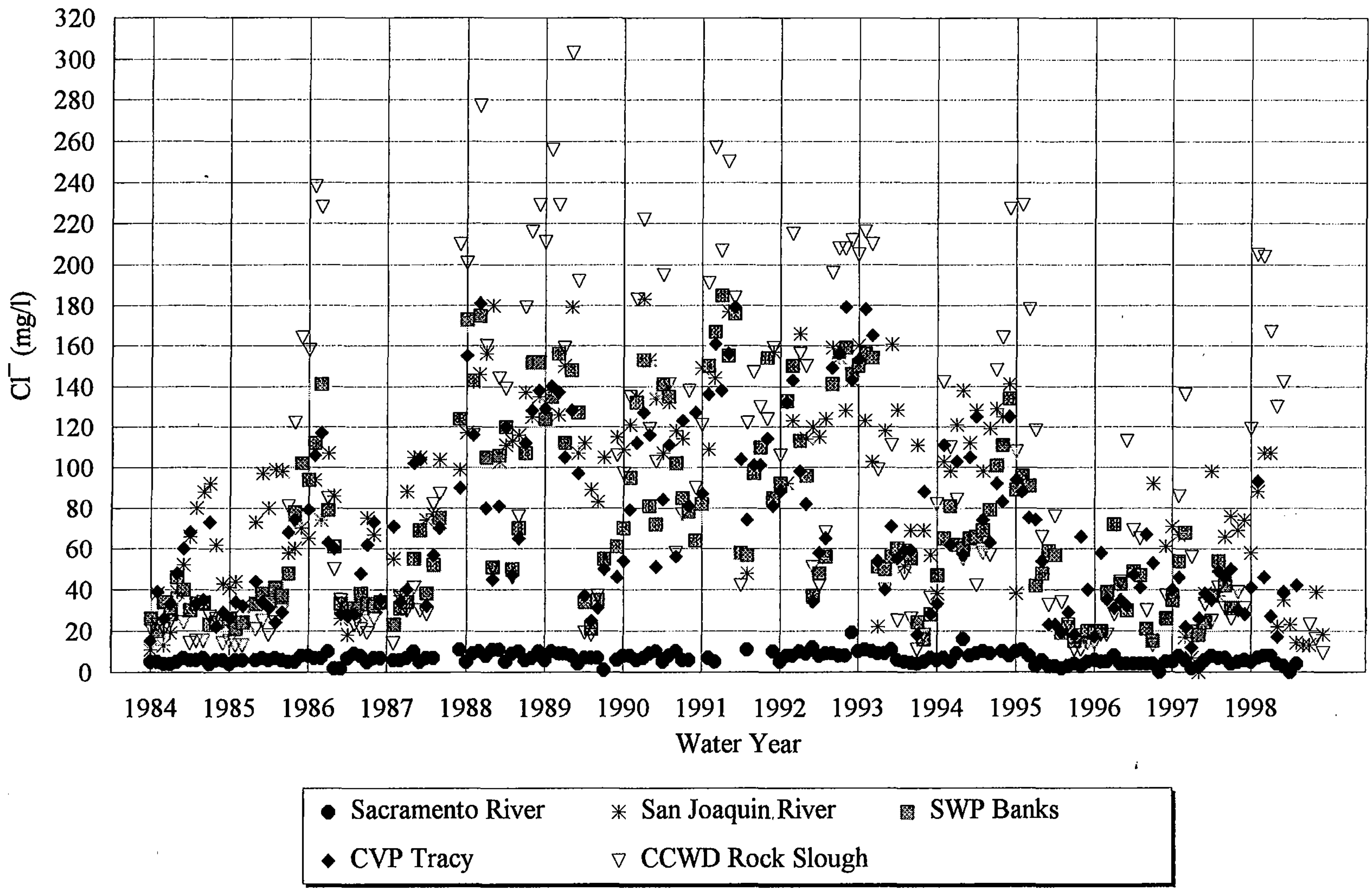

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Figure 4-4
1984-1998 MWQI Monthly Cl^- Values from the Sacramento and San Joaquin Rivers and at Delta Export Locations

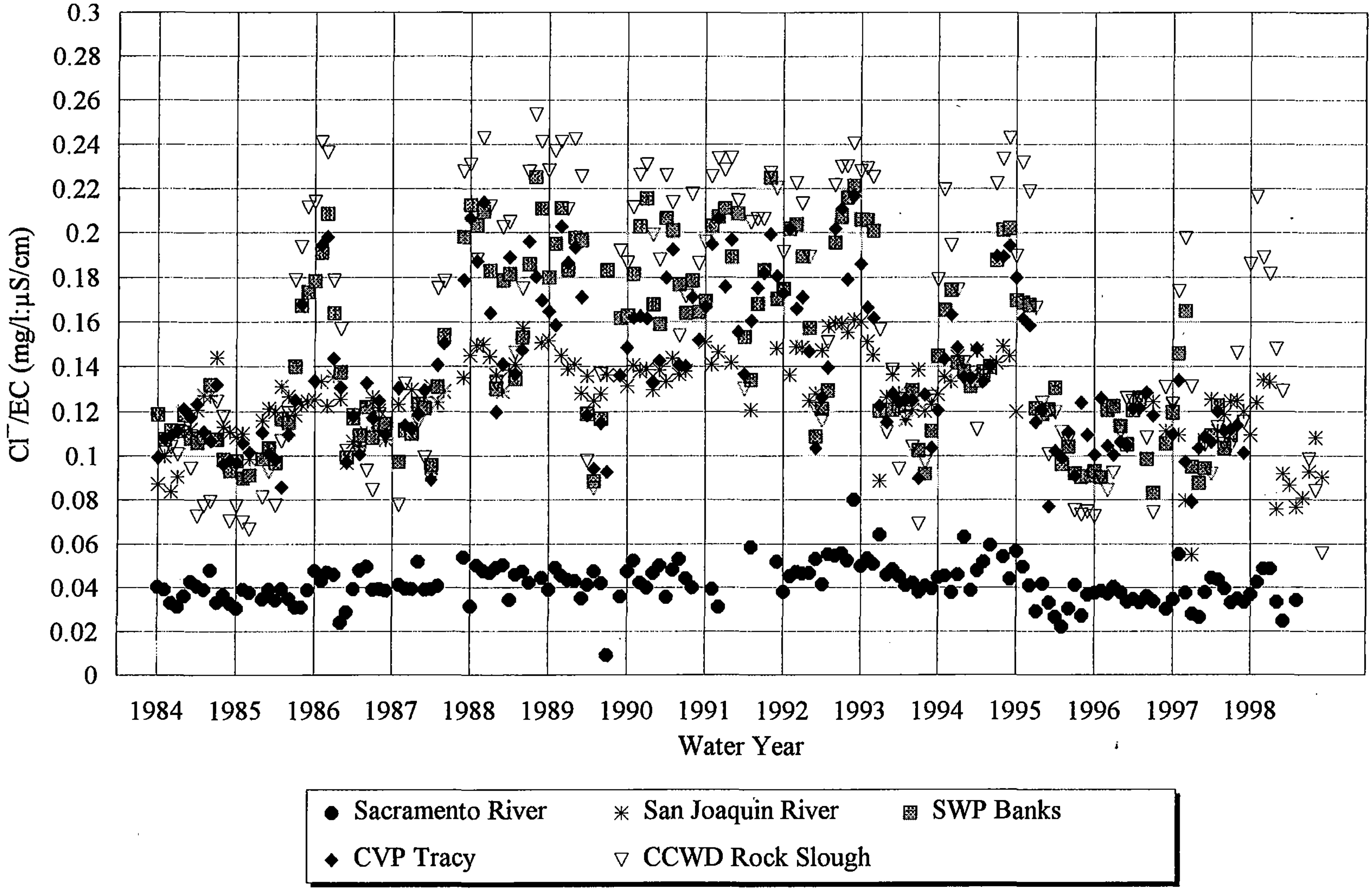

Figure 4-5
1984-1998 MWQI Monthly Cl^- :EC Ratio Values from the Sacramento and San Joaquin Rivers and at Delta Export Locations

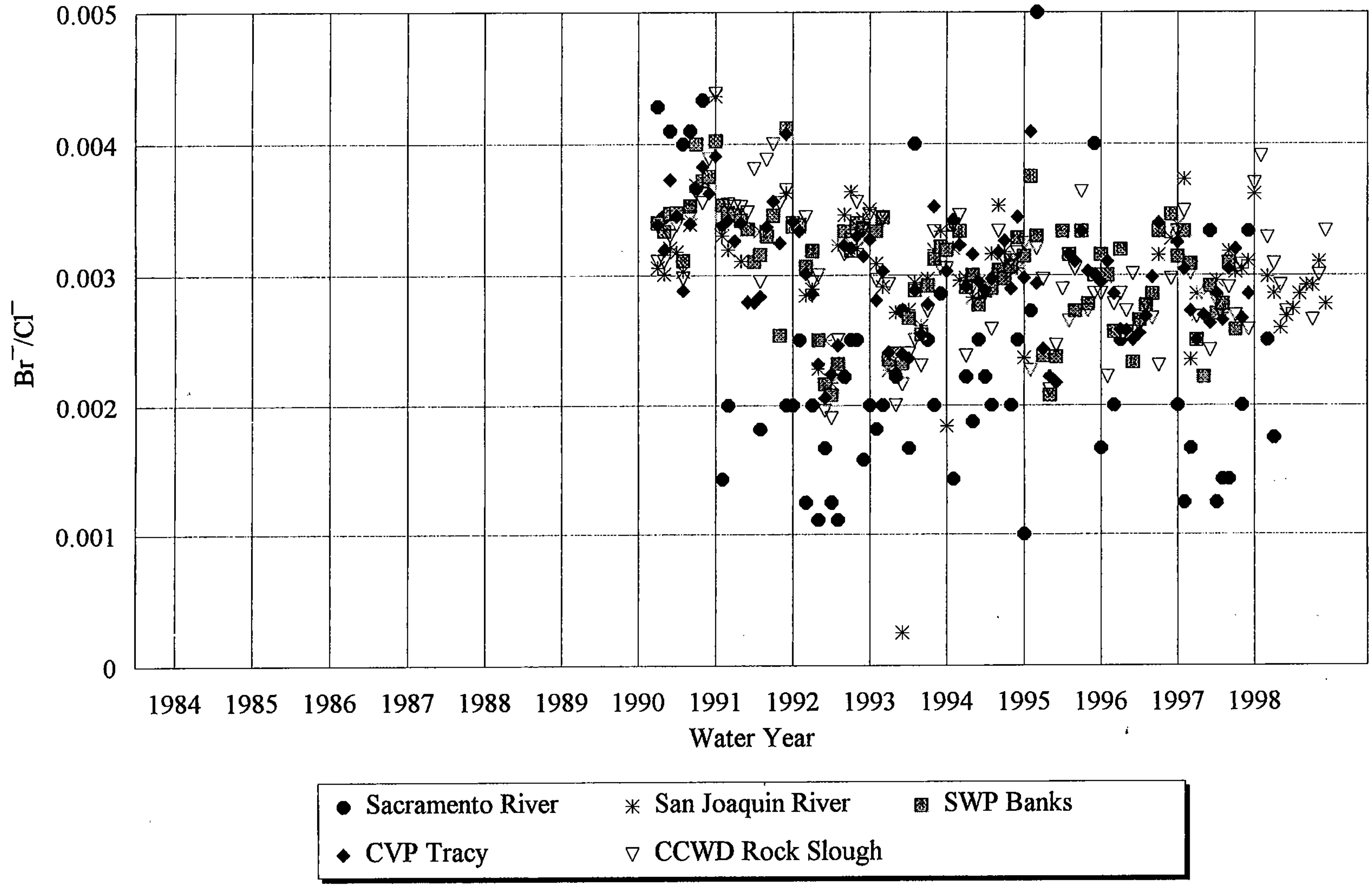

Figure 4-6
1984-1998 MWQI Monthly Br^-:Cl^- Ratio Values from the Sacramento and San Joaquin Rivers and at Delta Export Locations

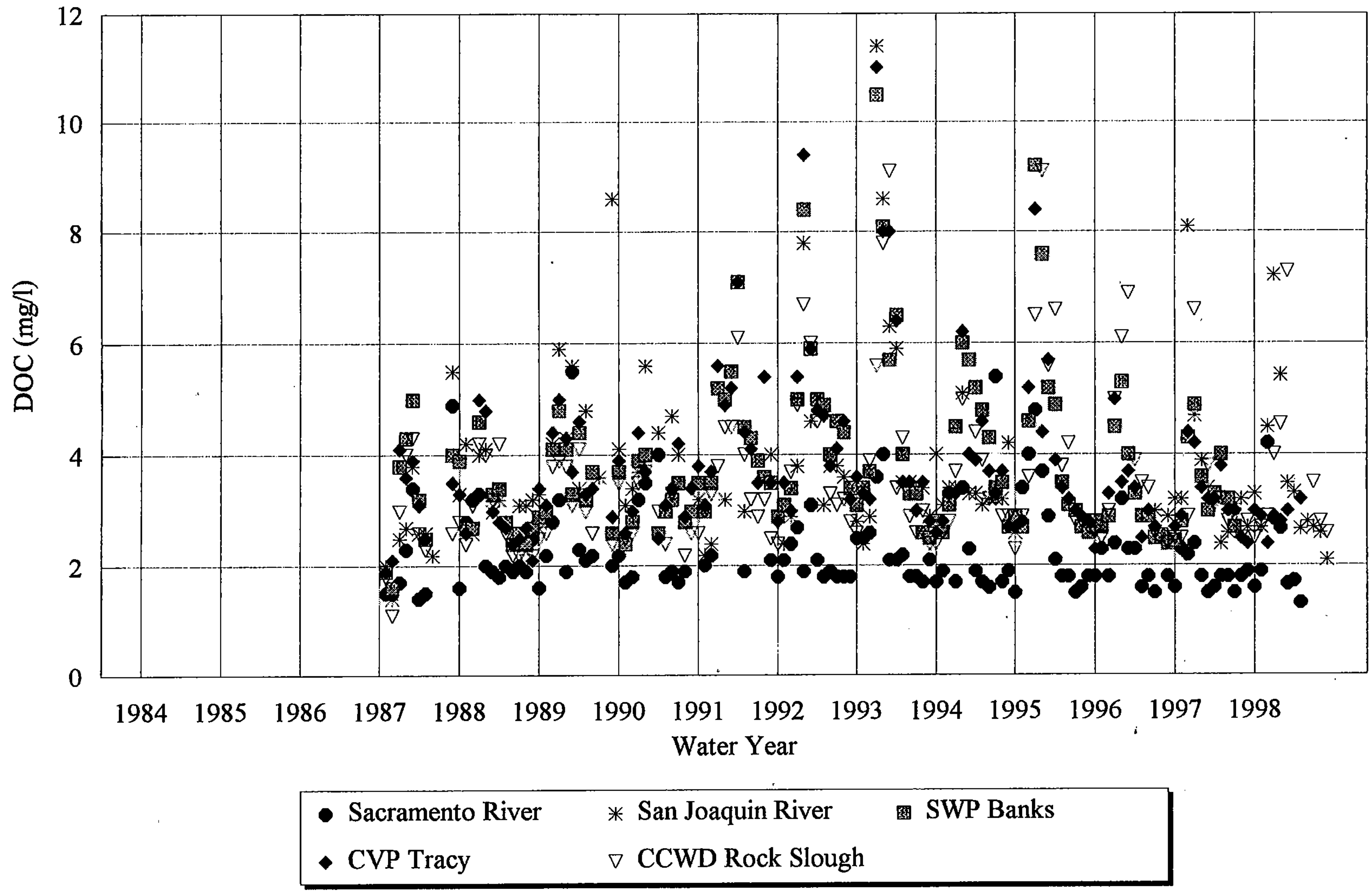

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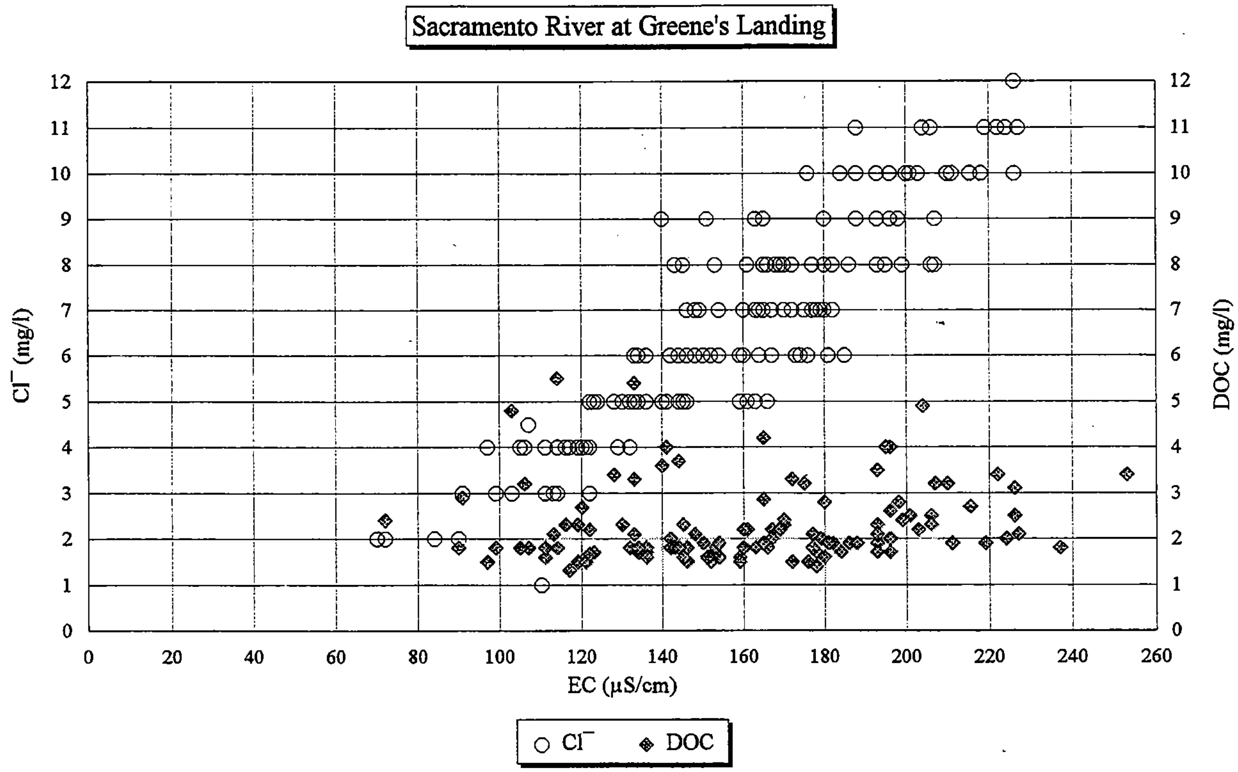
Figure 4-7
1984-1998 MWQI Monthly DOC Values from the Sacramento and San Joaquin Rivers and at Delta Export Locations



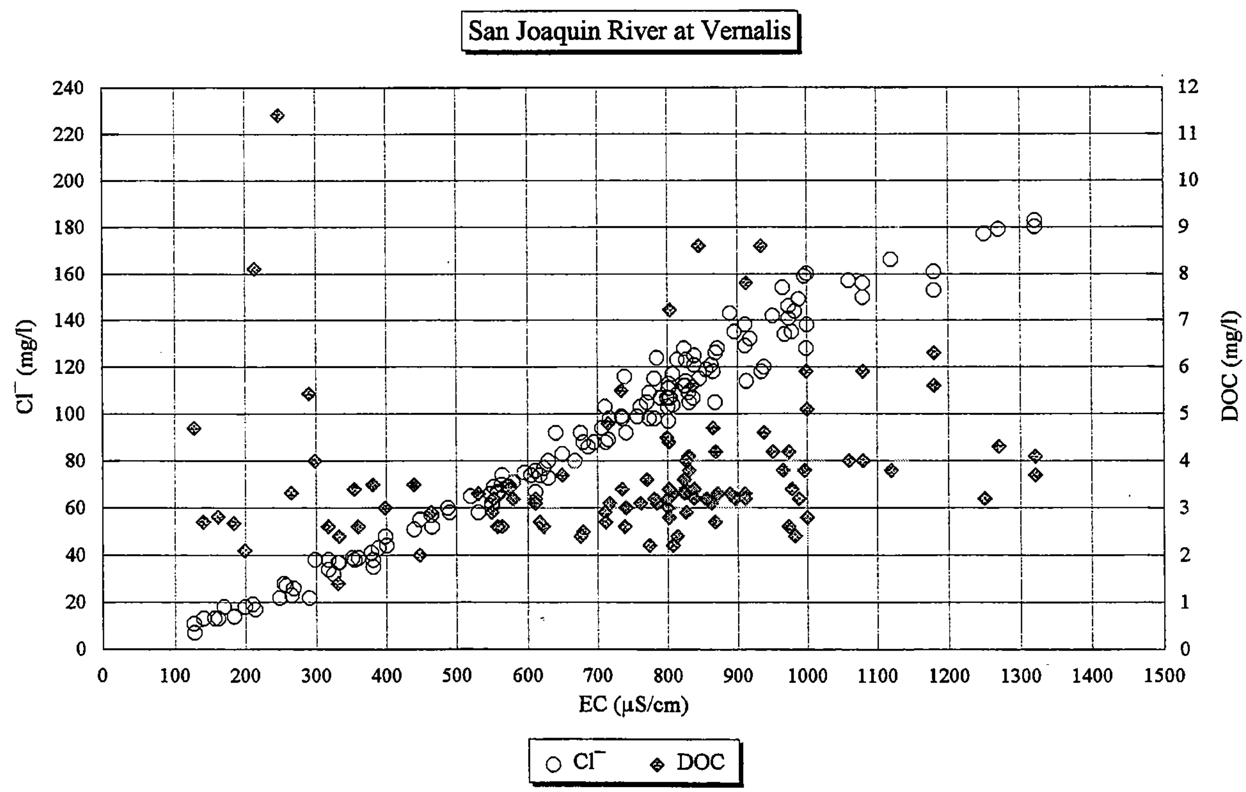


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Figure 4-8
DOC and Cl^- Compared to EC Values in 1984-1998 Monthly Sacramento and San Joaquin River Samples

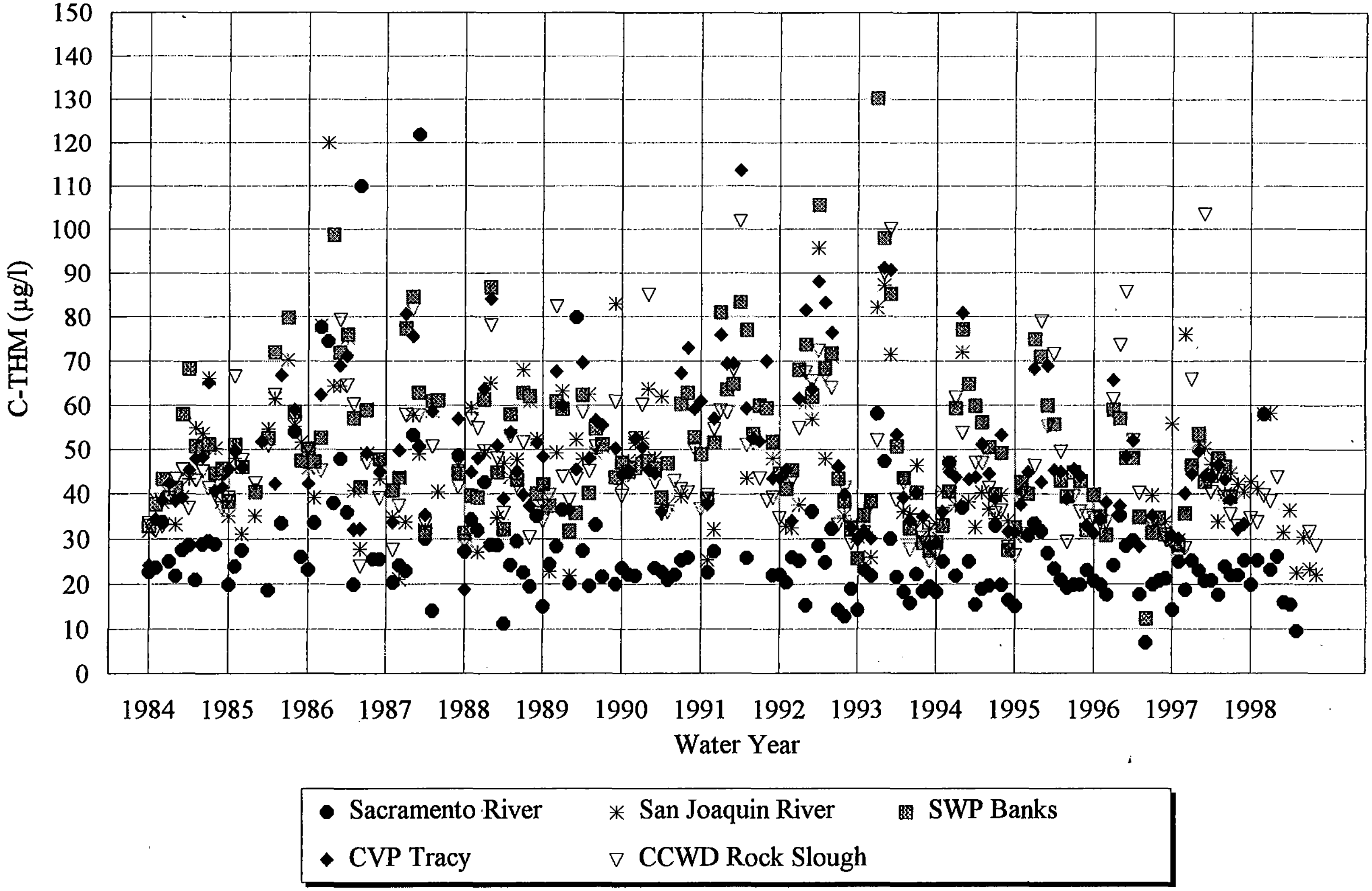

Figure 4-9
1984-1998 MWQI Monthly C-THM Values from the Sacramento and San Joaquin Rivers and at Delta Export Locations

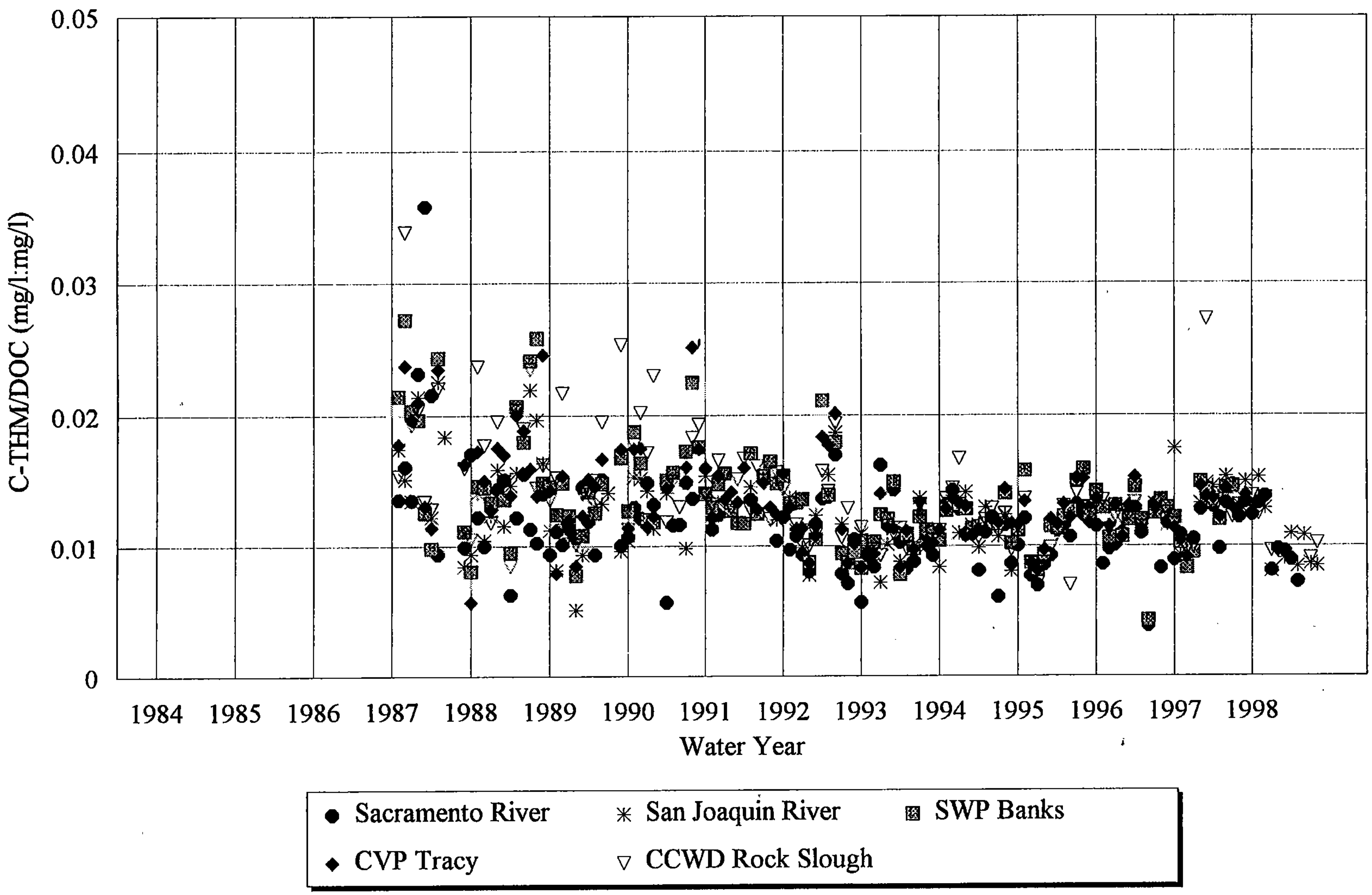

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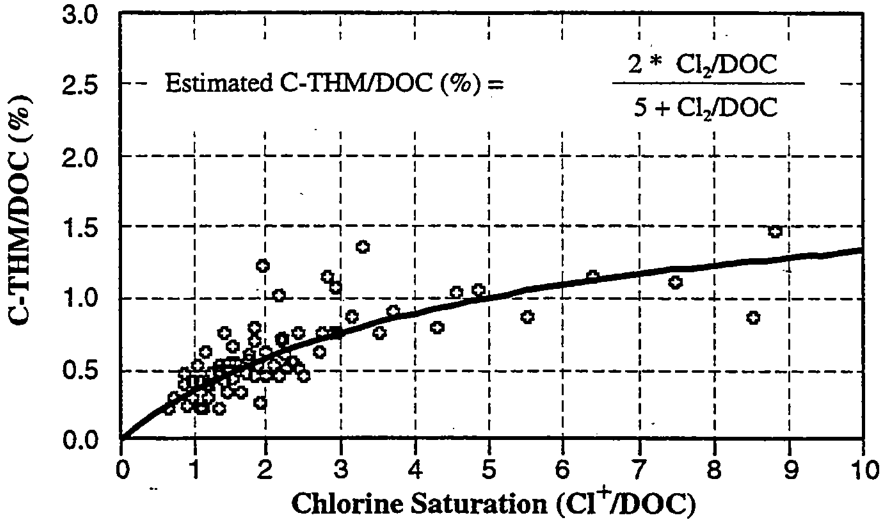
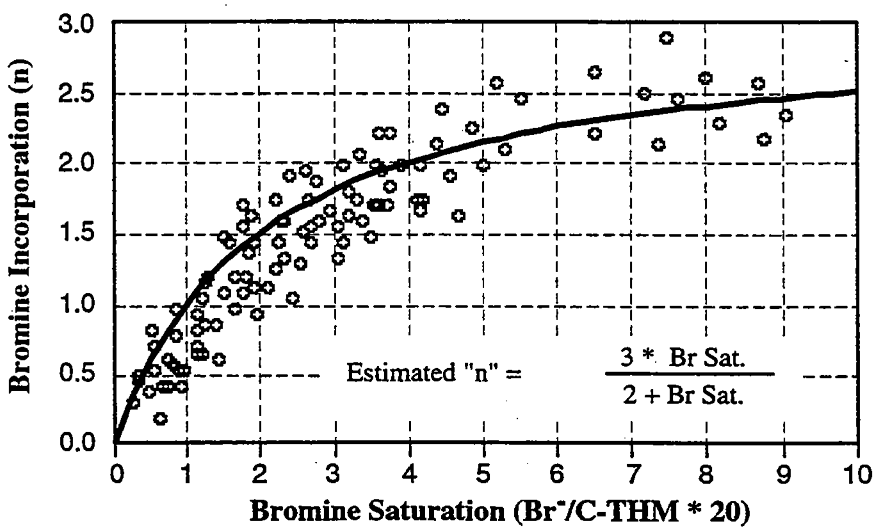
Figure 4-10
1984-1998 MWQI Monthly C-THM:DOC Ratio Values from the Sacramento and San Joaquin Rivers and at Delta Export Locations

Step 1: From measured DOC and chlorine dose, estimate the THM yield (the fraction of DOC that will become C-THM):



Step 2: From calculated bromide (chloride * 0.0035) and estimated C-THM, estimate bromine saturation and bromine incorporation (n):



Step 3: Estimate the THM molar weight and the distribution of THM species as a function of "n":

THM (Molar Weight) = 119 + 44.5 * n

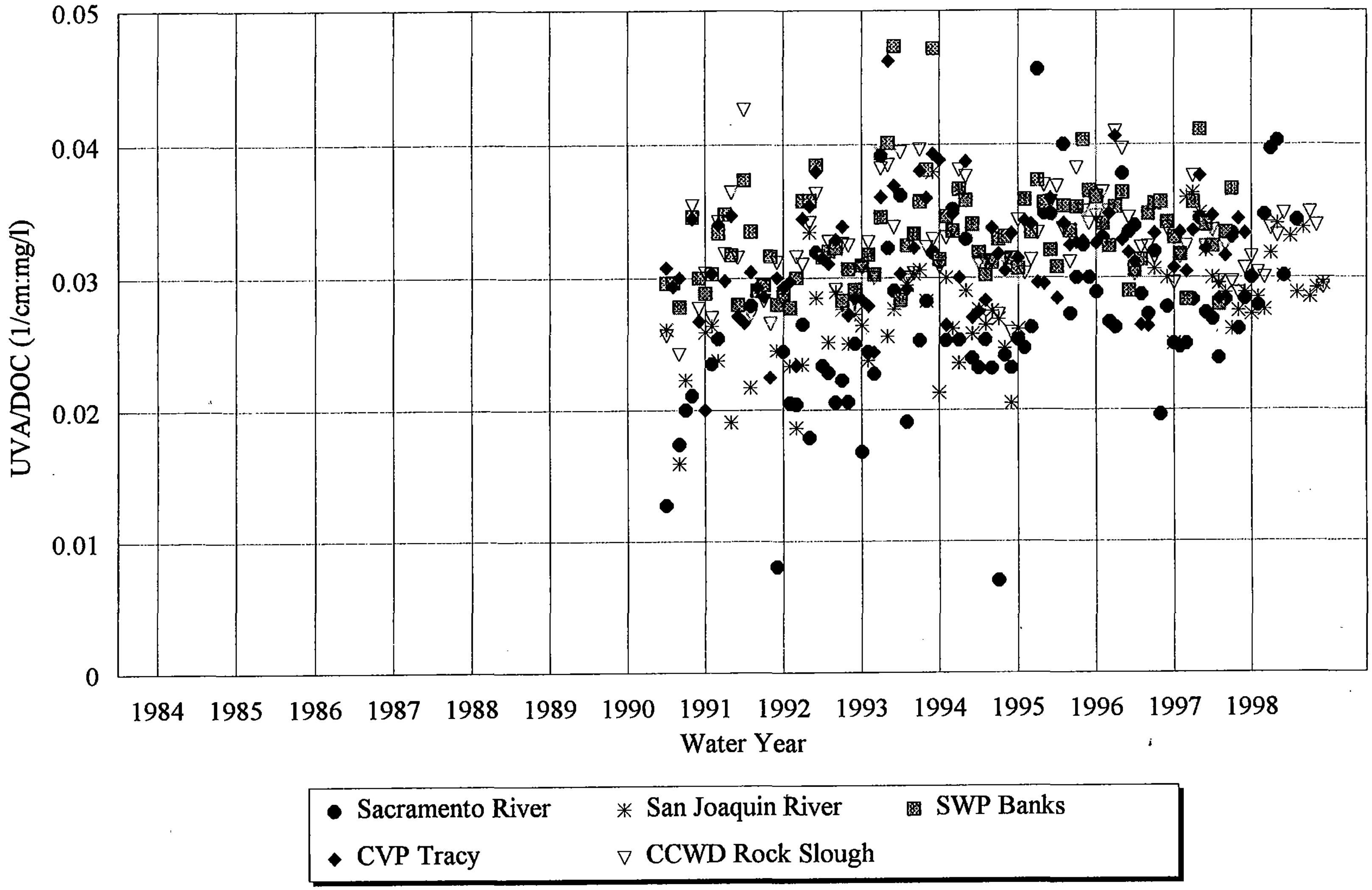
$CHCl_3 = (1 - \frac{1}{3}n)^3 = 1 - n + \frac{1}{3}n^2 - \frac{1}{27}n^3$

$CHCl_2Br = 3 * (1 - \frac{1}{3}n)^2 * \frac{1}{3}n = n - \frac{2}{3}n^2 + \frac{1}{9}n^3$

$CHClBr_2 = 3 * (1 - \frac{1}{3}n) * (\frac{1}{3}n)^2 = \frac{1}{3}n^2 - \frac{1}{9}n^3$

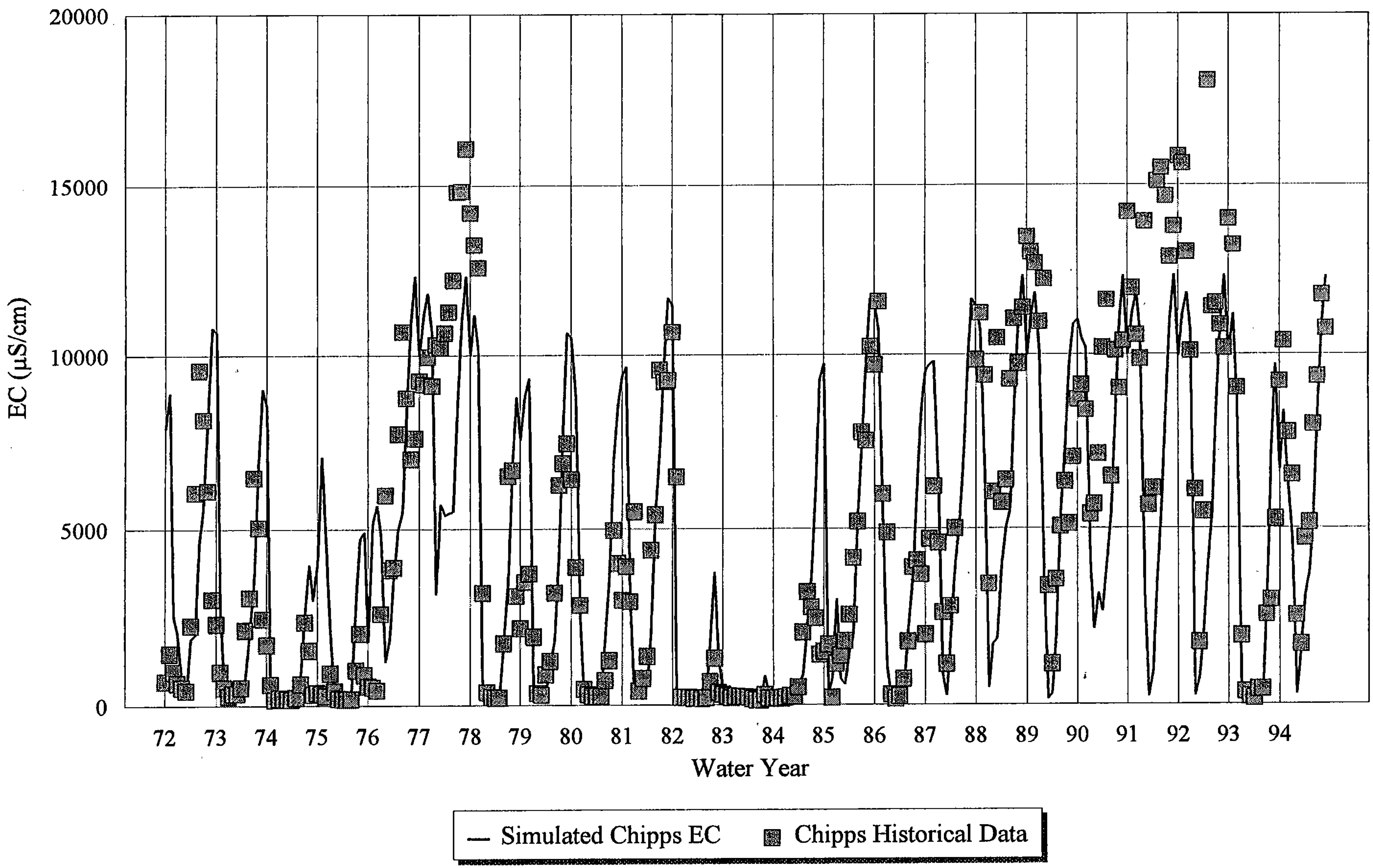
$CHBr_3 = (\frac{1}{3}n)^3 = \frac{1}{27}n^3$

Figure 4-11
General THM Prediction Model



Jones & Stokes

Figure 4-12
1984-1998 MWQI Monthly UVA:DOC Ratio Values from the Sacramento and San Joaquin Rivers and at Delta Export Locations



Jones & Stokes

Figure 4-13
Simulated No-Project Chipps Island EC Compared to Historical EC Data

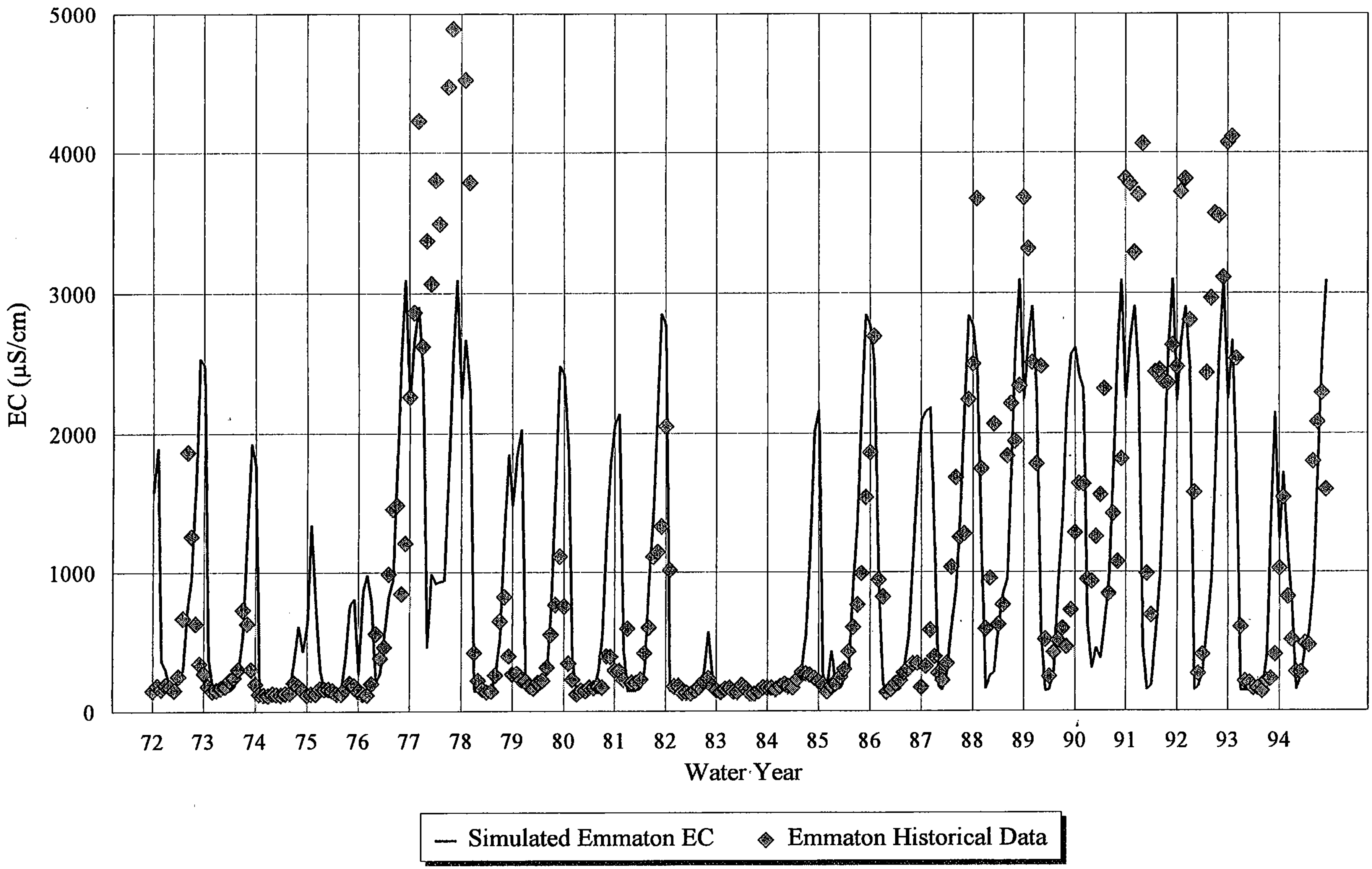


Figure 4-14
Simulated No-Project Emmaton EC Compared to Historical EC Data

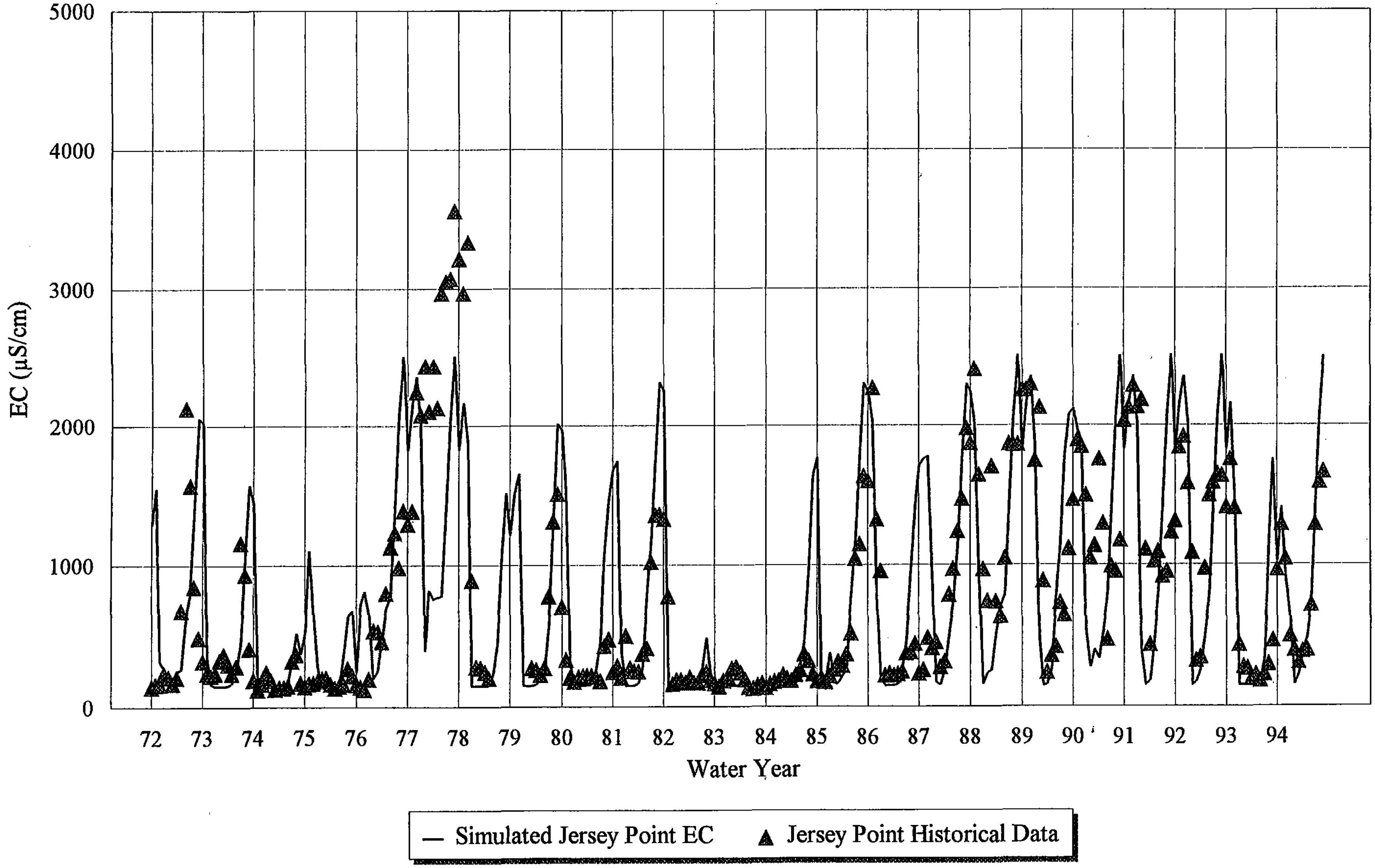


Figure 4-15
Simulated No-Project Jersey Point EC Compared to Historical EC Data

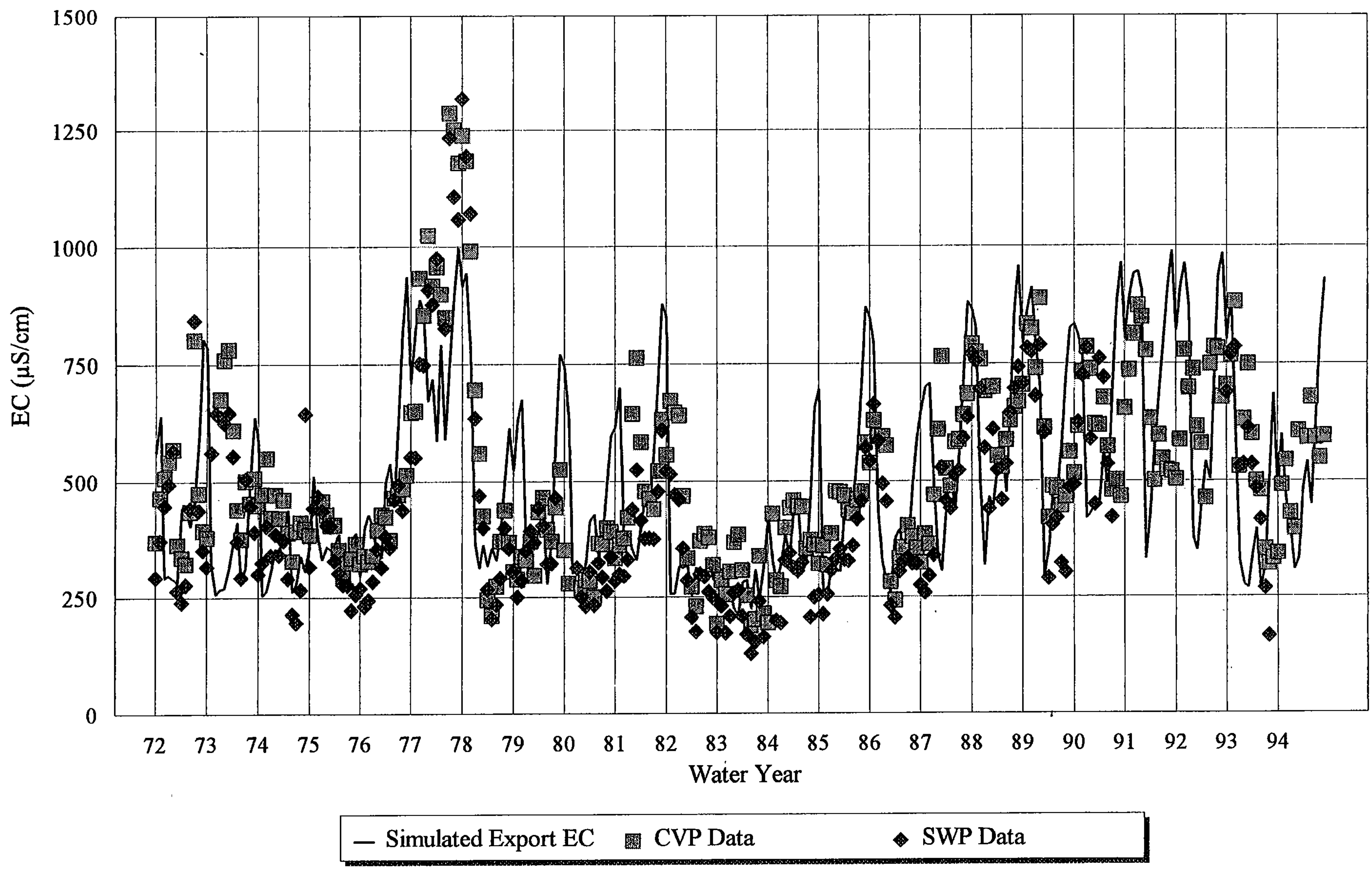


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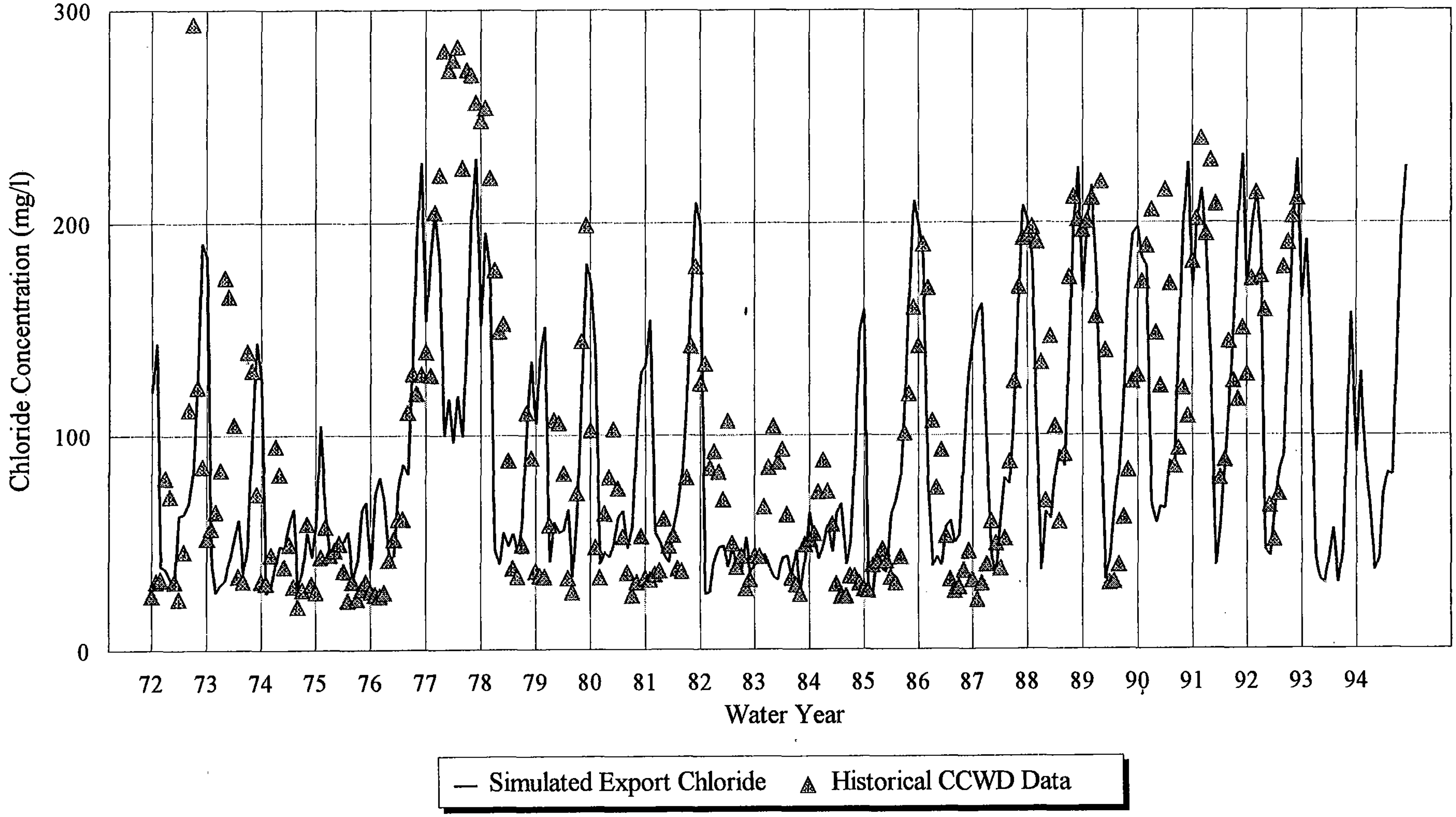
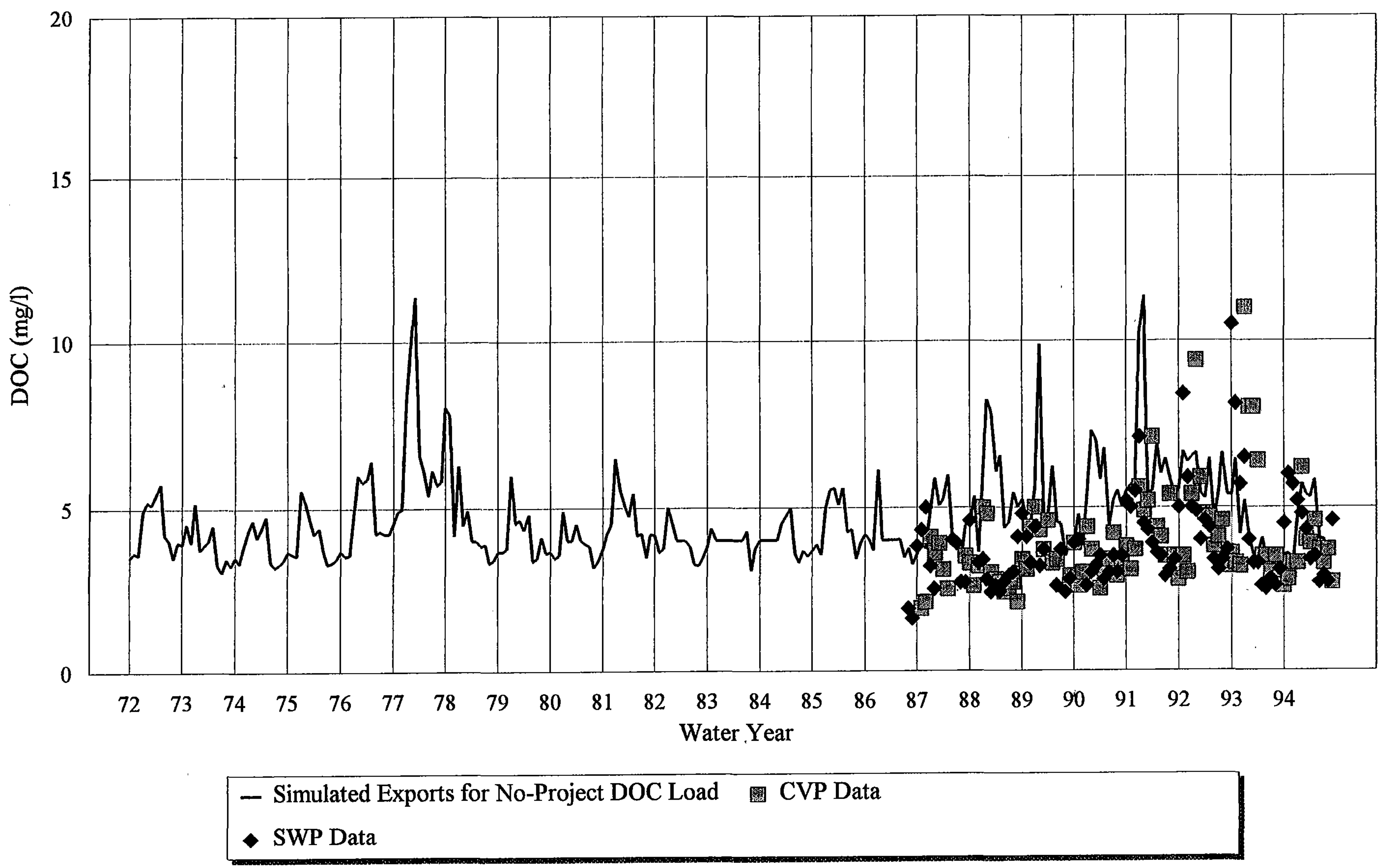
Figure 4-16
Comparison of Simulated No-Project Export EC with Historical MWQI Export EC Values



Note: CCWD data not available for 1993-1994.

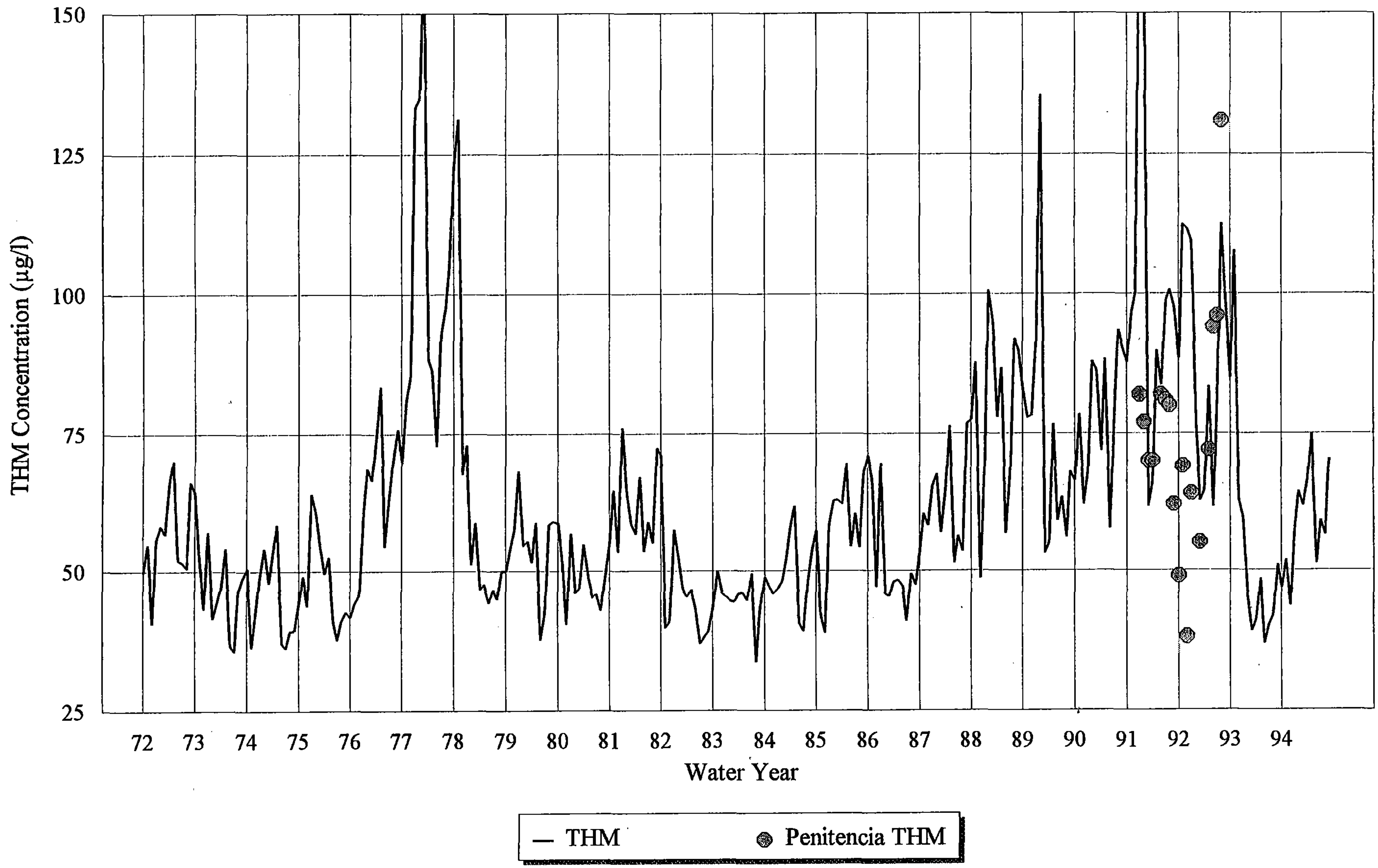
Jones & Stokes

Figure 4-17
Estimated Export Cl⁻ Concentration for No-Project and Historical CCWD Rock Slough Cl⁻ Values



Jones & Stokes

Figure 4-18
Simulated No-Project Delta Export DOC Concentrations with MWQI Drainage DOC Measurements



Jones & Stokes

Figure 4-19
Simulated Treated Water THM Concentration for the No-Project Condition

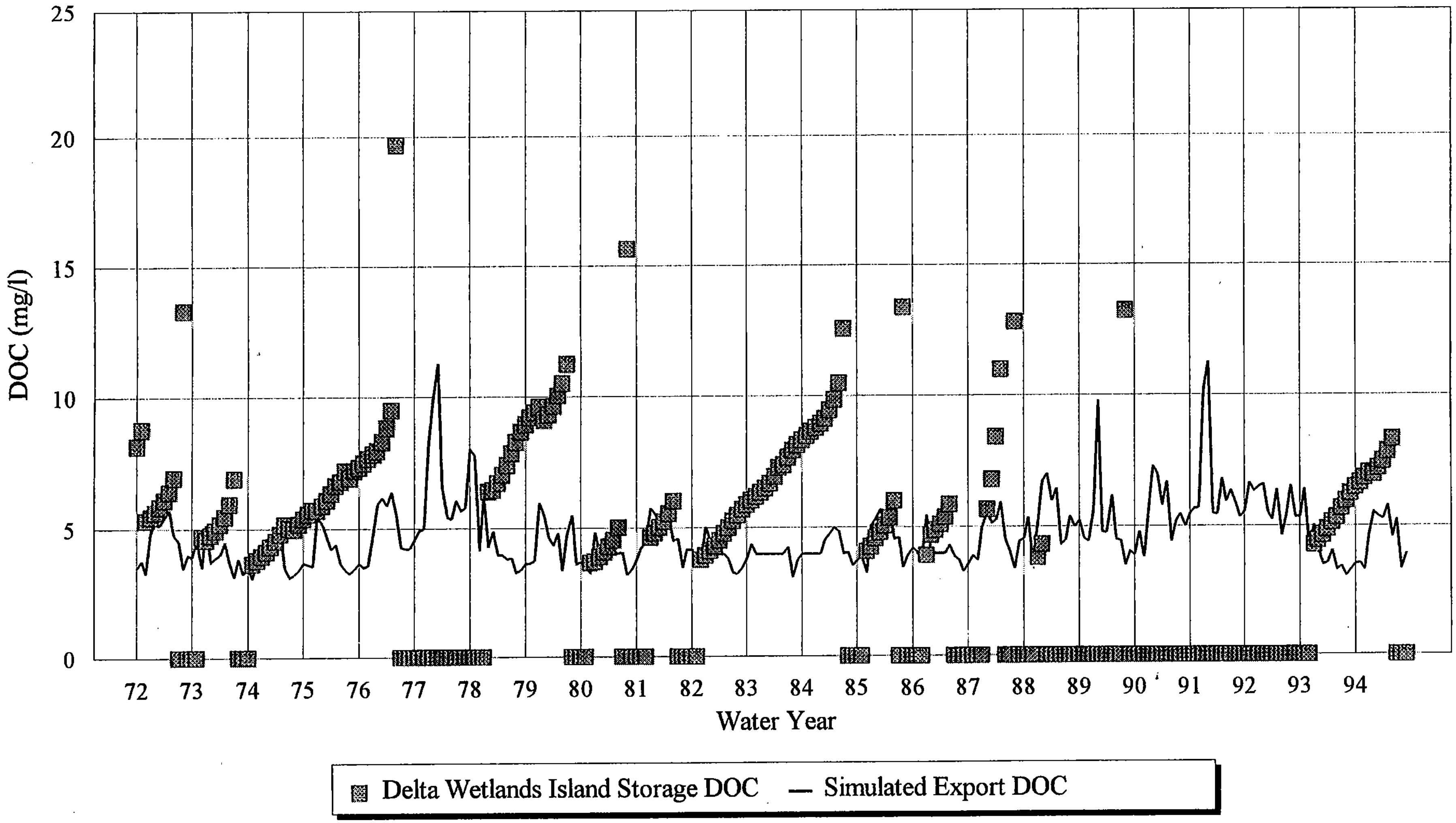


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Figure 4-20
Simulated Export DOC and Delta Wetlands Reservoir Island Storage DOC with Assumed Long-Term DOC Load (1 g/m²/mo)

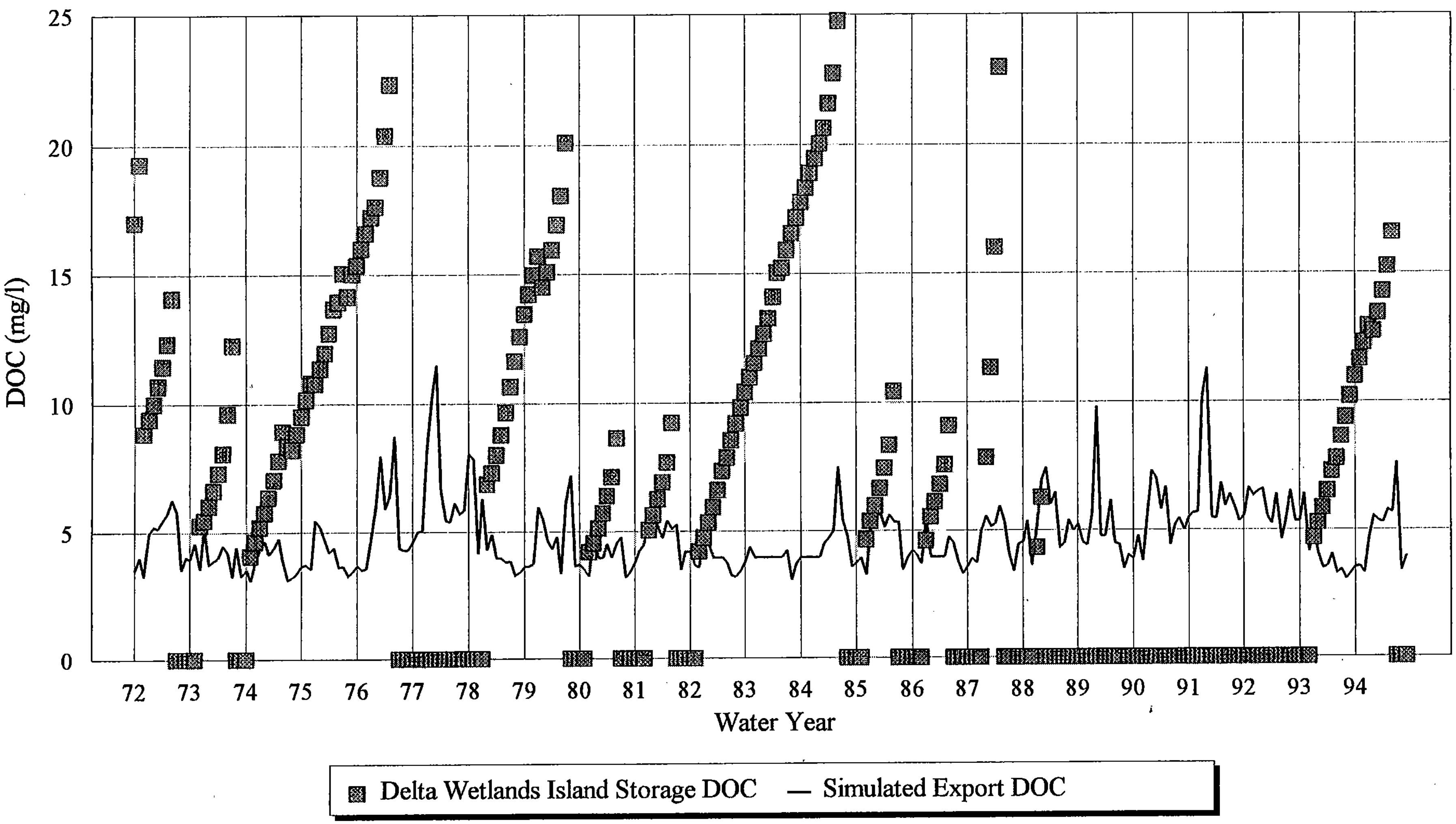
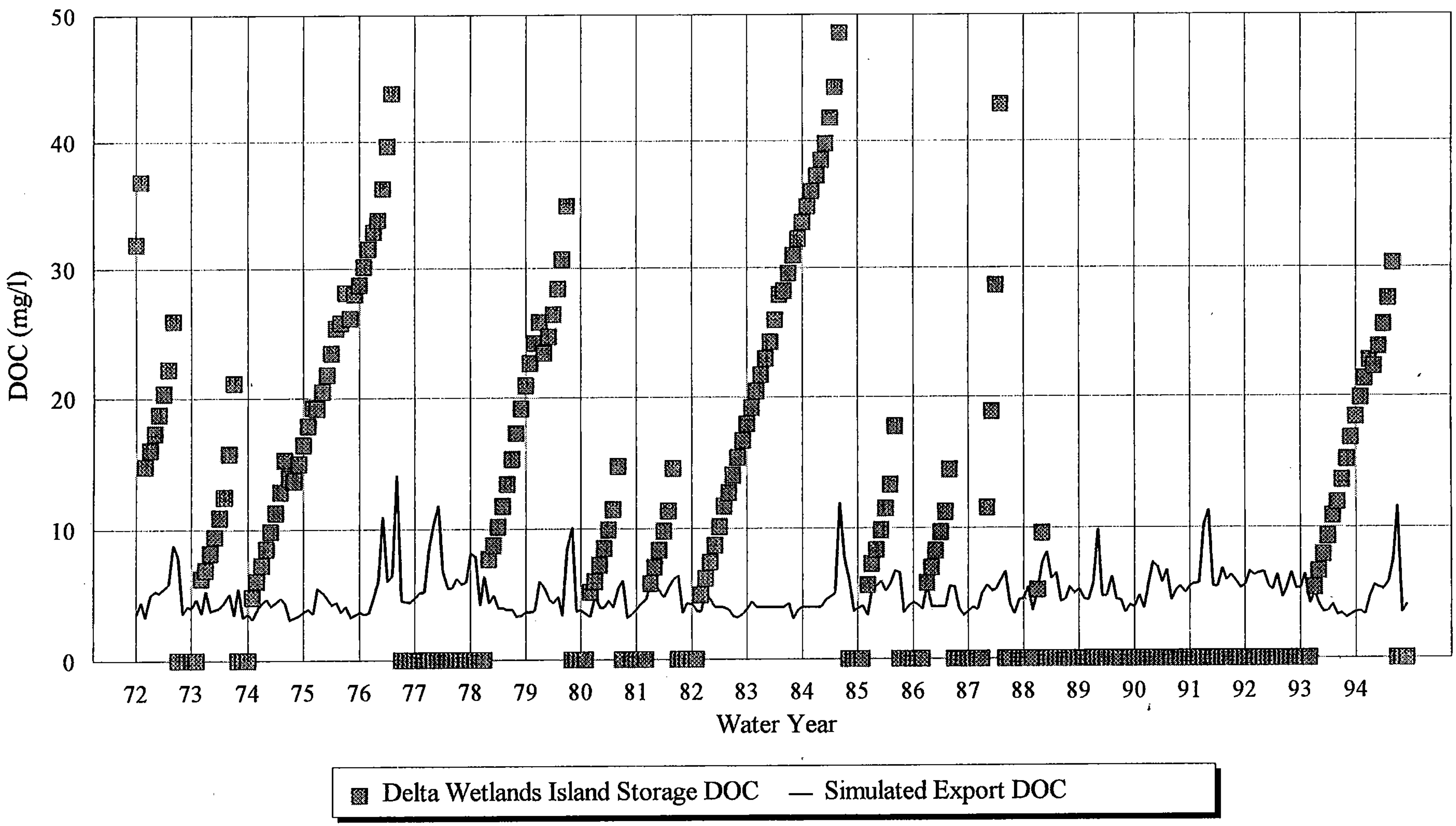


Figure 4-21
Simulated Export DOC and Delta Wetlands Reservoir Island Storage DOC with Assumed Initial DOC Load (4 g/m²/mo)



Jones & Stokes

Figure 4-22
Simulated Export DOC and Delta Wetlands Reservoir Island Storage DOC with Assumed High Initial DOC Load (9 g/m2/mo)

Chapter 5. Fisheries

This chapter updates the 1995 DEIR/EIS assessment of Delta Wetlands Project effects on fish species. The 1995 DEIR/EIS assessment focused on the project's effects on chinook salmon *(Oncorhynchus tshawytscha)*, steelhead *(O. mykiss)*, striped bass *(Morone saxatalis)*, American shad *(Alosa sapidissima)*, delta smelt *(Hypomesus transpacificus)*, splittail *(Pogonichthys macrolepidotus)*, and longfin smelt *(Spirinchus thaleichthys)*, all representative fish species that reside in the Delta, Suisun Bay, and San Francisco Bay for at least part of their lives. It examined project effects on habitat conditions that support these species and on factors that affect the species' abundance and distribution. The effects of Delta Wetlands Project facilities and operations on changes in Delta flows, water quality, local habitat conditions, and entrainment of fish in diversions were analyzed using simulations of project operations, data on fish habitat conditions, and information about the distribution and timing of fish life stages in the Delta.

After the 1995 DEIR/EIS was released, DFG, USFWS, and NMFS issued no-jeopardy biological opinions on Delta Wetlands Project effects on listed species (Appendices C, D, and E). The findings of no jeopardy for fish species are based on the inclusion of the FOC terms agreed to by Delta Wetlands during ESA consultation and the implementation of additional RPMs described in the biological opinions. By incorporating the FOC into proposed project operations, Delta Wetlands has modified the proposed project specifically to avoid or reduce effects on fish. As a result, conditions for fish under the project operations evaluated in this REIR/EIS will be improved from those conditions described in the 1995 DEIR/EIS analysis. With the FOC and RPMs in place, the significant impacts on fish habitat and populations identified in the 1995 analysis are reduced to a less-than-significant level.

FOCUS OF THE REVISED DRAFT EIR/EIS ANALYSIS

The terms of the FOC and the RPMs in the state and federal biological opinions address many of the concerns expressed in comments on the 1995 DEIR/EIS. The evaluation of project effects on fish species has been updated in this REIR/EIS to show how application of these measures will reduce project effects from those identified in the 1995 DEIR/EIS. The chapter also:

- discusses listings of fish species that have occurred since 1995 and the relevance of the 1995 DEIR/EIS analysis and the completed state and federal ESA consultations to assessment of project effects on those species, and

- evaluates the following information in response to concerns stakeholders expressed at the water right hearing or in comments on the 1995 DEIR/EIS:
  - new DFG data on spring-run chinook salmon and use of these data in the chinook salmon mortality model,
  - new EBMUD data on Mokelumne River chinook salmon, and
  - information regarding potential increases in predation with the construction of Delta Wetlands boat docks and other facilities.

Summary of Issues Addressed in This Chapter

The REIR/EIS analysis of fisheries addresses the following questions:

- How do the final terms of the federal and state biological opinions affect the analysis of fishery impacts and mitigation measures presented in the 1995 DEIR/EIS?
- How does incorporation of new data on spring-run chinook salmon affect the conclusions related to salmon mortality presented in the 1995 DEIR/EIS?
- Will Delta Wetlands Project operations significantly affect Mokelumne River anadromous fish, including outmigrating juvenile salmon, rearing juveniles, outmigrating hatchery-released fall yearlings, and returning adults?
- Will the Delta Wetlands Project's proposed boat docks and intake/discharge facilities affect predation in Delta waterways?

Definition of Terms

The following are definitions of key terms as they are used in this chapter:

- *Anadromous Species:* Fishes that mature in marine waters and migrate to fresh water to spawn.
- *Endangered Species:* Any plant or animal species or subspecies whose survival is threatened with extinction and that is included in the federal or state list of endangered species.

- *Entrainment:* The process in which fish are drawn into water diversion facilities along with water drawn from a channel or other water body by siphons and/or pumps. Entrainment loss includes all fish not salvaged (i.e., eggs, larvae, juveniles, and adults that pass through the fish screens, are impinged on the fish screens, or are eaten by predators).

- *Evolutionarily Significant Unit (ESU):* A distinctive group of Pacific salmon or steelhead.

- *Riprap:* A stone covering used to protect soil or surfaces from erosion by water or the elements.

- *Smolt:* A juvenile fish that has undergone physiological change enabling it to survive in saltwater.

- *Spawning:* Laying of eggs, especially by fish.

- *Take:* A term used in Section 9 of the federal ESA that includes harassment of and harm to a species, entrainment, directly and indirectly caused mortality, and actions that adversely modify or destroy habitat.

- *Threatened Species:* A species that is likely to become endangered in the foreseeable future and is included in the federal or state list of threatened species.

CHANGES IN THE PROPOSED PROJECT: FINAL OPERATIONS CRITERIA AND BIOLOGICAL OPINIONS

Since release of the 1995 DEIR/EIS, USACE and SWRCB have consulted with USFWS, NMFS, and DFG on potential effects of the Delta Wetlands Project on fish species listed or proposed for listing under the federal and state ESAs. During the consultation process, the SWRCB, USACE, and the project proponent worked with the resource agencies to revise the project to reduce or avoid adverse effects on fish species. The FOC measures are the result of that effort. The consultations also resulted in no-jeopardy biological opinions from USFWS and NMFS under the federal ESA and a no-jeopardy biological opinion from DFG under the state ESA. To minimize the impacts of incidental taking of fish species, the opinions include RPMs for the project. The FOC and RPMs also provide adequate protection to prevent significant impacts on nonlisted fish species (e.g., striped bass, American shad).

The FOC and RPMs change the conditions under which the Delta Wetlands Project could operate; these measures or criteria are more restrictive than the operations analyzed in the 1995 DEIR/EIS, so fisheries effects would be further reduced. The following section summarizes the changes in project operations that would result from the FOC and measures included in the federal and state biological opinions.

Final Operations Criteria

The FOC terms were developed in response to anticipated impacts of the proposed project, as analyzed in the 1995 DEIR/EIS, on fish species protected under the state and federal ESAs. To avoid or minimize the Delta Wetlands Project's effects on Delta fish populations and habitat, the FOC terms primarily revise the timing and magnitude of allowable diversions for storage and discharges for export or outflow. These restrictions are summarized in Table 2-2. Delta Wetlands also agreed to implement the following measures as part of the FOC:

- Meet design criteria for fish screens of 0.2 feet per second (fps) approach velocity.
- Conserve in perpetuity 200 acres of shallow-water rearing and spawning habitat.
- Contribute $100 per year for boat-wake-erosion mitigation for each boat berth constructed beyond preproject conditions.
- Mitigate on a 3:1 basis for the loss of aquatic habitat to construction activities.
- Minimize and avoid adverse effects of discharge through changes in water temperature.
- Minimize and avoid adverse effects of discharge through changes in dissolved oxygen.
- Compensate for incidental entrainment losses of striped bass, American shad, delta smelt, splittail, and longfin smelt from January through March and June through August (no diversions are permitted in April and May).
- Limit in-water construction to June through November.
- Implement a fish monitoring program that includes:
  - in-channel monitoring during diversions from December through August,
  - on-island monitoring during diversions,
  - monitoring during discharge for export from April through August,
  - reporting,
  - sample handling protocol,
  - coordination with IEP monitoring, and
  - a monitoring technical advisory committee.

The full text of the FOC is included in Appendix B.

Reasonable and Prudent Measures in the Biological Opinions

In their biological opinions for the protection of delta smelt and winter-run chinook salmon, DFG, NMFS, and USFWS specified RPMs that supplement the FOC measures agreed to by Delta Wetlands. These measures are nondiscretionary. Delta Wetlands is required to implement them. Therefore, the measures are included here as modifications to proposed project operations or as additional requirements for mitigating project effects on these listed species.

California Department of Fish and Game Biological Opinion

DFG issued a revised biological opinion in August 1998 regarding effects of the Delta Wetlands Project on state-listed species (California Department of Fish and Game 1998). The full text of the biological opinion is included in Appendix C. Following is a summary of the RPMs in the DFG biological opinion for the protection of delta smelt and winter-run chinook salmon. (The numbers refer to the original numbering in the biological opinion; missing numbers are for measures that pertain to the protection of terrestrial plant and wildlife species and requirements for communicating information to DFG.)

1.0 Delta Wetlands diversion to storage in March is limited by QWEST. (As mentioned in Table 2-2 and in Chapter 3, this is a calculated flow parameter representing net flow between the central Delta and the western Delta.)

2.0 Delta Wetlands will establish an environmental water fund to be controlled by DFG; the amount deposited into the fund will be based on the amount of project diversions from October through March and the amount of project discharge.

4.0 Aquatic habitat development measures will be implemented to offset impacts of moving X2 upstream from February through June.

6.0 Aquatic species monitoring will be implemented to minimize adverse impacts of take.

12.0 Fish screens will comply with DFG's fish screen policy.

15.0 Employee orientation on sensitive-species protection will be provided.

16.0 DFG will be notified of dead, injured, and entrapped state-listed species.

17.0 Compliance inspections will be conducted weekly during construction, assessing Delta Wetlands' compliance with the measures of DFG's biological opinion; compliance will be reported and confirmed.

18.0 Delta Wetlands will allow DFG access to the project site.

19.0 In lieu of monitoring for the entrainment of eggs, larvae, and fry as described in FOC measure 7, Delta Wetlands will provide funds to DFG based on the amount of water diverted to storage from January through March and from June through August. These funds will compensate for incidental entrainment.

20.0 Delta Wetlands will establish an aquatic habitat restoration fund.

National Marine Fisheries Service Biological Opinion

NMFS issued a biological opinion on Delta Wetlands Project effects on winter-run chinook salmon in May 1997 (National Marine Fisheries Service 1997). The full text of the biological opinion is included in Appendix D. The following is a summary of the RPMs specified by NMFS:

1. Properly designed fish screens will be used to reduce entrainment and predation during Delta Wetlands diversion operations.

2. Degradation of Delta habitat during construction, operation, and maintenance activities will be reduced.

3. Appropriate sampling and processing procedures will be used to reduce impacts on juvenile winter-run chinook salmon from discharge monitoring activities.

4. Delta Wetlands operations and daily Delta hydrologic conditions will be monitored.

U.S. Fish and Wildlife Service Biological Opinion

USFWS issued a biological opinion on Delta Wetlands Project effects on delta smelt in May 1997 (U.S. Fish and Wildlife Service 1997). The full text of the biological opinion is included in Appendix E. The following is a summary of the RPMs specified by USFWS:

1. Immersed plants will be avoided when riprap is placed and when recreation facilities and diversion and discharge structures are built.

2. Submersed aquatic plants will be avoided when riprap is placed and during all in-water work associated with constructing project facilities; in-water work will be limited to June through November.

3. The FOC and a fish monitoring program will be implemented.

An analysis of Delta Wetlands Project impacts under the FOC and RPMs developed during ESA consultation is presented below under "Environmental Consequences".

AFFECTED ENVIRONMENT: RELEVANT OR NEW INFORMATION

The fishery resources chapter (Chapter 3F) and appendices (Appendices F1 and F2) in the 1995 DEIR/EIS describe the life histories of Delta fish species and factors affecting their population abundance. Refer to those sections for an overview of Delta fish and their habitats. Since the 1995 DEIR/EIS was released, some additional fish species have been listed as threatened or endangered under the federal and state ESAs; these listings are described below. Also, the lead agencies have received additional information about chinook salmon survival and abundance. DFG has provided these data for spring-run chinook salmon throughout the Delta, and EBMUD has provided data for fall-run chinook salmon in the Mokelumne River. A literature review regarding enhanced feeding activity by predator species associated with boat docks and other in-water structures was also completed to address the comments received on the 1995 DEIR/EIS and during the water right hearing.

New Species Listings and Endangered Species Act Consultation Status

Additional Species Listed under the California and Federal Endangered Species Acts

Since the release of the 1995 DEIR/EIS, three additional species of fish that occur in the Delta have been listed as threatened under the federal ESA. These new listings are:

- Central Valley steelhead ESU (63 FR 11481, March 9, 1998),
- splittail (64 FR 5963, February 8, 1999), and
- Central Valley spring-run chinook salmon ESU (64 FR 50394, September 16, 1999).

Spring-run chinook salmon was also listed as threatened under the California ESA on February 5, 1999. In addition, the Delta has been designated critical habitat for steelhead and spring-run chinook salmon under the federal ESA (65 FR 7764, February 16, 2000).

Status of Consultation

The 1995 DEIR/EIS fully addressed potential effects of the Delta Wetlands Project on splittail and steelhead. In addition, because these species were proposed for listing at the time, the biological assessment prepared for the Delta Wetlands Project (Appendix F2 in the 1995 DEIR/EIS) analyzed project effects on splittail and steelhead.

The final biological opinion of "no jeopardy" received from NMFS on winter-run chinook salmon (Appendix D) also contained a "conference opinion" for the Central Valley ESU steelhead. (Similar to a biological opinion for listed species, a conference opinion is applicable to species proposed for listing.) This conference opinion found that the Delta Wetlands Project would not jeopardize the continued existence of steelhead. USACE has requested that NMFS formally adopt the conference opinion as its biological opinion on steelhead for the Delta Wetlands Project.

Similarly, the final biological opinion of "no jeopardy" received from USFWS on delta smelt (Appendix E) included a conference opinion for splittail, which found that the Delta Wetlands Project would not jeopardize the continued existence of splittail. USFWS has formally adopted the conference opinion as its biological opinion on splittail for the Delta Wetlands Project (Appendix E). Therefore, no additional consultation is needed to address Delta Wetlands Project effects on splittail.

To address potential project effects on Central Valley ESU spring-run chinook salmon, USACE has requested consultation with NMFS pursuant to Section 7 of the federal ESA. The project's FOC and other measures to be implemented as RPMs under the federal and California ESA biological opinions for the other species cover the period when spring-run chinook salmon occur in the Delta and, therefore, would minimize adverse effects of the project on spring-run chinook salmon as well. USACE has requested concurrence with this conclusion from NMFS and has also inquired whether any additional information or analysis may be required to complete consultation on spring-run chinook salmon.

Similarly, Delta Wetlands will request concurrence directly from DFG regarding the assertion that the FOC and RPMs from the existing biological opinions adequately address potential project effects on spring-run chinook salmon pursuant to Section 2081 of the California Fish and Game Code. The California ESA biological opinion assessed Delta Wetlands' impacts on spring-run chinook salmon, and the RPMs were indicated as minimizing adverse impacts of the incidental taking of spring-run chinook salmon. DFG will indicate whether additional information or analysis is required to complete consultation pursuant to the California ESA.

New California Department of Fish and Game Data on Spring-Run Chinook Salmon

On August 13, 1999, DFG gave the lead agencies new information about juvenile spring-run chinook salmon occurrence in the Delta (Wernette pers. comm.). The extent of occurrence of juvenile spring-run chinook salmon assumed in the 1995 DEIR/EIS assessment generally corresponds to the extent of occurrence in the information provided by DFG (Table 5-1).

DFG also furnished new information about the assumed survival of spring-run chinook salmon during migration through the Delta (Wernette pers. comm.). The survival information was incorporated into the chinook salmon mortality model as described below under "Environmental Consequences".

East Bay Municipal Utility District Data on Mokelumne River Chinook Salmon

During the water right hearing and the review period for the 1995 DEIR/EIS, EBMUD commented that the 1995 DEIR/EIS did not adequately address Delta Wetlands Project effects on Mokelumne River anadromous fish (i.e., fall-run chinook salmon and steelhead). The impact of Delta Wetlands diversions on juvenile chinook salmon originating from the Mokelumne River was considered significant in the 1995 DEIR/EIS and mitigation was identified.

In response to EBMUD's comment, the lead agencies asked EBMUD to provide data about tracking and movement of Mokelumne River fish, including timing data for juvenile migration. EBMUD provided raw data in spreadsheet and database files, including tables of summary statistics and summary histograms (Miyamoto pers. comm.). The data provided include adult spawning escapement for 1993-1998 (Table 5-2), juvenile outmigration for 1994-1999 (Table 5-3), and coded wire tag data for 1991-1998. This information was used in the revised assessment of Delta Wetlands Project effects on Mokelumne River chinook salmon described below under "Environmental Consequences".

Delta Wetlands Project Facilities and Fish Predation

A literature search was completed to update information presented in the 1995 DEIR/EIS about predation, including potential effects of boat docks and intake/discharge facilities on prey species vulnerability and predator species success. As described below, this information has been used to augment the discussion of potential effects of the project on predation presented in the 1995 DEIR/EIS.

IMPACT ASSESSMENT METHODOLOGY

Assessment of Delta Wetlands Project effects on Delta fish species and their habitat involves predicting fish and habitat responses to changes in Delta conditions that could result from project operations. The 1995 DEIR/EIS impact assessment used a variety of methods, including:

- Delta Wetlands Project operation modeling that determined changes in Delta flows (see Chapter 3, "Water Supply and Operations");
- water quality modeling that determined changes in Delta salinity and assessed other factors that could affect fish species and the amount of estuarine habitat available to them (see Chapter 4, "Water Quality");

- an entrainment index that was used to represent changes in potential entrainment of fish at the Delta Wetlands diversion facilities and the SWP and CVP pumping plants; and

- a salmon smolt survival model (mortality index) that was modified from the model developed by USFWS (Kjelson et al. 1989).

These methods were also used in the ESA consultation process; the results of the ESA consultation were the basis for the changes in the project described by the FOC and the RPMs.

For the analysis presented below, Delta Wetlands Project operations modeling was used to determine changes in Delta flows under the FOC and RPMs (see Chapter 3, "Water Supply and Operations"). The following summarizes the contents of this analysis:

- Because the FOC and RPMs improve conditions for fish, the project's effects as identified in the 1995 DEIR/EIS are compared with effects under the FOC and RPMs.

- Potential effects of the Delta Wetlands Project on spring-run chinook salmon are assessed using the new data provided by DFG on spring-run occurrence and using USFWS's recently modified salmon smolt survival model.

- Impacts on Mokelumne River fall-run chinook salmon are reassessed, considering recent data provided by EBMUD.

- Based on additional literature review, the potential impacts of new Delta Wetlands Project boat docks and other facilities on predator-prey interactions in the Delta are assessed in greater detail than in the 1995 DEIR/EIS.

The significance thresholds are the same as those used in the 1995 DEIR/EIS.

ENVIRONMENTAL CONSEQUENCES

Delta Wetlands Project Impacts under the Final Operations Criteria and Implementation of Reasonable and Prudent Measures

The FOC and RPMs developed during ESA consultation have been incorporated into the proposed Delta Wetlands Project assessed in this REIR/EIS. The revised Delta Wetlands operations and RPMs reduce project impacts on fish identified in the 1995 DEIR/EIS to less-than-significant levels, fulfilling the need for mitigation measures proposed in that document. Table 5-5 summarizes the impacts on fish species and habitat identified in the 1995 DEIR/EIS. It also discusses how the FOC and RPMs reduce those impacts to less-than-significant levels and supersede the mitigation measures previously recommended.

Project Impacts on Spring-Run Chinook Salmon

As shown in Figure 5-1, the occurrence of spring-run chinook salmon overlaps with the occurrence of winter- and fall-run juveniles. Spring-run yearlings occur in the Delta primarily from October through January; the timing of occurrence depends on flow and water temperature conditions (Table 5-1). Young-of-year juvenile spring-run chinook salmon may occur in the Delta from December through June, depending primarily on two factors—flow conditions that cause early-life-stage chinook salmon to move downstream and the growth of juveniles to smolt size. Analysis of effects on juvenile winter-run and fall-run chinook salmon in the 1995 DEIR/EIS covered the time periods identified for spring-run yearlings and young-of-year juveniles. The occurrence data provided by DFG are more specific than the assumptions used in the 1995 DEIR/EIS but do not alter the conclusion reached in the 1995 DEIR/EIS.

DFG also provided new information about assumed survival of spring-run chinook salmon through the Delta. USFWS has used this information to modify the relationship (i.e., slope) between migration pathway and survival in the USFWS salmon smolt survival model (mortality index). With this modification, the same model can be used to assess effects on late fall-, spring-, and winter-run chinook salmon. The modified slope was based on results of survival experiments carried out by USFWS during the months of December and January (Wernette pers. comm.) (the years of data collection were not specified in the DFG information). For assessment of Delta Wetlands Project effects on spring-run chinook salmon, the slope for the reach 2 relationship (central Delta) was changed from 0.000043 (fall-run relationship) to 0.000054 (spring-run relationship).

The USFWS model states that index values are not estimates of absolute survival and should be used only as tools to aid in evaluating the relative impacts associated with additional pumping. DFG concurs with this approach (Wernette pers. comm.). Therefore, as in the 1995 DEIR/EIS analysis, the model was used in this REIR/EIS analysis to assess impacts based on the changes in the mortality index between without-project and with-project conditions.

Using the assumed spring-run relationship in place of the assumed fall-run relationship does not affect conclusions about project effects reported in the 1995 DEIR/EIS. When both relationships were applied to export conditions under an assumed constant water temperature of 55 °F, the timing and magnitude of effects on the fish with and without the Delta Wetlands Project were similar (Figure 5-2). The effects illustrated in Figure 5-2 for both the fall- and spring-run relationships are worst-case scenarios; they assume a constant effect of Delta Wetlands diversion and CVP-SWP export, including export of Delta Wetlands discharge, regardless of water source and net channel flow conditions. These factors were considered in the assessment for the 1995 DEIR/EIS.

The revised analysis identifies Delta Wetlands Project effects on survival during the same years indicated in the 1995 simulation, although the magnitude of the effects varies slightly when the new data are used. The direction of change in response to exports, Delta Wetlands operations, and water temperature remains the same. Delta Wetlands Project effects found in this revised analysis of the spring run are consistent with conclusions reached in the 1995 DEIR/EIS, which were based on earlier USFWS data. Although flow changes resulting from Delta Wetlands diversions and discharges could indirectly cause spring-run chinook salmon mortality to increase, this potential increase would be less than significant. Relative to effects described in the 1995 DEIR/EIS, these impacts will be reduced with implementation of the FOC terms and RPMs from the biological opinions for delta smelt and winter-run chinook salmon.

For Sacramento River fish, the USFWS model assumes that increased mortality attributable to export occurs in the central Delta. Closure of the DCC gates reduces exposure of Sacramento River fish to export effects. The Delta Wetlands Project does not affect operations of the DCC or the proportion of flow drawn through the DCC and Georgiana Slough. Additionally, the FOC terms require reductions in Delta Wetlands diversions if the DCC gates are closed for fishery protection (from November through January).

The effects of water temperature are a primary factor in the survival of juvenile chinook salmon during migration through the Delta. The Delta Wetlands Project also does not affect water temperature in the Sacramento River or in the central Delta when it diverts water to storage. The FOC will minimize effects of Delta Wetlands Project discharge on water temperature, and effects will be limited to locations in channels near the discharge facilities. FOC terms require that project operations not cause a change in receiving water temperature greater than 7°C; they also prohibit channel temperature increases greater than 1°C where channel temperatures are 13° to 25°C, and increases greater than 0.5°C where channel temperatures are more than 25°C (see Appendix B).

Project Impacts on Mokelumne River Chinook Salmon

For the 1995 DEIR/EIS, a mortality index was developed for chinook salmon that originate in the Sacramento River, but not specifically for chinook salmon in the Mokelumne River. The impact assessment assumed that all juveniles originating in the Mokelumne River and adults returning to the Mokelumne River would be affected by Delta exports and Delta Wetlands Project diversions. The impact of such diversions on juvenile chinook salmon originating in the Mokelumne River was considered significant in the 1995 DEIR/EIS and mitigation was identified (Table 5-5).

When submitting data on salmon occurrence and survival, EBMUD did not identify any relationships between Delta channel flows (or Delta diversions) and adult migration or juvenile survival. Survival of adult and juvenile chinook salmon in the Mokelumne River does not appear to be affected by net flows in Delta channels.

The evaluations of project effects on migrating adults, juvenile outmigration, and flows from the Mokelumne River are described below.

Adult Spawning Migration

EBMUD indicated that release of Delta Wetlands Project water in August and September could confuse returning adult Mokelumne River salmon seeking cues from the river. The number of adults migrating past Woodbridge Dam daily was compiled to estimate the completion dates of

50% and 90% of the run (Table 5-2). The data were compared with the timing assumed for adult fall-run chinook salmon in Figure 5-1, which duplicates Figure 3F-1 from the draft EIR/EIS. In Figure 5-1 and in the data provided by EBMUD, most adult chinook salmon enter the Mokelumne River from September through December, with peak migration in October and November.

EBMUD did not identify, and analysis of the data provided did not show, a relationship between net Delta channel flow (QWEST) and adult migration to the Mokelumne River. Although Delta channel flows varied substantially, the new information indicated minimal variability in the 50% and 90% completion dates for adult chinook salmon migration into the Mokelumne River from 1993 through 1998. For example, average QWEST in October 1993 was -2,359 cfs and was 161 cfs in October 1994. The dates of 50% and 90% completion of annual migration past Woodbridge Dam, however, varied by only a few days between 1993 and 1994 (Table 5-2). Similarly, the dates of annual migration past Woodbridge Dam during 1994 and 1995 were similar even though QWEST in August averaged -1,780 cfs in 1994 and 1,948 cfs in 1995.

A negative QWEST indicates that very little Mokelumne River water will exit the Delta as outflow and that most of the Mokelumne River water will be present in the water mass moving toward the CVP and SWP export pumps. A negative QWEST (e.g., in October 1993 and August 1994) does not appear to have affected the timing of adult migration in the Mokelumne River when compared to years when QWEST was positive (e.g., October 1994 and August 1995).

Another indicator that adults could be confused by the presence of Mokelumne River water in the central and south Delta channels would be straying to other rivers. However, the coded wire tag data provided by EBMUD showed that regardless of their origin (i.e., Nimbus Fish Hatchery), more than 90% of juvenile chinook salmon released in the Mokelumne River returned as adults to the Mokelumne River. The data also indicated that 60% to 100% of the juvenile chinook salmon produced in the Mokelumne River or at the Mokelumne River fish hatchery returned to the Mokelumne River as adults regardless of release location. The coded wire tag data indicate that if straying occurs, juveniles originating from other rivers and released in various Delta locations are most likely to stray as returning adults.

Delta Wetlands discharge and diversion could change the amount of Mokelumne River water present in channels south of the San Joaquin River; however, the available data do not indicate that such changes would affect migration of adult chinook salmon. (See also "Effect of the Delta Wetlands Project on the Concentration of Mokelumne River Water in the Central and South Delta" below.)

Juvenile Outmigration

The EBMUD data on juvenile outmigration indicated that during wet years (water years 1995 through 1999), most annual production of juvenile chinook salmon passes Woodbridge Dam before March (Table 5-3). According to EBMUD, up to 70% of the entire annual production of juvenile chinook salmon would pass Woodbridge Dam as fry (Miyamoto pers. comm.). A similar pattern of outmigration has been noted in other systems. The high abundance of fall-run fry in the Delta before March coincides with high flows (U.S. Fish and Wildlife Service 1994).

EBMUD and USFWS have indicated concern about the entrainment of fry in Delta diversions after high flows. The available salvage data for the CVP and SWP, however, show that peak entrainment of juvenile chinook salmon occurs during April and May (Figure 5-3). It is likely that fry and young juvenile chinook salmon rear in the lower portion of rivers and in the Delta channels receiving the river discharge until they reach smolt size (i.e., a level of maturity that allows movement to the ocean). Smolt-sized salmon move past Chipps Island primarily from April through June (U.S. Fish and Wildlife Service 1994) and are salvaged at the CVP and SWP fish protection facilities primarily during April and May (Figure 5-3).

EBMUD also provided raw data on recovery (capture) of Mokelumne River juvenile chinook salmon marked with coded wire tags. EBMUD did not identify any relationship between net Delta channel flow, export, and entrainment in Delta diversions. The number of tagged fish salvaged at the CVP and SWP fish protection facilities appears to be related to the number and size of fish released: the larger the number and bigger the fish released, the larger the number recovered. In general, the number of fish recovered at the fish protection facilities was small, usually 1 or 2 fish and less than 0.02% of the number released, and was highly variable, ranging from none to as many as 27 fish out of 10,000 to 100,000 released. Because of the relatively high occurrence of zero recoveries and the variability of release dates, number of fish released, release locations, and size at release, the EBMUD data cannot be used to develop accurate relationships between facility operations and entrainment.

The available information does not indicate that Delta Wetlands operations, with the FOC and RPMs in place, would have significant adverse effects on juvenile chinook salmon that originate in the Mokelumne River and rear in the Delta from January through March. The data provided by EBMUD on the recovery of tagged juveniles did not include data on fish released during January through March. They also did not provide information on relationships between flow or diversion and entrainment at the CVP and SWP export facilities. SWP and CVP salvage data indicate that the months of highest entrainment of juveniles are April and May. The FOC terms specify that Delta Wetlands diversions would be limited by several factors during January through March and would not be allowed during April and May. Details of the applicable FOC restrictions are provided under "Summary of the Evaluation of Delta Wetlands Project Effects on Mokelumne River Chinook Salmon" below. (See also the following section, "Effect of the Delta Wetlands Project on the Concentration of Mokelumne River Water in the Central and South Delta".)

Effect of the Delta Wetlands Project on the Concentration of Mokelumne River Water in the Central and South Delta

EBMUD was concerned that discharge of Delta Wetlands Project water could confuse returning adult and juvenile chinook salmon during upstream and downstream migration. A worst-case assessment of the origin of central and south Delta water was completed, based on simulated Delta water supply and operations (Chapter 3). This assessment assumed that:

- tidal flows would not dilute the proportion of Mokelumne River water drawn into the central and south Delta,

- Delta Wetlands discharge would retain the Mokelumne River characteristics over the storage period, and

- Delta Wetlands discharge would mix completely in the central Delta and would not be drawn toward the export pumps. (This is a very conservative assumption for Bacon Island discharge, the only discharge for exports allowed during January through June.)

The results shown in Table 5-4 and Figure 5-4 indicate that the Delta Wetlands Project would have a minimal effect on the proportion of Mokelumne River water moving through the central and south Delta. In most years the Delta Wetlands discharge would have proportionately less Mokelumne River water than the channel receiving the discharge. Project operations, therefore, may reduce slightly the proportion of Mokelumne River water present, but the effect on chinook salmon is likely to be negligible. In addition, under normal operating circumstances, Delta Wetlands would infrequently release water in the winter months (see Table 3-15 in Chapter 3), further reducing the probability that the project would affect Mokelumne River salmon.

Summary of the Evaluation of Delta Wetlands Project Effects on Mokelumne River Chinook Salmon

The EBMUD data do not provide evidence that Delta Wetlands Project operations would significantly affect adult chinook salmon migration to the Mokelumne River. The 1995 DEIR/EIS identified project effects on juveniles originating in the Mokelumne River as a significant impact. With implementation of the FOC and RPMs described in the state and federal biological opinions, impacts on chinook salmon, including those originating in the Mokelumne River, would be less than significant. The FOC that would minimize adverse effects on juvenile chinook salmon from the Mokelumne River include the following (see Appendix B for details):

- Total annual export of Delta Wetlands stored water would be limited to 250,000 af; therefore, the amount of diversion and discharge that could occur in any one year would be restricted.

- The volume of Delta Wetlands diversions and potential effects on Delta channel flow conditions would be limited by:

  - the maximum X2 value (corresponding to a minimum Delta outflow);
  - the maximum allowable change in X2 value;
  - the March QWEST criteria;
  - the percentage of Delta surplus, Delta outflow, and San Joaquin River inflow; and
  - criteria during DCC closures for fish protection.

- Webb Tract would not be allowed to discharge to export during January through June, which includes the period of juvenile chinook salmon migration.

- The volume of Delta Wetlands discharges to export and potential effects on Delta channel flows would be limited to a percentage of unused export capacity.

- Fish screens would be designed to meet a 0.2-fps approach velocity, avoiding direct diversion effects on juvenile chinook salmon.

Effects of Delta Wetlands Project Facilities on Fish Predation

Numerous boat docks and fishing piers are found in the Delta region (see Chapter 3J of the 1995 DEIR/EIS, "Affected Environment and Environmental Consequences—Recreational and Visual Resources"). Docks and piers are present at more than 100 marinas, approximately 23 public recreation facilities that provide boat launching and fishing access, and several private waterfowl hunting clubs. Three of the four Delta Wetlands Project islands (Bacon Island, Webb Tract, and Bouldin Island) do not currently have public recreational boat docks (they do, however, have a limited number of private docks and ramps). The fourth project island, Holland Tract, supports two marinas, one with 335 berths and one with 21 berths. The Delta Wetlands Project may include construction of up to 40 new floating boat docks with as many as 30 berths each. Delta Wetlands may construct fewer and smaller facilities but is proposing the maximum amount, which necessitates worst-case environmental analysis. Also, pilings and other structures would be constructed as part of the siphon and pump facilities on Bacon Island and Webb Tract.

The presence of natural or artificial cover (e.g., trees, rootwads, brush piles, or aquatic plants) in water bodies is well known to attract relatively high concentrations of fish (Johnson and Stein 1979). Food may be more abundant in areas with cover (Johnson et al. 1988). Cover can disrupt streamflow patterns and therefore provide fish with refuges from elevated water velocities associated with high flows (Shirvell 1990). By providing small protected spaces and a diversity of space sizes, cover can effectively reduce predation risk for small fish and can ameliorate competitive interactions (Savino and Stein 1982, Bugert et al. 1991).

Installation of boat docks would not be expected to affect fish predator-prey interactions significantly. Pilings and shade associated with boat docks or fishing piers may be used as cover by both predator and prey fish. However, these structurally simple forms of cover attract fish species much less than more complex forms such as brush piles or aquatic plants (Savino and Stein 1982, Gotceitas and Colgan 1987, Lynch and Johnson 1989).

The construction of new boat docks and other facilities on the Delta Wetlands islands is not expected to increase the vulnerability of juvenile chinook salmon or other species to predation. Comprehensive data about predator-prey interactions involving juvenile salmonids and other species in the Delta are unavailable (U.S. Bureau of Reclamation 1983, Interagency Ecological Program 1995). However, juvenile chinook salmon and other species are known to be vulnerable to predators at locations such as Red Bluff Diversion Dam, Clifton Court Forebay, and release sites for fish salvaged from the SWP and CVP facilities (Hall 1980, Pickard et al. 1982, U.S. Bureau of Reclamation 1983). These facilities and release sites attract relatively high concentrations of juvenile salmonids and other fish species that may be substantially disoriented by turbulence and handling associated with diversion, flow constriction, bypasses, and trucking. The high concentration of disoriented fish could create exceptional predator habitat by increasing prey availability. Boat docks, however, would not divert water or constrict flows and would not cause conditions expected to disorient fish.

The additional information reviewed for this REIR/EIS evaluation does not provide evidence that predation would increase because of the presence of boat docks and other Delta Wetlands Project facilities or change the 1995 DEIR/EIS conclusion that effects of project facilities on fish predation would be less than significant.

Cumulative Impacts

When added to other past, present, and reasonably foreseeable future actions, effects of the Delta Wetlands Project would not be expected to increase cumulative impacts on fish and fish habitat relative to existing conditions. With implementation of the AFRP under the CVPIA, the Ecosystem Restoration Program under CALFED, and other ongoing programs, fish habitat conditions in and upstream of the Delta are expected to improve for chinook salmon and other species. The FOC terms for the Delta Wetlands Project avoid and minimize project effects on Delta fish and their habitat (Table 2-2). The FOC terms include compensatory measures that potentially improve and increase fish habitat, such as conservation of 200 acres of shallow-water rearing and spawning habitat, habitat replacement at a 3:1 ratio, setting aside of environmental water, and contribution of funds for DFG fish and habitat management (i.e., $100 per year per additional boat berth, compensation for incidental entrainment losses, establishment of aquatic habitat conservation and environmental water funds).

Impact Evaluation of Project Alternatives from the 1995 Draft EIR/EIS

Alternatives 1 and 2 described in the 1995 DEIR/EIS represented two scenarios for Delta Wetlands' proposed project, which differed only in terms of allowable discharges of stored water. The biological assessment for Delta Wetlands Project effects on fish species was based on project operations under the proposed project as described for Alternative 2, which would have the maximum amount of discharge pumping and the maximum effect on fisheries associated with discharges under the proposed project. The FOC and RPMs were developed through ESA consultation based on estimated project effects under Alternative 2 operations; as described above, application of the FOC and RPMs would improve conditions for fish in comparison with conditions described in the evaluation of project effects presented in the 1995 DEIR/EIS. Similarly, application of the FOC and RPMs under Alternative 1 operations would improve conditions for fish.

Alternative 3, the four-reservoir-island alternative, has not changed since the 1995 DEIR/EIS was published. The FOC and biological opinion terms were developed for the two-reservoir-island operations and are not applicable to a four-reservoir-island alternative. There is no change to the conclusions of the environmental impact analysis presented in the 1995 DEIR/EIS for Alternative 3.

Table 5-1. Comparison of Juvenile Spring-Run Chinook Salmon Occurrence in the Delta Assumed in the 1995 DEIR/EIS and Provided by DFG in August 1999

	Potential Occurrence in the Delta as a Proportion of Annual Production			
	1995 DEIR/EIS		DFG	
Month	Yearlings	Young-of-Year	Yearlings	Young-of-Year
October	X[a]			
November	X[a]		0.37	
December	X[a]	<0.26	0.42	0.01
January	X[a]	0.26-0.50	0.13	0.06
February		>0.50	0.05	0.17
March		0.26-0.50	0.03	0.28
April		<0.26		0.25
May		<0.26		0.16
June		<0.26		0.07

[a] The proportion in the Delta was not estimated, but occurrence was assumed during the months indicated.

Sources: Jones & Stokes Associates 1995, Wernette pers. comm.

Table 5-2. Dates of Annual Adult Chinook Salmon Migration Past Woodbridge Dam

Year	Date of Percentage of Annual Migration Past Woodbridge Dam	
	50%	90%
1993	November 2	November 20
1994	November 7	November 26
1995	October 28	November 23
1996	October 31	November 20
1997	November 7	November 22
1998	November 3	November 23

Source: Miyamoto pers. comm.

Table 5-3. Dates of Annual Juvenile Chinook Salmon Migration Past Woodbridge Dam

Year	Date of Percentage of Annual Migration Past Woodbridge Dam	
	50%	90%
1994	May 4	May 24
1995	March 6	June 3
1996	March 4	June 6
1997	February 22	May 30
1998	February 4	May 16
1999	February 19	May 14

Source: Miyamoto pers. comm.

Table 5-4. Frequency with which Concentrations of Mokelumne River Water in the South Delta Would Exceed the Percentages Given for Each Month, 1922-1991 Simulation

Frequency (%)	Mokelumne River Water Concentration in the South Delta without the Delta Wetlands Project (%)											
	October	November	December	January	February	March	April	May	June	July	August	September
0	15	48	55	51	63	51	54	41	26	16	16	12
10	8	10	28	38	38	33	28	25	14	5	8	7
20	5	7	13	25	31	28	27	23	8	5	5	5
30	4	6	10	14	24	21	25	21	7	4	5	4
40	3	5	7	11	20	18	22	20	6	4	5	4
50	2	4	5	7	15	16	21	17	5	3	4	4
60	2	3	4	5	11	14	19	15	5	3	4	4
70	2	2	3	5	9	12	16	13	5	3	3	3
80	1	2	3	3	6	7	15	12	5	3	3	3
90	1	1	2	2	3	3	12	11	5	3	3	3
100	0	0	0	0	0	0	0	0	0	0	2	1

Frequency (%)	Mokelumne River Water Concentration in the South Delta with Delta Wetlands Project Diversions (%)											
	October	November	December	January	February	March	April	May	June	July	August	September
0	15	48	55	51	63	51	54	41	26	16	16	12
10	7	8	26	38	37	33	28	25	14	5	8	7
20	4	6	11	25	30	28	27	23	8	5	5	5
30	4	5	9	12	24	21	25	21	7	4	5	4
40	3	5	7	9	18	18	22	20	6	4	5	4
50	2	4	5	7	15	16	21	17	5	3	4	4
60	2	3	4	5	11	14	19	15	5	3	4	4
70	2	2	3	4	9	11	16	13	5	3	3	3
80	1	2	3	3	6	7	15	12	5	3	3	3
90	1	1	2	2	2	3	12	11	5	3	3	2
100	0	0	0	0	0	0	0	0	0	0	2	1

Frequency (%)	Mokelumne River Water Concentration in the South Delta with Delta Wetlands Project Diversions and Discharge (%)											
	October	November	December	January	February	March	April	May	June	July	August	September
0	15	48	55	51	63	51	54	38	26	15	16	12
10	7	8	26	38	37	33	28	24	14	6	8	7
20	4	6	11	25	30	28	27	22	7	5	5	5
30	4	5	9	12	22	22	26	21	7	4	5	4
40	3	5	7	9	18	18	22	19	5	3	5	4
50	2	4	5	7	12	16	20	17	5	3	4	4
60	2	3	4	5	10	14	19	15	5	3	4	4
70	2	2	3	5	8	10	16	13	5	3	3	3
80	1	2	3	3	6	6	15	12	5	3	3	3
90	1	1	2	2	2	3	11	10	4	3	3	2
100	0	0	0	0	0	0	0	0	0	0	2	1

Table 5-5. Comparison between Delta Wetlands Project Impacts on Fisheries in the 1995 DEIR/EIS and in the 2000 REIR/EIS

Impacts and Mitigation Measures of 1995 DEIR/EIS Alternatives 1 and 2	Differences between 1995 DEIR/EIS and 2000 REIR/EIS
	CHAPTER 3F. FISHERY RESOURCES
Impact F-1: Alteration of Habitat (S) • **Mitigation Measure F-1**: Implement Fish Habitat Management Actions (LTS)	**Alteration of Habitat.** The impact would be less than significant based on inclusion of the following project elements identified in the California and federal Endangered Species Act (ESA) biological opinions (see final operations criteria [FOC] in Appendix B): - Conserve in perpetuity 200 acres of shallow-water rearing and spawning habitat. - Contribute $100 per year per additional boat berth for boat-wake-erosion mitigation. - Mitigate on a 3:1 basis for aquatic habitat lost to construction activities. - Limit in-water construction to June through November. (LTS) The project elements would minimize and avoid, where feasible, effects on habitat and would replace lost habitat. The following reasonable and prudent measures (RPMs) will further reduce Delta Wetlands Project impacts: *DFG Biological Opinion* - Provide employee orientation on sensitive-species protection. - Report and confirm compliance with construction guidelines. - Allow DFG personnel access to the project site. - Establish an aquatic habitat restoration fund. *NMFS Biological Opinion* - Complete project construction and maintenance in a manner that does not degrade Delta habitat. (Continued on next page)

Note: S = Significant; SU = Significant and unavoidable; LTS = Less than significant; B = Beneficial.

Impacts and Mitigation Measures of 1995 DEIR/EIS Alternatives 1 and 2	Differences between 1995 DEIR/EIS and 2000 REIR/EIS
	(Continued from previous page) *USFWS Biological Opinion* - Avoid areas of immersed plants while riprap is placed and diversion and discharge structures are built. - Avoid areas of submersed plants while riprap is placed and diversion and discharge structures are built; limit in-water work to June through November.
Impact F-2: Increase in Temperature-Related Mortality of Juvenile Chinook Salmon (S) • **Mitigation Measure F-2**: Monitor the Water Temperature of Delta Wetlands Discharges and Reduce Delta Wetlands Discharges to Avoid Producing Any Increase in Channel Temperature Greater than 1°F (LTS)	**Increase in Temperature-Related Mortality of Juvenile Chinook Salmon.** The impact would be less than significant based on inclusion of the following project elements identified in the California and federal ESA biological opinions (see FOC and RPMs in Appendices B, C, D, and E). (LTS) - Minimize and avoid adverse effects of discharge through changes in water temperature: • when the temperature differential between the discharge and receiving water is greater than 20°F, there shall be no discharge; • when channel water temperature is 55°F or higher and is less than 66°F, it shall not increase by more than 4°F; • when channel water temperature is 66°F or higher and is less than 77°F, it shall not increase by more than 2°F; • when channel water temperature is 77°F or higher, it shall not increase by more than 1°F; and • Delta Wetlands shall develop and implement water temperature monitoring.

Note: S = Significant; SU = Significant and unavoidable; LTS = Less than significant; B = Beneficial.

Table 5-5. Continued

Impacts and Mitigation Measures of 1995 DEIR/EIS Alternatives 1 and 2	Differences between 1995 DEIR/EIS and 2000 REIR/EIS
Impact F-3: Potential Increase in Accidental Spills of Fuel and Other Materials (LTS) • No mitigation is required.	**Potential Increase in Accidental Spills of Fuel and Other Materials.** The impact would be less than significant and would be further minimized by inclusion of the following project elements identified in the California and federal ESA biological opinions: (LTS) - Conserve in perpetuity 200 acres of shallow-water rearing and spawning habitat. - Contribute $100 per year per additional boat berth for boat-wake-erosion mitigation. - Mitigate on a 3:1 basis for aquatic habitat lost to construction activities.
Impact F-4: Potential Increase in the Mortality of Chinook Salmon Resulting from the Indirect Effects of Delta Wetlands Project Diversions and Discharges on Flows (S) • **Mitigation Measure F-3:** Operate the Delta Wetlands Project under Operations Objectives that Would Minimize Changes in Cross-Delta Flow Conditions during Peak Outmigration of Mokelumne and San Joaquin River Chinook Salmon (LTS) **Impact F-5**: Reduction in Downstream Transport and Increase in Entrainment Loss of Striped Bass Eggs and Larvae, Delta Smelt Larvae, and Longfin Smelt Larvae (S)	**Potential Impacts on Chinook Salmon, Striped Bass, Delta Smelt, Longfin Smelt, American Shad, and Other Species.** Interrelated operations criteria address Impacts F-4, F-5, F-6, F-7, and F-8. The impacts would be less than significant based on inclusion of the following project elements identified in the California and federal ESA biological opinions (see FOC and RPMs in Appendices B, C, D, and E). The impacts reduced or avoided are indicated for each operations criterion by the impact number in parenthesis. (LTS) Total Export Criteria: - Annual export of Delta Wetlands stored water will not exceed 250,000 acre-feet (af). This criterion limits the maximum operation effect that could occur in any given year, constraining impacts F-4 through F-8. Diversion Criteria: - Maximum X2 value limits start of Delta Wetlands diversion, September through November (F-4, F-6, F-7, F-8)

(Continued on next page)

Note: S = Significant; SU = Significant and unavoidable; LTS = Less than significant; B = Beneficial.

Impacts and Mitigation Measures of 1995 DEIR/EIS Alternatives 1 and 2	Differences between 1995 DEIR/EIS and 2000 REIR/EIS
• **Mitigation Measure F-4**: Operate the Delta Wetlands Project under Operations Objectives that Would Minimize Adverse Transport Effects on Striped Bass, Delta Smelt, and Longfin Smelt (LTS) **Impact F-6**: Change in Area of Optimal Salinity Habitat (LTS) • No mitigation is required. **Impact F-7**: Increase in Entrainment Loss of Juvenile Striped Bass and Delta Smelt (S) • **Mitigation Measure F-5**: Operate the Delta Wetlands Project under Operations Objectives that Would Minimize Entrainment of Juvenile Striped Bass and Delta Smelt (LTS) **Impact F-8**: Increase in Entrainment Loss of Juvenile American Shad and Other Species (LTS) • No mitigation is required.	Diversion Criteria (continued from previous page): - Maximum X2 value limits magnitude of Delta Wetlands diversion, September through March (all impacts) - Delta Wetlands diversion is limited by a maximum allowable change in X2, October through March (all impacts) - Delta Wetlands diversion to storage is limited by QWEST in March (see California ESA biological opinion) (F-4, F-5, F-6, F-7) - No water is diverted, April and May (F-4, F-5, F-6, F-8) - If the delta smelt fall midwater trawl (FMWT) index is less than 239, no diversion from February 15 through June (F-4, F-5, F-6, F-8) - Diversions are limited to a percentage of Delta surplus, year round (all impacts) - Diversions are limited to a percentage of Delta outflow, year round (all impacts) - Diversions are limited to a percentage of San Joaquin River inflow, December through March (all impacts) - Diversions are reduced when monitoring detects presence of delta smelt, December through August (all impacts) - Diversions are limited if the Delta Cross Channel is closed for fish protection, November through January (F-4, F-6, F-7, F-8)

(Continued on next page)

Note: S = Significant; SU = Significant and unavoidable; LTS = Less than significant; B = Beneficial.

Impacts and Mitigation Measures of 1995 DEIR/EIS Alternatives 1 and 2	Differences between 1995 DEIR/EIS and 2000 REIR/EIS
	(Continued from previous page) Discharge Criteria: - Bacon Island discharge for export is limited to 50% of San Joaquin River inflow, April through June (F-4, F-5, F-8) - Webb Tract discharge for export is prohibited, January through June (F-4, F-5, F-7, F-8) - Discharge for export or rediversion from habitat islands is prohibited (Bouldin Island, Holland Tract), all year (F-4, F-5, F-7, F-8) - Discharge is limited to a percentage of available unused export capacity, February through July (F-4, F-5, F-7, F-8) - Environmental water will be set aside and provided as a percentage of discharge, February through June (F-5, F-6, F-8) - Discharge is reduced when monitoring detects presence of delta smelt, April through August (F-4, F-5, F-8) Other Criteria: - Meet design criteria for fish screens: 0.2 fps approach velocity (F-7, F-8) - Conserve in perpetuity 200 acres of shallow-water rearing and spawning habitat (F-6) - Compensate for incidental entrainment losses, January through March and June through August (F-7, F-8) - Implement a fish monitoring program (all impacts) (Continued on next page)

Note: S = Significant; SU = Significant and unavoidable; LTS = Less than significant; B = Beneficial.

Impacts and Mitigation Measures of 1995 DEIR/EIS Alternatives 1 and 2	Differences between 1995 DEIR/EIS and 2000 REIR/EIS
	(Continued from previous page) California ESA RPMs: - Delta Wetlands will provide an environmental water fund based on diversions from October through March and discharge (all impacts) - Aquatic habitat development measures will be implemented to offset impacts of moving X2 upstream from February through June (F-6)
Cumulative Impacts	
Impact F-17: Alteration of Habitat under Cumulative Conditions (LTS) • No mitigation is required.	**Alteration of Habitat under Cumulative Conditions.** Similar to the descriptions provided above, Delta Wetlands Project cumulative impacts on fish populations and habitats would be less under the FOC and biological opinion measures than the impacts described in the 1995 DEIR/EIS. The FOC and other measures reduce the Delta Wetlands Project's contribution to cumulative adverse conditions in the Delta. The significance findings made above for the project's direct and indirect impacts are applicable to the related cumulative impact. (LTS) See above discussion under Impact F-1 (page 1).
Impact F-18: Potential Increase in Accidental Spills of Fuel and Other Materials under Cumulative Conditions (LTS) • No mitigation is required.	See above discussion under Impact F-3 (page 3).

Note: S = Significant; SU = Significant and unavoidable; LTS = Less than significant; B = Beneficial.

Table 5-5. Continued

Impacts and Mitigation Measures of 1995 DEIR/EIS Alternatives 1 and 2	Differences between 1995 DEIR/EIS and 2000 REIR/EIS
Impact F-19: Potential Increase in the Mortality of Chinook Salmon Resulting from the Indirect Effects of Delta Wetlands Project Diversions and Discharges on Flows under Cumulative Conditions (S) • **Mitigation Measure F-3:** Operate the Delta Wetlands Project under Operations Objectives that Would Minimize Changes in Cross-Delta Flow Conditions during Peak Outmigration of Mokelumne and San Joaquin River Chinook Salmon (LTS)	See above discussion under Impacts F-4 through F-8 (beginning on page 3).
Impact F-20: Reduction in Downstream Transport and Increase in Entrainment Loss of Striped Bass Eggs and Larvae, Delta Smelt Larvae, and Longfin Smelt Larvae under Cumulative Conditions (S) • **Mitigation Measure F-4:** Operate the Delta Wetlands Project under Operations Objectives that Would Minimize Adverse Transport Effects on Striped Bass, Delta Smelt, and Longfin Smelt (LTS)	See above discussion under Impacts F-4 through F-8 (beginning on page 3).
Impact F-21: Change in Area of Optimal Salinity Habitat under Cumulative Conditions (LTS) • No mitigation is required.	See above discussion under Impacts F-4 through F-8 (beginning on page 3).

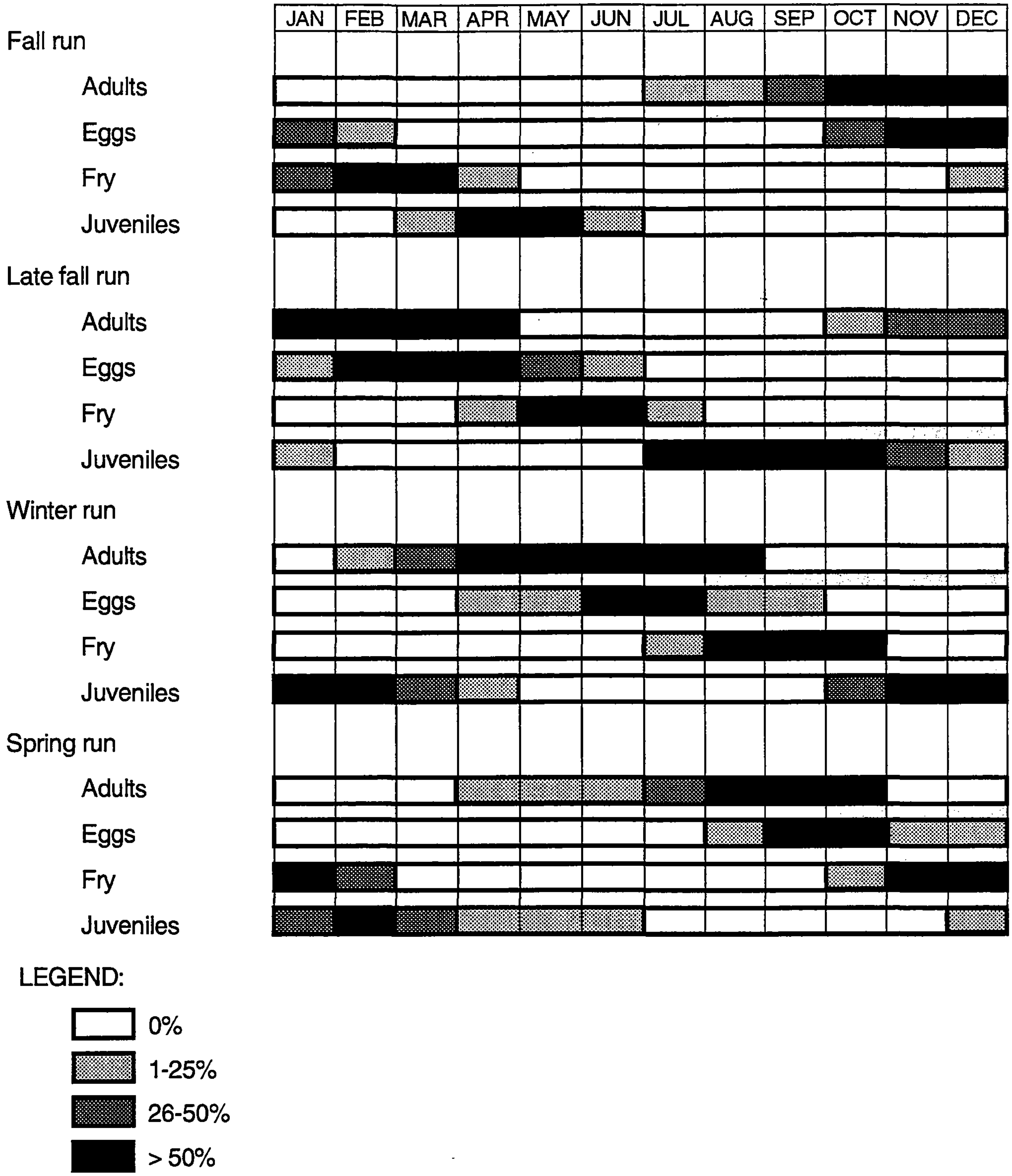
Note: S = Significant; SU = Significant and unavoidable; LTS = Less than significant; B = Beneficial.

Table 5-5. Continued

Impacts and Mitigation Measures of 1995 DEIR/EIS Alternatives 1 and 2	Differences between 1995 DEIR/EIS and 2000 REIR/EIS
Impact F-22: Increase in Entrainment Loss of Juvenile Striped Bass and Delta Smelt under Cumulative Conditions (S) • **Mitigation Measure F-5:** Operate the Delta Wetlands Project under Operations Objectives that Would Minimize Entrainment of Juvenile Striped Bass and Delta Smelt (LTS)	See above discussion under Impacts F-4 through F-8 (beginning on page 3).
Impact F-23: Increase in Entrainment Loss of Juvenile American Shad and Other Species under Cumulative Conditions (LTS) • No mitigation is required.	See above discussion under Impacts F-4 through F-8 (beginning on page 3).

Notes: Impacts F-9 through F-16 of the 1995 DEIR/EIS describe impacts of Alternative 3, the four-reservoir island alternative. There is no change to the assessment of Alternative 3; therefore, the impacts and mitigation measures have not changed.

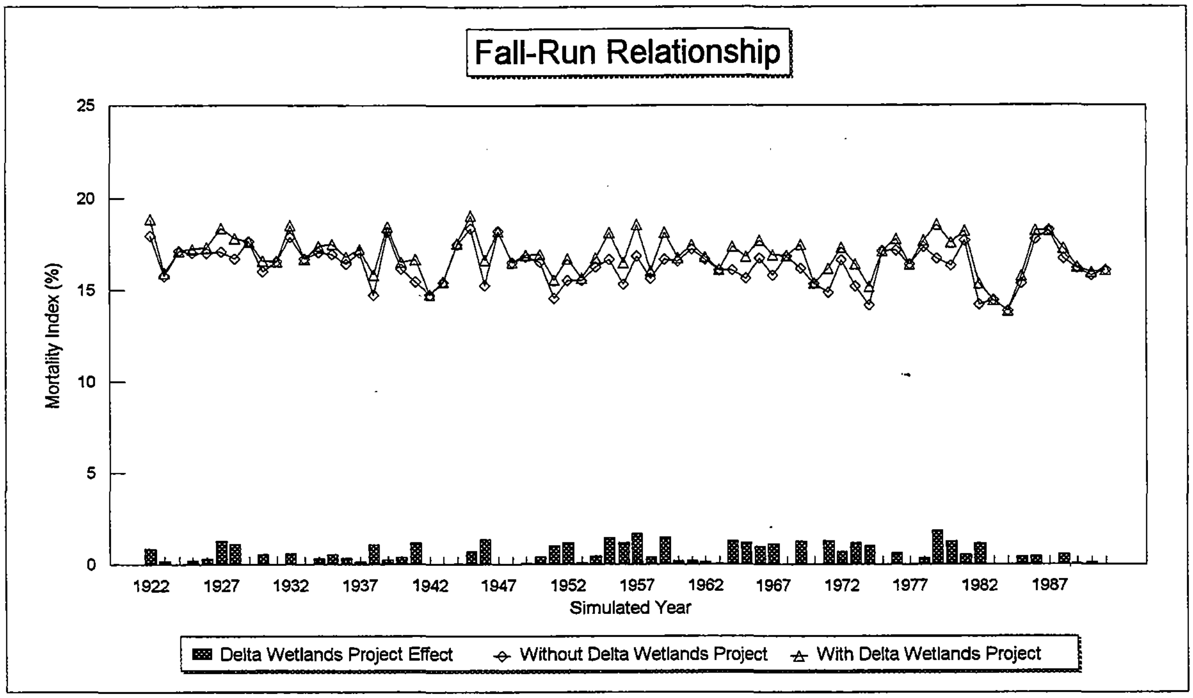
S = Significant; SU = Significant and unavoidable; LTS = Less than significant; B = Beneficial.



Note: Designations for adults represent the percentage of the spawning population that has arrived on the spawning grounds by the month shown. Designations for eggs, fry, and juveniles represent the percentage of the year's brood present during each month.

Jones & Stokes

Figure 5-1
Occurrence of Chinook Salmon by Life Stage in the Sacramento River Basin



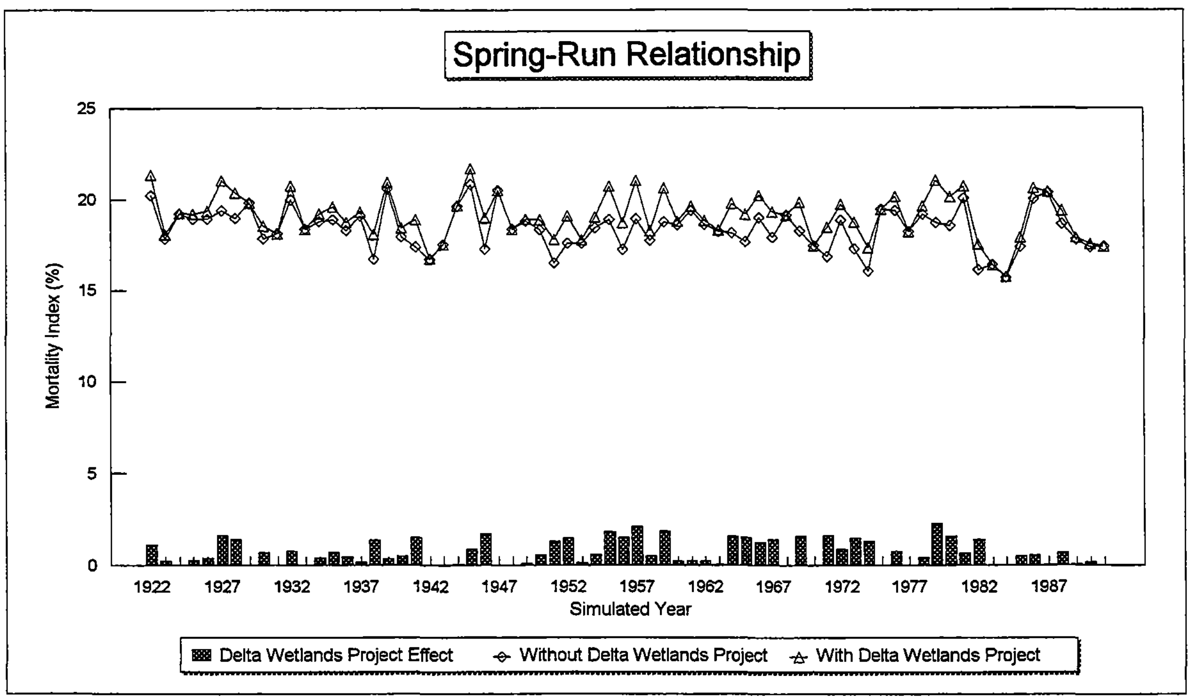
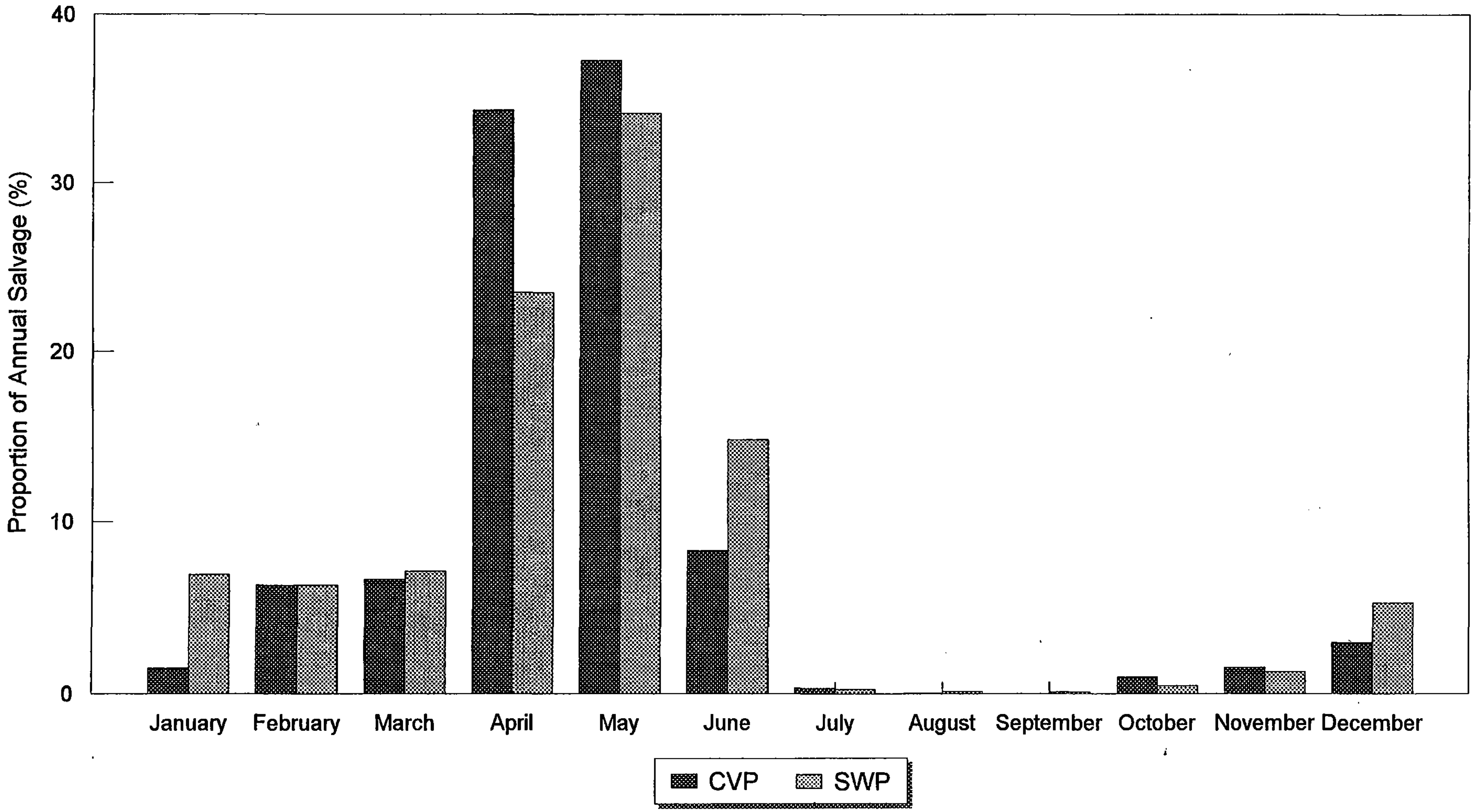


Figure 5-2
Comparison of the Fall-Run Relationship to the Spring-Run Relationship for Assessment of Delta Wetlands Project Effects on Survival of Juvenile Spring-Run Chinook Salmon



Source: California Department of Fish and Game Salvage Data 1980-1994, Stockton, CA.

Jones & Stokes

Figure 5-3
Proportion of Annual Salvage of Juvenile Chinook Salmon by Month for the CVP and SWP Fish Protection Facilities

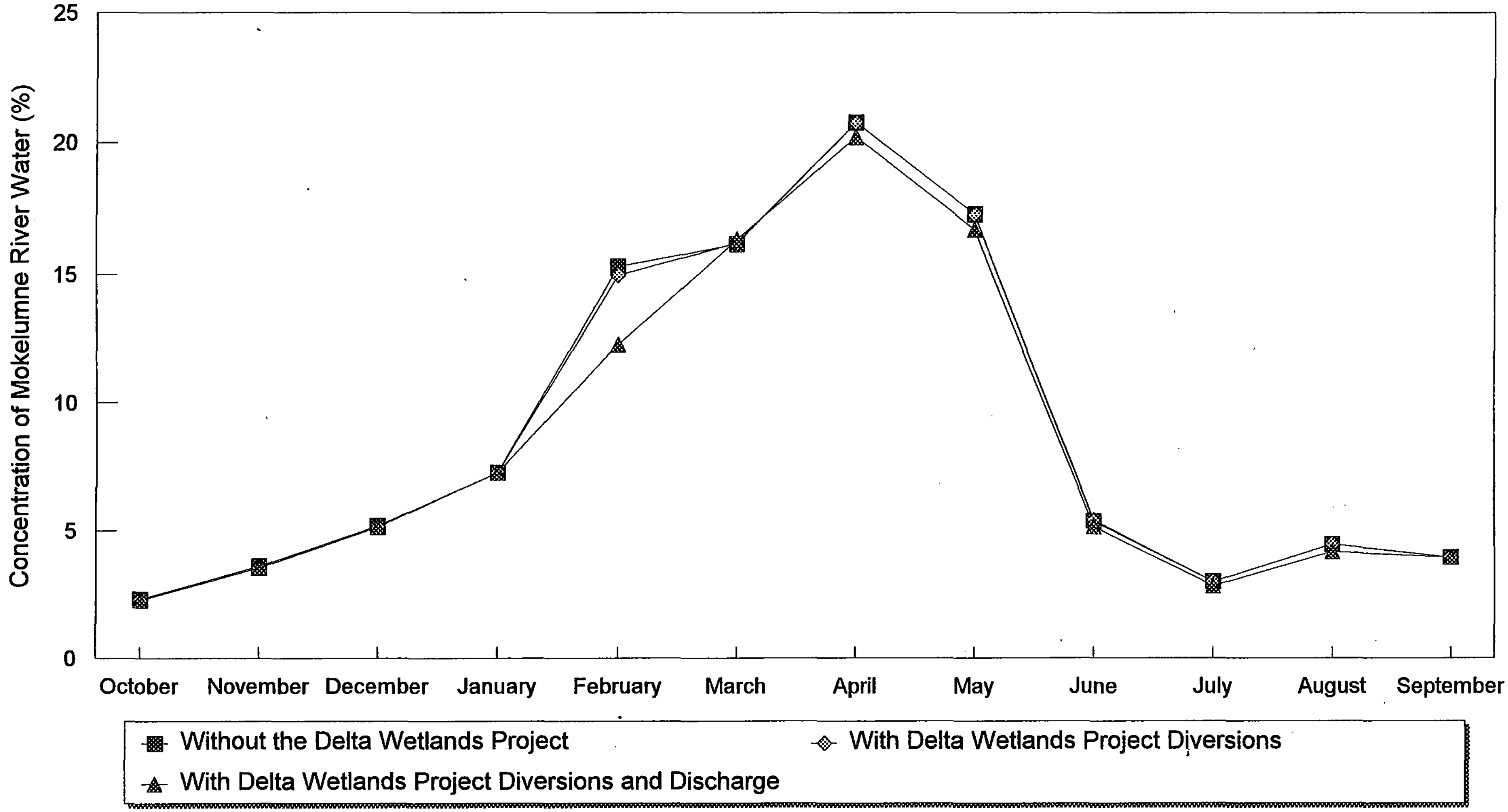


Figure 5-4
Median Concentration of Mokelumne River Water in the South Delta with and without Delta Wetlands Project Operations

Chapter 6. Levee Stability and Seepage

FOCUS OF THE REVISED DRAFT EIR/EIS ANALYSIS

This chapter presents information, developed since the 1995 DEIR/EIS was published, on potential Delta Wetlands Project effects on levee stability and seepage. The 1995 DEIR/EIS described Delta Wetlands' proposed preliminary levee design and seepage control system; that system includes operational measures developed by Delta Wetlands to avoid or reduce potential effects of project construction and operation on levee stability and use of adjacent islands for agriculture. In response to testimony presented at the Delta Wetlands water right hearing, the lead agencies determined that new information should be presented in this REIR/EIS to augment the evaluation presented in Chapter 3D, "Flood Control", of the 1995 DEIR/EIS.

Delta Wetlands' Proposed Levee Design and Seepage Control System

As described in Chapter 3D of the 1995 DEIR/EIS, Delta Wetlands proposes to improve the levees surrounding the reservoir islands. Under existing conditions, levee conditions are greatly variable. A typical present levee condition is a 20-foot-wide crest at an approximate elevation of +8.5 feet above mean sea level with an exterior (water-side) slope of 2:1 (horizontal to vertical) and an interior (land-side) slope of 4:1. Under the proposed project, a typical improved levee would have an exterior slope of 2:1, a crest about 22 feet wide (including the thickness of erosion protection on the interior slope) at an elevation of about +9 feet, a 3:1 or steeper initial interior slope down to an elevation near -3 feet, and wide land-side toe berms to buttress the levee. Alternatively, the interior slope may be inclined at about 5:1 and may not have toe berms. Figure 6-1 shows examples of potential initial levee improvements on levees with a 3:1 existing interior slope. The new slopes would meet or exceed criteria for Delta levees outlined in DWR Bulletin 192-82. Levee-improvement materials would be obtained primarily from sand deposits on the project islands. Each borrow area would generally be located more than 400 feet inward from the toe of a levee so that the borrow excavation would not cause structural impacts on the levee and would be at least 2,000 feet inward from the final toe of an improved levee where a greater setback is necessary to control seepage.

The interior slopes of these perimeter levees would be protected from erosion by conventional rock revetment similar to that used on existing exterior slopes, or by other conventional systems such as soil cement or a high-density polyethylene liner. In areas where final design studies indicate that wave splash and runup could potentially erode the levee crest if it is unprotected, the levee crest would be hardened or the erosion-protection facing would be extended up as a splash berm.

The proposed project includes a seepage-control system that would consist of interceptor wells installed in the exterior levees of the reservoir islands in locations where substantial seepage to adjacent islands through subsurface materials is predicted to occur (Figure 6-2). Water captured by the interceptor wells would be pumped back into the reservoirs. The interceptor wells would be used to maintain the hydraulic heads in subsurface materials within preproject ranges at distances of 500 to 1,000 feet from the project island perimeters (i.e., beneath levees of adjacent islands).

Delta Wetlands would implement a seepage monitoring program to provide early detection of seepage problems caused by project operations (Figure 6-2). A network of wells (i.e., piezometers) located immediately across the channels from the reservoir islands would be used to monitor seepage; background wells at distant locations would establish water-level changes that typically occur without project operations. Delta Wetlands has proposed seepage performance standards for the project that would be used to determine the amount of interceptor-well pumping needed to ensure that seepage is reduced to acceptable levels. The seepage-control system and seepage performance standards are described fully in Chapter 3D of the 1995 DEIR/EIS.

1995 Draft EIR/EIS Evaluation, Comments, and New Information

1995 Draft EIR/EIS Evaluation

The evaluation of project effects presented in the 1995 DEIR/EIS was performed by comparing the proposed levee improvement design with existing conditions as described in the results of the preliminary investigations performed by Delta Wetlands' geotechnical consultants. These investigations included numerous field studies, monitoring, modeling, and levee stability analyses (see Appendix D1 of the 1995 DEIR/EIS for a listing). The impact analysis concluded that because of the elements and operational measures incorporated into the project design, the project would have no significant impacts on levee stability and seepage.

New Information Developed for This Evaluation

Several commenters on the 1995 DEIR/EIS and protestants against Delta Wetlands' water right applications questioned the adequacy of Delta Wetlands' proposal with regard to levee stability and seepage to adjacent islands. To address this issue regarding the project's potential effects, an additional independent analysis of levee stability and seepage issues has been performed to provide information to supplement the 1995 DEIR/EIS discussion.

The analysis of these issues, performed by URS Greiner Woodward Clyde (URSGWC), is included as Appendix H of this REIR/EIS, "Levee Stability and Seepage Analysis Report for the Delta Wetlands Project Revised Draft EIR/EIS". This chapter updates the assessment of potential

Delta Wetlands Project effects presented in Chapter 3D of the 1995 DEIR/EIS by summarizing the findings of the URSGWC analysis and, as requested by the lead agencies, presenting new information on boat-wake effects on levee erosion.

Summary of Issues Addressed in This Chapter

The REIR/EIS analysis of issues related to flood control addresses the following questions, which represent the concerns expressed at the water right hearing and in comments on the 1995 DEIR/EIS:

- Can a pumped-well system (i.e., Delta Wetlands' proposed interceptor-well system) control groundwater seepage?
- What is the long-term reliability of the proposed interceptor-well system of seepage control?
- Would the proposed seepage monitoring program be adequate and effective?
- Could operation of the seepage-control system result in substantial water diversion onto the reservoir islands?
- Would the proposed setbacks for borrow-pit areas be adequate to prevent excessive seepage increases in the underlying sand aquifer?
- Would rapid changes in the reservoir water level cause additional stresses on underlying soil layers and additional settlement of the levees and interiors of reservoir islands?
- Would Delta Wetlands operations reduce the levees' dynamic or static stability?
- Would the construction and operation of the interceptor-well system reduce levee stability?
- What potential damage to adjacent islands could result if a reservoir island's levee failed or if the owner abandoned the project?
- Would increased wave action from Delta Wetlands Project-related boat use in Delta channels contribute to levee erosion and adverse effects on channel island habitats?

The information presented in this chapter adds more detail to the impact evaluation presented in the 1995 DEIR/EIS; however, the analysis does not address every extreme of conditions that could be encountered during project implementation. The discussion below is based on a proposed preliminary design of flood- and seepage-control features of the project and represents a general evaluation of the environmental feasibility of these features. Specific design issues, including site-specific geotechnical evaluations, will be addressed in detail as the lead agencies and the applicant proceed through the permit approval processes. Nonetheless, the level of detail presented below is adequate for purposes of CEQA and NEPA impact analysis and for determining the general feasibility of Delta Wetlands' proposal for levee stability and seepage control.

Definition of Terms

The following are definitions of key terms as they are used in this chapter:

- *Aquifer:* A porous soil or geological formation lying between impermeable strata that contains groundwater; yields groundwater to springs and wells.

- *Bearing Capacity:* The maximum load that a structure can support, divided by its effective bearing area (the part of the structure that carries the load).

- *Borrow Area:* An excavated area or pit created by the removal of earth material to be used as fill in a different location.

- *Buttress:* To steady a structure by providing greater resistance to lateral forces to prevent failure.

- *Design Response Spectrum:* The specified range of ground motion in response to seismic activity that is assumed for an analysis based on historical data and local soil conditions.

- *Dynamic and Static Stability:* The stability of levees under seismic movement or without seismic movement.

- *Factor of Safety for Slope Stability (FS):* A calculated number representing the degree of safety of a slope against instability. The FS is expressed mathematically as the ratio of stabilizing effects (forces or moments) and destabilizing effects acting on a potentially unstable soil mass in a slope. When the FS is greater than 1, the soil mass in the slope is, in theory, stable; when the FS is less than 1, the slope is, in theory, unstable. For a given slope geometry and soil conditions, a calculated FS is associated with a unique slope failure configuration. The most critical failure configuration is associated with the minimum FS calculated in a slope stability analysis. Several agencies (such as the Association of State Dam Safety Officials and USACE) have developed criteria that provide different design FSs stipulated for various slope conditions (e.g., under long-term loading, shortly after construction, etc.). These FSs are typically above 1 and are minimum values to be achieved for the slope to be considered stable.

- *Freeboard:* The vertical distance between a design maximum water level and the top of a structure such as a levee, dike, floodwall, or other control surface. The freeboard is a safety margin intended to accommodate unpredictable rises in water level.

- *Hydraulic Conductivity:* A measure of the capacity of a porous medium to transmit water, often expressed in centimeters per second. The hydraulic conductivity is equal to the rate of flow of water through a cross section of one unit area under a unit hydraulic gradient.

- *Hydraulic Gradient:* The rate of change in total hydraulic head per unit distance of flow measured at a specific point and in a given direction, often resulting from frictional effects along the flow path.

- *Hydraulic Head:* The force exerted by a column of liquid expressed as the height of the liquid above the point at which the pressure is measured (the force of the liquid column being directly proportional to its height).

- *Interceptor Well:* In the context of the Delta Wetlands Project, a pumped well located on an island levee for controlling groundwater flow off the island.

- *Interceptor-Well System:* A seepage-control system that would consist of actively pumped wells installed in the exterior levees of the reservoir islands in locations where substantial seepage to adjacent islands is predicted to occur.

- *Levee Crest*: The top of a levee.

- *Liquefaction:* The process in which loose saturated soils lose strength when subject to seismic activity (i.e., shaking).

- *Overtopping:* Passing of water over the top of a levee as a result of wave runup or surge action.

- *Passive-Flow Relief-Well System:* A system of wells that passively relieve elevated hydrostatic pressures in an aquifer by allowing flow to the surface. (Hydrostatic pressure is the pressure exerted by a liquid, such as water, at rest.)

- *Phreatic:* Of or pertaining to groundwater.

- *Phreatic Surface:* The surface of a body of unconfined groundwater at atmospheric pressure.

- *Piezometer:* A sandpipe monitoring well used to measure the depth to the groundwater surface in the aquifer.

- *Piping:* The removal of fine soil particles from the soil mass by high hydraulic gradients. For example, excessively high exit hydraulic gradients at the surface may cause upward transport of soil, resulting in sand boils.

- *Rock Revetment:* A stone covering used to protect soil or surfaces from erosion by water or the elements. Also referred to as riprap.

- *Seepage:* A slow movement of water through permeable soils caused by increases in the hydraulic head (see "hydraulic head" below).

- *Seepage Flux:* The rate of flow of water across a given line or surface, typically expressed in gallons per minute (gpm) or cfs.

- *Settlement:* The sinking of surface material as a result of compaction of soils or sediment caused by an increase in the weight of overlying deposits, by pressure resulting from earth movements, or by the removal of water from the soil or sediment.

- *Slope Deformations:* Changes in the shape or size of a slope.

- *Splash Berm:* An extended area of facing on an island levee designed to protect against erosion of the levee crest by wave splash and runup..

- *Stratigraphy:* The composition, characteristics, distribution, and age relation of layered rocks and soils.

- *Toe Berm:* The section projecting at the base of a dam, levee, or retaining wall.

- *Wave Runup*: The vertical height above stillwater level to which water from an incident wave will run up the face of a structure.

- *Wind Fetch:* An area of water over which wind blows, generating waves.

- *Yield Acceleration:* Pseudostatic horizontal force that will give a calculated factor of safety of 1 in slope-stability analyses.

NEW INFORMATION

Information used to prepare the discussion of levee stability and seepage in this chapter is summarized from URSGWC's report of new technical analyses of Delta Wetlands' proposed levee design and seepage-control system (Appendix H of this REIR/EIS) and from testimony presented at the water right hearing. Information on boat-wake-induced erosion is based on a literature review and discussion with knowledgeable individuals.

Results of the New Analysis of Delta Wetlands Project Effects on Seepage

As described in Chapter 3D of the 1995 DEIR/EIS and confirmed by the URSGWC seepage analysis, Delta Wetlands Project operations would increase the potential for seepage onto islands adjacent to the reservoir islands. These seepage effects would occur because deep sand aquifers underlie the reservoir islands and adjacent islands, as well as the channels or sloughs separating them. Storing water on the reservoir islands would increase the elevation of the phreatic (i.e., groundwater) surface and the hydraulic pressure on the aquifer, thereby inducing seepage through the sand aquifer onto the neighboring islands.

Delta Wetlands considered several technically feasible methods for controlling seepage onto the adjacent islands. These measures include pumping from reservoir island levees, pumping from levees of adjacent islands, using passive or active relief wells or trenches on adjacent islands, and using a continuous cutoff wall in the reservoir island levees. Installing seepage control measures on the adjacent islands may be hydraulically more efficient because it would require less pumping; however, these potential solutions were eliminated from consideration because of concerns about land ownership and access. A continuous cutoff wall was likewise eliminated by Delta Wetlands from consideration because it would be cost prohibitive. Delta Wetlands has therefore proposed to install a system of interceptor wells on the reservoir island levees to control seepage.

The following discussions summarize URSGWC's seepage analysis methodology and the findings of the analysis; where appropriate, references are given to specific sections of URSGWC's analysis (Appendix H).

Seepage Analysis Methodology

Previous analyses prepared by Delta Wetlands' consultants (Hultgren and Tillis, Harding Lawson Associates, and Moffat & Nichols) used plan-view modeling techniques to estimate seepage conditions. Plan-view modeling considered only horizontal seepage within the sand aquifer, where most seepage would occur. This approach does not include seepage through other elements of the subsurface strata or the effects of vertical infiltration from the storage reservoirs or adjacent channels. Consequently, the plan-view modeling approach does not adequately simulate the localized seepage conditions near the proposed interceptor-well system.

To better evaluate the performance of the proposed interceptor-well system, URSGWC used a two-dimensional finite element model (SEEP/W) (Geo-Slope International Ltd. 1994) for two cross sections each of Bacon Island and Webb Tract. The cross sections were selected based on available data to be conservative and reasonably representative of relatively high seepage conditions that would be encountered on the reservoir islands. The two-dimensional modeling approach considers all major elements of subsurface stratigraphy and vertical infiltration from the reservoir islands and channels.

The following parameters deemed critical for the evaluation of seepage effects of reservoir operations were considered in the URSGWC analysis:

- average total hydraulic head in the sand aquifer near the levee centerline on a reservoir island,
- seepage flux (seepage flow through a vertical section) near the project-island levee centerline,

- average total hydraulic head in the sand aquifer at an adjacent-island levee,
- seepage flux at the centerline of the adjacent-island levee, and
- water-table level at the far inland toe of the adjacent-island levee.

No site-specific investigation or testing was performed as a part of the URSGWC analysis. The lead agencies considered the previously collected soil profiles adequate for the level of analysis presented in this REIR/EIS. The characterizations of soils, levee properties, seismic setting, and hydraulic and hydrologic conditions were based on available data, publications, and professional engineering judgment and experience. As discussed in Appendix H, significant additional detailed predesign soil profiling and analysis will be required before construction.

The model input parameters, calibration, and sensitivity analyses are described in Section 2, "Seepage Issues", of Appendix H.

Ability of a Pumped-Well System to Control Groundwater Seepage

Using the SEEP/W model, URSGWC evaluated three conditions:

- existing seepage conditions,
- a full reservoir with no interceptor well pumping, and
- a full reservoir with pumping.

The analysis determined that a pumped-well system (i.e., the proposed interceptor-well system) with wells spaced at 160 feet on center and a pumping rate of 5 to 12 gpm, depending on local conditions, would be adequate to maintain seepage at existing levels beneath the levees on adjacent islands (Table 2.3.2 of Appendix H). For both Webb Tract and Bacon Island, URSGWC notes that the interceptor well system should extend to the bottom of the sand aquifer, the pumping well should be screened over the entire length of the aquifer to achieve the required drawdown at the well, and the pumps should be sized to efficiently handle the required pump rate.

URSGWC concluded that the interceptor-well system of seepage control as proposed by Delta Wetlands "appears effective to control undesirable seepage effects" and that "a properly functioning interceptor well system can be used to minimize the effects of the proposed reservoirs on adjacent islands, including the potential for rises in the groundwater table or flooding". The summary of findings also notes that the proposed spacing of 160 feet between interceptor wells appears to be adequate. The findings indicate that spacings and pumping rates will be more precisely defined for each levee section during the final design of the project and note that adjustments in the design of the interceptor-well system will be required to accommodate varying site-specific conditions. Following detailed investigations of subsurface conditions, adjustments in the well interceptor system design will be required to accommodate varying conditions, ranging from areas where little or no pumping may be needed to areas where pumping rates may be much higher than is typical (e.g., along localized gravelly portions of the aquifer). For example, previous studies have shown variations in the hydraulic conductivity of the sand aquifer up to five to six times those used in the URSGWC analyses. Such a higher conductivity could require pumping rates of as much as 50 to 60 gpm in some portions of the reservoir levee pump field for wells spaced at 160 feet to maintain seepage at existing levels. (See Sections 2.3.5 and 4.1 of Appendix H.)

Long-Term Reliability of the Proposed Interceptor-Well System

As described in Chapter 3D of the 1995 DEIR/EIS, Delta Wetlands' geotechnical consultants conducted a series of demonstration projects on McDonald Island in 1990 to show the effectiveness of a pumped-well system and a passive-flow relief-well system in lowering the hydraulic head in the sand aquifer. Mildred Island, located immediately west of McDonald Island, has been flooded since 1983. The analysis showed that both a pumped-well system and a passive-flow relief-well system reduced the hydraulic head, but that the passive-relief system resulted in less drawdown. Evidence was presented in water right hearing testimony that McDonald Island land became saturated and unfarmable after the demonstration projects were completed. Delta Wetlands' geotechnical consultant Ed Hultgren testified, however, that the relief wells became less effective with time as they became clogged with silt. Hultgren added that the demonstration wells were constructed for the demonstration project only, not for long-term use, and that when the demonstration projects were complete, the wells were not maintained.

URSGWC reviewed the previously prepared reports and generally concurred with their findings that the drawdown test on McDonald Island showed:

- the interceptor-well system could be effective in controlling seepage, and
- an interceptor-well system installed on the perimeter of the reservoir islands could be a viable system to control the seepage into the neighboring islands.

URSGWC also concluded, however, that the McDonald Island demonstration projects show that final design and proposed maintenance programs must address the potential migration of fine materials from the sand aquifer to a pumped-well system (Section 2.2.7 of Appendix H). Migration of fine materials from the sand aquifer could decrease the efficiency of the wells and could result in subsidence or slumping of the levees (see "Effect of the Interceptor-Well System on Levee Stability" below.) Regular performance monitoring, maintenance, and "redevelopment" (cleaning) of the wells will be required to ensure long-term effectiveness of the proposed interceptor-well system. The report states the following (Section 2.5 of Appendix H):

- The design of the well screen and surrounding gravel pack will need to accommodate the grain sizes of the aquifer.
- The perforated section of the well casing should stay submerged (i.e., should not extend above the elevation of the deepest expected drawdown of the water table) to minimize the possibility of fouling of the screen by organic growths.

- It would be useful for the individual wells to be equipped with flow meters so that any dropoff in output can be identified.

- It would be necessary, during the final design, to evaluate the likelihood of power outages and their consequences on seepage control and to consider whether providing standby generators would be advisable.

Adequacy and Effectiveness of the Proposed Seepage Monitoring Program

Delta Wetlands has proposed a monitoring program to ensure that there is no net seepage onto adjacent islands. The proposed monitoring program includes hourly measurements of water levels in seepage monitoring wells (i.e., piezometers), background monitoring wells, and adjacent sloughs and channels. The seepage and background monitoring wells are located on the levees of islands adjacent to the reservoir islands; the locations proposed by Delta Wetlands are shown in Figure 6-2. Delta Wetlands proposes to implement additional seepage control measures if the monitoring data indicate that water levels in the seepage monitoring wells have exceeded performance standards (see Chapter 3D of the 1995 DEIR/EIS) and the increased seepage is attributable to reservoir-island filling. URSGWC reviewed the monitoring program and determined that it is appropriate in concept, but recommends modifying the program as follows (Section 2.4 of Appendix H):

- The background monitoring wells should not be more than 1 mile from the seepage monitoring wells.

- More than one background monitoring well should be used for each row of seepage monitoring wells.

- At least 3 years of data should be used to establish reference water levels in the background monitoring wells and in at least half of the seepage monitoring wells before reservoir operations begin.

- A running straight-line mean from the monitoring well data should be used in the application of the seepage performance standards.

- The seepage performance standard of 1 foot should be reduced to 0.5 foot for the single-well condition.

- The seepage performance standards should be reevaluated periodically after reservoir operations begin.

Additionally, URSGWC notes that the proposed seepage monitoring system does not account for the relationship between groundwater elevations and seasonal or local variation within each adjacent island. Local conditions could include changes in groundwater levels attributable to local pumping for farming operations. To monitor trends in groundwater management on the neighboring islands, URSGWC recommends that Delta Wetlands supplement the proposed background well system with shallow background wells (10 to 20 feet deep) installed across each neighboring island. These additional background wells would be placed one-half mile to 1 mile apart, beginning near the levee adjacent to the reservoir island and continuing across the adjacent island, so that groundwater levels at increasing distance from the reservoir island can be compared. During final design, the specific location and spacing of these wells should be finalized based on groundwater conditions in each neighboring island.

Water Diversion onto the Storage Islands through Interceptor-Well Pumping

Under certain water-level conditions in the reservoir islands and adjacent channels, water from adjacent channels could be inadvertently diverted onto the reservoir islands through operation of the interceptor-well system or direct seepage. Using the SEEP/W model, URSGWC evaluated the volume of seepage and the rate of interceptor-well pumping under full-reservoir conditions. For this evaluation, it was assumed that water pumped from the interceptor wells would be returned to the reservoirs. The study concluded that if Delta Wetlands operated the seepage-control system at the minimum rate necessary to prevent net seepage on adjacent islands, the simulated flux of water from the slough toward the reservoir islands would be about the same as the flux under simulated existing conditions for most locations and would constitute approximately 8% of the total water pumped from the wells (Section 2.6 of Appendix H). The proposed seepage monitoring program could be used in conjuction with pumping-rate monitoring to determine the volume of channel water being pumped onto the reservoir through the interceptor-well system or through direct seepage.

Adequacy of Borrow-Area Setbacks

URSGWC used the SEEP/W model to evaluate whether Delta Wetlands' proposed borrow-area setbacks would be adequate to prevent excessive seepage increases in the underlying sand aquifer. URSGWC concluded that borrow areas located 400 feet from the toe of the reservoir island levees would have an insignificant effect on the total hydraulic head conditions within the sand aquifer near the levees or the required pump rate at the interceptor-well system. The modeling showed that setting the borrow area back 800 feet from the levee in accordance with USACE standards would result in no effects (i.e., no additional benefit) on seepage conditions or operation of the interceptor-well system (Section 2.3 of Appendix H).

Effects of Rapid Changes in Reservoir Water Levels on Settlement of Island Interiors

URSGWC evaluated the conceptual mechanisms that would lead to land-surface subsidence on the interiors of the reservoir islands and concluded that additional settlement caused by operation of the Delta Wetlands Project would be nominal. The weight of water stored on the reservoir islands would compact the soil and lead to settlement of the reservoir island interiors. The evaluation determined that project operations would result in approximately 1 foot of additional settlement over the life of the project, with most soil compaction occurring during the first year of water storage operations. This predicted settlement is only a fraction of the land-surface subsidence that would be expected to occur if the existing agricultural practices are continued in the future. Under existing agricultural practices, land-surface subsidence would continue until all peat materials have oxidized, which would result in a long-term lowering of the ground surface of approximately 15 feet on Webb Tract and 10 feet on Bacon Island. (Section 2.7 of Appendix H.)

Results of the New Analysis of Delta Wetlands Project Effects on Levee Stability

The four Delta Wetlands islands are bounded by "nonproject" levees. Federal "project" levees are maintained to USACE standards by the State of California or by local landowners under state supervision; nonproject levees are defined as levees constructed and maintained by local landowners and reclamation districts. Delta Wetlands' proposed improvements to its levees are described in Chapter 3D of the 1995 DEIR/EIS and are summarized above under "Delta Wetlands' Proposed Levee Design and Seepage Control System". Placement of toe berm fill and fill on the levee slopes and crest would take place in stages to allow for consolidation of material. Delta Wetlands' proposed project includes regular inspection and maintenance of the levees.

The main objective of the levee-stability analysis performed by URSGWC was to evaluate Delta Wetlands' proposed levee-strengthening method for the reservoir islands. The analysis focused on the static and dynamic slope stability of the proposed levee configuration. Other performance conditions were studied as well, including:

- load bearing capacity;
- slope deformations and settlement and their effects on levee stability; and
- potential effects associated with geologic and seismic hazards, such as liquefaction.

The following discussions summarize URSGWC's methodology for analyzing levee stability and the findings of the analysis; where appropriate, references are given to specific sections of URSGWC's analysis (Appendix H).

Methodology Used for the Levee Stability Analysis

For the evaluation of Delta Wetlands project effects on levee stability, URSGWC reviewed published literature on peat soil as well as the geotechnical studies, including slope-stability analyses, previously prepared for Delta Wetlands by its own consultants. URSGWC reviewed the assumptions and results of these studies and used information from these reports to develop the soil parameters included in its analysis.

The URSGWC analysis considered both the dynamic and static stability of the proposed levee improvements by using four cross sections, two for each of the reservoir islands. The cross sections were selected to be reasonably representative of conditions that would be encountered on the reservoir islands, and that would represent conservative estimates for stability issues. (Some cross sections were therefore different from the cross sections used for the seepage analysis, which were selected to allow for conservative analysis of seepage effects.) The analysis considered the potential for failure of the slope toward the island and the slope toward the slough. For both slopes, the following cases were considered:

- existing conditions;
- the end of construction (i.e., soil-consolidation condition);
- long-term conditions;
- sudden drawdown (i.e., an emergency evacuation of stored water); and
- pseudostatic conditions (i.e., the stability of the slope during seismic loading, which is analyzed to determine yield acceleration and estimate earthquake-induced deformation).

Static Stability Analysis. URSGWC analyzed the static stability of levees using the limit equilibrium method based on Spencer's procedure of "slices" using the computer program UTEXAS3 (Wright 1991). The program iteratively balances the FS and the side force inclination until both force and moment equilibrium forces are satisfied. The UTEXAS3 model can simulate rapid undrained loading that follows a period of soil consolidation (end of levee construction) and rapid drawdown (emergency evacuation of stored water). Section 3, "Slope Stability Issues", of Appendix H details the review of previous studies and describes selected parameters and methods used in this analysis.

Dynamic (i.e., Seismic) Stability Analysis. For the evaluation of seismically induced levee deformations and geologic hazards, URSGWC reviewed previous ground-motion studies for the project area, developed and updated dynamic soil parameters based on recent findings and published data, and developed design earthquake ground motions based on horizontal earthquake acceleration time histories recorded during the 1992 Landers and 1987 Whittier Narrows earthquakes. Results from the recent CALFED study on seismic hazards and probability of levee failure in the Delta (CALFED Bay-Delta Program 1999b) were used to construct the design response spectrum.

The design earthquake ground motions developed for the analysis used a hazard exposure level corresponding to a 10% probability of exceedance in 50 years; this level corresponds to a return period of about 1 in 475 years and is consistent with the requirement adopted by the 1997 Uniform Building Code. Dynamic responses and deformations of the levee induced by the design earthquake motions were computed for the long-term levee conditions at two cross sections each for Webb Tract and Bacon Island. The seismically induced geologic hazards assessed for the analysis included liquefaction, loss of bearing capacity, settlement, and levee overtopping. The evaluation also considered wave-height estimates and erosion, borrow requirements, and the effect of interceptor wells on slope stability. The literature reviewed and methods used for this analysis are described in Appendix A to the URSGWC report (see Appendix H of this REIR/EIS).

Effect of Delta Wetlands Operations on Levee Stability

In the1995 DEIR/EIS, levee improvements were estimated to increase the long-term FSs in comparison with existing conditions, resulting in a beneficial effect. Independent review of levee stability issues by URSGWC verified that Delta Wetlands' proposed levee improvements would increase the long-term FS toward the reservoir islands in comparison with existing conditions but determined that the long-term FS toward the slough would decrease (Table 6-1).

The URSGWC evaluation also found that, compared with existing conditions, the FS toward the reservoir islands would decrease for both the end-of-construction case and the sudden drawdown condition. (Section 3.5 of Appendix H.)

The "end-of-construction" results presented in Table 6-1 represent conditions after construction of levee improvements in a single stage; the single-stage analysis was conducted to demonstrate that the levees cannot be constructed in a single stage. Delta Wetlands has proposed to construct the levees in multiple stages to facilitate consolidation of levee materials. Delta Wetlands has proposed two conceptual land-side levee slope configurations—a 3:1 initial slope flattening to a 10:1 slope or a uniform 5:1 slope (Figure 6-1). The uniform 5:1 slope fill configuration results in a lower end-of-construction FS than the 3:1-to-10:1 fill configuration, so Table 6-1 presents the FS results for the uniform 5:1 slope configuration to provide the most conservative estimates of levee stability.

The seismic-stability evaluation of the reservoir island levees indicated that as much as 2 feet of deformation on the reservoir side of the levees and 4 feet on the slough side could be experienced during a probable earthquake in the region (Section 3.6 of Appendix H). Stability is improved from existing conditions on the reservoir side and is less than existing conditions on the slough side.

With regard to levee stability, URSGWC concluded that the "levee strengthening measures conceptually proposed by Delta Wetlands are generally appropriate and adequate to provide stability of the reservoir islands' levees". The report notes that construction of the levee-strengthening fills must be implemented in carefully planned staged construction to prevent stability failures to the new fill loads. URSGWC estimated that construction of the levees could take 4 to 6 years, depending on final levee design. The report also outlines conceptual measures that would improve the long-term stability of the slough side of the levees, improve stability under sudden drawdown conditions, and mitigate slough-side deformation under seismic conditions. Delta Wetlands plans to implement detailed subsurface exploration programs along the reservoir island levees, stability evaluations, and site-specific design and construction methods as part of final design. The report concludes that these steps will be essential to achieving safety and effectiveness of the proposed levee system. (Section 4.2 of Appendix H.)

Effect of the Interceptor-Well System on Levee Stability

As discussed previously, a network of interceptor wells would be used to control seepage onto adjacent islands. Delta Wetlands has suggested that these wells would probably be 6 inches in diameter and spaced approximately 160 feet on center. A 6-inch-diameter well could require drilling a 12-inch-diameter space to accommodate the well and packing. URSGWC determined that the wells would not substantially affect stability of the levees or the supporting levee foundation because the area occupied by the wells is so small compared to the area occupied by the levees.

A high rate of continuous pumping in the interceptor wells can result in the migration of fine materials from the sand aquifer, which can cause internal erosion or piping in the levee material, and over time, lead to weakened levee foundations and potential settlement and stability problems. URSGWC recommends that to minimize the risk to levee stability from excessive migration of fine-grained material from the aquifer, Delta Wetlands should:

- monitor individual wells' flows to judge well pumping efficiency (an indicator of internal soil erosion);
- redevelop (i.e., clean) the wells periodically or in response to flow monitoring that indicates a drop in well efficiency; and
- in severe cases, abandon and rebuild the well. (Section 3.10 of Appendix H.)

Delta Wetlands may be required to identify the criteria by which they would judge when an interceptor well would need to be replaced.

Wave Runup and Erosion

The 1995 DEIR/EIS evaluated levee erosion and overtopping as a result of wind and wave runup. The proposed flooding of reservoir islands could result in wave runup on the interior levee slopes because of the long wind fetch across the islands, the water depths during storage, and wind conditions. Longer wind fetch, deeper water, and faster winds increase wave height. Delta Wetlands estimated wave runup on the reservoir islands and is proposing to include erosion protection on the interior levee slopes. These slopes would be protected from erosion by conventional rock revetment (i.e., riprap) or other conventional systems, such as soil cement or high-density polyethylene liner. During final design, site-specific requirements for erosion protection will be evaluated and riprap or other suitable erosion protection measures will be designed for each levee section. Delta Wetlands is also proposing an erosion monitoring program, which includes weekly inspections of levees and maintenance measures to address potential erosion problems (see Chapter 3D in the 1995 DEIR/EIS).

URSGWC completed an independent analysis of wave runup to evaluate freeboard and erosion potential of the reservoir island levees (see Section 3.8 in Appendix H). The analysis used the most severe wind conditions in the area (i.e., 60 miles per hour in fall), the longest wind fetch on Bacon Island and Webb Tract (i.e., 3.15 miles and 2.83 miles, respectively), and full storage conditions to represent worst-case wave runup potential. Both the 3:1 and 5:1 levee slope configurations were evaluated. The results of the analysis are shown in Table 6-2. URSGWC concluded that these results are consistent with the wave runup estimates published in DWR Bulletin 192-82. The proposed reservoir island levees will have an interior slope freeboard of 3 vertical feet (Figure 6-1) and, as described above, will include placement of riprap on the interior slopes. As shown in the table, the estimated worst-case runup could result in overtopping if a 3:1 levee design is used. However, the analysis concludes that the proposed flatter (5:1) levee slope would reduce wave runup and avoid overtopping under the worst-case conditions. The final design of the levee will consider the potential for wave runup, and Delta Wetlands will implement a final levee design according to those site-specific conditions. Additionally, during project operations, the erosion monitoring program would be implemented. In conclusion, wave runup will not result in substantial erosion or overtopping of the proposed levees on the reservoir islands.

Potential Damages to Adjacent Islands in the Event of a Reservoir Island Levee Failure

Although a worst-case, or catastrophic-failure, analysis is not required under CEQA or NEPA, the lead agencies asked URSGWC to evaluate the potential for damages to neighboring Delta islands in the event that a reservoir island levee failed.

URSGWC's levee stability analysis indicates that failure of a Delta Wetlands Project levee is unlikely, but that the most probable types of failure are:

- failure of a reservoir island levee toward the adjacent channel or slough with a full reservoir,
- failure of the levee into the reservoir island with the reservoir low or empty, and
- failure of an adjacent island's levee caused by seepage effects attributable to reservoir operations.

To evaluate the potential effects of a levee breach under full reservoir conditions, URSGWC performed hydraulic analyses assuming breach widths (i.e., lengths of failed levee) of 40, 80, 200, and 400 feet. Assuming that the reservoir was full at the time of a breach, URSGWC determined that the maximum velocity of water on the bank opposite the breach would be 2, 9, 12, and 16 fps, respectively. The maximum breach width of 400 feet would result in a maximum discharge rate of 123,000 cfs. Figure 3.5.47 of Appendix H shows the velocity distribution of flows under this failure scenario. The maximum velocity on the opposite bank would be approximately 16 fps for 30-40 minutes. It is expected that the riprapped levee would be able to withstand these velocities, although floating structures and moored boats might be damaged (Section 3.5.4 of Appendix H).

The analysis concluded that the proposed conceptual levee design would provide adequate protection against failure of the reservoir levee with the reservoir empty, with high FSs for long-term failure into the reservoir island and adequate FSs for sudden drawdown at most locations. The report notes that adjustments to levee geometry may be needed at some locations to provide an adequate FS during sudden drawdown (Section 3.5.4 of Appendix H).

Failure of an adjacent island's levee caused by seepage effects attributable to reservoir operations is addressed by the seepage analysis.

New Information on Erosion Effects of Boat Wake

After the 1995 DEIR/EIS was released, the lead agencies received comments from several parties about the impacts on Delta island levees of increased boat wake that could result from increased boating activity if the proposed project were implemented. Consequently, the lead agencies believed it would be helpful for REIR/EIS reviewers to be given information about this subject, and directed that such information be included in this revised chapter on levee stability and seepage. Concerns about potential boat-wake impacts relate to the potential contribution of increased wake action to significant levee erosion and the erosion of channel islands and water-side habitats.

A literature search and conversations with knowledgeable individuals indicates that there are no current data related to wake-action impacts on channel islands. In the 1970s, the California Department of Navigation (now the California Department of Boating and Waterways) and DWR conducted two studies; however, these studies were based on unsubstantiated assumptions and reported conflicting findings, and are not reliable sources of information. The California Department of Boating and Waterways is currently conducting a 6-year study with Scripps Institute of Oceanography that addresses wake-action impacts; the study had not been completed as of the date of release of this REIR/EIS.

Margit Aramburu, executive director of the Delta Protection Commission; Don Waltz, chief of the Facilities Division of the California Department of Boating and Waterways; and Ron Flick, research associate at Scripps Institute of Oceanography and staff oceanographer for the California Department of Boating and Waterways, were each contacted for information on this issue during April and May 1999. Each indicated that impacts of boat wakes on Delta islands are difficult to generalize. They explained that impacts vary according to several factors related to boat use, including boat size, boat speed, proximity of boats to the islands, and type of boating activity, and that these factors should be considered with others such as currents and the presence of wind-blown waves.

Because of the lack of data to quantify the relationship between boating and wake effects, it is not currently possible to estimate the erosion or habitat effects of increased wake action resulting from increased boating use of Delta waterways under the proposed project. However, the lead agencies recognize the potential for such effects. This issue was considered during the endangered-species consultation between the lead agencies and DFG, NMFS, and USFWS. As a result, the FOC terms developed in the consultation process include a measure (number 53) specifically intended to mitigate boat-wake effects. Under this term, Delta Wetlands is required to contribute a set fee for each boat berth added to any of the project islands beyond pre-project conditions; these funds would be used for aquatic habitat restoration (see also page 55 of the DFG biological opinion in Appendix C). This measure is in addition to the requirement that Delta Wetlands mitigate the effects of project construction and operations on aquatic habitat and shallow shoal habitat. The FOC terms have been adopted as part of the federal and state biological opinions for Delta Wetlands Project effects on listed fish species, and Delta Wetlands is required to incorporate these terms into the proposed project. No additional mitigation is recommended in this REIR/EIS.

IMPACT ASSESSMENT METHODOLOGY

Analytical Approach and Impact Mechanisms

Impacts on seepage and levee stability were assessed based on the ways in which construction and operation of the Delta Wetlands project alternatives would affect seepage on adjacent islands and levee stability. Effects of the project alternatives on seepage and levee stability were based on previous work prepared by Delta Wetlands' consultants and new technical analyses prepared by URSGWC (Appendix H).

Criteria for Determining Impact Significance

An alternative is considered to have a significant impact on seepage or levee stability if it would:

- induce additional seepage on adjacent islands when compared to no-project conditions,
- decrease levee stability on the Delta Wetlands Project islands during or immediately following project construction,
- decrease long-term levee stability when compared to existing levee conditions, and
- cause property damage in the event of levee failure.

Levee Standards and Significance Criteria

During and subsequent to the water right hearing, parties expressed an interest in using existing levee standards as a significance criterion in the levee stability analysis or in identifying which standard or standards would be applied to the Delta Wetlands Project. Table 6-3 summarizes standard FSs for various levee or dam conditions, as adopted or recommended by USACE, DWR, and the Division of Safety of Dams (DSOD). FSs are only one element used to regulate levees and dams; other design considerations are also used. Figure 6-3 compares different levee standards for minimum freeboard, maximum slopes, and crest width. As shown in Table 6-3 and Figure 6-3, USACE has published standards and guidelines for project and nonproject levees; DWR has published guidelines for levee rehabilitation in the Delta; and DSOD establishes standards for dams.

The purpose of the impact assessment is to determine the difference in levee stability between existing conditions and with-project conditions. The relative change in the FSs between the project and existing conditions is used as the basis for evaluating the impact of the proposed project. Because the analysis evaluates the *change* in levee conditions, a given FS standard cannot be used to determine the significance of the change. However, these standards would be considered during project approval and final design.

The lead agencies can choose to adopt a given standard to be applied to the final levee design for the Delta Wetlands islands. Because the Delta Wetlands levees are nonproject levees, rehabilitation of those levees under existing conditions would follow DWR and USACE's recommendations for nonproject levees. Delta Wetlands has committed to improving levees on all four project islands to meet levee design criteria for Delta levees identified in DWR Bulletin 192-82; Bulletin 192-82 does not include FS but requires a given levee design (Figure 6-3). The lead agencies, however, may include more conservative standards or guidelines for the reservoir island levees in the terms and conditions of project approval.

Additionally, if the levees are determined to be "dams" as defined by the California Water Code (Sections 6002 through 6008), Delta Wetlands would be required to meet DSOD's standards and design review requirements. DSOD has oversight and approval authority for structures that are considered dams under the Water Code. Dams under jurisdiction are artificial barriers that are at least 25 feet high or have an impounding capacity of at least 50 af. However, Water Code Section 6004(c) provides the following exclusion for structures in the Sacramento-San Joaquin Delta:

> The levee of an island adjacent to tidal waters in the Sacramento-San Joaquin Delta, as defined in Section 12220, even when used to impound water, shall not be considered a dam and the impoundment shall not be considered a reservoir if the maximum possible water storage elevation of the impounded water does not exceed four feet above mean sea level, as established by the United States Geological Survey 1929 Datum.

Therefore, if the Delta Wetlands levee structure is built to impound water to a level of 6 feet above mean sea level as proposed in the 1995 DEIR/EIS and evaluated in this REIR/EIS, it would be considered a dam within DSOD jurisdiction and would be subject to DSOD review and permit approval. The levees would be required to meet DSOD standards for dams (Table 6-3). Delta Wetlands would submit final design drawings, specifications, geotechnical reports, survey data, and an application to DSOD for approval before levee construction (Driller pers. comm.).

ENVIRONMENTAL CONSEQUENCES

The following section addresses project impacts on seepage and levee stability. The text addresses the four criteria listed above that are used to determine significance. Table 6-4 compares the 1995 EIR/EIS and REIR/EIS impact conclusions.

Potential Seepage on Adjacent Islands Resulting from Project Operations

As described in the1995 DEIR/EIS, operation of the Delta Wetlands Project would induce seepage on adjacent islands if seepage control measures were not implemented. The Delta Wetlands Project includes a network of pumped wells to control seepage and a seepage monitoring program. It also has a set of seepage performance standards that, if exceeded, would trigger implementation of other measures to control seepage, including drawdown of the reservoir islands' water levels. Independent review of the seepage control program, seepage monitoring program, and performance standards by URSGWC (Appendix H) indicated that the proposed seepage control program could effectively control the seepage onto adjacent islands. However, the review also indicated that the seepage monitoring program and performance standards might not provide adequate warning that an adverse effect was about to occur and might not trigger additional mitigation measures in a timely enough manner to prevent adverse effects on adjacent islands. Therefore, potential seepage on adjacent islands is considered significant and the following mitigation is recommended.

Mitigation Measure: Modify Seepage Monitoring Program and Seepage Performance Standards. URSGWC has recommended that the seepage monitoring program and the seepage performance standards be modified to include the following requirements:

- Locate the background monitoring wells no more than 1 mile from the seepage monitoring wells.
- Use more than one background monitoring well for each row of seepage monitoring wells.
- Use at least 3 years of data to establish reference water levels in all the background monitoring wells and in at least half of the seepage monitoring wells.
- Use a running straight-line mean from the monitoring-well data when applying the seepage performance standards.
- Reduce the seepage performance standard for the single-well condition from 1 foot to 0.5 foot.
- Reevaluate seepage performance standards 2, 5, and 10 years after reservoir operations begin and then every 10 years.

Implementing the recommended changes to the seepage monitoring program and seepage performance standards would reduce this impact to a less-than-significant level.

Potential Decrease in Levee Stability on the Delta Wetlands Project Islands during or Immediately after Project Construction

As described in the 1995 DEIR/EIS, levee improvements would be completed in layers or lifts less than 5 feet thick and allowed to settle to ensure that an appropriate FS would be maintained. Delta Wetlands estimated that it would take several years to complete levee improvements. Independent review of levee stability issues by URSGWC (Appendix H) verified that levee improvements could not be completed in a single lift. As shown in Table 6-1, if the levees were constructed in a single lift, the FSs would be less than 1, indicating that the levees would not be strong enough to support their own weight. The levee construction methods described in the 1995 DEIR/EIS are adequate to maintain an appropriate FS; therefore, this impact is considered less than significant and no mitigation is required.

Potential Decrease in Long-Term Levee Stability on the Delta Wetlands Reservoir Islands

In the 1995 DEIR/EIS, levee improvements were estimated to increase the long-term FSs when compared to the existing conditions, resulting in a beneficial effect. Independent review of levee stability issues by URSGWC (Appendix H) verified that levee improvements would increase the FSs toward the reservoir islands when compared to the existing conditions. As shown in Table 6-1, the long-term FS toward the reservoir islands at the cross sections evaluated would increase by 27 to 36 percent. However, the long-term FS toward the slough would decrease by 10 to 17 percent when compared to existing conditions. URSGWC suggests that slough-side levee improvements would achieve an appropriate FS with the proposed levee design. However, slough-side levee improvements would have substantial adverse environmental effects (e.g., significant fishery habitat and water quality impacts); consequently, although slough-side levee improvements would be technically feasible, they would not be environmentally feasible or practical. Therefore, this impact is considered significant and the following mitigation measure is recommended.

Mitigation Measure: Adopt Final Levee Design that Achieves Recommended Factor of Safety and Reduces the Risk of Catastrophic Levee Failure. Delta Wetlands' final levee design shall provide a minimum FS of 1.3 in accordance with DWR's requirements for rehabilitating levees in the Delta (Table 6-3). This recommended FS is more conservative than USACE's recommended 1.25 FS for nonproject levees. After detailed geotechnical studies have been completed to support the levee design efforts, it is anticipated that the conceptual levee design will be modified (e.g., change in slope, crest width, lift compaction, and other levee design and construction factors) to achieve the desired FS without affecting the existing levees' slough faces and incurring the significant environmental impacts.

Alternately, at locations where there are no practical design options to achieve this FS, measures could be implemented to reduce the risk of catastrophic levee failure. URSGWC has recommended increasing the width of the levee cross section to provide additional buffer if the slough side of the levee fails. The buffer would provide sacrificial material that could be allowed to erode until emergency action could be taken to restore levee integrity. Although this option would not improve the factor of safety, it would greatly reduce the risk of catastrophic failure.

Potential Levee Failure on Delta Wetlands Project Islands during Seismic Activity

By improving the reservoir island levees, the stability of reservoir island levee slopes under seismic conditions would increase toward the reservoir island and would decrease toward the slough. Results of the dynamic stability analysis concluded that as much as 4 feet of levee deformation could occur under seismic conditions. This impact is considered significant. The following mitigation measure is recommended to reduce this impact to a less-than-significant level.

Mitigation Measure: Adopt Final Levee Design that Achieves Recommended Factor of Safety and Reduces the Risk of Catastrophic Levee Failure.

This mitigation measure is described above.

Potential Property Damage Resulting from Levee Failure

Implementing the Delta Wetlands project would increase the levees' FS toward the reservoir islands and decrease their FS toward the adjacent sloughs when compared to existing conditions. Levee failure is unlikely, however, because the long-term FSs exceed 1 (Table 6-1). Failure into the reservoir island with the project would have no greater effect on property than a failure under the existing conditions, although the risk of failure would be somewhat less because of increased long-term FSs.

URSGWC evaluated the potential effects of a worst-case levee failure, a levee breach toward the slough when the reservoir islands are full. Hydraulic analyses were completed assuming breach widths of 40, 80, 200 and 400 feet. The maximum likely breach of 400 feet would result in a maximum discharge rate of 123,000 cfs. Figure 3.5.47 of Appendix H shows the velocity distribution of flows under this failure scenario. The maximum velocity on the opposite bank would be approximately 16 fps. Assuming the reservoir was at full storage (+6 feet) and the channel was at a relatively low tide (-2 feet) when the levee failed, the adjacent levees would experience the 16 fps velocity for approximately 30-40 minutes. The adjacent riprapped levee would be expected to withstand these velocities for the limited amount of time. Because the potential risk of a levee failure is very small, this impact is considered less than significant and no mitigation is required.

Cumulative Impacts

Levee stability conditions in the Delta are expected to improve in the future through the implementation of levee improvements using existing and future state and federal funding and implementation of proposed projects under the CALFED Bay-Delta Program. Since 1988, federal, state, and local agencies have completed more than $160 million in improvements to Delta levees using Senate Bill (SB) 34 funds, Assembly Bill (AB) 360 funds, emergency levee repair funds for work performed by USACE under Public Law (PL) 84-99, and local funds (CALFED Bay-Delta Program 1999a). Improvements to Delta levees are ongoing. The CALFED Bay-Delta Program's Long-term Levee Protection Plan outlines a long-term strategy to reduce the risk of catastrophic breaching of Delta levees. The CALFED Levee Program includes a cost-sharing program to reconstruct Delta levees, the "Special Flood Control Projects" program to provide additional flood protection for key Delta levees that protect public benefits of statewide significance, improvements to existing emergency response capabilities, and development of a risk management strategy in response to the threat that earthquakes pose to Delta levees (CALFED Bay-Delta Program 1999c).

Implementing the Delta Wetlands Project would not contribute significantly to cumulative flood hazards in the Delta. The proposed project would improve long-term levee stability on the habitat islands and would improve long-term stability of the levee slope toward the reservoir islands. As described above, long-term stability toward the slough would be reduced on the reservoir islands; however, because the resulting FS still would be greater than 1, the likelihood of levee failure under the proposed project is low. Additionally, analysis indicates that neighboring levees would not be significantly damaged if the levee failed when the reservoir was full. Therefore, the cumulative effect on levee failure in the Delta is considered less than significant and no mitigation is required.

Impact Evaluation of Project Alternatives from the 1995 Draft EIR/EIS

As described in Chapter 2, the difference between Alternative 1 in the 1995 DEIR/EIS and Alternative 2 (the proposed project) is water discharge operations. Consequently, the levee system and proposed seepage control plan are the same under Alternative 1 as under the proposed project. The impacts and mitigation measures described above would also apply to Alternative 1.

Under Alternative 3, water would be stored on all four islands, so levee improvements and seepage control measures would be implemented on all islands. Although the REIR/EIS did not analyze levee stability and seepage for Bouldin Island and Holland Tract, it can be reasonably assumed that the levee stability and seepage impact conclusions presented above for the proposed project would be similar to the findings for the other reservoir islands under Alternative 3.

Table 6-1. Summary of Factors of Safety

Cross Section	Factor of Safety							
	Existing Conditions		End of Construction[a]		Long-Term		Sudden Drawdown[b]	
	Toward Island	Toward Slough	Toward Island	Toward Slough	Toward Island	Toward Slough	Toward Island	Toward Slough
Webb Tract (Station 160+00)	1.24	1.29	0.62	1.29	1.57	1.12	0.88	1.12
Webb Tract (Station 630+00)	1.40	1.34	0.89	1.34	1.82	1.12	1.18	1.12
Bacon Island (Station 25+00)	1.23	1.48	0.90	1.48	1.63	1.33	1.07	1.33
Bacon Island (Station 265+00)	1.21	1.49	0.86	1.49	1.64	1.23	0.98	1.23

Notes:

[a] Represents conditions after construction of levee improvements in a single stage. It was assumed that at the end of construction, the toward-slough factor of safety would be the same as under existing conditions.

[b] Under the sudden-drawdown scenario, the toward-slough factor of safety would be the same as the long-term toward-slough factor of safety.

Source: Section 3, "Slope Stability Issues", of Appendix H of this REIR/EIS.

Table 6-2. Summary of Results from the Worst-Case Runup Analysis

	Bacon Island		Webb Tract	
	5:1 interior levee slope	3:1 interior levee slope	5:1 interior levee slope	3:1 interior levee slope
Wave runup without riprap (feet)	4.0	6.4	3.8	6.1
Wave runup with riprap[1] (feet)	2.2	3.5	2.1	3.4
Reservoir setup[2] (feet)	0.4	0.4	0.3	0.3

Assumptions:

- Wind speed = 60 mph
- Fetch on Bacon Island = 3.15 miles
- Fetch on Webb Tract = 2.83 miles

Notes:

[1] If riprap is used on the bank slopes, the runup would be reduced to 55% of the estimated runup values.

[2] Reservoir setup is defined as a general tilting of the reservoir due to sheer stresses caused by winds.

Source: Appendix H.

Table 6-3. Stability Criteria Adopted for Levees and Used for Dam Safety Evaluations

	Design Condition Factor of Safety		
Criterion	End of Construction	Long Term	Sudden Drawdown
U.S. Army Corps of Engineers minimum factors of safety for "project" levees[a]	1.3	1.4	1.0
U.S. Army Corps of Engineers guidelines for nonfederal levee rehabilitations in the Delta under PL 84-99[b]	–	1.25	–
California Department of Water Resources criteria for "nonproject" levee rehabilitations in the Delta[c]	–	1.3	–
Factors of safety for dam safety evaluations under DSOD jurisdiction[d]	–	1.5	1.25

Notes:

[a] U.S. Army Corps of Engineers 1978.
[b] U.S. Army Corps of Engineers 1988.
[c] California Department of Water Resources 1989b.
[d] Association of State Dam Safety Officials 1989.

Definitions:

"Project" levees = Levees maintained to USACE standards by the State of California or by local landowners under state supervision.

"Nonproject" levees = Levees constructed and maintained by local landowners and reclamation districts.

Table 6-4. Comparison between Delta Wetlands Projects on Flood Control in the 1995 DEIR/EIS and the 2000 REIR/EIS

Impacts and Mitigation Measures of 1995 DEIR/EIS Alternatives 1 and 2	Differences between 2000 REIR/EIS and 1995 DEIR/EIS
CHAPTER 3D. FLOOD CONTROL	
Impact D-1: Increase in Long-Term Levee Stability on Reservoir Islands (B) • No mitigation is required.	**Potential Decrease in Long-Term Levee Stability on the Delta Wetlands Reservoir Islands.** Independent analyses by URSGWC indicate that the levee's long-term factor of safety would increase by 27 to 36 percent toward the reservoir islands but would decrease by 10 to 17 percent toward the sloughs. This impact is considered significant and mitigation is recommended to reduce the impact to a less-than-significant level. (S) • Adopt Final Levee Design that Achieves Recommended Factor of Safety and Reduces the Risk of Catastrophic Levee Failure (LTS)
----	**Potential Decrease in Levee Stability on the Delta Wetlands Project Islands During or Immediately After Project Construction.** Independent analyses by URSGWC verified that the levee construction methods described in the 1995 DEIR/EIS are adequate to maintain an appropriate factor of safety. Therefore, the impact is considered less than significant and no mitigation is required. (LTS)
Impact D-2: Potential for Seepage from Reservoir Islands to Adjacent Islands (LTS) • Measures that would minimize effects of this impact have been incorporated by the project applicant into this alternative's project description. No additional mitigation is required.	**Potential Seepage on Adjacent Islands Resulting from Project Operations.** Analyses by URSGWC indicate that seepage control measures proposed by Delta Wetlands would be adequate to control seepage; however, the seepage control performance criteria were not adequate to detect adverse impacts. This impact is considered significant and mitigation is recommended to reduce the impact to a less-than-significant level. (S) • Modify Seepage Monitoring Program and Seepage Performance Standards (LTS)

Note: S = Significant; SU = Significant and unavoidable; LTS = Less than significant; B = Beneficial.

Table 6-4. Continued

Impacts and Mitigation Measures of 1995 DEIR/EIS Alternatives 1 and 2	Differences between 2000 REIR/EIS and 1995 DEIR/EIS
Impact D-3: Potential for Wind and Wave Erosion on Reservoir Islands (LTS) • Measures that would minimize effects of this impact have been incorporated by the project applicant into this alternative's project description. No additional mitigation is required.	**Potential for Wind and Wave Erosion on Reservoir Islands.** Analysis by URSGWC confirmed that the levee design and erosion protection measures proposed by Delta Wetlands would be adequate to address the potential for erosion and overtopping of the levees under worst-case wave runup conditions. This impact is considered less than significant. (LTS)
Impact D-4: Potential for Erosion of Levee Toe Berms at Pump Stations and Siphon Stations on Reservoir Islands (LTS) • Measures that would minimize effects of this impact have been incorporated by the project applicant into this alternative's project description. No additional mitigation is required.	These effects were not reevaluated in the REIR/EIS. The impact conclusions and mitigation remain the same as presented in the 1995 DEIR/EIS.
Impact D-5: Decrease in Potential for Levee Failure on Delta Wetlands Project Islands during Seismic Activity (B) • No mitigation is required.	**Potential Levee Failure on Delta Wetlands Project Islands during Seismic Activity.** Analyses by URSGWC indicate that deformation of as much as 4 feet of the reservoir island levee slopes would be experienced during a probable earthquake in the region. Compared to existing conditions, levee stability on the reservoir islands would be greater on the reservoir side and would be less on the slough side. This impact is considered significant and mitigation is recommended to reduce the impact to a less-than-significant level. (S) • Adopt Final Levee Design that Achieves Recommended Factor of Safety and Reduces the Risk of Catastrophic Levee Failure (LTS)

Note: S = Significant; SU = Significant and unavoidable; LTS = Less than significant; B = Beneficial.

Table 6-4. Continued

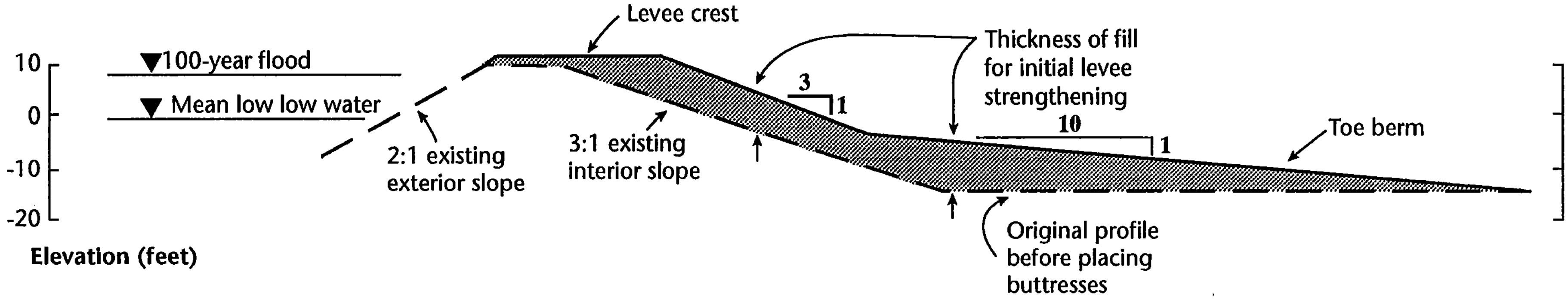
Impacts and Mitigation Measures of 1995 DEIR/EIS Alternatives 1 and 2	Differences between 2000 REIR/EIS and 1995 DEIR/EIS
----	**Potential Property Damage Resulting from Levee Failure.** The project would have no effect on property compared to existing conditions if a levee were to fail into a reservoir island. There would be potential for property damage to occur if a levee failed toward the slough under full reservoir conditions, but the effect is considered less than significant because the risk of levee failure is very low. (LTS)
Impact D-6: Increase in Long-Term Levee Stability on Habitat Islands (B) • No mitigation is required.	These effects were not re-evaluated in the REIR/EIS. The impact conclusions and mitigation remain the same as presented in the 1995 DEIR/EIS.
Cumulative Impacts	
Impact D-12: Decrease in Cumulative Flood Hazard in the Delta (B) • No mitigation is required.	**Cumulative Effects on Delta Flood Hazard.** Implementation of the Delta Wetlands Project would not significantly contribute to cumulative flood hazards in the Delta. This impact is considered less than significant and no mitigation is required. (LTS)
Impact D-13: Decrease in the Need for Public Financing of Levee Maintenance and Repair on the Delta Wetlands Project Islands (B) • No mitigation is required.	This impact was not re-evaluated in the REIR/EIS. The impact conclusion remains the same as presented in the 1995 DEIR/EIS.

Notes:

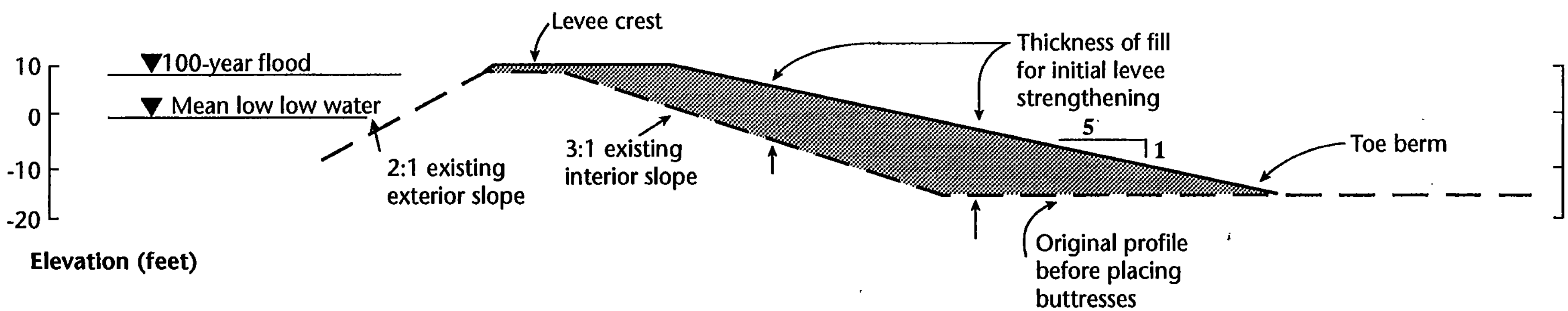
Impacts D-7 through D-11 of the 1995 DEIR/EIS describe impacts of Alternative 3, the four-reservoir-island alternative. The REIR/EIS does not analyze levee stability and seepage for Bouldin Island and Holland Tract. However, it can be reasonably assumed that the impact conclusions shown here for the proposed project would also apply to these islands under Alternative 3.

S = Significant; SU = Significant and unavoidable; LTS = Less than significant; B = Beneficial.

Example A: Broken-Slope Buttress



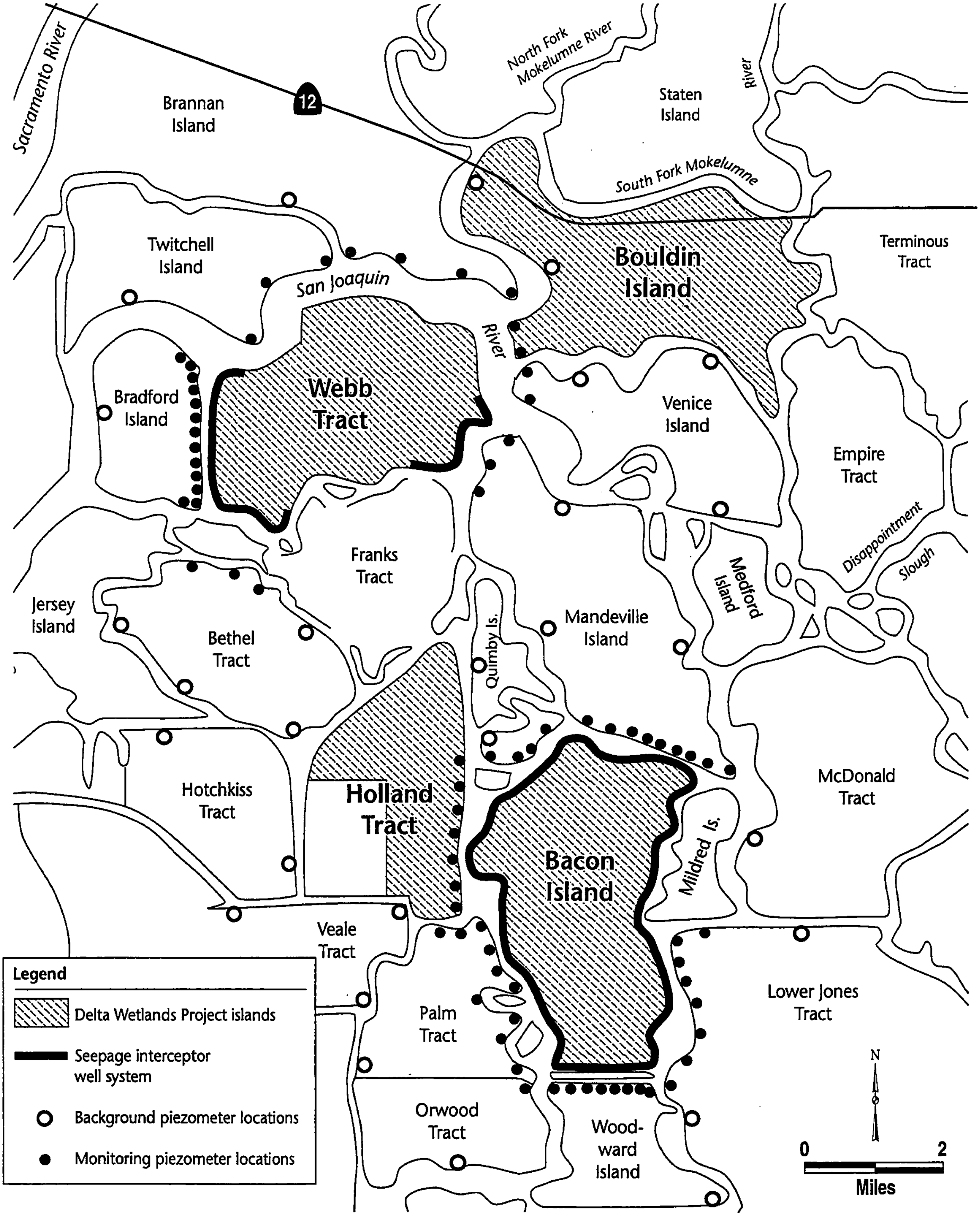
Example B: Constant-Slope Buttress



Source: Harding Lawson Associates 1993.

Jones & Stokes

Figure 6-1
Examples of Initial Levee Strengthening on Reservoir Islands



Jones & Stokes

Figure 6-2
Seepage Interceptor Well System and Proposed Locations of Seepage Monitoring Piezometers under the Proposed Project

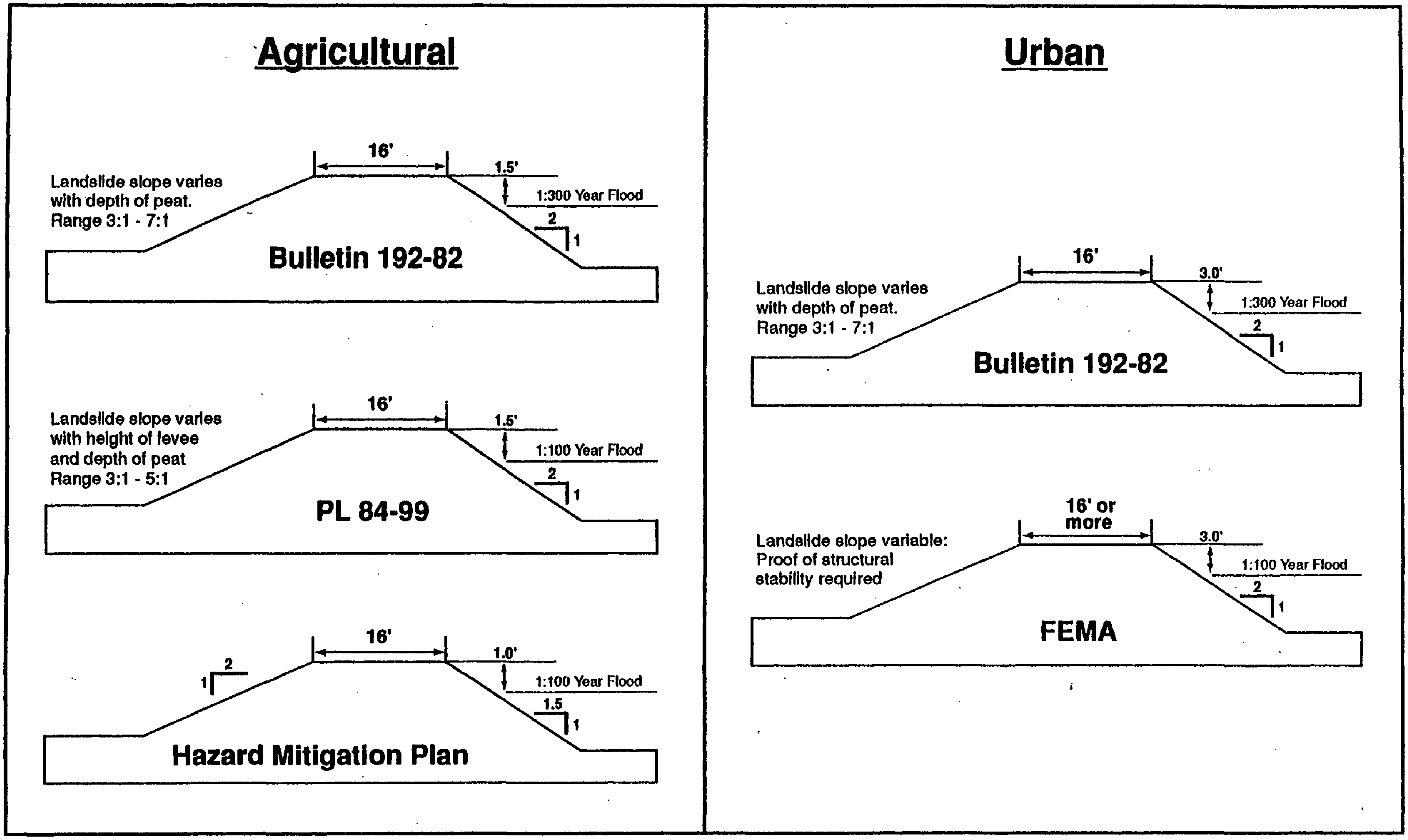


Figure 6-3
Levee Geometric Standards

Chapter 7. Natural Gas Facilities and Transmission Pipelines

FOCUS OF THE REVISED DRAFT EIR/EIS ANALYSIS

This chapter updates the 1995 DEIR/EIS assessment of Delta Wetlands Project effects on PG&E natural gas facilities and transmission pipelines. During the Delta Wetlands water right hearing, PG&E presented testimony regarding its easements and natural gas pipelines that cross Bacon Island. The testimony focused on the ways in which proposed Delta Wetlands water storage operations could:

- adversely affect PG&E's ability to use its easements,
- decrease the useful life of the pipelines,
- require additional pipeline maintenance,
- increase the threat of pipeline damage,
- reduce or inhibit pipeline access for routine or emergency repairs, and
- interrupt gas supply.

The future use of PG&E's easement is a private property rights dispute. The real property issues are not addressed in this REIR/EIS. Issues related to the operation and maintenance of the pipeline on Bacon Island and the possibility of impacts on regional natural gas service are considered potential environmental effects that require explanation and analysis. This chapter updates and supplements the discussions of the Bacon Island pipeline issues originally described in Chapter 3E, "Utilities and Highways", of the 1995 DEIR/EIS.

Summary of Issues Addressed in This Chapter

The analysis presented in this chapter addresses the following questions:

- What effect will reservoir operations have on the integrity, operation, and maintenance of PG&E's natural gas pipelines across Bacon Island?

- What effect will reservoir operations have on emergency access to the pipeline?

Sources of Information

Information used to prepare this chapter is taken from comments on the 1995 DEIR/EIS and from evidence and testimony provided by PG&E and Delta Wetlands at the water right hearing. In addition, data from the U.S. Department of Transportation (DOT), Office of Pipeline Safety (U.S. Department of Transportation 1999), were used in this assessment.

Definition of Terms

The discussion of gas facilities and pipelines in this chapter includes some terms that may not be familiar to all readers. The following are definitions of these terms as they are used in this chapter:

- *Anticorrosion Coating:* The coating of pipelines with paint, epoxy, or other materials to prevent contact of dissimilar metals. The barrier prevents establishment of a corrosion current and corrosion of the pipe.

- *Bending Load:* The result when the opposite ends of an item are forced together (as when a sheet of paper is folded). Pipelines can be subject to this type of load.

- *Cathodic Protection System:* A process used to prevent pipeline corrosion by passing an electric current through the pipe. When dissimilar metals (the pipeline and soil minerals) are placed in solution together, a corrosion current is established. The cathodic protection system creates an opposite current to minimize corrosion.

- *Firm Storage Capacity:* An amount equivalent to guaranteed storage capacity. Utility rates usually vary based on guarantee of service. The first priority is to meet firm demands; consequently, this demand is most expensive. Demands that can be met with less reliability are less expensive.

- *Internal Inspection:* A process required for pipelines. A robotic device, commonly called a "pig", is sent along the inside of the pipe. The pig measures the resistance of electrical current from the pipe to the ground. Areas with abnormally low resistance indicate damage to the pipe's anticorrosion coating.

- *Load Center:* In the utility business, a concentration of demand or users. For example, the Sacramento metropolitan area is a load center. The area consists of a large group of residential, municipal, and industrial users. The cumulative demand of the load center is considered when utility transmission and storage facilities are developed.

- *Pipeline Balancing:* The process of distributing pipeline capacity to efficiently provide service to competing load centers.

- *Shear Load:* The result when force is applied perpendicular to or on opposite sides of an item (as when a sheet of paper is cut with scissors). Pipelines can be subject to this type of load.

- *Third Party:* An entity that affects a property, but is not the owner of the property (first party) or an agent of the owner (second party).

- *Unbundled Rates:* The individual rates for separate service components of a particular utility. For example, natural gas utilities can be broken down into separate service components such as gas procurement, transportation, storage, and delivery, with distinct rate schedules for each service. Deregulation of the utility industry has allowed this unbundling of services to promote market competition.

AFFECTED ENVIRONMENT

PG&E owns two high-pressure gas transmission pipelines that cross Bacon Island (Figure 7-1). Line 57-B, constructed in 1974, serves as an input and output conduit for gas stored in the McDonald Island Storage Field; Line 57-A has been removed from operation and has been capped. However, Line 57-A could be used in the future.

Natural Gas Service

Line 57-B connects PG&E's interstate and intrastate gas transmission and distribution system to the utility's underground natural gas storage facility under McDonald Island (Figure 7-2). The McDonald Island Storage Field is used primarily to supply gas to the Bay Area and Sacramento/Stockton load centers when other resources, such as gas production fields in Canada and the southwestern United States, are inadequate to meet instantaneous (i.e., peak) demands. The McDonald Island storage facility has supplied gas for up to one-third of PG&E's customers during peak demand periods (Stoutamore pers. comm.).

In 1996, PG&E and other natural gas industry representatives adopted the Gas Accord Settlement. This settlement is the result of an extensive negotiation process that PG&E initiated several years ago. The settlement parties, representing a diverse cross-section of natural gas industry participants, have achieved a far-reaching and comprehensive settlement that restructures PG&E's natural gas services, redefines its role in the gas market, and establishes guaranteed transmission rates. The Gas Accord significantly increases competition and economic efficiency in the Northern California gas industry. It enables customers and marketers to participate fully in the increasingly deregulated, inter-regional natural gas markets, with the goal of achieving lower energy prices through increased competition and customer choice. The accord provides for guaranteed, unbundled, cost-based transmission rates.

The Gas Accord allows continued operational integration of PG&E's gas storage and transmission facilities. PG&E will reserve firm storage capacity for pipeline balancing services. PG&E's Core Procurement Department will contract for a portion of the utility's firm storage capacity on behalf of the core (PG&E's customers). The remaining storage capacity will be marketed in an unbundled storage program that requires PG&E to provide storage to third parties. The McDonald Island Storage Field is PG&E's largest underground natural gas storage facility, and Line 57-B is the only link between the storage field and the PG&E distribution system. Under the new Gas Accord, PG&E's role as a storer of natural gas will increase; consequently, PG&E's use of the McDonald Island Storage Field and reliance on Line 57-B will also increase.

Pipeline Design Criteria

The DOT Office of Pipeline Safety comprehensively regulates the design, construction, testing, operation, and maintenance of natural gas pipelines and associated facilities in accordance with 49 CFR 192. The following general requirements govern the use of natural gas pipelines:

- The materials for the pipe and components for use in pipelines must maintain structural integrity under temperature and other environmental conditions that may be anticipated. They must be chemically compatible with any gas that they transport.
- The pipe must be designed with sufficient wall thickness or installed with adequate protection to withstand anticipated external pressures or loads.
- Each pipeline component must be able to withstand operating pressures and other anticipated loadings without impairment of its serviceability.
- The pipeline must be protected from external corrosion by an external protective coating and a cathodic protection system.
- Before a new, repaired, or relocated pipeline can be placed into service, it must be tested to substantiate its maximum allowable operating pressure and to confirm that each leak has been located and eliminated.
- The operator shall prepare and follow a manual of written procedures for conducting operations and maintenance activities, responding to emergencies, and handling abnormal conditions.
- The operator shall have a patrol program to observe surface conditions on and adjacent to the pipeline right-of-way for indications of leaks, construction activity, and other factors affecting safety and operation.
- A pipeline that is abandoned in place or deactivated must be disconnected from all gas sources, purged of gas, and sealed at the ends.

Line 57-A is 18 inches in diameter and Line 57-B has a diameter of 22 inches. Both pipelines are buried as they cross Bacon Island and are designed to operate under temporarily flooded conditions or in saturated soils. The pipelines as constructed are engineered and built to withstand more than the external pressure that would be applied by the load, or weight, of water under full reservoir conditions. Normal operation or integrity of a pipeline would not be impaired by the pressure of overlying water in a full reservoir. According to PG&E's easements, Line 57-A is buried at a minimum of 4 feet and as much as 8 feet below the ground surface; Line 57-B is buried at a minimum of 3.5 feet below the ground surface. Line 57-A has concrete weights, except along approximately 900 feet on the west side of the island, where the pipeline is concrete coated. Line 57-B is entirely concrete coated. Concrete coating and weighting prevents the pipeline from floating out of the trench when inundated or when saturated soils would not have the strength to resist the pipeline's buoyancy. Line 57-B is currently rated for pressures up to 2,160 pounds per square inch (psi) and can convey approximately 1.25 billion cubic feet per day (Bcf/day). As mentioned previously, Line 57-A has been removed from operation and has been capped.

Pipeline Safety

Historically, natural gas transmission and distribution lines and associated facilities have had a very low probability of a full-scale rupture that could lead to an explosion resulting in property damage or fatalities. The most recent data available from the DOT Office of Pipeline Safety for 1985 through 1999 (U.S. Department of Transportation 1999) indicate the following:

- Approximately 1.7 million miles of natural gas transmission and distribution pipelines are present in the United States; these lines are subject to DOT jurisdiction. Transmission pipelines include pipelines of similar diameter and operating pressure to the PG&E pipeline crossing Bacon Island. Distribution pipelines are smaller in diameter and operated at a lower pressure than the PG&E pipeline crossing Bacon Island.

- During the data collection period, 1,302 reportable incidents (significant leaks) occurred in the nation on natural gas transmission projects similar to the proposed project. The causes of the leaks were identified as follows (totals less than 100% because of rounding):

  - 527 incidents (40%) were related to various construction or operating errors, or to other unspecified causes (e.g., improper welding or maintenance);

  - 368 incidents (28%) were caused by a third party, such as agricultural operations, and 62 of these occurred on pipelines that were unmarked;

  - 300 incidents (23%) were caused by corrosion, and 261 of these were related to uncoated pipelines; and

  - 107 incidents (8%) were caused by natural or geologic forces (8 by subsidence, 4 by flooding, and 3 by channel scour).

- Of the 1,302 incidents:

  - 880 (68%) were on projects constructed before the current Minimum Federal Safety Standards (CFR 49 Part 192) were promulgated in 1970 (35 FR 13257), and therefore on pipelines greater than 30 years old.

  - Most leaks were repaired or made safe in less than 1 day:

    - 540 leaks (41%) were repaired or made safe in less than 1 hour;

    - 1,062 leaks (81% inclusive) were repaired or made safe in 3 hours or less; and

    - 36 leaks (less than 3%) took 24 hours or longer to repair or make safe.

  - 35 incidents were reported in California.

From the DOT data presented above, it can be concluded that the transmission pipelines that are least prone to leaks or other accidents are those that have been constructed since 1970 and operated in accordance with minimum federal safety standards, are coated to prevent corrosion, and are well marked. In the Delta region of California, where there is risk of subsidence, flooding, channel scour, and seismic activity, no incidents of pipeline rupture or leak related to natural forces have been reported. In addition, no incidents related to corrosion or outside forces were reported. The only incident reported occurred at an above-ground metering facility where a seal failed on an odorant pump.

IMPACT ASSESSMENT METHODOLOGY

Analytical Approach and Impact Mechanisms

Impacts on natural gas facilities and service were assessed based on the ways in which construction and operation of the Delta Wetlands Project alternatives would benefit or adversely affect the existing utility infrastructure or service. Effects of the project alternatives on gas transmission lines and facilities on the project islands were determined through correspondence with the affected utility company and other experts. Under the Delta Wetlands Project, Bacon Island, which is now used for agricultural operations, would be used for reservoir storage. The levees around the island would be reinforced and the island would be inundated when water is available for diversion from the Delta. Flooding the island and improving the project levees may affect the conditions under which the existing gas pipeline is operated and maintained.

Criteria for Determining Impact Significance

An alternative is considered to have a significant impact on the gas facilities and services if, when compared to existing conditions, it would:

- result in a substantial disruption to existing natural gas service;
- increase risk of structural failure of gas facilities and pipelines;
- result in a need for substantial alterations to, or increased maintenance of, natural gas facilities; or
- result in increased demand for existing emergency services beyond their current capacity.

An alternative is considered to have a beneficial effect if it would improve the existing utility infrastructure when compared to existing conditions.

ENVIRONMENTAL CONSEQUENCES

Flooding of the PG&E easement on Bacon Island under proposed Delta Wetlands Project operations would not increase the risk of structural failure of the operating gas pipeline or cause a physical change in PG&E's ability to supply gas to Bay Area or Sacramento/Stockton load centers. Flooding the island would probably change the manner in which PG&E monitors its pipelines and repairs leaks to the pipeline. These impacts are discussed below; Table 7-1 provides a comparison between the 1995 EIR/EIS and REIR/EIS impact conclusions.

Risk of Pipeline Leak or Rupture Resulting from Island Inundation

In the long term, the risk of pipeline leak or rupture, which is generally caused by corrosion, ground settlement, or physical damage from ground-disturbing equipment (e.g., farm equipment), would not increase under proposed project operation. The risk of pipeline rupture would decline because implementation of the Delta Wetlands Project would substantially reduce ground-disturbing activities by eliminating agricultural practices such as installation of internal drainage ditches that may cross the pipeline easement on Bacon Island. However, as described in the next section, risks to the pipeline could increase during Delta Wetlands' construction of levees.

The pipelines across Bacon Island would not require major structural modification for use under the submerged conditions caused by implementation of the proposed project. The operating gas pipeline (Line 57-B) on Bacon Island is concrete coated to prevent it from floating when the land is flooded or when the overlying soils are not strong enough when saturated to overcome pipeline buoyancy. The soils along the easement are already likely to be saturated at the depth of the pipeline because of a high water table.

The currently unused pipeline (Line 57-A) on Bacon Island may need additional weighting before the island is flooded to prevent the line from floating (Grimm pers. comm.). As mentioned previously, Line 57-A has concrete weights, except for approximately 900 feet on the west side of the island where the pipe is concrete coated. Under inundated conditions, Line 57-A could float, resulting in unanticipated bending loads that could damage its anticorrosion coating and disrupt the cathodic protection system. Therefore, inundating the island without proper weighting may substantially damage Line 57-A. Although Line 57-A is not used now, PG&E may choose to use it in the future. The need to weight the pipeline is considered a substantial alteration to the existing system. This impact is considered significant and the following mitigation is recommended.

Mitigation Measure: Securely Anchor Line 57-A before Bacon Island Flooding. Delta Wetlands shall reimburse PG&E for engineering studies, materials, and construction expenses to securely anchor Line 57-A before reservoir operations begin on Bacon Island.

Risk of Pipeline Leak or Rupture Resulting from Levee Improvements

The proposed levee buttressing could locally increase the rates of levee settlement or subsidence where the gas pipelines penetrate the Bacon Island exterior levees. Levee settlement or subsidence could increase the shear or bending loads on the pipeline, depending on the location of the pipeline with respect to the compressible levee foundation materials.

Under existing conditions, PG&E is required to maintain these pipelines at levee crossings and to improve or modify the lines in response to ongoing levee repair activities. PG&E designs and installs pipelines in the Delta region with an understanding of internal island subsidence problems (see Chapter 3D in the 1995 EIR/EIS for a discussion of subsidence in the central Delta) and of ongoing levee maintenance activities that can increase risks of pipeline failure through differential settlement and line exposure. PG&E commonly practices corrective measures necessary to relieve excessive pipeline stress resulting from levee settlement. The levee improvements proposed by Delta Wetlands are greater than those conducted under ongoing levee maintenance activities. As a result, the need for corrective measures and associated costs may increase during levee construction and settlement when compared to existing pipeline maintenance requirements. The potential for substantial pipeline stress resulting from Delta Wetlands levee improvements is considered a significant impact. The following mitigation measures are recommended.

Mitigation Measure: Monitor Locations Where Gas Pipelines Cross Bacon Island Levees during and after Levee Construction. During levee strengthening, Delta Wetlands engineers will install equipment to monitor levee settlement and subsidence rates. After levee completion, Delta Wetlands will conduct weekly inspections to check for potential problems at the gas pipeline crossings, including concerns about levee stability, settlement, and subsidence. If the weekly inspection indicates that settlement, erosion, or slumping at the gas pipelines has occurred, Delta Wetlands will notify PG&E and will implement corrective measures to mitigate any decrease in levee stability near the gas lines (see below).

Mitigation Measure: Implement Corrective Measures to Reduce Risk of Pipeline Failure during Levee Construction. Delta Wetlands shall reimburse PG&E for the incremental increase in maintenance costs associated with installation of new pipeline segments under Bacon Island levees or implementation of other appropriate corrective measures, which would prevent damage to the gas pipeline from increased bending or shear loads at levee crossings during levee construction and settlement.

Potential Interference with Pipeline Inspection Procedures

As part of its pipeline operation, inspection, and maintenance procedures required by federal and state regulations (49 CFR 192 and California Public Utilities Commission [CPUC] General Order 112), PG&E conducts annual aerial and walking inspections along the pipeline route to check for small leaks, evidence of internal or external corrosion, or easement encroachment (e.g., new drainage ditches). Valves are also regularly monitored for pressure fluctuations that could be caused by leaks (Grimm pers. comm.). Implementation of the Delta Wetlands Project would not alter PG&E's methods for routine inspection of the pipeline. Walking inspections for minor leaks would have to be scheduled during dry periods, or inspections could be conducted by boat when the island is flooded. To ensure that PG&E has access to the line for annual inspections under wet as well as dry conditions, the following mitigation is recommended.

Mitigation Measure: Provide Adequate Facilities on Bacon Island for Annual Pipeline Inspection. Delta Wetlands shall provide a suitable ramp and turnaround facilities to launch a boat for regular pipeline inspections, and should provide a suitable staging area for equipment and materials needed for gas pipeline repairs.

PG&E also monitors the pipelines using internal inspection and cathodic protection testing. No valves are located on Bacon Island, and internal inspection ("pigging") could occur regardless of dry or wet conditions. Flooding the island would inundate cathodic protection test stations, rendering them unusable. The cathodic protection test stations would need to be relocated before flooding of Bacon Island. This impact is considered significant and the following mitigation is recommended.

Mitigation Measure: Relocate Cathodic Protection Test Stations before Bacon Island Flooding. Delta Wetlands shall reimburse PG&E for engineering studies, materials, and construction expenses to relocate cathodic protection test stations to the perimeter levee system, and shall grant PG&E an easement to access the relocated cathodic protection test stations.

Potential Delay in Emergency Repairs and Unscheduled Interruption of Service

As described previously, the risk is very low that a pipeline leak or rupture would occur on Bacon Island, and if a leak or rupture occurred, it is equally likely to occur under dry conditions as under wet (i.e., full or partial-storage) conditions. This conclusion is based on the following considerations:

- Pipeline ruptures or leaks on Bacon Island under the proposed project would be caused by internal or external corrosion or levee settlement or subsidence loads. In recent years, no pipeline ruptures in the Delta have been caused by these modes (U.S. Department of Transportation 1999). PG&E more often must respond to leaks caused by farm equipment; emergency repairs in the Delta caused by ground-disturbing equipment generally occur once or twice a year (Warner pers. comm.).

- Annual inspections to detect small leaks, identify internal or external pipeline corrosion, identify potential levee subsidence or settlement problems, and prevent future pipeline ruptures or substantial pipeline leaks in those areas by prescribing immediate repair work will still be conducted in accordance with federal and state regulations.

- Based on modeling of water storage operations for the proposed project (see Chapter 3), it is estimated that Bacon Island would be at full storage (filled by the end of December) fewer than 50% of winters, and the reservoir islands would be empty in 437 of the 864 months simulated for the 72-year hydrologic record, or approximately 51% of the time. Therefore, opportunities for repair and replacement of damaged pipeline segments under dry conditions will occur about 50% of the time.

If repairs are needed during flooded conditions on Bacon Island, the Delta Wetlands Project could increase the cost of repair operations, extend the time required by PG&E to make necessary repairs, and possibly increase the duration of service curtailments. The following sections describe the emergency repair procedures and the effects on service under existing conditions and with the Delta Wetlands Project in operation.

Existing Conditions

Emergency Repair Procedures. PG&E is required by the CPUC (CPUC General Order 112(e), which adopts 49 CFR 192) to maintain an emergency-preparedness plan. As described in the hearing testimony, PG&E has a supply of materials and specially trained welders and equipment operators for emergency shallow-water repairs of its pipeline facilities. PG&E's testimony also states that the pipelines crossing Bacon Island are under water most of the time because of shallow groundwater, and that those conditions require special procedures to facilitate repairs.

PG&E stated that it could probably mobilize crews within several weeks under existing (i.e., dry) conditions. The time required for repair cannot be estimated without knowing the conditions that led to the rupture and the extent of the rupture; PG&E would assess both of these factors after excavating and inspecting the damaged portion of the pipeline. To respond to a pipeline failure on Bacon Island under existing conditions, PG&E would:

- shut off gas flowing through the line at the nearest valves (on McDonald Island, 2.9 miles east of the east side of Bacon Island, and 5.2 miles west of the west side of Bacon Island) and isolate the pipeline segment;
- release gas within the pipeline section that crosses the island at one of the shut-off valves; and
- drive equipment to the leak site, excavate the pipeline, dewater the working pit (because of shallow groundwater levels, some dewatering is probably necessary even during the summer), cut out the damaged section, weld a new section in place, and test the pipeline (Warner pers. comm.).

Effects on Service. If Line 57-B were damaged and removed from service, PG&E would curtail deliveries to customers if supplies were not adequate to meet demand. PG&E stated in its testimony that, under existing conditions, it distributes natural gas from three sources: the 400 and 401 lines from Canada, the 300 line from southern California, and local production. Additionally, PG&E stated that these sources of gas currently cannot meet the peak gas demand that occurs during cold weather. Line 57-B connects the McDonald Island storage facility to the distribution system to provide peak capacity and redundancy of supply if one of the other sources is interrupted. If the McDonald Island storage facility were not online during a peak-demand period, PG&E would attempt to balance its system and purchase additional gas to minimize service interruptions; however, PG&E's ability to respond to the situation is limited because the pipelines that connect to the gas sources have limited capacity.

Natural gas, like other utility services, has multiple price schedules based on delivery of the service. A supply that is interruptible is less expensive than a firm supply. If gas service must be curtailed, customers with interruptible supplies would be affected first. Customers with interruptible supplies are usually industrial users that can switch to alternative fuels, such as the electricity-generating facilities in Pittsburg, which can switch to fuel oil when natural gas supplies are curtailed (which occurred during the winter of 1997). Many firm-supply customers may not have an alternative fuel supply. During service interruptions, PG&E would not be able provide alternative service to all customers, and it would be up to customers to meet their individual needs.

Delta Wetlands Project Conditions

Emergency Repair Procedures. Under Delta Wetlands Project conditions, the procedure for pipeline repair described previously would still be used when the reservoir island is not flooded (i.e., during dry periods). PG&E testified that a repair conducted when Bacon Island is partially flooded could be completed using similar techniques as under without-project conditions, except that access to the site may require use of a boat or barge, depending on the depth of stored water relative to the height of existing roads across the island. After accessing the site, PG&E could install sheet piles around the damaged area, dewater a work area, and then complete the pipeline repair as if it were under dry conditions (Clapp testimony). However, because of the logistical problems associated with accessing the site and installing sheet piles around a larger area, PG&E would require additional resources and planning time and would incur greater costs using these techniques under flooded conditions than under dry conditions.

Alternatively, as suggested in the water right hearings, underwater repair methods could be used to repair a damaged pipeline. PG&E stated that it is not currently equipped to service pipelines through water with divers and underwater welding equipment (Warner pers. comm.). However, PG&E staff also testified that the utility has a supply of materials and specially trained welders and equipment operators for emergency shallow-water repairs of its pipeline facilities (Clapp testimony). Nevertheless, underwater repair methods would be costly and require specialized equipment and do not appear to be a practical alternative at this time.

The final practicable repair option is to shut down the pipeline, empty the reservoir, and use dry-condition repair techniques. If a significant pipeline leak occurred on Bacon Island during water-storage operations and the leak could not be repaired by installing sheet piles and dewatering a work area, the pipeline would probably have to be shut down until the reservoir could be drawn down and conventional dry-conditions construction techniques could be used. According to Delta Wetlands' testimony, drawing the stored water down at the maximum rate assuming a full reservoir would take at least three weeks, assuming that Delta Wetlands' operational rules would allow discharge at the maximum rate. Additional time would be required to allow the land surface to dry before equipment could be operated on the ground surface, possibly substantially increasing the waiting period before the pipeline could be repaired. This repair technique, in addition to using sheet piling, appears to be the most practical repair method available if an emergency occurred during reservoir operations.

Additionally, the 1995 DEIR/EIS suggested that directional drilling, which is used for pipeline repairs at Delta channel crossings, would be a practical repair solution. When a line fails under a Delta channel, PG&E directionally drills under the channel adjacent to the damaged line and pulls a new pipeline segment. The new pipeline segment is welded into the existing line on both sides of the channel, and the damaged line is sealed (usually filled with concrete) and abandoned in place. However, under closer review, this technique is not a practicable solution to repair the line across Bacon Island. To drill entirely under Bacon Island, the entrance and exits of the bore would need to be located on the land on Palm Tract and McDonald Island, greatly increasing the bore length (from about 2 miles to 5 miles).

Although technically possible, the construction of a new line under Bacon Island when the reservoir is full would be costly and time-consuming. It could take months to design the new pipeline segment, mobilize the appropriate equipment, obtain the pipe, and secure the necessary permits and leases from the regulatory agencies. For example, the California State Lands Commission requires that detailed engineering plans be prepared and approved before it will grant a lease to cross state lands (the channels adjacent to the Delta Wetlands islands), and the California State Reclamation Board requires that PG&E receive an encroachment permit from the local reclamation district before construction.

Shorter pipeline segments could be installed using directional-drilling techniques by creating temporary gravel islands within Bacon Island. However, the necessary equipment would be difficult to transport to the site. Barges are typically used to move such equipment, but they would not have access to the island interior. A large crane would be required to lift equipment over the levee, from the adjacent channel to the island interior. The storage level (water depth) at the time of repair could limit the size of equipment that could be used, further slowing the repair process. As with a single directional drill, it could take months to design the new pipeline segment, mobilize the appropriate equipment, obtain the pipe, and secure the necessary permits and leases from the regulatory agencies. This does not appear to be a practicable repair technique on Bacon Island.

PG&E contends that the only suitable solution to potential adverse effects on its pipelines and potential interruption of service would be construction of new pipelines around the proposed project. The pipeline incident data collected by the DOT, however, do not support this conclusion. Pipelines very rarely fail catastrophically without external forces or third-party actions. Flooding Bacon Island and discontinuing the current agricultural activities would all but eliminate any potential third-party action that could damage the pipeline. Internal inspection, required by federal and state regulations, detects corrosion or abnormalities in the pipeline walls in advance of potential failure. Furthermore, it is a common industry practice to allow small leaks to go unremedied for months while engineering studies are completed and specialized equipment and personnel are mobilized.

In summary, conducting a repair while the reservoir is inundated or drawing the reservoir down before conducting a dry-land repair would take longer and cost more during Delta Wetlands reservoir operations when compared to existing conditions. Without knowing the specifics of the pipeline rupture, it is difficult to determine the magnitude of the effect on PG&E's repair time and associated costs of the additional time needed to plan for a shallow-water repair or the time required to draw down the reservoir.

Effects on Service. Inundation of the island under Delta Wetlands Project operations could slow PG&E's response time to repair a pipeline leak and could interrupt service for a longer period than would occur under existing conditions. As described above, a severe leak or pipeline rupture would take longer to repair under flooded reservoir conditions than the existing dry conditions. This delay in repairs could result in longer periods of using alternative gas sources.

Impact Conclusion for Potential Delay in Emergency Repair

As evidenced by the Office of Pipeline Safety data, the long-term risk of catastrophic pipeline failure is very low under existing conditions, and implementation of the project would further reduce the risk to the pipeline from potentially damaging third-party activities. Flooding of Bacon Island could delay and complicate repairs to PG&E's pipeline facilities if a rupture occurred during water-storage operations. Flooding the island would also increase the cost of such repairs. If a repair required an immediate drawdown of the reservoir, it is simulated that all the water could be removed within three weeks (under full-reservoir storage) while appropriate engineering studies are being completed and before repair equipment and personnel could be mobilized. The three-week drawdown estimate assumes that Delta Wetlands discharges from Bacon Island would not be restricted by water quality mitigation measures or other operational constraints. The potential impact on PG&E's operations is an economic one. The incremental costs to PG&E (e.g., lost revenue and purchase cost of alternative supplies) and its customers resulting from an extended time required to repair the pipeline under project conditions cannot be determined but are recognized as a potential economic effect of the Delta Wetlands Project. Because economic effects are not considered environmental impacts under CEQA and NEPA, no significance conclusion is made and no mitigation is identified (see also Chapter 3K, "Economic Conditions and Effects", in the 1995 DEIR/EIS).

Cumulative Impacts

Implementing the Delta Wetlands Project would not contribute significantly to cumulative risk of gas pipeline failure in the Delta. Activities in the Delta that could affect gas pipelines include agricultural activities and levee strengthening or maintenance. Because the Delta Wetlands Project would substantially reduce ground-disturbing activities, it would reduce the cumulative risk to pipelines from third-party activities (e.g., farming). PG&E monitors some levee crossings, including the Bacon Island and McDonald Island levee crossings, using monthly inspections of installed tilt meters at the levee crossings (Clapp testimony). Cumulative risks to gas pipelines at levee crossings in the Delta are considered less-than-significant because PG&E applies monitoring procedures and implements pipeline improvements in response to levee maintenance or settlement on an ongoing basis. Therefore, the cumulative effect on gas pipelines in the Delta is considered less than significant and no mitigation is required.

Impact Evaluation of Project Alternatives from the 1995 Draft EIR/EIS

As described in Chapter 2, Bacon Island would be used for water storage under all three project alternatives evaluated in the 1995 DEIR/EIS. Consequently, effects on PG&E's gas pipeline would be the same under all alternatives. The impacts and mitigation measures described above for the proposed project (Alternative 2 in the 1995 DEIR/EIS) would also apply to Alternatives 1 and 3.

Table 7-1. Comparison between Delta Wetlands Project Impacts on Natural Gas Facilities in the 1995 DEIR/EIS and in the 2000 REIR/EIS

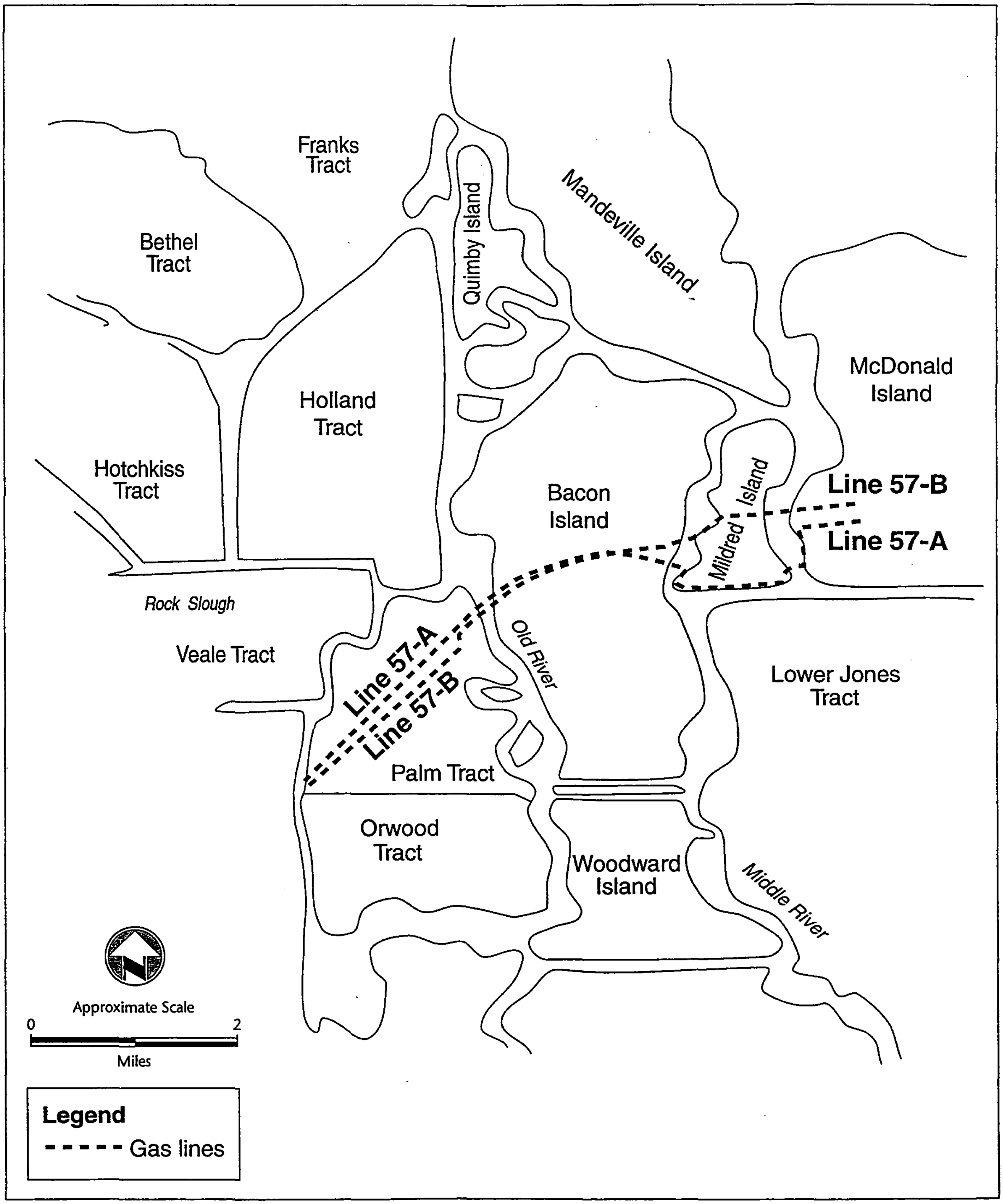
Impacts and Mitigation Measures of 1995 DEIR/EIS Alternatives 1 and 2	Differences between 1995 DEIR/EIS and 2000 REIR/EIS
----	**Risk of Pipeline Leak or Rupture Resulting from Island Inundation.** The risk of pipeline rupture would decline under project conditions because the project would substantially reduce ground-disturbing activities, such as agricultural practices, that could result in line rupture. This effect is considered beneficial. However, Line 57-A may require additional weighting before the island is flooded. The line could float under inundated conditions, resulting in increased risk of damage to this pipeline and the need for pipeline modifications. Therefore, this impact is considered significant and the following mitigation measure is recommended. (S) • Securely Anchor Line 57-A before Bacon Island Flooding. (LTS)
Impact E-3: Increase in the Risk to Gas Lines Crossing Exterior Levees on Bacon Island (LTS) • No mitigation is required.	**Risk of Pipeline Leak or Rupture Resulting from Levee Improvements.** Potential settlement issues or increased loads on the pipelines at the levee crossings may require corrective measures during levee construction and settlement. This impact is considered significant and the following mitigation measures are recommended. (S) • Monitor Locations Where Gas Pipelines Cross Bacon Island Levees during and after Levee Construction and • Implement Corrective Measures to Reduce Risk of Pipeline Failure during Levee Construction. (LTS)

Note: S = Significant; SU = Significant and unavoidable; LTS = Less than significant; B = Beneficial.

Table 7-1. Continued

Impacts and Mitigation Measures of 1995 DEIR/EIS Alternatives 1 and 2	Differences between 1995 DEIR/EIS and 2000 REIR/EIS
----	**Potential Interference with Pipeline Inspection Procedures.** To the extent practical, walking inspections would be completed during dry periods; however, PG&E would need to modify its inspection practices during inundated conditions by using a boat rather than a walking inspection. According to PG&E, this represents a substantial alteration in PG&E's maintenance procedures. Additionally, flooding Bacon Island would inundate cathodic protection test stations. This impact is considered significant and the following mitigation measures (described in the text) are recommended to assist PG&E in conducting its routine maintenance and reduce the impact to a less-than-significant level. (S) • Provide Adequate Facilities on Bacon Island for Annual Pipeline Inspection. • Relocate Cathodic Protection Test Stations before Bacon Island Flooding. (LTS)
Impact E-4: Increase in PG&E Response Time to Repair a Gas Line Failure on Bacon Island (LTS) • No mitigation is required.	**Potential for Delay in Emergency Repairs and Unscheduled Interruption of Service.** Project operations would not preclude routine inspections and emergency repairs. However, reservoir operations on Bacon Island would delay and complicate the repairs of PG&E's pipeline facilities that would be needed if a rupture occurred during water-storage operations. Flooding the island would also increase the cost of such repairs. The potential impact on PG&E's operations is an economic one. The incremental costs, if any, to PG&E and its customers resulting from an extension of time required to repair the pipeline under project conditions are recognized as a potential economic effect of the Delta Wetlands Project. Because economic effects are not considered environmental impacts under the California Environmental Quality Act (CEQA) and National Environmental Policy Act (NEPA), no significance conclusion is made and no mitigation is identified (see also Chapter 3K, "Economic Conditions and Effects" in the 1995 DEIR/EIS).

Note: S = Significant; SU = Significant and unavoidable; LTS = Less than significant; B = Beneficial.



Source: Bennett pers. comm., Forkel pers. comm.

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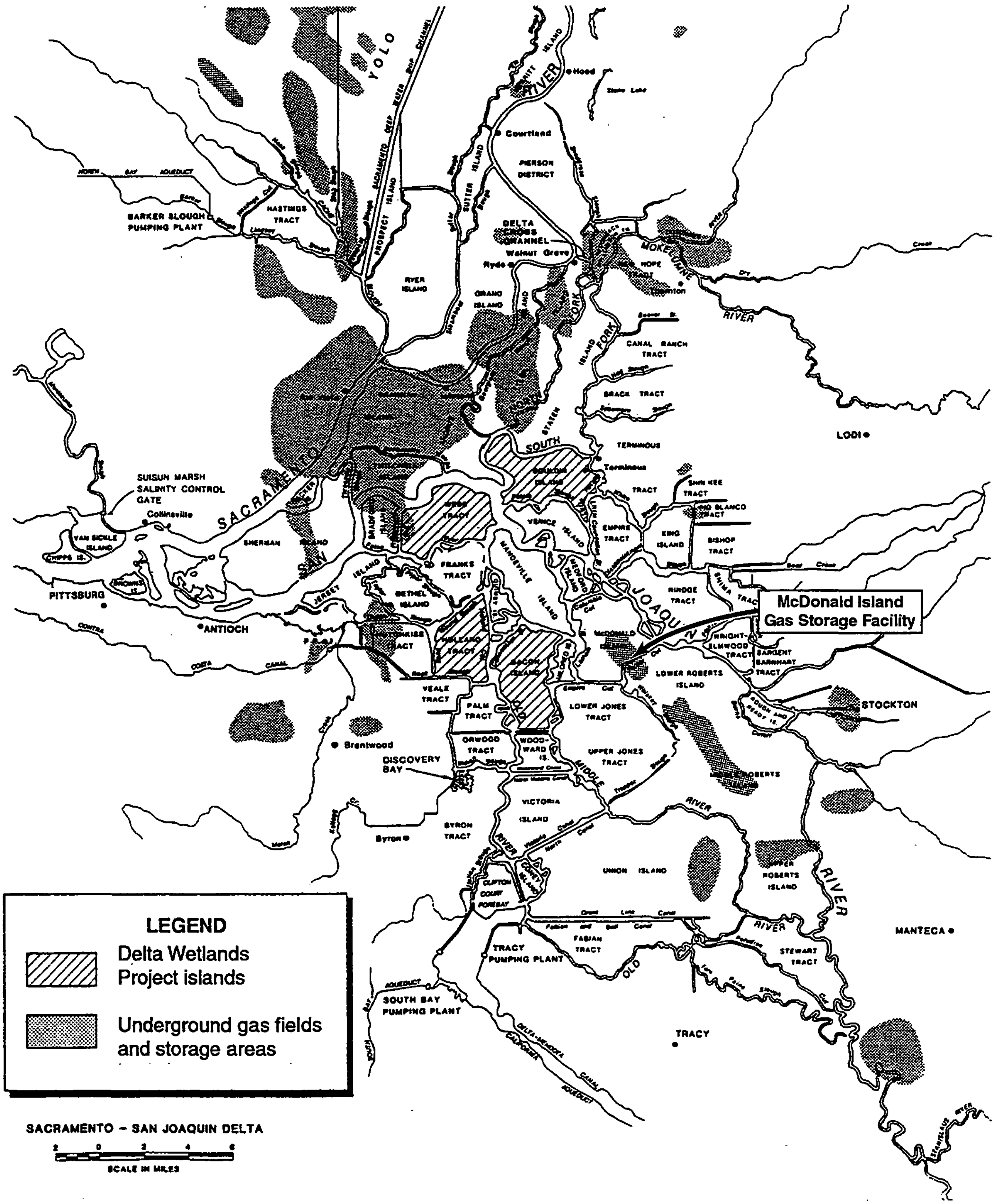
Figure 7-1
Gas Transmission Lines on Bacon Island



Source: DWR 1993.

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Figure 7-2
Underground Gas Fields and Storage Areas in the Delta Wetlands Project Vicinity

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Chapter 9. Glossary of Technical Terms

Note: All acronyms used in the text are defined under "List of Acronyms" found after the Table of Contents and Lists of Tables and Figures in the front of this document.

Acre-foot. The quantity of water that would cover 1 acre to a depth of 1 foot (43,560 cubic feet or 326,700 gallons).

Allowable export. The amount of water allowable for export under the 1995 WQCP; the lesser of the amount specified by the export limits (i.e., percentage of total Delta inflow) and the amount remaining after outflow requirements are met (i.e., available water).

Anadromous species. Fishes that mature in marine waters and migrate to fresh water to spawn.

Anticorrosion coating. The coating of pipelines with paint, epoxy, or other materials to prevent contact of dissimilar metals. The barrier prevents establishment of a corrosion current and corrosion of the pipe.

Appropriative water rights. Water rights held in the form of conditional permits or licenses from SWRCB, which allow the diversion of a specified amount of water from a source for reasonable and beneficial use during all or a portion of the year. In California, previously issued appropriative water rights are superior to and take precedence over newly granted rights. SWRCB's authorizations contain terms and conditions to protect prior water right holders, including Delta and upstream riparian water users, and to protect the public interest in fish and wildlife resources. To a varying degree, SWRCB reserves jurisdiction to establish or revise certain permit or license terms and conditions for salinity control, protection of fish and wildlife, protection of vested water rights, and coordination of terms and conditions between the major water supply projects.

Aquifer. A porous soil or geological formation lying between impermeable strata that contains groundwater; yields groundwater to springs and wells.

Available water. Under the 1995 WQCP, total Delta inflow less Delta outflow requirements.

Bearing capacity. The maximum load that a structure can support, divided by its effective bearing area (the part of the structure that carries the load).

Bending load. The result when the opposite ends of an item are forced together (as when a sheet of paper is folded). Pipelines can be subject to this type of load.

Blowout ponds. Small lakes on Webb and Holland Tracts scoured in the island bottoms by inrushing floodwaters caused by levee failures in 1950 on Webb Tract and in 1980 on both islands.

Borrow area. An excavated area or pit created by the removal of earth material to be used as fill in a different location.

Buttress. To steady a structure by providing greater resistance to lateral forces to prevent failure.

Calibration. See "model calibration".

Candidate species (also candidate threatened or endangered species). Taxa (species or subspecies) of plants and animals currently being considered for listing to be protected as special-status species by USFWS.

Carryover storage. The amount of stored water remaining at the end of the water year (end of September) in San Luis Reservoir (for CVP and SWP) or on the Delta Wetlands reservoir islands.

Cathodic protection system. A process used to prevent pipeline corrosion by passing an electric current through the pipe. When dissimilar metals (the pipeline and soil minerals) are placed in solution together, a corrosion current is established. The cathodic protection system creates an opposite current to minimize corrosion.

Central Delta water. Used in the DeltaSOQ model to represent the source of export water from the central Delta, which includes a mixture of water from the Sacramento, Mokelumne, and Cosumnes Rivers; seawater intrusion from the western Delta; and some portion of the Sacramento River that does not flow directly to the export locations.

Central Valley Project (CVP). The federal water project in California's Central Valley operated by Reclamation.

Channel depletion. The water removed from Delta channels by diversions for irrigation and by open-water evaporation.

Confirmation. See "model confirmation".

Consumptive use. Loss of water on the Delta Wetlands Project islands and other Delta islands through crop ET and open-water evaporation and use for shallow-water management for wetlands and wildlife habitat. Rainfall and channel depletion supply the consumptive-use water.

Conveyance capacity. The volume of water that can be transported by a canal, aqueduct, or ditch. Conveyance capacity is generally measured in cfs.

Cubic feet per second (cfs). A measure of a moving volume of water, sometimes shortened to "second-feet".

DailySOS. A daily operations model used to confirm the adequacy of the analysis completed using DeltaSOS (which simulates the effects of regulatory standards and water management projects on the Delta on a monthly basis).

Delta Cross Channel (DCC). An existing gated structure and channel connecting the Sacramento River at Walnut Grove to the North Fork of the Mokelumne River. The facility was constructed as part of the CVP to control movement of Sacramento River water into the central Delta and to the south-Delta export pumps. Operating criteria currently require the gates to be closed for specific periods to keep downstream migrating fish in the Sacramento River and to prevent flooding of the central Delta.

Delta Drainage Water Quality model (DeltaDWQ). A model developed for the 1995 DEIR/EIS analysis to estimate how much the Delta Wetlands islands contribute to EC, DOC, Cl^-, and Br^- levels at Delta channel locations and in Delta diversions and exports under no-project conditions and under project operations.

Delta exports. The water pumped from the Delta to south-of-Delta users by DWR at Banks Pumping Plant and by Reclamation at the CVP Tracy Pumping Plant, and the amount diverted by CCWD at its Rock Slough and Old River intakes.

Delta in-balance/in-excess conditions. Conditions in the Delta, designated by DWR and Reclamation, that help determine when the Delta Wetlands Project may divert water for storage on its designated reservoir islands. When conditions are "in balance", all Delta inflow is required to meet Delta objectives and satisfy diversions by CCWD, the CVP, the SWP, and Delta riparian and senior appropriative water users. Delta Wetlands would not be allowed to divert water when the Delta is designated as being "in balance" because no additional water would be available for diversion by the Delta Wetlands Project under new water rights; Delta Wetlands reservoir releases may be necessary to increase exports when the Delta is in balance. When DWR and Reclamation determine that Delta conditions are "in excess" and other terms and conditions are met, the Delta Wetlands Project would be allowed to divert available excess water for storage under new appropriative water rights.

Delta-Mendota Canal (DMC). The major conveyance facility of the CVP, which carries water from the Delta to as far south as the southern San Joaquin Valley.

Delta outflow criteria. Minimum water quality or flow standards for the Delta and Suisun Marsh, such as those required by the 1995 WQCP.

Delta standards. A general term referring to all applicable water quality objectives; flow requirements; and other restrictions on diversions, exports, channel flows, or gate operations.

Delta Standards and Operations Simulation model (DeltaSOS). A computer spreadsheet model developed by Jones & Stokes that simulates the effects of regulatory standards and water management projects on the Delta.

Delta Standards, Operations, and Quality model (DeltaSOQ). A modified version of the DeltaSOS model that incorporates equations that predict the water quality of agricultural drainage and Delta Wetlands reservoir island storage. This model also incorporates equations that predict the effects of agricultural drainage and Delta Wetlands discharges on EC levels and DOC concentrations in Delta channels and exports.

Design response spectrum. The specified range of ground motion in response to seismic activity that is assumed for an analysis based on historical data and local soil conditions.

Direct fishery effects. Mortality of fish attributable to Delta Wetlands diversions, including entrainment in Delta Wetlands diversions and losses resulting from changes in habitat.

Disinfection byproducts (DBP). A class of chemicals created during chlorination or other oxidation treatment processes used to disinfect municipal water supplies. Organic content and chloride (Cl^-) and bromide (Br^-) concentrations are the primary variables that influence the formation of DBP compounds.

Dissolved oxygen (DO). Oxygen dissolved in water that is available to supply oxidation and respiration requirements.

Diversions. Water diverted at control points, including reservoir control points. Diversions typically represent basin irrigation diversions, water transfers, municipal diversions, and exports.

Drawdown. The lowering of the water level of a reservoir or other body of water as a result of the withdrawal of water.

DWRSIM. DWR's operations planning model, used to estimate possible effects of increased demands, new facilities, or new standards on SWP operations.

Dynamic and static stability. The stability of levees under seismic movement or without seismic movement.

Electrical conductivity (EC). A general measure of dissolved minerals (i.e., salinity); the most commonly measured variable in Delta waters.

Endangered species. Any plant or animal species or subspecies whose survival is threatened with extinction and that is included in the federal or state list of endangered species.

Entrainment. The process in which fish are drawn into water diversion facilities along with water drawn from a channel or other water body by siphons and/or pumps. Entrainment loss includes all fish not salvaged (i.e., eggs, larvae, juveniles, and adults that pass through the fish screens, are impinged on the fish screens, or are eaten by predators).

Entrapment zone. An area or zone of the Bay-Delta estuary where riverine current meets upstream-flowing estuarine currents and variations in flow interact with particle settling to trap particles. The entrapment zone generally corresponds to a surface salinity range of 2 to 10 mS/cm conductance. The entrapment zone is an important aquatic habitat region associated with high levels of biological productivity.

Erosion. A combination of processes (e.g., wind or tidal action) in which the materials of the earth's surface are loosened, dissolved, or worn away and transported from one place to another by natural agents.

Evapotranspiration (ET). Loss of water from the earth's surface by evaporation from soil or water and by transpiration from plants.

Evolutionarily Significant Unit (ESU). A distinctive group of Pacific salmon or steelhead.

Export limits. A specification in the 1995 WQCP. Delta exports are limited to a percentage of total Delta inflow (generally 35% during February-June and 65% during July-January).

Exports. The water pumped from the Delta to south-of-Delta users by DWR at Banks Pumping Plant and by Reclamation at the CVP Tracy Pumping Plant, and the amount diverted by CCWD at its Rock Slough and Old River intakes.

Factor of safety for slope stability (FS). A calculated number representing the degree of safety of a slope against instability. The FS is expressed mathematically as the ratio of stabilizing effects (forces or moments) and destabilizing effects acting on a potentially unstable soil mass in a slope. When the FS is greater than 1, the soil mass in the slope is, in theory, stable; when FS is less than 1, the slope is, in theory, unstable. For a given slope geometry and soil conditions, a calculated FS is associated with a unique slope failure configuration. The most critical failure configuration is associated with the minimum FS calculated in a slope stability analysis. Several agencies (such as the Association of State Dam Safety Officials and USACE) have developed criteria that provide different design FSs stipulated for various slope conditions, e.g., under long-term loading, shortly after construction, etc. These design FSs are typically above 1 and are minimum values to be achieved for the slope to be considered stable.

Firm storage capacity. An amount equivalent to guaranteed storage capacity. Utility rates usually vary based on guarantee of service. The first priority is to meet firm demands; consequently, this demand is most expensive. Demands that can be met with less reliability are less expensive.

Freeboard. The vertical distance between a design maximum water level and the top of a structure such as a levee, dike, floodwall, or other control surface. The freeboard is a safety margin intended to accommodate unpredictable rises in water level.

Future permitted export pumping capacity. A capacity that may be established for the SWP in the future. If new permit conditions are established for the SWP, the permitted export pumping rate of the SWP pumps would be increased to the physical export pumping capacity of 10,300 cfs. If that occurs, the combined permitted export pumping rate of the SWP and CVP pumps could then equal up to 14,900 cfs or 14,500 cfs.

Gas field. An area that contains closely contiguous reservoirs of commercially valuable gas.

Geotechnical. Of or pertaining to the practical application of geologic science to civil engineering problems.

Historical conditions. The combination of measured inflows and exports, estimated channel depletion and Delta outflow, simulated channel flows, and measured or simulated EC and other water quality variables.

Historical Delta flows. Measured Delta inflows and exports, estimated Delta outflow, and simulated net channel flows corresponding to the inflows and exports.

Hydraulic conductivity. A measure of the capacity of a porous medium to transmit water, often expressed in centimeters per second. The hydraulic conductivity is equal to the rate of flow of water through a cross section of one unit area under a unit hydraulic gradient.

Hydraulic gradient. The rate of change in total hydraulic head per unit distance of flow measured at a specific point and in a given direction, often resulting from frictional effects along the flow path.

Hydraulic head. The force exerted by a column of liquid expressed as the height of the liquid above the point at which the pressure is measured (the force of the liquid column being directly proportional to its height).

Hydraulics. Study of the practical effects and control of moving water; used to refer to the relationship between channel geometry and flow, velocity, and depth of water.

Hydrology. General description of the movement of water in the atmosphere, on the earth surface, in the soil, and in the ground; used in this REIR/EIS to refer to rainfall and streamflow conditions.

Indirect fishery effects. Mortality of fish attributable to other diversions that results from Delta Wetlands effects on Delta flow conditions.

Inflow. The rate (cfs) or volume (TAF) of total streamflow entering the Delta from the Sacramento and San Joaquin Rivers, Yolo Bypass, and the eastside streams.

Interceptor-well system. A seepage-control system that would consist of actively pumped wells installed in the exterior levees of the Delta Wetlands reservoir islands in locations where substantial seepage to adjacent islands is predicted to occur.

Internal inspection. A process required for pipelines. A robotic device, commonly called a "pig", is sent along the inside of the pipe. The pig measures the resistance of electrical current from the pipe to the ground. Areas with abnormally low resistance indicate damage to the pipe's anticorrosion coating.

Interruptible demand. An assumed additional demand for SWP water above the specified monthly demands. Interruptible demand is simulated as 84 TAF/month for 5 months, or 1,400 cfs/month during November through March when San Luis Reservoir is full. DWRSIM assumes that additional SWP deliveries are made to meet interruptible demand when there is unused export capacity and available water in the Delta.

Joint point of diversion. Allowance of CVP and SWP export pumping at either the Banks or Tracy pumping plants.

Leaching. The removal of soluble substances from soil by percolating water.

Levee crest. The top of a levee.

Liquefaction. The process in which loose saturated soils lose strength when subject to seismic activity (i.e., shaking).

Load center. In the utility business, a concentration of demand or users. For example, the Sacramento metropolitan area is a load center. The area consists of a large group of residential, municipal, and industrial users. The cumulative demand of the load center is considered when utility transmission and storage facilities are developed.

Local water supply. In the DWRSIM model, the assumed amount of captured rainfall in areas south of the Delta that can be used to satisfy CVP and SWP demands.

Midwater trawl index. The sum of the weighted catch of fish of four monthly samples (September-December) from numerous locations in the Delta and Suisun Bay. The index is assumed to be a measure of abundance when considered in relation to the catch for all other years of the sampling record (1967-1995). In the Bay-Delta estuary, the index has been developed for striped bass, American shad, delta smelt, Sacramento splittail, longfin smelt, and other species.

Mitigation. Methods to avoid, reduce, rectify, eliminate, or compensate for adverse project impacts.

Mixing. Exchange of mass between two volumes; used in this REIR/EIS to refer to the movement of salt or fish from one location to another caused by the tidal movement of water within the Delta channels.

Model calibration. Adjustments made to a model (i.e., equations or coefficient values) to provide results that more closely follow observed data; used especially during initial model development and testing.

Model confirmation. Comparative testing of model results with measured data to determine the adequacy of model simulations for describing the observed behavior of the modeled variables; used especially during model application to conditions different from those used to calibrate the model.

Municipal Water Quality Investigations (MWQI) program. A program conducted by the DWR Division of Planning and Local Assistance that collects data on a wide variety of water quality variables in Delta inflows and exports. These data provide baseline water quality information in this REIR/EIS.

Net flow. Long-term average of flows in a channel; used to describe the magnitude and direction of flow in a channel after flows during a tidal cycle are averaged.

Outflow. The water flowing out of the Delta into San Francisco Bay.

Outflow requirements. Specifications for the Delta in the 1995 WQCP that encompass water quality protection for agricultural and municipal and industrial uses, Suisun Marsh, and fish habitat. In standard DWR calculations of Delta operations (using DWRSIM), "outflow" represents the difference between inflow and exports; the outflow term therefore includes in-Delta consumptive use.

Overtopping. Passing of water over the top of a levee as a result of wave runup or surge action.

Passive-flow relief-well system. A system of wells that passively relieve elevated hydrostatic pressures in an aquifer by allowing flow to the surface. (Hydrostatic pressure is the pressure exerted by a liquid, such as water, at rest.)

Peak flow. The maximum discharge of a stream during a specified period of time.

Peat soils. Acidic, humus-rich soils that contain a large amount of unconsolidated, semicarbonized, partially decomposed plant debris formed in an anaerobic, water-saturated environment.

Permeability. The capacity of a porous rock, sediment, or soil for transmitting a fluid.

Permitted pumping rate. A rate that may be established by USACE. USACE does not require a permit under Section 404 of the CWA for current SWP export pumping. However, USACE would require a permit if SWP export pumping were to exceed a maximum 3-day average rate of 6,680 cfs. Therefore, the maximum combined export pumping rate that does not require a USACE permit is 11,280 cfs (6,680 cfs for the SWP pumps and 4,600 cfs for the CVP pumps). The restrictions for the period of December 15 to March 15, as interpreted by DWR, allow a combined rate of 11,700 cfs in December and March and a combined maximum 3-day average rate of 12,700 cfs in January and February. (See also "future permitted export pumping capacity".)

Phreatic. Of or pertaining to groundwater.

Phreatic surface. The surface of a body of unconfined groundwater at atmospheric pressure.

Piezometer. A sandpipe monitoring well used to measure the depth to the groundwater surface in the aquifer.

Pipeline balancing. The process of distributing pipeline capacity to efficiently provide service to competing load centers.

Project yield. Average annual water discharged for export from the Delta Wetlands Project islands. Reported in TAF/yr.

QWEST. A calculated flow parameter representing net flow between the central Delta and the western Delta. QWEST criteria have previously been considered for protection of central Delta fish.

Ramping of exports. Gradual change in export pumping that may be required to moderate the effects of rapid changes.

Riparian. Living on or adjacent to a water body, such as a river, lake, or pond.

Riparian habitat. Woody vegetation (trees and shrubs) that grows in soils saturated for a substantial portion of the year, especially on the edges of open water bodies (e.g., lakes, rivers, or ditches) or on levees.

Riparian water rights. Correlative entitlements to water that are held by owners of land bordering natural watercourses. California requires a statement of diversion and use of natural flows on adjacent riparian land under a riparian right.

Riprap. A stone covering used to protect soil or surfaces from erosion by water or the elements.

Rock revetment. A stone covering used to protect soil or surfaces from erosion by water or the elements.

Salinity. Salt measured in ppt, TDS, EC units, or mg/l.

Salvage. Removal of fish from screens on diversion structures and the subsequent return of the fish to the water body.

Sediment. Fragmented mineral or organic material transported or deposited by air, water, or ice.

Seepage. A slow movement of water through permeable soils caused by increases in the hydraulic head. (See also "hydraulic head".)

Seepage flux. The rate of flow of water across a given line or surface, typically expressed in gpm or cfs.

Seismicity. The frequency, intensity, and distribution of earthquake activity in a given area.

Settlement. The sinking of surface material as a result of compaction of soils or sediment caused by an increase in the weight of overlying deposits or by pressure resulting from earth movements.

Shear load. The result when force is applied perpendicular to or on opposite sides of an item (as when a sheet of paper is cut with scissors). Pipelines can be subject to this type of load.

Simulated Disinfection System (SDS). A method of determining THM formation potential. This laboratory analytical method was developed to simulate municipal water treatment facilities' actual disinfection process (and THM concentrations) more closely than other methods; it uses a much lower chlorine (Cl_2) dose and much less contact time.

Simulation. The application of a mathematical representation or model to analyze a theoretical or physical process.

Slope deformations. Changes in the shape or size of a slope.

Smolt. A juvenile fish that has undergone physiological change enabling it to survive in saltwater.

South-of-Delta delivery deficit. Unmet demand, that is, total demand for CVP and SWP water minus total CVP and SWP deliveries. Total deliveries are calculated based on water exported from the Delta and the change in San Luis Reservoir storage. (When San Luis Reservoir storage drops, that amount is added to Delta exports to determine total CVP and SWP deliveries. When San Luis Reservoir storage increases, that amount is subtracted from Delta exports to determine total CVP and SWP deliveries.)

South-of-Delta demands. Demands for CVP and SWP contractors that export water from the Delta.

Spawning. Laying of eggs, especially by fish.

Special Multipurpose Applied Research Technology Station (SMARTS). A test facility at the DWR Bryte facility in West Sacramento that conducts a variety of peat-soil-flooding water-quality experiments under controlled static or continuous water-flow conditions.

Special-status species. Those species listed as threatened or endangered by the state and federal governments or identified as possibly warranting such protection.

Species. The basic category of biological classification intended to designate a single kind of animal or plant.

Splash berm. An extended area of facing on an island levee designed to protect against erosion of the levee crest by wave splash and runup.

State Water Project (SWP). The water project operated by DWR that delivers water from the Sacramento Valley to southern California.

Stratigraphy. The composition, characteristics, distribution, and age relation of layered rocks and soils.

Subsidence. A local or regional sinking of the ground. In the Delta, this results primarily from peat soil being converted into gas.

Surplus Delta outflow. Outflow in excess of the amount required to meet all monthly water demands, protect Delta salinity standards, and comply with the export/inflow objectives of the 1995 WQCP.

Take. A term used in Section 9 of the federal Endangered Species Act that includes harassment of and harm to a species, entrainment, directly and indirectly caused mortality, and actions that adversely modify or destroy habitat.

Threatened species. A species that is likely to become endangered in the foreseeable future and is included in the federal or state list of threatened species.

Tidal flow. Flow caused by tidal changes in stage and hydraulic gradient; describes the fluctuating flows in a channel caused by the tide.

Toe berm. The section projecting at the base of a dam, levee, or retaining wall.

Total dissolved solids (TDS). A measure of the total concentration of disintegrated organic and inorganic material or salt in water.

Transport. Movement of mass from one location to another; used in this REIR/EIS to refer to the movement of salt or fish from one location to another caused by net flows.

Trihalomethane (THM). A class of carcinogenic substances, including chloroform ($CHCl_3$) and bromoform ($CHBr_3$), formed from chlorination of drinking-water supplies.

Trihalomethane formation potential (THMFP). The potential for creation of THMs during chlorination or other oxidation treatment processes used for disinfection of municipal water supplies; an index of the maximum possible THM concentrations that could be produced by maximum chlorination of Delta water.

Ultraviolet absorbance (UVA). A physical measurement used in the study of humic acids and THM precursors, often found to be linearly related to DOC concentration. UVA may provide a measure of the humic and fulvic acid portion of total DOC in a water sample; this portion of total DOC is thought to be the precursor for THM.

Unbundled rates. The individual rates for separate service components of a particular utility. For example, natural gas utilities can be broken down into separate service components such as gas procurement, transportation, storage, and delivery with distinct rate schedules for each service. Deregulation of the utility industry has allowed this unbundling of the services to promote market competition.

Vernalis Adaptive Management Plan (VAMP). Multiyear program for studying the survival of salmon smolts from the San Joaquin River; uses pulse flows and export restrictions.

Water demand. A monthly schedule of water deliveries specified at a point of diversion in an operations model analysis.

Water right. A grant, permit, decree, appropriation, or claim to the use of water for beneficial purposes. California has a dual system of water rights. riparian and appropriative. *Riparian water rights* are held by owners of land bordering a surface water source. *Appropriative water rights* allow the exclusive diversion of a specified amount of water from a source for a reasonable and beneficial use. (See also "riparian water rights" and "appropriative water rights".)

Water Treatment Plant (WTP) model. An EPA model used for the 1995 DEIR/EIS to estimate THM concentrations at a typical water treatment plant that may use Delta exports containing water released from the Delta Wetlands Project islands. The model consists of a series of subroutines that simulate removal of organic THM precursor compounds and formation of THM. A more detailed description of the operation of the WTP model is provided in Appendix C5 of the 1995 DEIR/EIS. The model predicts total THM concentration, then estimates the relative concentrations of each of the four types of THM molecules by using separate regression equations for each type of THM molecule.

Wetlands. Areas supporting vegetation typical of soils that are saturated for a major portion of the year.

Wheeling. Use of SWP or CVP Delta pumping facilities to pump and convey water for another party.

Wind fetch. An area of water over which wind blows, generating waves.

X2. The location in the Bay-Delta estuary of the 2-ppt-TDS isohaline 1 meter off the bottom; an isohaline is a line connecting all points of equal salinity.

Yield. An annual quantity of water that can be delivered to a service area from a water project on a specified delivery schedule.

Yield acceleration. Pseudostatic horizontal force that will give a calculated factor of safety of 1 in slope-stability analyses. (See "factor of safety for slope stability".)

Chapter 10. Report Preparers

The following individuals contributed to the preparation of this document.

State Water Resources Control Board

Jim Sutton	Project Lead, Water Rights Division
Barbara Leidigh	Legal Counsel
Jean McCue	Project Engineer

U.S. Army Corps of Engineers

Mike Finan	Project Lead, Sacramento District Regulatory Branch

Jones & Stokes

Jordan Lang	Principal-in-Charge
Aimee Dour-Smith	Project Manager
Roberta Childers	Assistant Project Manager
Ken Bogdan	Environmental Counsel
Seema Sairam	Project Coordinator
Russ Brown	Lead, Water Supply and Operations, Water Quality
Jeff Lafer	Water Supply and Operations, Water Quality
Brant Jorgensen	Water Quality
Warren Shaul	Lead, Fisheries
Beth Campbell	Fisheries
Simon Page	Natural Gas Facilities and Transmission Pipelines, Levee Stability and Seepage
Julie Nichols	Editor
Debbie Bloom	Graphic Artist

URS Greiner Woodward Clyde

Said Salah-Mars	Senior Project Manager, Levee Stability and Seepage
Ulrich Luscher	Senior Engineer, Levee Stability and Seepage

Appendix A. Summary of Stipulated Agreements between Delta Wetlands and Parties to the Hearing on Delta Wetlands' Water Rights Applications

Appendix A. Summary of Stipulated Agreements between Delta Wetlands and Parties to the Hearing on Delta Wetlands' Water Rights Applications

In 1997, the State Water Resources Control Board (SWRCB) convened a water right hearing to consider Delta Wetlands' petitions for new water rights and changes to existing water rights. Eighteen parties filed protests with the SWRCB against Delta Wetlands' water rights applications. Delta Wetlands entered into negotiations with some of these protestants. As a result of these discussions, Delta Wetlands entered into stipulated agreements with the U.S. Bureau of Reclamation (Reclamation), California Department of Water Resources (DWR), Amador County, the City of Stockton, and North Delta Water Agency that affirm the seniority of the protesting parties' water rights. To preclude interference with those water rights, the stipulated agreements outline general conditions under which the Delta Wetlands Project would operate. These terms are incorporated into the proposed project and are summarized below.

U.S. BUREAU OF RECLAMATION

Two stipulations were included in the agreement between Delta Wetlands and Reclamation. The first requested that a term be included in any permits issued by the SWRCB to Delta Wetlands prohibiting any diversion that would adversely affect the operation of the Central Valley Project (CVP) or the State Water Project (SWP). After entering into the stipulated agreement with Delta Wetlands, however, Reclamation delivered a letter to the SWRCB dated October 31, 1997, which stated that Reclamation would accept DWR's terms (see below) instead of this first term in the Reclamation-Delta Wetlands agreement.

The stipulated agreement between Reclamation and Delta Wetlands also includes a condition regarding an operations agreement. This second stipulation prohibits discharge for export under water rights established under Application Nos. 29061, 29062, 29063, 29066, 30267, 30269, and 30270 before Reclamation, DWR, and Delta Wetlands execute one or more formal agreements for surplus Delta export pumping capacity at the SWP and CVP pumping plants. Any agreement(s) must include operations coordination procedures consistent with all of the following:

- the Delta Wetlands Operating Criteria and Plan (i.e., final operations criteria),
- Endangered Species Act (ESA) requirements,
- PL 102-575,

- Title 34,
- the 1995 Water Quality Control Plan, and
- the 1986 Agreement Between the U.S. and the State of California for Coordinated Operation of the Central Valley Project and State Water Project, and any amendments to this agreement.

The condition in the stipulated agreement additionally states that any formal agreement(s) between Reclamation, DWR, and Delta Wetlands will recognize SWP and CVP pumping priorities, ESA requirements, state or federal regulatory limitations, and the costs of the export pumping.

CALIFORNIA DEPARTMENT OF WATER RESOURCES

The stipulated agreement between Delta Wetlands and DWR includes three terms. Term 1 of the agreement between Delta Wetlands and DWR—the Los Vaqueros term—is included to determine when the operations of the Delta Wetlands Project "would be 'deemed' or presumed to be causing injury to" the SWP and CVP, "namely, when the Delta is in balanced conditions under the Coordinated Operating Agreement". Generally speaking, Term 1 prohibits Delta Wetlands diversions when the Delta is determined to be in balanced conditions. The term "in balance" indicates that all Delta inflow is required to meet Delta objectives and satisfy diversions by the Contra Costa Water District (CCWD), the CVP, the SWP, and Delta riparian and senior appropriative water users.

Term 2 of this agreement limits the amount of water Delta Wetlands can take under excess Delta conditions to the amount by which the Delta is "in excess" as reasonably determined by DWR and Reclamation. This will be the amount of water that may be diverted by Delta Wetlands "without putting the Delta back into balanced conditions".

Term 3 specifies that Delta Wetlands must stop or reduce any reservoir releases if, as a result of releases, the SWP or the CVP would have to modify operations to meet a legal requirement (e.g., ESA requirements, water rights terms and conditions such as export limits and salinity standards for exported water, or U.S. Army Corps of Engineers [USACE] requirements).

AMADOR COUNTY

Delta Wetlands and Amador County agreed that the Delta Wetlands "permit (or license) shall be junior in priority to any permit or license issued on any application regardless of application date that authorizes the provision of water for beneficial uses within Amador County".

Delta Wetlands and Amador County also agreed that "whether or not SWRCB includes the above term in any permit granted" for the Delta Wetlands Project, Delta Wetlands will operate the project "so as not to deprive directly or indirectly the inhabitants or property owners in Amador County of the prior right to all of the water reasonably required for beneficial uses within said County".

Further, Delta Wetlands agrees, through this stipulated agreement, "not to protest any water right applications hereafter filed to the extent that the applicants for said applications propose to use the applied-for water in Amador County". Delta Wetlands, under this agreement, "reserves its right to protest to the extent that the water will not be used within said County".

CITY OF STOCKTON

Delta Wetlands' agreement with the City of Stockton stipulates that any and all permits or licenses issued to the Delta Wetlands Project by the SWRCB must include a term specifying that Delta Wetlands' permit or license "shall be junior in priority to any application filed by the City of Stockton to obtain the water reasonably required to adequately supply the beneficial needs of the Stockton Urban Area or any of the inhabitants or property owners therein".

NORTH DELTA WATER AGENCY

The stipulated agreement between Delta Wetlands and North Delta Water Agency specifies that Delta Wetlands will support the inclusion of the following condition in any permits or licenses issued by the SWRCB for the Delta Wetlands Project:

> Delta Wetlands agrees that it will not operate the Delta Wetlands Project reservoir islands if the water quality criteria for salinity in effect pursuant to the "Contract Between State of California Department of Water Resources and North Delta Water Agency for the Assurance of a Dependable Water Supply of Suitable Quality" dated January 28, 1981, as amended, are not being met until Delta Wetlands can demonstrate, to the reasonable satisfaction of North Delta Water Agency, that Project reservoir operations are not adversely affecting salinity levels at any of the monitoring locations established by that Contract.

Appendix B. Delta Wetlands Project Final Operations Criteria

AVOIDANCE MEASURES

Introduction

This narrative reflects final operations criteria for the Delta Wetlands (DW) project that would take the place of the operations criteria previously proposed by Jones & Stokes Associates on March 1, 1996. These operations criteria are intended to ensure that the DW project operations do not jeopardize the continued existence of delta smelt, Sacramento splittail, winter-run chinook salmon, or steelhead trout. DW expects that non-listed species will also benefit from these criteria and such criteria will replace the related mitigation measures for fishery impacts proposed in the context of the CEQA/NEPA process.

Under these operations criteria, DW will be consistent with, and in many instances, exceed the conditions set forth in the State Water Resources Control Board's (SWRCB) 1995 Water Quality Control Plan for the Bay-Delta estuary. These revised operations criteria set forth multi-layered diversion and discharge parameters. In the instance where two or more conditions apply, the condition that is the most restrictive on DW operations will control.

Additional restrictions apply if the Fall Mid-Water Trawl (FMWT) index shows a significant decline in delta smelt abundance. The FMWT Index refers to the most current four month (Sep-Dec) FMWT index in place at the time of the intended diversion. A diversion prior to January can utilize either the previous year's FMWT Index or the partial FMWT Index for the months available, whichever is greater. Any changes in the FMWT Index calculation methodology will be adjusted so that the FMWT Index values applied herein can continue to be the standard for DW operations criteria.

A delta smelt Fall Mid-Water Trawl index measurement of less than 84 (FMWT<84) is new information under the reinitiation regulations (50 C.F.R. § 402.16) and may require reinitiation of the USFWS biological opinion. [#26,45][1]

The following text represents the final language for replacement of Term I of the USFWS draft biological opinion: [#1]

> DW will not enter into any contractual agreement(s) which would provide for the export of more than 250,000 AF of DW water on a yearly (calendar year) basis. This provides for, but is not limited to, the following types of transfers: a c-user,

[1] The number(s) in brackets are provided as a reference to the DW ESA Matrix which summarizes the final operations criteria as compared to the March 1, 1996 JSA proposed terms.

short-term, opportunistic water transfer; a long-term water transfer; and any other such agreement, or contract for sale or transfer which is consistent with the March 6, 1995 biological opinion on the CVP/SWP, the SWRCB's 1995 Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (1995 WQCP), and the improved environmental baseline established under the March 6, 1995, CVP/SWP Section 7 consultation performed in conjunction with implementation of the *Principles for Agreement on Bay-Delta Standards Between the State of California and the Federal Government* (Bay-Delta Agreement). If such agreement(s) were determined to result in an adverse effect to delta smelt, delta smelt critical habitat or the Sacramento splittail in a manner or to an extent not previously identified, the contractual agreement(s) would be subject to some level of further environmental review.

Diversion Measures

DW shall limit diversions to the four project islands as set forth in the following measures:

1. In the period from September through November, DW shall not undertake its initial diversion to storage for the current water year until X2 is located at or downstream of Chipps Island. If DW's initial diversion to storage has not taken place by November 30, 1996, DW shall not undertake its initial diversion to storage for the current water year until X2 is located at or downstream of Chipps Island for a period of ten (10) consecutive days. After the initial X2 condition is met, diversions shall be limited to a combined maximum rate of 5,500 cfs for five consecutive days. Information documenting achievement of the X2 condition and resultant operational changes shall be submitted to the CDFG, USFWS, and NMFS within 24 hours of implementation of operational changes. [#2, 3, 4]

   The location of X2 shall be defined as the average daily location of a surface water salinity of 2.64 EC, determined by interpolating the average daily surface EC measurements at existing Bay-Delta monitoring stations. Should this traditional X2 methodology be replaced, superseded, or become otherwise unavailable, DW shall follow whatever equivalent practice is developed, subject to approval of the resources agencies and notice to the responsible agencies.

2. In the period from September through March, DW shall not divert water to storage when X2 is located upstream (east) of the Collinsville salinity gauge. When the delta smelt Fall Mid-Water Trawl index is less than 239 (FMWT<239), DW shall not divert water to storage when X2 is located upstream of a point 1.4 kilometers west of the Collinsville salinity gauge. [#5, 6, 7, 19]

3. In the period from October through March, DW shall not divert water to storage if the effect of DW diversions would cause an upstream shift in the X2 location in excess of 2.5 km. The resultant shift in X2 shall be determined by a comparison of the modeled estimates of the X2 location outflow, with and without the DW project, using a mathematical model, e.g., Kimmerer and Monismith equation. [#8, 9]

4. In the period from April through May, DW shall not divert water to storage. If the delta smelt Fall Mid-Water Trawl index is less than 239 (FMWT<239), DW shall not divert water for storage from February 15 through June 30. [#10, 20]

5. DW diversions to storage shall be limited to the following percentage of available surplus water as derived pursuant to the 1995 WQCP (e.g., E/I ratio, outflow). [#13]

Table 1: Surplus Availability

Month	FMWT>239	FMWT<239
October	90%	90%
November	90%	90%
December	90%	90%
January	90%	90%
February 1-14	75%	75%
February 15-28	75%	NA
March	50%	NA
April	NA	NA
May	NA	NA
June	50%	NA
July	75%	75%
August	90%	90%
September	90%	90%

6. DW diversions to storage shall not exceed a percentage of the previous day's net Delta outflow rate (cfs), as set forth in the following table: [#11, 23]

Table 2: Outflow Diversion Limit

Month	Percent Outflow [1]	
	FMWT>239	FMWT<239
October	25%	25%
November	25%	25%
December	25%	25%
January	15%	15%
February 1-14	15%	15%
February 15-28	15%	NA
March	15%	NA
April	NA	NA
May	NA	NA
June	25%	NA
July	25%	25%
August	25%	25%
September	25%	25%

(1) The percent of Delta outflow is calculated without consideration of DW diversions; therefore, the calculation could use the previous day's actual Delta outflow added to the previous day's DW diversions to yield an outflow value that would not include DW operations.

7. In the period from December through March, DW diversions to storage shall not exceed the percentage of the previous day's San Joaquin River inflow rate (cfs) for the maximum number of days, as set forth in the following table: [#12, 24]

Table 3: SJR Diversion Limit

Month	Percent SJR Inflow [1]	
	FMWT > 239	FMWT < 239
Application [2]	15 days	30 days
December	125%	125%
January	125%	100%
February 1 - 14	125%	50%
February 15 - 28	125%	NA
March	50%	NA

(1) The percent of SJR inflow is calculated from the previous day's inflow at Vernalis.

(2) The application of the SJR diversion limit is subject to a specific election on the part of the responsible fishery agencies for a maximum number of days, as specified above. The election to invoke the SJR diversion limit shall be based upon available monitoring data (e.g., project specific monitoring, MWT data).

8. DW shall implement a monitoring program to minimize or avoid adverse impacts of DW diversions to storage, as set forth below: [#15, 16, 21, 22]

a. DW shall implement a monitoring program in accordance with the attached "Delta Wetlands Fish Monitoring Program."

b. DW shall provide daily in-channel monitoring from December through August during all diversions to storage, except as provided below.

c. DW shall provide daily on-island monitoring from January through August during all diversions to storage, except as provided below.

d. Monitoring shall not be required at a diversion station if the total diversion rate at the station is less than 50 cfs and the maximum fish screen approach velocity is less than 0.08 fps (e.g., topping-off).

e. DW shall reduce the diversions at a diversion station to 50% of the previous day's diversion rate during the presence of delta smelt. Should delta smelt be detected on the first day of diversions to storage, the diversion rate shall be immediately reduced to 50%. This reduced diversion rate will remain in place until the monitoring program no longer detects a presence of delta smelt at the diversion station. For the purpose of this mitigation measure, delta smelt presence is defined as a two-day running average in excess of one (1) delta smelt per day at any reservoir diversion station. The definition of presence may be revisited from time to time as new information or monitoring techniques become available.

9. During periods when the DCC gates are closed for fisheries protection purposes, between November 1 and January 31, and the inflow into the Delta is less than or equal to 30,000 cfs, DW shall restrict diversions onto the reservoir islands to a combined instantaneous maximum of 3,000 cfs. When the DCC gates are closed for fishery protection purposes and the inflow into the Delta is between 30,000 and 50,000 cfs, DW shall restrict diversions onto the reservoir islands to a combined instantaneous maximum of 4,000 cfs. At Delta inflows greater than 50,000 cfs, DW diversions shall not be restricted by the closure of the DCC for fishery protection purposes. For purposes of this provision, Delta inflow is defined in accordance with the 1995 WQCP. [#17]

10. Nothing in measures 1 through 9 above shall limit DW from diverting water onto Bacon Island and Webb Tract from June through October in order to offset actual reservoir losses of water stored on those islands, hereafter referred to as "topping-off" reservoirs. Daily topping-off diversions shall be subject to the following conditions: [#18, 25]

a. Topping-off diversions shall not exceed the maximum diversion rate (cfs) and maximum monthly quantity (TAF) listed in below:

Table 4: Maximum Topping-Off Diversion Rates

Month	Jun	Jul	Aug	Sep	Oct
Maximum diversion rate (cfs)	215	270	200	100	33
Maximum monthly quantity (TAF)	13	16	12	6	2

b. Topping-off diversions shall occur through screened diversions with approach velocities less than 0.10 fps.

c. A mechanism acceptable to USFWS, NMFS, and CDFG shall be devised and used by DW to document actual reservoir losses.

d. The maximum topping-off diversion rates shown above shall be further limited by diversions onto the habitat islands. The maximum topping-off diversion rate and quantity shall be reduced by an amount equal to the habitat island diversions during the same period.

Discharge Measures

Delta Wetlands (DW) shall limit discharges from the four project islands as set forth in the following measures:

1. In the period from April through June, DW shall limit discharges for export or rediversion from Bacon Island to one-half (50%) of the San Joaquin River inflow measured at Vernalis. [#34]

2. In the period from January through June, DW shall not discharge for export or rediversion from Webb Tract. [#33]

3. DW shall not discharge for export or rediversion any water from the habitat islands. [#41]

4. In the period from February through July, DW discharges for export shall be limited to the following percentage of the available unused export capacity at the CVP and SWP facilities as derived pursuant to the 1995 WQCP. [#35, 36]

Table 5: Export Availability

Month	Bacon	Webb
February	75%	NA
March	50%	NA
April	50%	NA
May	50%	NA
June	50%	NA
July	75%	75%

6. DW shall provide a quantity of "environmental water" for release as additional Delta outflow, as set forth in the following terms and conditions: [#38, 42]

   a. DW shall provide a quantity of environmental water equal to 10% of all discharges for export that occur in the period from December through June. If the delta smelt Fall Mid-Water Trawl index is less than 239 (FMWT<239), this environmental water percentage shall be increased to 20% of all discharges for export that occur in the period from December through June.

b. Environmental water shall be released between February and June of the same water year as the discharge for export that generated the water and may not be banked for future use in subsequent water years.

c. Habitat island discharges may be credited toward the environmental water quantities required above, if:

I. habitat island discharges occur between February and June;
ii. habitat island discharge credits are limited to the net flow quantity (e.g., habitat discharge minus habitat diversion);
iii. habitat island discharges occur during a period of time when 75% of the spacial distribution of the delta smelt population is located downstream of the discharge location, where the determination of spacial distribution is based on the most recent distribution data available (e.g., IEP);
iv. the habitat island discharge rate does not vary on a daily basis more than 1% of the average gross flow rate in the adjacent channel, either upstream or downstream, when delta smelt are spawning in the area;
v. DW makes a best effort to minimize fluctuations in daily discharge rates;
vi. and the habitat island discharges are consistent with the HMP.

d. Environmental water, less habitat island discharge credits, shall be discharged at the discretion of USFWS, NMFS and CDFG to maximize fishery benefits. Coordination of these discharges shall be performed by the CDFG Bay-Delta office.

7. DW shall implement a monitoring program to minimize or avoid adverse impacts of DW discharges for export, as set forth below: [#39, 40, 43, 44]

a. DW shall implement a monitoring program in accordance with the attached "Draft Proposed Delta Wetlands Fish Monitoring Program."

b. DW shall provide daily in-channel monitoring from April through August during all discharges for export, except as provided below.

c. Monitoring shall not be required if the total discharge for export rate is less than 50 cfs.

d. DW shall reduce the discharge for export rate to 50% of the previous day's diversion rate during the presence of delta smelt. Should delta smelt be detected on the first day of discharges for export, the discharge rate shall be immediately reduced to 50%. This reduced diversion rate will remain in place until the monitoring program no longer detects a presence of delta smelt at the in-channel sampling sites. For the purpose of this mitigation measure, delta smelt presence is defined as a two-day running average in excess of one (1) delta smelt per day at the Old and Middle River sampling sites. The definition of presence may be revisited from time to time as new information or monitoring techniques become available.

e. DW shall provide for this monitoring either by contributing financial support commensurate with the proportionate share of DW exports to the Bay/Delta monitoring programs, or when no other monitoring is being conducted at appropriate sites, DW shall provide for direct monitoring in river channels as described above.

Other Measures

1. Fish screen design: [#49]

The DW fish screens will be generally consistent with the design presented in the DEIR/EIS except that DW shall maintain a 0.2 fps approach velocity for diversions. Final design elements and installation guidelines will be subject to approval by the responsible agencies with concurrence by the resource agencies. Final design, including a monitoring program to evaluate performance criteria will be submitted for approval at least 90 days prior to commencing operations.

2. Rearing and Spawning Habitat. [#50, 51]

Prior to construction, DW will secure a perpetual conservation easement (easement) for 200 acres of shallow-water aquatic habitat not currently protected by easement or covenant. The easement shall fully protect in perpetuity the shallow-water aquatic habitat. A management plan for the easement area shall be developed for the habitat covered by the easement, and shall be incorporated as an exhibit to the easement.

Additionally, DW shall provide to the USFWS documentation that there is adequate financing for the perpetual management of the habitat protected by the conservation easement consistent with the terms of this biological opinion and the management plan including that (1) adequate funds for the management of habitat in perpetuity protected by the conservation easement have been transferred to an appropriate third-party, and (2) the third party has accepted the funds and (3) such funds have been deposited in an interest-bearing account intended for the sole purpose of carrying out the purposes of this easement.

The easement (along with a title report for the easement area) and management plan shall be approved by the USFWS prior to recordation. After approval, the easement and management plan shall be recorded in the appropriate County Recorders Office(s). A true copy of the recorded easement shall be provided to the USFWS within 30 days after recordation.

3. Boat Wake Erosion [#53]

DW shall contribute $100 per year for each net additional berth beyond pre-project conditions added to any of the four project islands. These funds shall be in January 1996 dollars and shall be adjusted annually for inflation.

4. Aquatic Habitat [#54]

The actual impact to aquatic habitat acreage for construction and operation of siphon and pumping facilities and waterside boat docks shall be verified prior to construction and mitigation shall take place on a 3:1 basis.

5. Temperature Limits [#55]

DW shall implement a temperature program to minimize or avoid adverse impacts of DW discharges for export, as set forth below:

a. DW shall not discharge reservoir water for export if the temperature differential between the discharge and the adjacent channel temperature is greater than or equal to 20°F.

b. If the natural receiving water temperature of the adjacent channel is greater than or equal to 55°F and less than 66°F, DW discharges for export shall not increase the channel temperature by more than 4°F.

c. If the natural receiving water temperature of the adjacent channel is greater than or equal to 66°F and less than 77°F, DW discharges for export shall not cause an increase of more than 2°F.

d. If the natural receiving water temperature of the adjacent channel is greater than or equal to 77°F, DW discharges for export shall not cause an increase of more than 1°F.

e. DW shall develop temperature monitoring and implementation plans to ensure that the project does not adversely impact the channel temperature levels as described above. The monitoring plan shall include reservoir and channel temperature monitoring. The monitoring and implementation plans shall be completed after the project is permitted, but at least 90 days prior to project operations. The plans shall be submitted to the responsible agencies for approval with the concurrence of the resource agencies.

6. DO Limits [#56]

DW shall implement a dissolved oxygen (DO) program to minimize or avoid adverse impacts of DW discharges for export, as set forth below:

a. DW shall not discharge reservoir water for export if the discharge DO level is less than 6.0 mg/l without authorization from the resource agencies and notice to the responsible agencies.

b. DW shall not discharge reservoir water for export if the discharge would cause channel water DO levels to fall below 5.0 mg/l.

c. DW shall develop DO monitoring and implementation plans to ensure that the project does not adversely impact the channel DO levels as described above. The monitoring plan shall include reservoir and channel DO monitoring. The monitoring and implementation plans shall be completed after the project is permitted, but at least 90 days prior to project operations. The plans shall be submitted to the responsible agencies for approval with the concurrence of the resource agencies.

7. Incidental Entrainment Compensation [#57]

Certain life stages of key fish species may not be effectively screened during periods of diversions for storage. DW will, therefore, sample DW diversions during the periods specified below and compensate for losses to selected target fish. DW diversions onto the reservoir islands will be sampled for egg, larval, and juvenile life stages of the selected target fish. Those losses will be mitigated using a formula which ties measured losses with mitigation as specified below.

This provision covers entrainment of non-listed species, as well as, delta smelt and splittail (that are, respectfully, listed and candidate species). Coverage of non-listed species is intended as a CEQA/NEPA mitigation measure and is only included here for ease of understanding.

Should on-island monitoring detect the presence of eggs, larvae, and juveniles during the months specified in the incidental entrainment monitoring guidelines, DW shall provide monetary compensation for incidental entrainment, as set forth in the following tables:

Table 6: Incidental Entrainment Monitoring Guidelines

Species and Life Stages	Jan	Feb	Mar	Jun	Jul	Aug
Striped Bass						
larvae and juveniles				X	X	X
American Shad						
larvae and juveniles				X	X	X
Delta Smelt						
larvae	X	X	X	X	X	
juveniles		X	X	X	X	X
Splittail						
larvae	X	X	X	X	X	X
juveniles		X	X	X	X	X
Longfin Smelt						
eggs and larvae	X	X	X			
juveniles	X	X	X	X	X	X

Table 7: Incidental Entrainment Compensation

Measured Density	Mitigation/TAF
10-999 eggs, larvae, and juveniles/AF	$500
1,000-5,000 eggs, larvae, and juveniles/AF	$750
>5,000 eggs, larvae, and juveniles/AF	$1,000

Should DW be unable to perform on-island monitoring, the maximum mitigation compensation will be assumed, unless waived or modified by the responsible agencies, with concurrence of the resource agencies. Funds are in January 1996 dollars and shall be adjusted annually for inflation. Monetary reimbursement shall be deposited into a mitigation fund on a semi-annual basis. The use of the mitigation funds shall be at the discretion of the resource agencies (e.g., CDFG Bay-Delta office) but shall be used to the fullest extent possible to plan and implement actions that improve habitat for the target species in the Estuary.

8. Construction Period [#60]

All construction activities taking place in the tidal waters of the adjacent channels or impacting a tidal water habitat shall occur between June and November.

Delta Wetlands Fish Monitoring Program

The following sets forth a general description of the fish monitoring program Delta Wetlands (DW) will implement to provide data to minimize, avoid, and mitigate adverse impacts of DW project operations on fish. There are seven components of the program: 1) daily in-channel monitoring for the presence of juvenile and adult delta smelt in the immediate vicinity of DW diversion sites during diversions to storage, 2) daily on-island multiple species monitoring of entrainment of eggs, larvae, and juveniles during diversions to storage, 3) daily in-channel monitoring for the presence of juvenile and adult delta smelt in the general vicinity of DW reservoir islands during discharges for export, 4) reporting requirements, 5) sample handling and quality assurance/quality control (QA/QC) requirements, 6) Interagency Ecological Program (IEP) coordination, and 7) establishing a monitoring technical advisory committee (MTAC). The monitoring program as set forth below is intended to establish general parameters, with final details and specifications determined during final design of the monitoring program. This final design shall be completed after the project is permitted and must be accepted, in writing, by the responsible agencies prior to project operations with concurrence by the resource agencies.

1) In-Channel Monitoring of Diversions to Storage

The objective of this component shall be to provide for the detection of juvenile and adult delta smelt that could be vulnerable to entrainment at DW diversions. This DW sampling program would be supplementary to the existing IEP monitoring programs in the Delta. In the event that IEP monitoring is being conducted in a manner and location that satisfies DW sampling requirements, with the concurrence of the resource agencies and notice to the responsible agency, DW would use those data and would not be required to duplicate monitoring effort at those locations (e.g., Real-Time Monitoring Program sampling in Middle River and Old Rivers near DW reservoir islands). To the extent possible, sampling frequency will be stratified to obtain samples representative of any variation in specific conditions with respect to diel and tidal periodicity at each site. In-channel monitoring will utilize sampling technologies consistent with current IEP protocol (sampling gear may vary with season and life stage). Complete siting and sampling specifications will be determined during final design of the DW monitoring program.

DW shall provide daily in-channel monitoring during diversions to storage during allowable periods from December through August, except as provided below. Monitoring stations shall be located in the immediate vicinity of each of the four (4) DW diversion points. Each diversion point shall require two monitoring sites, for a maximum of eight (8) sites. The final location of each monitoring site shall be determined during final design of the DW monitoring program. Monitoring shall begin at a diversion point on the first day of diversions to storage from that site and shall continue throughout the diversion event. In-channel monitoring shall not be required if the total diversion rate at the diversion point is less than 50 cfs and the fish screen approach velocity is less than 0.08 fps (e.g., topping-off).

Should DW be unable to perform in-channel monitoring for any reason except operational safety constraints, the monitoring mitigation measure shall automatically trigger unless waived by the responsible agencies, with concurrence by the resource agencies.

2) On-Island Monitoring of Entrainment during Diversions

The objective of this component shall be to provide for the detection of eggs, larvae, and juveniles entrained by DW diversions to storage. Certain life stages of key fish species may not be effectively screened during diversions to storage. These incidental losses shall therefore be mitigated using a monetary formula which ties measured losses to compensation that can be utilized, to the fullest extent possible, to plan and implement actions that maintain or enhance habitat for target species in the Bay-Delta estuary.

DW shall provide on-island monitoring during diversions to storage during allowable periods from January through August, except as provided below. A typical siphon located at each reservoir diversion point shall be fitted with a sampling apparatus attached to the floating siphon platform at the discharge end of the assembly. The final selection of the specific siphon to be monitored and complete specifications of the sampling apparatus will be determined during final design of the DW monitoring program. These sampling sites shall provide for installation of a variety of fish entrainment sampling gear using CDFG-approved methodologies. Therefore, four sampling sites would be constructed (i.e., 1 sampling site within a sixteen-siphon station times 2 siphon stations, times 2 reservoir islands, equals 4 total sampling sites). To the extent possible, sampling at each operating siphon station will be conducted as stratified subsamples with respect to diel and tidal periodicities so that total daily sampling time will be at least two hours each day. Monitoring shall begin at a diversion point on the first day of diversions to storage from that site and shall continue throughout the diversion event. On-island monitoring shall not be required if the total diversion rate at the diversion point is less than 50 cfs and the fish screen approach velocity is less than 0.08 fps (e.g., topping-off).

3) In-Channel Monitoring of Discharge for Export

The objective of this component shall be to provide for the detection of juvenile and adult delta smelt that could be vulnerable to entrainment at the Delta export facilities during the export of DW discharges. This DW sampling program would be supplementary to the existing IEP monitoring programs in the Delta. In the event that IEP monitoring is being conducted in a manner and location that satisfies DW sampling requirements, with concurrence by the resource agencies and notice to the responsible agency, DW would use those data and would not be required to duplicate monitoring effort at those locations (e.g., Real-Time Monitoring Program sampling in Middle and Old Rivers near DW reservoir islands). To the extent possible, sampling frequency will be stratified to obtain samples representative of any variation in specific conditions with respect to diel and tidal periodicity at each site. In-channel monitoring will utilize sampling technologies consistent with current IEP protocol (sampling gear may vary with season and life stage). Complete siting and sampling specifications will be determined during final design of the DW monitoring program.

DW shall provide daily in-channel monitoring during discharges for export from April through August, except as provided below. Monitoring stations shall be located at paired transects at each of the two discharge stations, one in Middle River near Webb Tract and one in Old River near Bacon Island to be selected based on Real-Time Monitoring Program results and technical experience to provide indication of delta smelt density and distribution in this region of the Delta. The final location of each of monitoring site will be determined during final design of the DW monitoring program. Monitoring shall begin on the first day of discharges for export from Webb Tract and shall continue throughout the discharge event. In-channel monitoring shall not be required if the total discharge for export rate is less than 50 cfs.

Reporting

Weekly monitoring reports will be transmitted by FAX and daily reports by INTERNET to the fishery agencies as follows:

USFWS, Sacramento Fish and Wildlife Office
NMFS, Protection Resources and Habitat Conservation Division
CDFG, Bay-Delta and Special Water Projects Division

5) Sample Handling Protocol

DW will retain samples for a minimum of one year after collection. Agency biologists and law enforcement personnel shall have 24 hour access to fish monitoring personnel, fish samples, and daily fish capture data. A QA/QC protocol, acceptable to the fishery agencies, will be developed by DW and provided to the fishery agencies as part of the final monitoring program plan. The QA/QC protocol will include, but is not limited to, measures to ensure correct identification of larval and juvenile fishes.

6) Coordination with IEP Monitoring Programs

DW will be solely responsible for conducting the required monitoring. In the event that IEP monitoring is being conducted in a manner and location that satisfies the previously described operations requirements, DW may use the data collected and will not be required to conduct duplicate monitoring at those sites. If DW is able to make use of the IEP monitoring data in lieu of project specific monitoring, DW shall compensate IEP for the use of this data by contributing financial support to the IEP monitoring program commensurate to the proportionate share of DW exports to the total Delta exports for the period.

7) Monitoring Technical Advisory Committee

The objective of this component is to establish a monitoring technical advisory group (MTAC) to advise and resolve monitoring issues that may develop over the life of the DW project. The MTAC shall be made up of voluntary participants from a variety of agencies, including, but not limited to, invitees from SWRCB, USACE, USFWS, NMFS, CDFG, DWR, USBR, USEPA, and DW. DW may convene the MTAC to evaluate and recommend adjustments to the DW monitoring program.

Initially, DW shall work directly with CDFG to resolve daily technical monitoring issues but may convene the MTAC to act in a technical capacity to provide review and address any technical inadequacies or disagreements that may occur. The committee may also provide advisory review on issues of waiver occurring during implementation of the monitoring program. Any modifications to the monitoring program must be made with the approval of the responsible agencies and concurrence of the resource agencies who will continue to retain final approval or disapproval of any monitoring changes.

DIVERSION LIMITS

Ref	Measure	JSA BA Alternative	Final Operations Criteria
1	Export cap	None	250 TAF (see Term I language)
2	Initial diversion Sep-Nov	10 days past Chipps 5 day ramp @ 5500 cfs	X2 at or downstream of Chipps 5 day ramp @ 5500 cfs - no split
3	Initial diversion Dec-Jan	10 days past Chipps 5 day ramp @ 5500 cfs	10 days past Chipps 5 day ramp @ 5500 cfs - no split
4	Initial diversion Feb-Mar	None	10 days past Chipps 5 day ramp @ 5500 cfs - no split
5	X2 position Sep-Nov	West of km 81 (Collinsville)	West of Collinsville salinity gauge
6	X2 position Dec-Jan	West of km 81 (Collinsville)	West of Collinsville salinity gauge
7	X2 position Feb-Mar	None	West of Collinsville salinity gauge
8	X2 shift Oct-Jan	Shift < 2.5 km	Shift < 2.5 km
9	X2 shift Feb-Mar	None	Shift < 2.5 km
10	Fixed prohibitions	No diversions during Apr-May pulse	No diversion Apr-May
11	Outflow limits Oct/Nov/Dec Jan/Feb/Mar Apr/May/Jun Jul/Aug/Sep	Outflow limit (%) 25/25/25 25/na/na na/na/na na/na/na	Outflow limit (%) 25/25/25 15/15/15 na/na/25 25/25/25

DIVERSION LIMITS

Ref	Measure	JSA BA Alternative	Final Operations Criteria
12	SJR limits Oct/Nov/Dec Jan/Feb/Mar Apr/May/Jun Jul/Aug/Sep	None	SJR flow limit (%) (applies up to 15 days) na/na/125 125/125/50 na/na/na na/na/na
13	Available limits Oct/Nov/Dec Jan/Feb/Mar Apr/May/Jun Jul/Aug/Sep	% of available surplus na/na/na na/75/50 25/25/50 75/na/na	% of available surplus 90/90/90 90/75/50 0/0/50 75/90/90
14	Enviro-water Oct/Nov/Dec Jan/Feb/Mar	None	None
15	DS monitoring period	None	In-channel monitoring Dec-Aug if > 50cfs On-island monitoring Jan-Aug if > 50 cfs
16	DS monitoring restrictions	None	Reduce diversions to 50% of previous day's rate during presence of delta smelt
17	DCC gate limits Nov-Jan	None	If DCC is closed for fishery protection, reduce maximum diversion rate to: 3,000 cfs if Delta inflow ≤ 30,000 cfs 4,000 cfs if inflow is 30,000 to 50,000 cfs
18	Summer top-off for evaporation Jun-Oct	None	Max. top-off rate for Jun-Oct in cfs: 215/270/200/100/33 including habitat island diversions
19	FMWT < 239 X2 position	Not applicable	1.4 km west of Collinsville salinity gauge
20	FMWT < 239 Fixed prohibitions	Not applicable	No diversions Feb 15 - Jun 30 except top-off (see # 25)

DIVERSION LIMITS

Ref	Measure	JSA BA Alternative	Final Operations Criteria
21	FMWT < 239 DS monitoring period	Not applicable	In-channel monitoring Dec-Aug if > 50cfs On-island monitoring Jan-Aug if > 50 cfs
22	FMWT < 239 DS monitoring restrictions	Not applicable	Reduce diversions to 50% of previous day's rate during presence of delta smelt
23	FMWT < 239 Outflow limits Jan/Feb/Mar	Not applicable	Outflow limit (%) 15/15/na
24	FMWT < 239 SJR limits Dec/Jan/Feb	Not applicable	SJR flow limit (%) 125/100/50 (applies up to 30 days)
25	FMWT < 239 Summer top-off for evaporation Jun-Oct	Not applicable	Max. top-off rate for Jun-Oct in cfs: 215/270/200/100/33 including habitat island diversions
26	FMWT < 84 Fixed prohibitions	Not applicable	Considered "new information" and reinitiation of BO may occur
27	FMWT < 84 DS monitoring period	Not applicable	Not applicable
28	FMWT < 84 DS monitoring restrictions	Not applicable	Not applicable
29	FMWT < 84 Outflow limits	Not applicable	Not applicable
30	FMWT < 84 SJR limits	Not applicable	Not applicable
31	FMWT < 84 Summer top-off for evaporation	Not applicable	Not applicable

DISCHARGE FOR EXPORT LIMITS

Ref	Measure	JSA BA Alternative	Final Operations Criteria
32	Delta inflow	DW not included	BO will adopt a neutral position with respect to this action, see DW letter of 10/18/96
33	Fixed prohibitions	None	Webb: no discharges Jan-Jun
34	SJR limits: Bacon	None	50% SJR Apr-Jun
35	Export capacity fraction: Webb	Feb 75% Mar-Jun 50% Jul 75%	Feb-Jun NA Jul 75%
36	Export capacity fraction: Bacon	Capacity available Feb 75% Mar-Jun 50% Jul 75%	Feb 75% Mar-Jun 50% Jul 75%
37	Bacon pulse-flow period exports	Only if Old & Middle flow south	None
38	Enviro-water	None	10% match for export during Dec-Jun subject to Feb-Jun habitat island credit
39	DS monitoring period	None	In-channel monitoring Apr-Aug if > 50cfs
40	DS monitoring restrictions	Not applicable	Reduce diversions to 50% of previous day's rate during presence of delta smelt
41	Habitat island discharge limits	None	No export but may be used for enviro-water match from Feb-Jun (see #38)

DISCHARGE FOR EXPORT LIMITS

Ref	Measure	JSA BA Alternative	Final Operations Criteria
42	FMWT<239 Enviro-water	Not applicable	20% match for export during Dec-Jun subject to Feb-Jun habitat island credit
43	FMWT < 239 DS monitoring period	Not applicable	In-channel monitoring Apr-Aug if > 50cfs
44	FMWT < 239 DS monitoring restrictions	Not applicable	Reduce diversions to 50% of previous day's rate during presence of delta smelt
45	FMWT < 84 Fixed prohibitions	Not applicable	Considered "new information" and reinitiation of BO may occur
46	FMWT < 84 Enviro-water	Not applicable	Not applicable
47	FMWT < 84 DS monitoring period	Not applicable	Not applicable
48	FMWT < 84 DS monitoring restrictions	Not applicable	Not applicable

OTHER MEASURES

Ref	Measure	JSA BA Alternative	Final Operations Criteria
49	Fish screen design	Not included	0.2 fps approach velocity
50	Rearing habitat	Not included	200 acres
51	Spawning habitat	Not included	Included above
52	SRA habitat	Not included	None
53	Boat wake erosion	Not included	$100/yr/berth for each net additional berth
54	Aquatic habitat	Not included	Replace actual losses at 3:1 ratio
55	Temperature limits	Per CVRWQB (Basin Plan)	No ΔT > 20°F No channel increase > 4°F for 55°F to 66°F No channel increase > 2°F for 66°F to 77°F No channel increase > 1°F over 77°F
56	DO limits	Per CVRWQB (Basin Plan)	No DO discharge < 6 mg/l Do not cause channel to drop below 5 mg/l
57	Incidental entrainment comp.	None	$500-$1000 per TAF for scheduled species, Jan through Aug
58	Service area conditions	None	None
59	HMP conditions	None	Actual costs plus overhead
60	Construction period	Not included	Jun-Nov for in-water work

Appendix C. California Department of Fish and Game Biological Opinion

Revised

California Endangered Species Act

Biological Opinion

Delta Wetlands Project

[2090-1995-085-2]

August 6, 1998

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Revised
CALIFORNIA ENDANGERED SPECIES ACT BIOLOGICAL OPINION
issued by
THE CALIFORNIA DEPARTMENT OF FISH AND GAME
for
THE DELTA WETLANDS PROJECT

I. SUMMARY

Pursuant to Fish & Game Code §2090 of the California Endangered Species Act, Fish & Game Code §2050, et seq. ("CESA"), the State Water Resources Control Board ("Board") has requested a consultation with the Department of Fish and Game ("DFG") to determine whether the Delta Wetlands Project ("Project") and the Board's issuance of a Water Right permit to Delta Wetlands will jeopardize the continued existence of any species protected under CESA or will result in the destruction or adverse modification of habitat essential to the continued existence of any such species.

DFG has determined that the State endangered winter-run chinook salmon (*Oncorhynchus tshawytscha*), State threatened delta smelt (*Hypomesus transpacificus*), State threatened Swainson's hawk (*Buteo swainsoni*), State threatened greater sandhill crane (*Grus canadensis tabida*), State endangered western yellow-billed cuckoo (*Coccyzus americanus occidentalis*), State threatened willow flycatcher (*Empidonax traillii*), State threatened giant garter snake (*Thamnophis couchii gigas*), State threatened California black rail (*Laterallus jamaicensis coturniculus*), State endangered bald eagle (*Haliaeetus leucocephalus*), State endangered riparian brush rabbit (*Sylvilagus bachmani riparius*), State endangered American peregrine falcon (*Falco peregrinus anatum*), and State rare Mason's lilaeopsis (*Lilaeopsis masonii*) (the "Listed Species") exist at or in the vicinity of Delta Wetlands' proposed project, located in Contra Costa and San Joaquin counties.

The following additional candidate and special status species; State candidate threatened spring-run chinook salmon (*O. tshawytscha),* steelhead (*O. mykiss*), splittail (*Pogonichthys macrolepidotus*), longfin smelt (*Spirinchus thaleichthys*), Sacramento perch (*Archoplites interruptus*), green sturgeon (*Acipenser medirostris*), northwestern pond turtle (*Clemmys marmorata marmorata*), southwestern pond turtle (*Clemmys marmorata pallida*), Aleutian Canada goose (*Branta canadensis leucopareia*), tricolored blackbird (*Agelaius tricolor*), loggerhead shrike (*Lanius ludovicianus*), burrowing owl (*Athene cunicularia*), riparian woodrat (*Neotoma fuscipes riparia*), rose mallow (*Hibiscus lasiocarpus*), Delta tule pea (*Lathyrus jepsonii var. jepsonii*), and Suisun aster (*Aster lentus*) are also known to exist at or in the vicinity of Delta Wetlands' proposed project, located in Contra Costa and San Joaquin counties. A diverse assemblage of special status species are also known to exist in the potential service areas of the proposed Delta Wetlands Project.

This Biological Opinion presents findings for the Listed Species only. Descriptions of life histories and preliminary evaluations of impacts to other species listed above, such as spring-run chinook salmon, are also included. If and when the spring-run chinook salmon is listed by the Fish and Game Commission this information will facilitate an expedited consultation when it is requested.

II. DEFINITIONS

The following definitions shall govern interpretation of this Biological Opinion:

"Wildlife" means all wild animals, birds, plants, fish, amphibians, and related ecological communities, including the habitat upon which the wildlife depends for its continued viability, as provided in Fish & Game Code §711.2.

"Take" means to hunt, pursue, catch, capture, or kill an individual of a listed species, or to attempt any such act, as set forth in Fish & Game Code §86. The term *"kill"*, as used in Fish & Game Code §86, includes any act that is the proximate cause of the death of an individual of a species or any act a natural, probable, and foreseeable consequence of which is the death of any individual of a species.

"Management measure" means any action deemed necessary by the DFG to sustain a species within a natural ecological system. *"Management measures"* include legal, biological, and administrative measures.

"Habitat Management Lands" means those lands located on Bouldin Island and Holland Tract as well as lands acquired, restored, and managed as aquatic habitat in the estuary.

"Project Lands" means those lands located on Bacon Island and Webb Tract.

"Adjusted for Inflation" means that whenever funds are to be provided to the DFG by Delta Wetlands pursuant to this CESA Biological Opinion they will be referenced as January 1998 dollars and will be adjusted using cost indices published in the U.S. Bureau of Reclamation's "Water Systems Operations and Maintenance Cost Trends" or, in the event that index is no longer calculated, another cost indexing approach mutually acceptable to the DFG and Delta Wetlands.

"Shallow Shoal Habitat" means tidally influenced aquatic habitat, vegetated or not, that is $<$ 3 meters in depth at Mean High Water.

III. STATE AGENCY CONSULTATION PURSUANT TO ARTICLE 4 OF CESA.

CESA establishes a state policy to conserve, protect, restore, and enhance endangered species and threatened species and their habitat (Fish & Game Code, §2052). State agencies are mandated to conserve endangered and threatened species and utilize their authority to advance CESA's purposes (Fish & Game Code §2055). In addition, State agencies are charged not to approve projects that would jeopardize the continued existence of any endangered or threatened species or harm habitat essential to the continued existence of those species, if there are reasonable project alternatives that would conserve the species or the species' habitat and would prevent jeopardy (Fish & Game Code §2053).

To effectuate this policy, CESA requires State agencies that are lead agencies pursuant to the California Environmental Quality Act, Public Resources Code §21000, et seq. ("CEQA"), to consult with the DFG "to ensure that any action authorized, funded, or carried out by the state lead agency is not likely to jeopardize the continued existence of any endangered or threatened species" (Fish & Game Code §2090(a)). Whenever it consults with a CEQA State lead agency, the DFG is required to issue a written finding, based on the best available scientific information, of its determination of whether the State agency's proposed project "would jeopardize the continued existence of any endangered species or threatened species or result in the destruction or adverse modification of habitat essential to the continued existence of the species" (Fish & Game Code §2090(b)). The DFG's written finding must also include the DFG's determination of whether the agency's proposed project "would result in the taking of an endangered species or a threatened species incidental to the proposed project" (Fish & Game Code §2090(c)).

If the DFG determines in its written finding that the State agency's proposed project would result in jeopardy, the DFG must "determine and specify to the state lead agency reasonable and prudent alternatives consistent with conserving the species which would prevent jeopardy to the continued existence of the species or the destruction or adverse modification of the habitat essential to the continued existence of the species" (Fish & Game Code §2091). Similarly, if the DFG determines that the State agency's proposed project would result in a taking, the DFG must "determine and specify to the state lead agency reasonable and prudent measures that are necessary and appropriate to minimize the adverse impacts of incidental taking" (id.).

If the State agency's project is carried out in compliance with the alternatives and measures that the DFG specifies, any take that is incidental to the project is not prohibited by CESA (id.). Take of threatened or endangered species that is not in compliance with the DFG's alternatives and measures is prohibited by Fish & Game Code §2080.

If the DFG determines that the State agency's proposed project would result in jeopardy, the State agency must implement the alternatives specified by the DFG to prevent jeopardy, except in limited circumstances (Fish & Game Code §2092(a) & (b)).

Where a project may affect species listed under the federal Endangered Species Act (16 U.S.C. §1531 et seq.) ("ESA") as well as CESA, CESA requires the DFG to participate to the greatest extent practicable in the federal ESA consultation for the project (Fish & Game Code §2095). CESA encourages cooperative and simultaneous consultation between State and federal agencies for such projects, such that a coordinated federal biological opinion may be developed that reflects consistent and compatible findings between State and federal agencies (id.). If possible, and if consistent with CESA, the DFG must adopt a federal biological opinion as its written findings with respect to State lead agencies (id.), unless species that are affected by the project are State listed only.

In the event Article 4 of the CESA expires on January 1, 1999, this Biological Opinion and the Reasonable and Prudent Measures contained herein will satisfy the requirements for the issuance of incidental take authorization pursuant to Article 3, Section 2081 of the CESA.

IV. PROJECT DESCRIPTION

The Project is the subject of federal biological opinions issued pursuant to Federal Endangered Species Act, Section 7 consultations between the United States Army Corps of Engineers ("Corps") and the United States Fish and Wildlife Service ("USFWS") and National Marine Fisheries Service ("NMFS"). The federal biological opinions are attached as Attachment 1. The Project, as it is described in the federal biological opinions and described in Attachment 2, together with the Reasonable and Prudent Measures prescribed in the federal biological opinions, and the Terrestrial Resources Habitat Management Plan (Attachment 3), along with the water budget for the Habitat Management Lands as displayed for "DW Project Islands Wildlife Habitat Use" in Table A1-8 of Appendix A of the Project's DEIR/EIS (contained in Attachment 6) are adopted by the DFG as the "Project" for purposes of this biological opinion.

This CESA Biological Opinion applies only to the project described and does not assess the project as being coordinated with the State-Water Project (SWP) or Central Valley Project (CVP) or managed as a component of the SWP or CVP. This CESA Biological Opinion specifically does not address reoperations of SWP or CVP facilities. The reoperation of the Project in coordination with the SWP or CVP may require a new consultation pursuant to Section 2090 or 2081. If the Project is sold all measures and operational criteria shall apply to the new owner. To the extent that the new owner seeks to change operations so that operations are coordinated with the SWP or CVP, reconsultation may be necessary and, if the DFG deems it necessary, a revised CESA Biological Opinion will be issued. In addition, if any component of the Project, such as the HMP or the operation of the habitat islands and the associated water budget for the Habitat Management Lands, deviates from the current project description as set forth in the DEIR/EIS, and the deviation results in a significant additional adverse impact and a significant degradation of Reasonable and Prudent Measure 2.0 set forth in this Biological Opinion to minimize the adverse impacts of take of winter-run and delta smelt, this shall represent a significant project modification and formal consultation shall be reinitiated pursuant to Section 2090 or in its absence, 2081. However, DFG recognizes that June diversions onto the habitat islands shown in Table A1-8 (Attachment 6) could be reduced below the level shown and acknowledges that a significant reduction in June diversions would not constitute a significant project modification.

V. LISTED SPECIES

Listed and special status species in the Project area are included in Table 1. The summary of life history information for the Listed Species contained in the federal biological opinions is hereby adopted by the DFG for purposes of this Biological Opinion and supplemented by the life history information contained in Attachment 4. A summary life history of the other State Listed Species is included in Attachment 4.

VI. EFFECTS ON LISTED SPECIES

The DFG evaluated the proposed action for its likelihood to affect those species listed in Table 1. A number of species are found within or immediately adjacent to the Estuary but will not be affected, either directly or indirectly, by the Project. Those species will not be discussed further in this Biological Opinion. The species remaining include those that may be adversely affected by the proposed project or those that are not currently present on the project islands but which may begin to use either the Habitat Management Lands or Project Lands following project implementation. Those species will be discussed and the impacts of the proposed action described.

A. PROJECT IMPACTS OVERVIEW

The Project may subject the Listed Species to both direct and indirect adverse impacts, and temporary and permanent impacts, including the take of individuals of the Listed Species. The Project will result in temporary and permanent impacts to 21,000 acres of potential habitat for the terrestrial Listed Species. Listed Species displaced by the Project may escape direct injury, but will have to compete for food and living space in adjacent areas. Relocated individuals will be more vulnerable to disease, predation, and accidental death. Disturbance of the existing habitat will temporarily reduce the prey base and/or foraging area for individuals residing in the Project vicinity.

The Project's impacts on its potential service areas could result in land use changes that adversely affect the habitats of special status species (Appendix A of Attachment 4).

Other impacts include temporary impacts to terrestrial habitats associated with the required routine operation and maintenance of the Habitat Management Lands and Project Lands as provided for in the Habitat Management Plan (HMP). Impacts include, but are not limited to, discing, excavating supply and drainage ditches, and selective herbicide applications.

Table 1. California Endangered Species Act Biological Opinion for the Delta Wetlands Project. Listed Species and Special Status Species.

Species	Status
Fish	
Splittail (Pogonichthys macrolepidotus)	FPT
Winter-run chinook salmon (Oncorhynchus tshawytscha)	FE,SE
Spring-run chinook salmon (Oncorhynchus tshawytscha)	SCT
Steelhead (Oncorhynchus mykiss)	FT
Delta smelt (Hypomesus transpacificus)	FT,ST
Longfin smelt (Spirinchus thaleichthys)	1/
Sacramento perch (Archoplites interruptus)	1/
Tidewater goby (Eucyclogobius newberryi)	FE
Green sturgeon (Acipenser medirostris)	1/
Amphibians	
California red-legged frog (Rana aurora draytonii)	FT
California tiger salamander (Ambystoma californiense)	1/
Western spadefoot toad (Scaphiophus hammondi)	1/
Reptiles	
Giant garter snake (Thamnophis couchii gigas)	FT,ST
Northwestern pond turtle (Clemmys marmorata marmorata)	1/
Southwestern pond turtle (Clemmys marmorata pallida)	1/
San Francisco garter snake (T. sirtalis tetrataenia)	SE,FE
Birds	
California brown pelican (Pelecanus occidentalis californicus)	FE,SE
Bald eagle (Haliaeetus leucocephalus)	FE,SE
American peregrine falcon (Falco peregrinus anatum)	FE,SE
Aleutian Canada goose (Branta canadensis leucopareia)	FT
California black rail (Laterallus jamaicensis coturniculus)	1/,ST
Western snowy plover (Charadrius alexandrinus nivosus)	FT
California clapper rail (Rallus longirostrus obsoletus)	FE,SE
California least tern (Sterna antillarum browni)	FE,SE
Tricolored blackbird (Agelaius tricolor)	1/
Saltmarsh common yellow throat (Geothylpis trichos sinuosa)	1/
Suisun song sparrow (Melospiza melodia maxillaris)	1/
San Pablo song sparrow (Melospiza melodia samuelis)	1/
Swainson's hawk (Buteo swainsoni)	ST
Greater sandhill crane (Grus canadensis tabida)	ST
Bank swallow (Riparia riparia)	ST
Western yellowbilled cuckoo (Coccyzus americanus occidentalis)	SE,1/
Loggerhead shrike (Lanius ludovicianus)	1/
Burrowing Owl (Athene cunicularia)	SSC

Mammals

Suisun ornate shrew (Sorex ornatus sinuosus)	1/
Salt marsh harvest mouse (Reithrodontomys raviventris)	FE,SE
Yuma myotis/bat (Myotis yumanensis)	1/
Riparian woodrat (Neotoma fuscipes riparia)	1/
Riparian brush rabbit (Sylvilagus bachmani riparius)	SE
San Joaquin kit fox (Vulpes macrotis mutica)	ST,FE
Salt marsh wandering shrew (Sorex vagrans halicoetes)	1/

Plants

Rose mallow (Hibiscus lasiocarpus)	1/
Delta tule pea (Lathyrus jepsonii var. jepsonii)	1/
Suisun slough thistle (Cirsium hydrophilum var. hydrophilum)	FE
Suisun aster (Aster lentus)	1/
Mason's lilaeopsis (Lilaeopsis masonii)	1/,SR
Soft bird's beak (Cordylanthus mollis ssp. mollis)	FE,SR
Hispid bird's beak (Cordylanthus mollis spp. hispidus)	1/
Delta button-celery (Eryngium racemosum)	SE,1/
Salt marsh bird's beak (Cordylanthus maritimus ssp maritimus)	SE,FE
Contra Costa wallflower (Erysimum capitatum ssp. angustatum)	SE,FE
Antioch Dunes evening-primrose (Oenothera deltoides spp. howellii)	SE,FE
Pitkin Marsh Indian paintbrush (Castilleja uliginosa)	SE,1/
Slough thistle (Cirsium crassicaule)	1/
San Joaquin saltbush (Atriplex joaquiniana)	1/
California beaked-rush (Rhynchospora californica)	1/
Contra Costa goldfields (Lasthenia conjungens)	1/
Heart Scale (Atriplex cordulata)	1/
Tiburon Indian paint brush (Castilleja affinis neglecta).	1/
Contra Costa buckwheat (Eriogonum truncatum)	1/
Legenere (Legenere limosa)	1/
Northern California black-walnut (Juglans californica var. hinksii)	1/
Sanford's arrowhead (Sagittaria sanfordii)	1/
Gairdner's yampah (Perideridia gairdneri ssp. gairdneri)	1/
Fountain thistle (Cirsium fontinale var. fontinale)	SE,1/
Burke's goldfields (Lasthania burkei)	SE,1/
Mt. Hamilton thistle (Cirsium fontinale var. campylon)	1/
San Francisco gumplant (Grindelia maritima)	1/
Hairless popcorn flower (Plagiobothrys glaber)	1/
Bearded popcorn flower (Plagiobothrys hystriculus)	1/
Calistoga popcorn flower (Plagiobothrys strictus)	1/
Swamp sandwort (Arenaria paludicola)	1/
Showy indian clover (Trifolium amoenum)	1/
Sepastopol meadowfoam (Limnanthes vinculans)	SE,1/
Kenwood marsh checkerbloom (Sidalcea oregana ssp. valida)	SE,1/
Marin knotweed (Polygonum marinense)	1/
Palmate-bracted bird's-beak (Cordylanthus palmatus)	FE
White sedge (Carex albida)	SE,1/
Pitkin marsh lily (Lilium pardalinum ssp. pitkinense)	SE,1/
Napa bluegrass (Poa napensis)	SE,1/

Insects

Lange's metalmark butterfly (*Apodemia mormo langei*)	FE
Valley elderberry longhorn beetle (*Desmocerus californicus dimorphus*)	FT
Sacramento anthicid beetle (*Anthicus sacramento*)	1/
Delta green ground beetle (*Elaphrus viridis*)	FT

Other Invertebrates

Longhorn fairy shrimp (*Branchinecta longiantenna*)	FE
California freshwater shrimp (*Syncaris pacifica*)	SE, FE
Conservancy fairy shrimp (*Branchinecta conservatio*)	FE
Vernal pool fairy shrimp (*Branchinecta lynchi*)	FT
California linderiella (*Linderiella occidentalis*)	FPE
Vernal pool tadpole shrimp (*Lepidurus packardi*)	FE

FE = Federal Endangered
FT = Federal Threatened
FPT = Federal proposed Threatened
FPE = Federal proposed Endangered
SCT = State Candidate Threatened
1/ = Former Federal Candidate continues to be species of concern
ST = State Threatened
SE = State Endangered
SSC = Species of Special Concern
SR = State Rare

The Delta Wetlands Project will also result in impacts to the aquatic Listed Species including:

1. Direct entrainment of delta smelt larvae onto the Project Lands due to additional, new diversions of up to 9,000 cfs.

2. Increased entrainment of delta smelt larvae, juveniles, and adults into other south Delta diversions and increased mortality due to new diversions in the central and south Delta and increased exports associated with the discharge and export of Delta Wetlands Project water at the State and Federal export facilities.

3. Increased loss of juvenile winter-run and spring-run chinook salmon from adverse modifications to internal Delta channel hydraulics which can increase the diversion of fish into the western, central, and south Delta where they are exposed to increased entrainment into other south Delta diversions including the State and Federal export facilities and increased mortality from other factors such as predation.

4. Increased erosion of in-channel habitat for delta smelt and winter-run chinook salmon associated with increased boating activity facilitated by the Project.

5. Degradation of spawning and rearing habitat for delta smelt and splittail due to construction.

6. Increased losses of adult and juvenile delta smelt and juvenile winter-run and spring-run chinook salmon due to increased predation losses associated with fish screen structures, siphon and pump stations, and boat docks.

7. Temperature-related mortality of winter-run and spring-run chinook salmon and delta smelt from elevated temperatures caused by the discharge of water.

8. Impacts to aquatic Listed Species habitat from decreased dissolved oxygen (DO) levels caused by the discharge of water from the reservoir islands.

9. Reduced Delta Outflow and loss of associated biological benefits due to increased project diversions onto the reservoir islands.

10. Upstream shifts of X2 due to increased project diversions onto the reservoir islands.

11. Reductions in QWEST due to increased project diversions onto the reservoir islands.

12. Other adverse Delta channel hydraulics that impact the nutrient cycling, rearing, food web support, and transport functions of the Delta and the Delta's ability to provide a healthy nursery and migratory habitat that supports the continued existence of the delta smelt and winter-run and spring-run chinook salmon.

1. WILDLIFE IMPACTS

Using 1987 aerial photographs along with cropping data, the habitat and crop types, and their areal extent were calculated by Jones and Stokes Associates (JSA) for both the habitat islands as well as the reservoir islands. Based on those data the acreage of suitable habitat for the greater sandhill crane and Swainson's hawk was determined. The proposed project will impact 7,028 acres of suitable sandhill crane habitat and 10,048 acres of suitable Swainson's hawk habitat.

No immediate effect is expected on the other terrestrial Listed Species such as the yellow-billed cuckoo, giant garter snake, western pond turtle, or black rail. Once the habitat islands are functioning, suitable habitat will likely be restored and benefit these species. However, once established they may become vulnerable to routine management and maintenance activities.

2. PLANT IMPACTS

Special status plants such as Mason's lilaeopsis, rose mallow, and Delta tule pea are found in the project area. Direct impacts on these species due to project implementation is expected to be minor.

3. FISH IMPACTS

This evaluation describes the effects of Delta Wetlands Project operation on winter-run, spring-run, and delta smelt as it would be allowed to operate by the federal biological opinions.

The Delta Wetlands Project, as allowed by the federal biological opinions:

- Would result in increases in take of delta smelt, winter-run, and spring-run at key times for all three species:
    - Adult delta smelt begin their upstream movement into Delta spawning areas in January through March; delta smelt larvae and juveniles in February through July; winter-run juveniles in January through March; spring-run yearlings in October through March; young-of-the-year spring-run juveniles in March through June.

- Would increase take of delta smelt, winter-run, and spring-run due to the exacerbation of adverse hydraulic conditions in the Delta by:

    - Increasing reverse flows toward the central and south Delta; reducing Delta Outflow; decreasing QWEST; and, allowing unmodified project operations during conditions of low San Joaquin River flows in the late winter and early spring. Through reduced Delta outflow and reduction in net westerly flow, Project operation is expected to degrade conditions for proper smolt outmigration stimulus and seaward orientation, and generally reduce smolt survival.

- Would result in increased entrainment of juvenile winter-run and spring-run chinook salmon into the interior Delta and reduce their survival rates. Lower survival rates are expected due to the longer migration route where fish are exposed to increased predation, higher water temperatures, unscreened agricultural diversion, poor water quality, reduced availability of food, and entrainment at the CVP/SWP export facilities.

- Would result in adverse changes in Delta hydrodynamics during the period when adult delta smelt are migrating upstream into the Delta and during portions of the critical spawning and rearing period for larval and juvenile delta smelt are expected to result in increased losses of adult, larval, and juvenile delta smelt. Lower survival rates are expected due to conditions where delta smelt are exposed to increased entrainment at the CVP/SWP facilities. Reduced outflow, decreases in net westerly flow, and shifts in the position of X2 are expected to degrade delta smelt spawning and rearing habitat in the Bay-Delta, degrade conditions for natural transport flows westward, and generally reduce delta smelt survival.

- Would not reduce take under most conditions because the Project does not include a mechanism for improving hydraulic conditions for delta smelt and winter-run at other times through the release of "environmental water" that can be used to offset those unavoidable losses.

- Could result in increased take due to deficient water quality protection, particularly for winter-run and spring-run chinook salmon. Could allow discharge water to degrade receiving water temperatures by up to 4° F when receiving water temperatures are between 58° and 66° F. This level of increase, when winter-run chinook salmon are present, could cause a significant increase in the levels of chronic stress and result in increased mortality as a result of impaired smoltification, reduced ability to complete osmoregulatory adaptations, increased risk of disease, and increased predation.

Unless modified, the Project will continue to cause significant, unmitigated adverse impacts to delta smelt, winter-run, and spring-run. Hydrodynamic changes associated with the Project will degrade important ecosystem functions that support nutrient cycling, spawning, rearing, migration, and larval transport in the Delta. Impairment of those functions has degraded the ecological health of the Delta and contributed to the listing of delta smelt and winter-run chinook salmon and the candidacy of the spring-run chinook salmon. The Project will result in reduced survival of delta smelt, winter-run, and spring-run chinook salmon.

B. METHODS

The DFG used a broad assortment of analytical tools and approaches to conduct its evaluation of the proposed project and to ultimately develop its Reasonable and Prudent Measures. The principle approach used by the DFG was to assess how aquatic habitat conditions would be affected by Delta Wetlands project operations. Aquatic habitat variables and project operation impacts included Delta channel hydraulics, QWEST, Delta outflow, project diversions, discharges for export, and water quality. The DFG also assessed the extent of entrainment into diversions of larval delta smelt. Most of the analytical tools and data have been provided by JSA on behalf of the Board and U.S. Army Corps of Engineers. While much of it was contained in the Biological Assessment dated June 21, 1995, JSA has supplemented it with information such as more detailed entrainment data, alternative strategies for estimating the percent of out-migrating winter-run present in the Delta in any given month, and data on the results of modeling alternative operation approaches to that originally proposed in the Biological Assessment. The DFG used data output provided by JSA and life history data assembled from the Biological Assessment and contacts with agency species experts.

The results of JSA's computer model analyses were provided to the DFG in writing in a March 25, 1997 memorandum and electronically in April 1997. Those analyses compared the no-project alternative, the updated project operated using the January 27, 1997 Operations Criteria as allowed by the federal biological opinions, and the updated project with additional operating criteria proposed by the DFG. The model run data bases were used in the following assessment to evaluate impacts to listed fish.

The DFG used the operations model data to assess project impacts and develop the Reasonable and Prudent Measures in recognition that the modeled hydrologic conditions may not be repeated in the future. The DFG also used the operations model data recognizing that the model presents data in monthly time steps and that monthly averages can mask more significant changes that occur over shorter periods of time. The DFG, therefore, developed Reasonable and Prudent Measures that would be effective in avoiding or minimizing impacts regardless of future hydrologic patterns or magnitude of daily changes. Measures are described which avoid large changes in Delta hydrodynamics during critical periods for listed species. This approach will help support important ecological functions including providing proper flow cues for migrating adult and juvenile winter-run and spring-run chinook salmon and suitable transport flows for delta smelt.

1. MODELING TOOLS

The DFG used the results of three modeling tools, DWRSIM, Delta Standards and Operations Simulation (DeltaSOS), and DeltaMOVE as part of its overall approach to evaluating the impacts of the Delta Wetlands project on listed fish.

DWRSIM- The results of DWRSIM 1995-C6B-SWRCB-409, performed in January 1995, were provided to the Board for use by JSA as the initial Delta water budget in the DeltaSOS simulations to evaluate proposed Delta Wetlands Project impacts.

DeltaSOS- The simulations used to estimate Delta Wetlands Project effects were performed with the DeltaSOS model. The primary assumptions used in the DeltaSOS are that the 1995 Water Quality Control Plan (WQCP) objectives will be satisfied, and that all in-Delta diversions and allowable CVP/SWP exports will be made prior to any Delta Wetlands diversions for storage. The Delta Wetlands diversions are limited by the available water within the 1995 WQCP objectives with maximum CVP/SWP exports assumed. Since the DeltaSOS is a monthly model, it may underestimate the magnitude of project induced changes. Appendix A4 of the draft EIR/EIS, for instance, concludes that simulated daily operations of the Delta Wetlands Project and subsequent impacts on listed fish would likely be greater than simulated with the monthly model.

DeltaMOVE- DeltaMOVE is the other basic tool used to evaluate project impacts and to develop operational criteria for the Delta Wetlands Project. Delta Wetlands Project operations could affect delta smelt survival and abundance by affecting transport flows. After hatching, larvae require net flow movement for transport to downstream optimal low-salinity habitat. DeltaMOVE was used to simulate transport of delta smelt to downstream habitat following hatching in the Delta. The estimated percentage of the spawned population that is entrained provides an indicator of losses during transport to downstream optimal low-salinity habitat. This indicator was used to describe related project impacts. Impacts to winter-run were assessed by using DeltaMOVE data for the northern portion of the Delta only.

The entrainment index for Delta conditions with the Delta Wetlands Project indicates the direction and magnitude of potential change in entrainment loss relative to conditions simulated for the No-Project Alternative. The entrainment index should not be construed as the actual level of entrainment that would occur. Simulated monthly conditions, fixed spawning distribution, and assumed transport characteristics of a life stage cannot accurately characterize the complex conditions and variable time periods that affect entrainment during occurrence of planktonic life stages or occurrence of rearing juveniles in the Delta.

JSA used the entrainment index for one portion of the Delta to estimate changes in winter-run mortality associated with Project operations. Limitations of the mortality index, as described by the NMFS in its October 26, 1995 letter to the Corps (Attachment 6), were also carefully weighed by the DFG and resulted in a decision to depend on changes in the entrainment index values themselves to assess potential impacts to winter-run. Thus, data provided by DeltaMOVE yielded important information used by the DFG to assess changes in entrainment and changes in internal Delta hydrodynamics.

Factors Modeled and Evaluated

The following factors were evaluated in order to evaluate the impacts of the Delta Wetlands Project for all 70 years of modeling. To depict a more accurate assessment of how the Delta Wetlands Project affects aquatic resources the DFG also evaluated data specific to only those months when the Delta Wetlands Project is predicted to operate. Based on Appendix A4 of the Draft EIR/EIS, the frequency of actual operation could be as much as 25 to 50 percent greater than modeled. Project modification described in the January 27, 1997 Final Operations Criteria, however, may have limited the magnitude of this enhanced operation.

The habitat variables that were evaluated by the DFG included changes in the X2 location (the location of the 2 ppt isohaline relative to the Golden Gate Bridge), changes in the area of suitable salinity habitat in Suisun Bay, various modeled indices which help define changes in internal Delta hydrodynamic conditions, QWEST, and net flow changes in selected Delta channels.

North and Central Delta Flows- An indicator of north and central Delta flow conditions was evaluated. Called the Cross Delta Flow Parameter (CDFP), it is calculated with the DeltaMOVE fish transport model discussed in "Methods for Assessing Effects on Fish Transport" and Appendix A of the Biological Assessment. The model simulates introduction of a concentration of particles into the Mokelumne River side of the Delta at the beginning of a month. The proportion of the concentration entrained in exports and other Delta diversions is the monthly CDFP.

Other Indices- Other indices were also used, including the lower Sacramento River and lower San Joaquin River to get a more complete picture of how fish in the Sacramento River or west Delta may be affected by project operations.

X2 and Aquatic Habitat in Suisun Bay- Salinity is an important habitat factor and is strongly affected by Delta outflow. The maximum and average upstream shifts in X2 were assessed by the DFG in order to calculate project induced reductions in the amount of shallow shoal and low elevation tidal rearing habitat in Suisun Bay. The area of suitable rearing habitat in Suisun Bay, based on the location of X2, was calculated for delta smelt. Figure 9 in Appendix A of the Biological Assessment was used along with data on the predicted upstream shift in X2 to estimate changes in area of suitable rearing habitat in Suisun Bay using a planimeter.

QWEST- QWEST is a calculated flow parameter representing net flow between the central Delta and the western Delta (i.e., flow past Antioch other than the Three-mile Slough contribution). Although QWEST criteria are not included in the 1995 WQCP, QWEST criteria have previously been considered for protection of central Delta fish (NMFS 1993) and continues to be an important measurement tracked by the DFG for this Biological Opinion.

Net Flows in Middle and Old Rivers- The net flow in Middle and Old rivers is generally to the south in most months. Delta Wetlands Project operations can exacerbate that by increasing flows south and further degrading central Delta hydraulic conditions.

Diversion Rates and Diversion Timing- Diversion rates and diversion timing predicted by operation modeling were used extensively by the DFG to assess project impacts and identify effective avoidance measures. Modeling also provides predictions on the frequency of Delta Wetlands Project operations during the 70 years simulated. Diversions made outside of periods of species occurrence avoid direct impacts to those species. Diversion limits were used to reduce impacts on aquatic habitat and to control entrainment of fish and other aquatic organisms, including direct mortality caused by increased predation, abrasion, and impingement. Diversion rate alone, however, does not account for variability in entrainment loss caused by variable species abundance, species distribution, and species and life stage vulnerability. The DFG, therefore, considered other factors such as indices of abundance; e.g. the fall mid-water trawl (FMWT), in-channel monitoring in the vicinity of the project's intakes and discharges, and diversion restrictions during periods when vulnerability to entrainment was highest.

2. ENTRAINMENT DATA AND HYDRAULIC CONDITIONS

Since the largest impacts occur when project operations take place during months when the populations and life stages are the most vulnerable and when internal Delta hydrodynamics are adverse; e.g. high levels of diversions relative to Delta outflow and San Joaquin River inflow, the DFG focused on evaluating impacts and defining more favorable conditions when project operations could occur and take could be reduced. These conditions needed to be defined in a manner that minimized the likelihood that modeled monthly averages would mask daily operational influences that can result in greater impacts than the monthly data suggest. The process included several modeling iterations of alternative approaches that were inspected to assess the performance for a given set of measures. JSA performed these model analyses using the assumptions provided by the DFG for each alternative evaluated.

3. SPECIES LIFE HISTORY

The DFG inspected life history data from a variety of sources to identify periods of greatest vulnerability such as migration periods and the presence of more vulnerable life forms such eggs, larvae, and juveniles. Those data combined with field sampling data were used to fine tune information on monthly distribution of winter-run chinook salmon and delta smelt in the Delta. Figure 1, for instance, displays the percent of annual production of juvenile winter-run chinook salmon in the Delta by month. Figure 2 displays important life history information for winter and spring-run chinook salmon and delta smelt.

a. Factors Influencing Project Impacts on Winter-Run Chinook Salmon

Attachment 4 provides the relevant information on the life history of this species used to conduct the impact analysis. It contains significant information which helps to understand the reasons for the Reasonable and Prudent Measures. It should be carefully reviewed as a step in reviewing the rationale for the Reasonable and Prudent Measures. Several important elements include the timing of upstream adult migration through the Delta and the timing of the downstream migration of juvenile winter-run chinook salmon.

Rearing Habitat- The Delta provides important rearing habitat for chinook salmon prior to smoltification and continued migration to the ocean. The extent of use likely varies depending on factors such as upstream hydrologic conditions. Rearing habitat is most vulnerable to impacts from the beginning of January to the end of March.

January through April are the primary months when juvenile winter-run salmon are present in the Delta based on USFWS trawl and seine data for 1992-1995. These data suggest that a portion of the chinook salmon population use the Delta as a migration corridor, remaining in the Delta approximately one month and are affected by Delta conditions only during that month. Juvenile salmon also rear in the Delta until they are ready to migrate to the ocean. Those juvenile chinook salmon are exposed to several months of Delta conditions and their vulnerability to the adverse impact of the Delta Wetlands Project increases in diversions. From year to year juvenile migration timing is affected by hydrologic conditions.

The USFWS trawl and seine data for 1992-1995 indicate that winter-run chinook salmon are affected most by increased diversions or exports during February and March. The evaluation of Delta Wetlands Project impacts on winter-run chinook salmon for the Biological Opinion took into account their occurrence in the Delta based on their distribution as depicted in Figure 1.

The monthly percentages of the annual production of juvenile winter-run chinook salmon present in the Delta used to assess the Delta Wetlands project's effects on juvenile

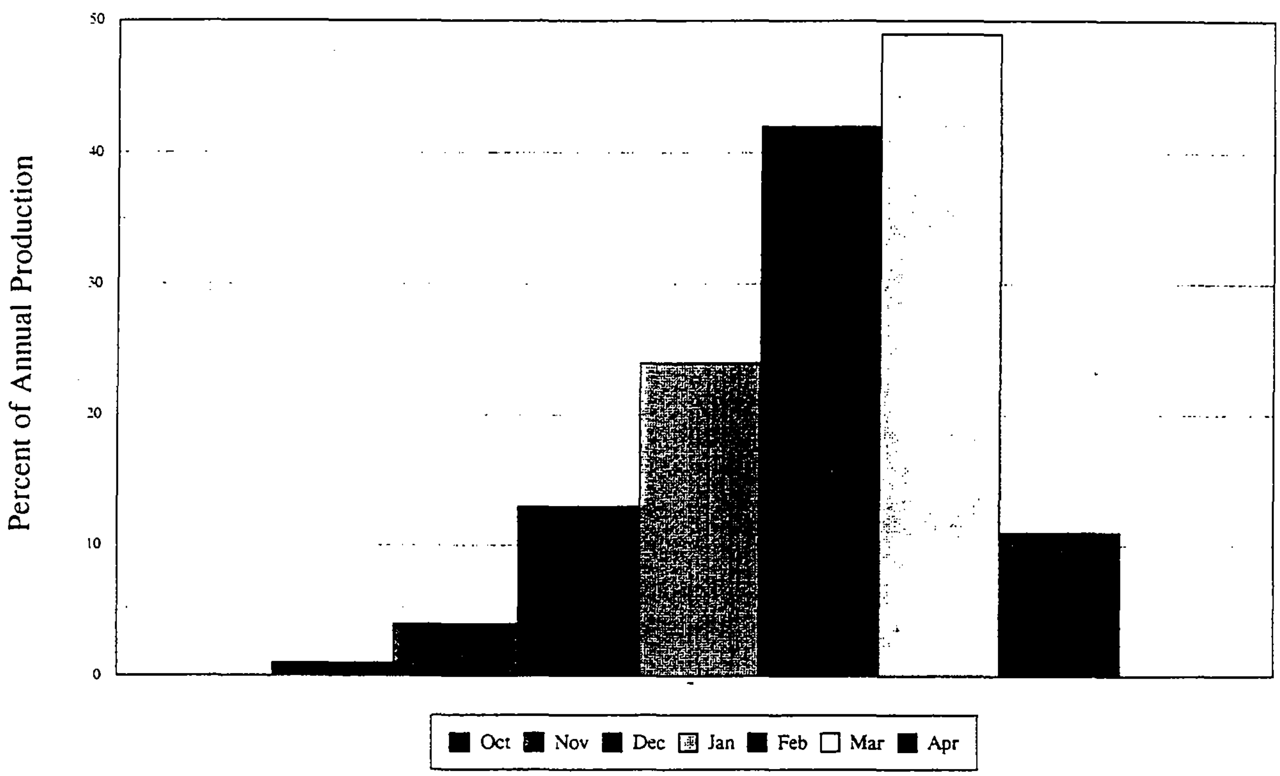


Figure 1. California Endangered Species Act Biological Opinion for the Delta Wetlands Project. Percent of Annual Production of winter-run Chinook salmon present in the Delta by month.

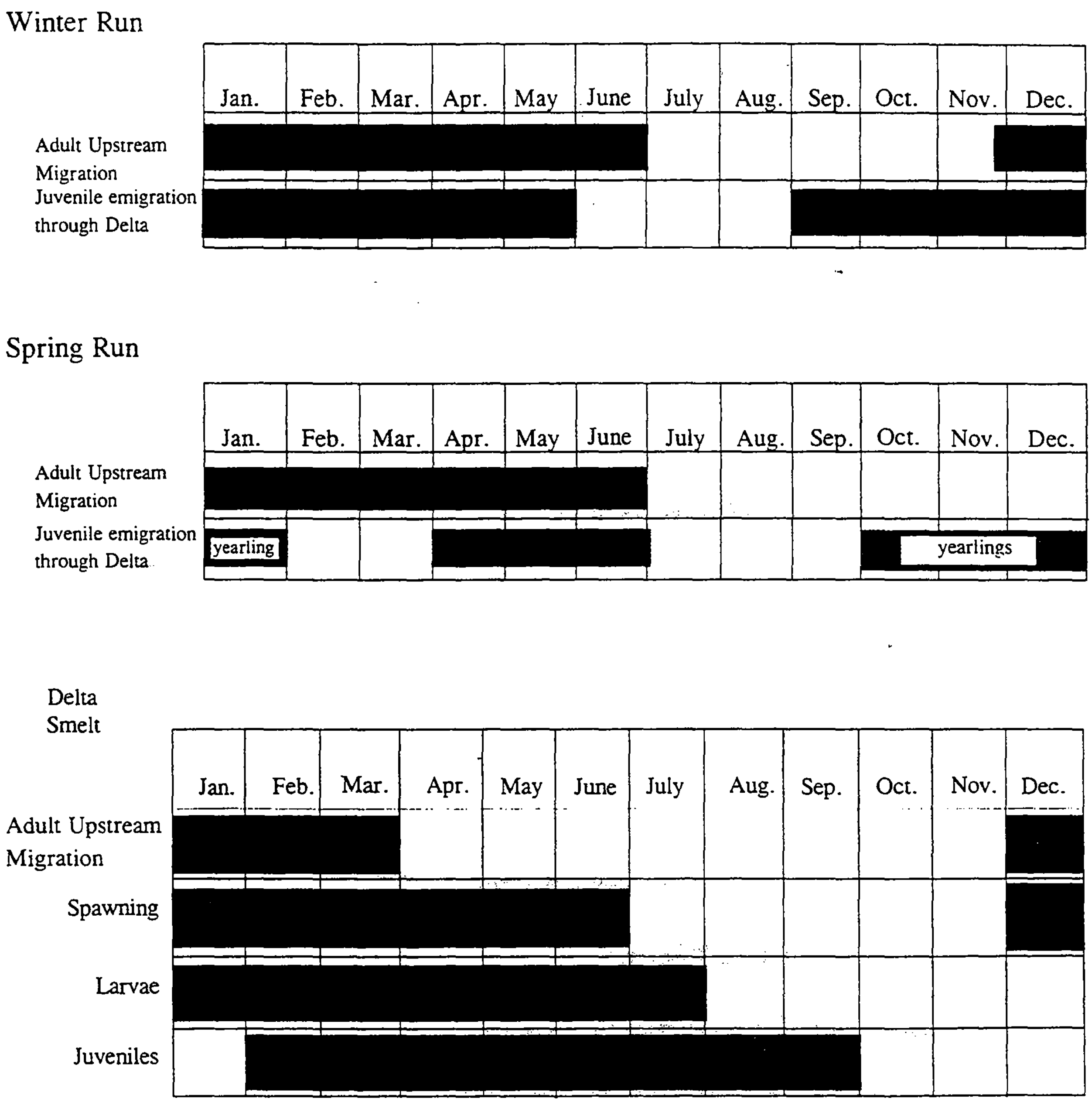


Figure 2. California Endangered Species Act Biological Opinion for the Delta Wetlands Project. In Delta life history information for winter-run and spring-run Chinook salmon and delta smelt.

winter run were: winter run were:

October	1%	February	42%
November	4%	March	49%
December	13%	April	11%
January	24%		

Juvenile Migration- Juvenile winter-run chinook salmon are present in the Delta in the vicinity of the Delta Wetlands Project islands between early September through May. During this period they are vulnerable to physical disturbance, entrainment, elevated water temperatures, and flow disruptions.

Increasing entrainment indices reflect a degradation of Delta hydraulic conditions and decrease survival for juvenile winter-run chinook salmon as they are drawn through the Delta Cross Channel (DCC) and Georgiana Slough and east through Three-Mile Slough and the lower San Joaquin River.

Mark-recapture experiments conducted in the Sacramento River suggest improved survival when juvenile salmon continue down the Sacramento River rather than through the DCC or Georgiana Slough. Nevertheless, the adverse habitat conditions associated with hydraulic changes in the central Delta which results in entrainment of juveniles into the central and south Delta, decreases survival for juvenile winter-run chinook salmon as they are drawn through the DCC and Georgianna Slough and east through Three-Mile Slough and the lower San Joaquin River.

Adult Migration- Adequate flows and suitable water quality are needed to ensure that adults can move upstream towards their spawning habitat and are not subjected to elevated water temperatures. The timing of adult migration varies from late November through June. The channels around Webb Tract and Bouldin Island are areas that adult winter-run may use during their upstream migration and where winter-run are vulnerable to physical disturbance and flow disruption during migratory periods.

b. Factors Influencing Project Impacts on Spring-Run Chinook Salmon

Attachment 4 contains significant information on this species' life history. It should be carefully reviewed as a step in understanding the basis for the DFG's conclusions regarding Project impacts on spring-run. Several important elements include the timing for upstream migration of adults through the Delta and the timing of the downstream migration of juvenile spring-run chinook salmon.

Juvenile Migration- Yearling spring-run chinook salmon are present in the Delta in the vicinity of the Delta Wetlands Project islands between early October through January (Figure 2). During this period they are vulnerable to physical disturbance, entrainment, elevated water temperatures, and flow disruptions. Spring-run smolts are present in the Delta in the vicinity of the Delta Wetlands Project islands between early April through June. During this period they are also vulnerable to physical disturbance, entrainment, elevated water temperatures, and flow disruptions.

The same adverse habitat conditions described for winter-run, such as the entrainment of juveniles into the central and south Delta, also decrease survival for juvenile winter-run chinook salmon as they are drawn through the DCC and Georgianna Slough and east through Three-Mile Slough and the lower San Joaquin River.

Adult Migration- Adequate flows and suitable water quality are needed to ensure that adults can move upstream towards their spawning habitat and are not subjected to elevated water temperatures. The timing of adult migration varies from early January through May. The channels around Webb Tract and Bouldin Island are areas that adult spring-run may use during their upstream migration and where spring-run are vulnerable to physical disturbance and flow disruption during migratory periods.

c. Factors Influencing Project Impacts on Delta Smelt

Attachment 4 contains significant information which helps to understand the reasons for the Reasonable and Prudent Measures. It should be carefully reviewed as a step in reviewing the rationale for the Reasonable and Prudent Measures. Several important elements include the timing for upstream migration of adult delta smelt into the Delta for spawning and the timing of spawning.

Adult Migration- Adequate flows, suitable water quality, and reduced diversions are needed to attract migrating adults into the Delta's Sacramento and San Joaquin river channels and their associated tributaries and ensure that adults are not subjected to elevated levels of entrainment. These areas are vulnerable to physical disturbance and flow disruption during migratory periods (Figure 2).

Spawning- The spawning season for delta smelt varies from year to year, and may occur from late winter (December) to early summer (July). Moyle (1976) collected gravid adults from December to April, although ripe delta smelt were most common in February and March. In 1989 and 1990, Wang (1991) estimated that spawning had taken place from Mid-February to late June or early July, with peak spawning occurring in late April and early May.

A recent study of delta smelt eggs and larvae (Wang and Brown 1994, as cited in DWR and Reclamation 1994) confirmed that spawning may occur from February through June, with a peak in April and May. The variation in timing of spawning is affected by both biological and environmental factors (Meng and Moyle 1995, Stevens and Miller 1983, Sweetnam and Stevens 1993, USFWS 1996). Examined collectively, the life history information on listed species such as delta smelt indicates that the various life stage activities may occur over broad time periods. However, when individual years are examined these various life stage activities occur over narrower windows of time. These data indicate that year-to-year variation in periodicity of the early life stages may range over several months with peaks of abundance varying considerably among months.

Although, the duration of the spawning season or period of larval transport may to be a significantly narrower window of time, actual year-to-year periods of vulnerability of each life stage are generally shorter than shown in this Biological Opinion.

The DFG used the following percentages for the monthly distribution of delta smelt larvae in the Delta and vulnerable to Delta Wetlands Project impacts (Figure 3):

February	10%	May	25%
March	25%	June	5%
April	35%		

Larval and Juvenile Transport- Habitat conditions suitable for transport of larvae and juveniles and larval rearing are needed by the species as early as February 1 and as late as August 31, because the spawning season varies from year to year and may start as early as December and extend until July. Although entrainment indices were calculated for all months, the transport effects on delta smelt larvae would occur primarily during February-June.

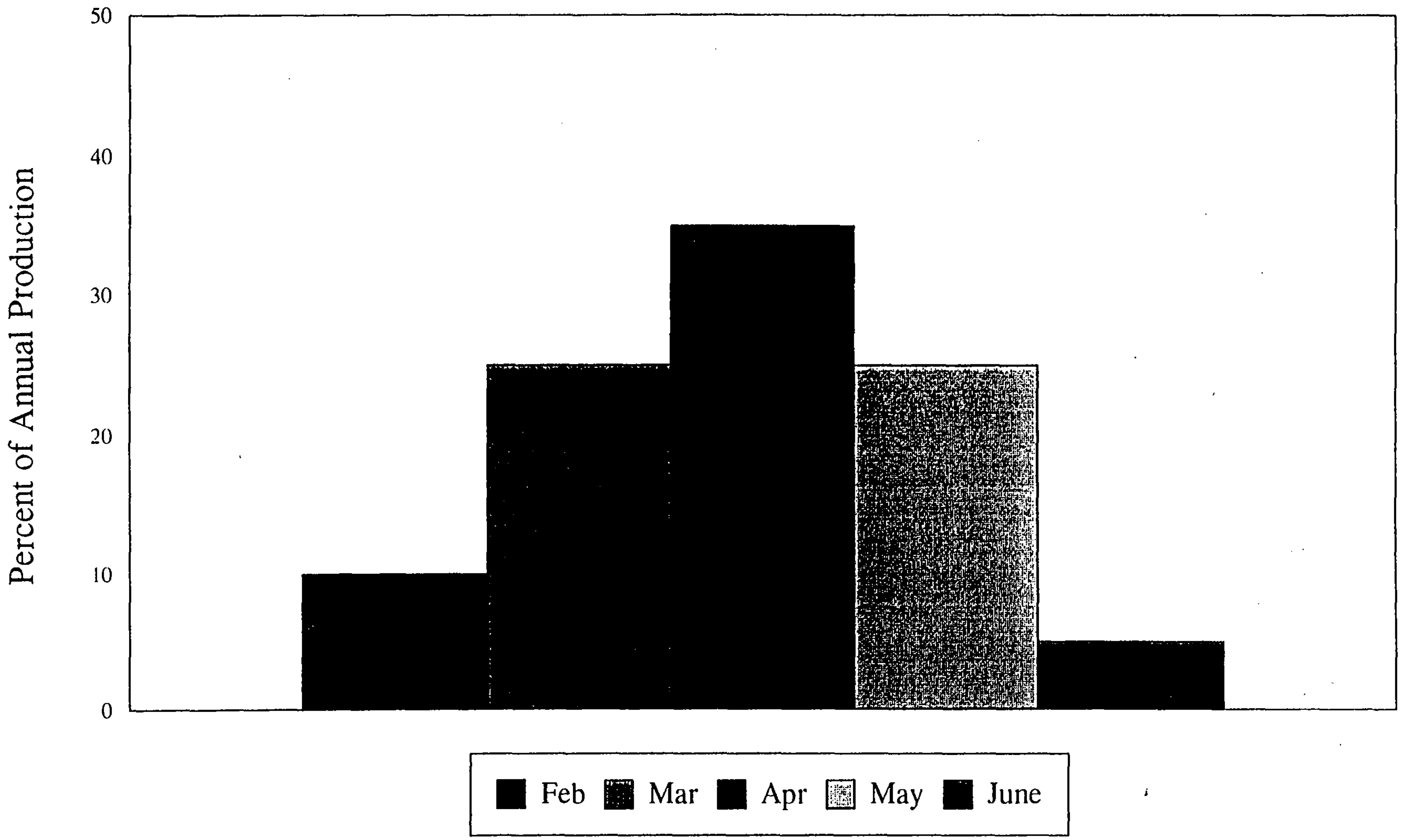


Figure 3. California Endangered Species Act Biological Opinion for the Delta Wetlands Project. Percent of delta smelt larvae present in the Delta by month.

Rearing Habitat- The delta smelt's principle rearing habitat is located in an area extending from Carquinez Straits, including Suisun, Grizzly, and Honker bays, Montezuma Slough and its tributary sloughs, up the Sacramento River to its confluence with Three-Mile Slough. Three-Mile Slough represents the approximate location of the most upstream extent of historical tidal excursion. Rearing habitat is vulnerable to impacts from the beginning of February to the end of August. The location of an indicator, X2, is a measure of rearing habitat quality and quantity.

4. TRANSPORT CONDITIONS

Transport has been identified as important to the survival of delta smelt and winter-run and spring-run chinook salmon. Transport to the Delta export facilities reduces survival, while transport toward Suisun Bay increases survival of both delta smelt and chinook salmon. JSA described using a numerical index in the Board's Biological Assessment as a reliable indicator of transport conditions in the Delta. This "entrainment" index is calculated by JSA's DeltaMOVE model and is a function of Delta diversions, facility operations, and average tidal flows. Entrainment indices are specific to each of six areas of the Delta. For example, the entrainment index for the Mokelumne River, or northern, part of the Delta represents the portion of water originating from the Mokelumne River, Sacramento River through the DCC and Georgiana Slough (and associated particles such as fish larvae) that is potentially diverted by any Delta diversion. Under identical Delta flow and diversion conditions, entrainment indices are highest for parts of the Delta nearest the largest diversions (i.e., near the export facilities of the SWP and the CVP) in the south. The impact of diversions on transport conditions (i.e., the entrainment index) is partially determined by the geographical location of diversions and the inflow source of diverted water.

5. OTHER FACTORS

The DFG recognizes the mortality rate curve differences between larval and adult delta smelt and that the earliest life phases of fish such as delta smelt, have high natural mortality rates compared to later life phases. Also, increases in larval mortality rates are unlikely to result in the same level of effects at the adult population level because of compensatory mortality/survival effects. The DFG assumed that a given rate of mortality of larval fish would not be carried, unchanged to the adult life phase consistent with accepted scientific principles in population dynamics. The DFG took these factors into account when analyzing project impacts and preparing its Biological Opinion.

The simulations of entrainment indices for delta smelt differ from the simulations for winter-run chinook salmon. Delta smelt are blocked from moving downstream of the 2-ppt isohaline and the blockage increases exposure to the effects of Delta diversions and exports, especially for larval smelt in the Sacramento River and San Joaquin River parts of the Delta.

C. IMPACTS OF PROPOSED PROJECT

Following is a description of impacts on listed fish and their habitat from implementation of the Delta Wetlands Project, as allowed by the federal biological opinions and using the final operations criteria dated January 27, 1997.

1. GENERAL IMPACTS

Impacts include increased predation and Delta Wetlands Project pumps, siphons, and recreational boat docks; effects of increased boating; erosion associated with project discharges; adverse effects of degraded internal Delta hydrodynamics such as higher reverse flows in central and south Delta waterways; and, entrainment in local diversions of the central and southern Delta and entrainment at the CVP/SWP pumping plants.

Juvenile salmon emigrating from spawning and rearing areas in the Sacramento River may be diverted into the interior Delta through the manmade Delta Cross Channel, Georgiana Slough, or Three-Mile Slough. Fisheries investigations by Schaffter (1980) and Vogel et al. (1988) suggest winter-run chinook salmon juveniles are diverted in proportion to flow into the central Delta at the Delta Cross Channel.

The Delta Wetlands Project operations, particularly in February and March, will adversely affect the endangered winter-run chinook salmon and threatened delta smelt and diminish the fisheries habitat benefits gained in the Bay-Delta Accord. Juvenile winter-run will be adversely affected though reduced Delta outflow, higher reverse flows in central and south Delta waterways, and entrainment in local diversions of the central and southern Delta and entrainment at the CVP/SWP pumping plants. Impacts to winter-run and delta smelt will occur during the filling of the reservoir islands and during the discharge of water for subsequent export at the CVP /SWP pumping plants.

The export/inflow criteria established by the Accord were developed to replace and lead to, at a minimum, equivalency with the historic QWEST criteria for protecting juvenile winter-run chinook salmon. In addition to the Accord's water quality criteria, the NMFS assessment and equivalency determination during the development of the Accord assumed the CVP and SWP exports were limited by: (1) current CVP/SWP pumping plant capacities, (2) existing Corps permits; (3) south of Delta storage capacity, (4) the independent operation of the CVP/SWP pumping plants under existing water rights, and (5) inflow originating from upstream sources, These limits on export and the Accord's criteria resulted in Delta conditions which are frequently better than the conditions provided by the minimum WQCP standards.

2. OPERATIONAL IMPACTS

The DW reservoir islands have the capacity to store up to 238 thousand acre-feet (TAF). This is expected to gradually increase to 260 TAF due to island subsidence. As proposed, DW diversion operations will frequently reduce Delta outflow. The decrease in outflow may reach an average daily maximum rate of 9,000 cfs and an average monthly maximum rate of 4,000 cfs. Delta outflows would be reduced by 5 percent or greater in approximately 9.2 percent of the simulated years (1922-1991) with a maximum reduction of 25 percent. On an annual basis, DW diversions would directly decrease outflow by a mean of 192 TAF and a maximum of 490 TAF. In comparison, the CVP and SWP export an average of 6.1 million acre-feet per year. Water diversion onto the DW islands can increase the percent of inflow diverted in any month of the year.

Operations studies completed by JSA indicated that the project operated according to the January 27, 1997 Final Operations Criteria (Attachment 2) diverted to storage at maximum monthly rates of 3,600 cfs, 4,000 cfs, and 1,144 cfs in January, February, and March respectively (Table 2). Project diversions occurred nearly two-thirds of the time in January, February, and March and were essentially unchanged from the project originally proposed in the Board's Biological Assessment. Diversions in April and May were eliminated, however, those diversions occurred only 5 to 7 percent of the time and did not exceed monthly average flows of 76 cfs and 172 cfs respectively. This measure, therefore, avoided a relatively small impact associated with that alternative. Maximum diversions remained nearly unchanged from July through December. The frequency did decrease in December from 56 percent with the project as proposed in the Board's Biological Assessment to 40 percent for the project operated as allowed by the federal biological opinions.

The project operated as allowed by the federal biological opinions discharged for export at maximum rates of 956 cfs, 1,742 cfs, and 1,088 cfs in January, February, and March respectively (Table 3). Project discharges were reduced in December through March for the project operated as allowed by the federal biological opinions. The frequency of discharges was also reduced in February and March. The maximum amounts discharged were essentially unchanged in the months of July and August but the frequency increased substantially from the project originally proposed in the Board's Biological Assessment. Discharges increased dramatically September and October for the project operated as allowed by the federal biological opinions. No discharge occurred in September and October with the project as proposed in the Board's Biological Assessment.

Total annual diversions onto the Delta Wetlands reservoir islands as proposed in the Board's Biological Assessment ranges from zero to 501 TAF, with an average of 217 TAF. Total annual diversions, as allowed by the federal biological opinions, ranges from zero to 490 TAF, with an average of 192 TAF.

Table 2. California Endangered Species Act Biological Opinion for the Delta Wetlands Project. Frequency of Diversions During the 70 year Period of Simulation and the Maximum Diversion Rates under the Biological Assessment and ESA Alternatives (from JSA 1997).

Month	Diversions (Months)		Maximum Monthly Diversion Rate (cfs)	
	BA	ESA	BA	ESA
October	22	21	3,871	3,871
November	31	29	4,000	4,000
December	39	28	3,871	3,871
January	49	45	3,871	3,600
February	40	40	4,000	4,000
March	39	39	3,871	1,144
April	5	0	76	0
May	4	0	172	0
June	8	8	1,325	296
July	34	34	130	130
August	10	10	115	115
September	10	8	4,000	4,000

Table 3. California Endangered Species Act Biological Opinion for the Delta Wetlands Project. Frequency of Discharges During the 70 year Period of Simulation and the Maximum Discharge Rates under the Biological Assessment and ESA Alternatives (from JSA 1997).

Month	Discharges (Months)		Maximum Monthly Discharge Rate (cfs)	
	BA	ESA	BA	ESA
October	0	8	0	962
November	3	5	515	743
December	6	6	3,335	1,758
January	2	2	2,388	956
February	17	5	3,871	1,742
March	16	4	3,822	1,088
April	27	20	3,450	450
May	25	29	3,136	599
June	15	17	3,056	917
July	11	28	3,741	3,741
August	4	36	3,755	3,730
September	0	15	0	1,777

Annual discharges from the Delta Wetlands reservoir islands, as proposed in the Board's Biological Assessment, ranged from zero to 378 TAF, with an average of 197 TAF. Annual discharges from the Delta Wetlands reservoir islands, as allowed by the federal biological opinions, ranged from zero to 306 TAF, with an average of 154 TAF.

Figures 4 and 5 illustrate the levels of diversions and discharges that occur with the project as allowed by the federal opinions. Figure 4 illustrates diversion data for months during which project operations actually occur, therefore, the average impacts are not just the average for the 70 years simulated. The federal opinions allowed for increased diversions averaging 908 cfs, 871 cfs, and 172 cfs in the period January through March. The peak diversion months are September through November.

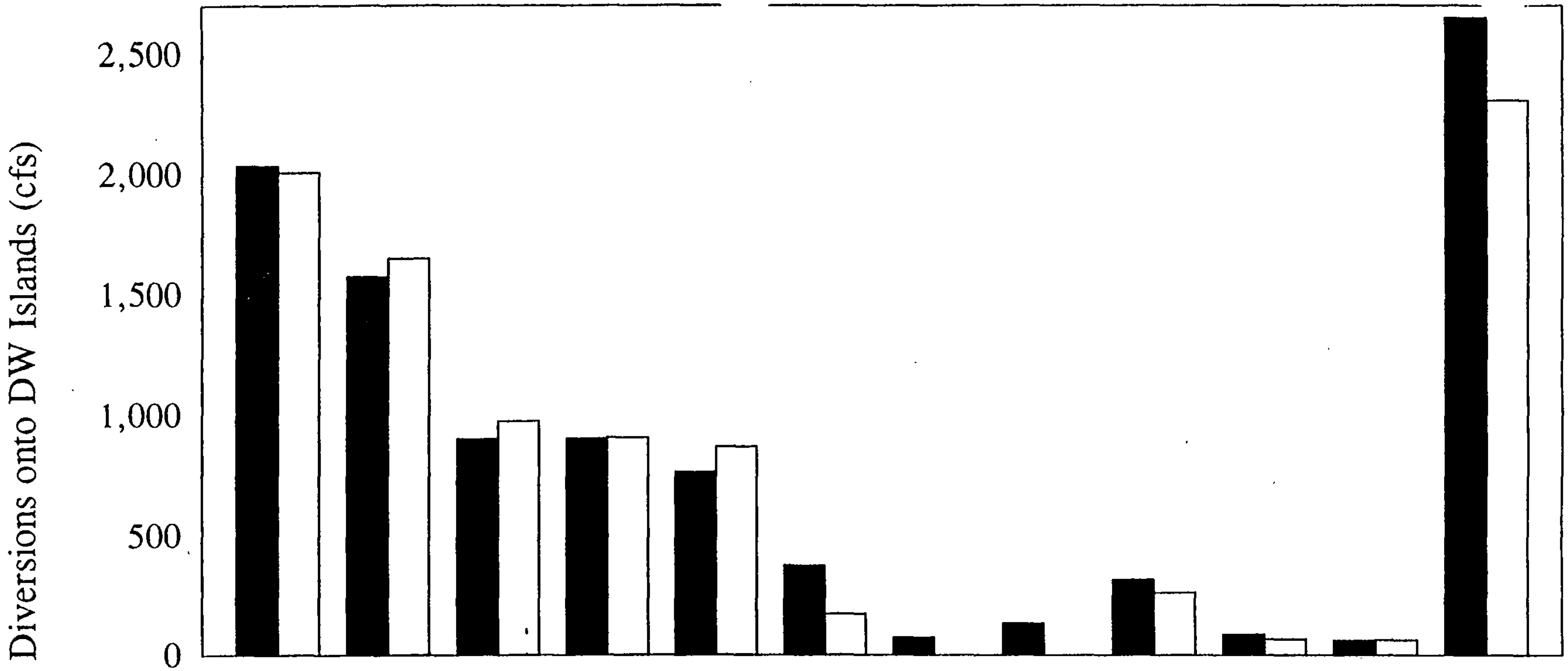
Figure 5 illustrates the level of discharges to export that occur with the project as allowed by the federal opinions. This figure illustrates data for months during which project operations actually occur, therefore, the average impacts are not for the 70 years simulated. The federal opinions allowed for increased discharges and exports averaging 1,172 cfs, 629 cfs, 1,098 cfs, and 503 cfs in the period December through March.

3. FLOW AND HYDRODYNAMIC IMPACTS

a. Winter- and Spring-run Chinook Salmon

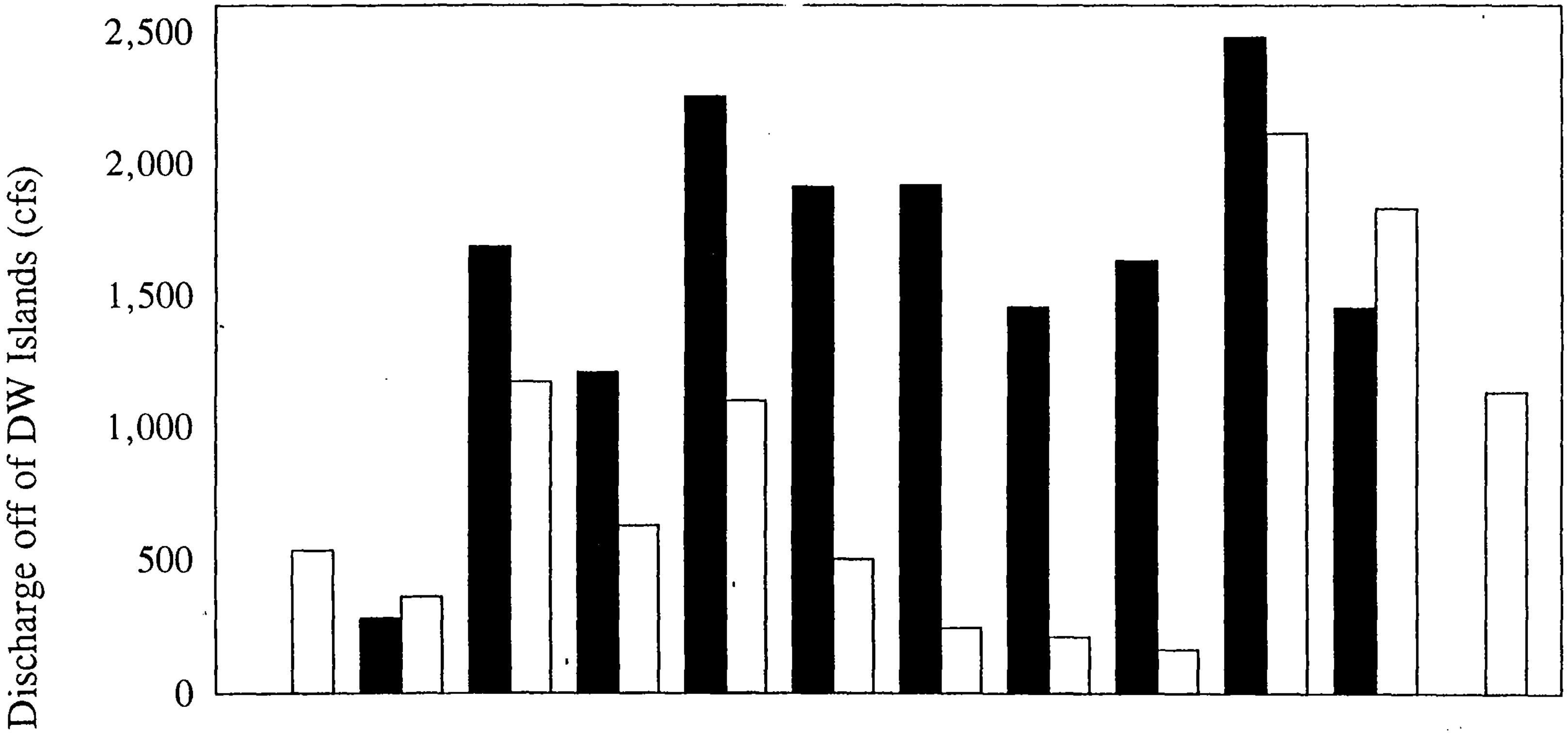
Changes in Delta hydrodynamics resulting from the diversions shown in Table 2 during the critical rearing and migration period for juvenile winter-run chinook salmon is expected to adversely affect the species. Decreases in Delta outflow, increases in export/inflow levels, and reduction in QWEST are likely to reduce the survival of rearing and emigrating juvenile fish. Existing reverse flows conditions in the lower San Joaquin, Old, and Middle rivers will be exacerbated by Delta Wetlands diversions. Natural flow cues for emigrating winter-run chinook salmon smolts and migrating adults will be adversely affected. The number and rate of juvenile winter-run chinook salmon drawn from their typical migration route into central and southern Delta waterways is also likely to increase.

Lower survival rates are expected due to the longer migration route, where fish are exposed to increased predation, higher water temperatures, unscreened diversions, poor water quality, reduced availability of food, and entrainment at the CVP/SWP export facilities. Through reduced Delta outflow and decreases in net westerly flow, Delta Wetlands diversions are expected to degrade chinook salmon rearing habitat in the Delta, degrade conditions for migrating juvenile winter-run chinook salmon. Increased diversions interfere with the natural



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sept
BA ■	2,039	1,577	902	904	767	373	75	136	316	89	64	2,651
ESA □	2,011	1,653	977	908	871	172	0	0	261	68	66	2,312

Figure 4. California Endangered Species Act Biological Opinion for the Delta Wetlands Project. Modeled diversions onto the Delta Wetlands reservoir islands for the Biological Assessment and ESA alternatives. Zero values were not factored into monthly averages. (Source: JSA)



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sept
BA ■	0	284	1,685	1,207	2,257	1,913	1,921	1,460	1,634	2,481	1,458	0
ESA □	537	365	1,172	629	1,098	503	248	214	166	2,119	1,833	1,132

Figure 5. California Endangered Species Act Biological Opinion for the Delta Wetlands Project. Modeled discharges from the Delta Wetlands reservoir islands for the Biological Assessment and ESA alternatives. Zero values were not factored into monthly averages. (Source: JSA)

smolt outmigration stimulus and seaward orientation, and generally reduce smolt survival. During dryer water year types, Delta Wetlands diversions have an even greater potential for adversely affecting channel hydrodynamics and reducing winter-run chinook salmon survival

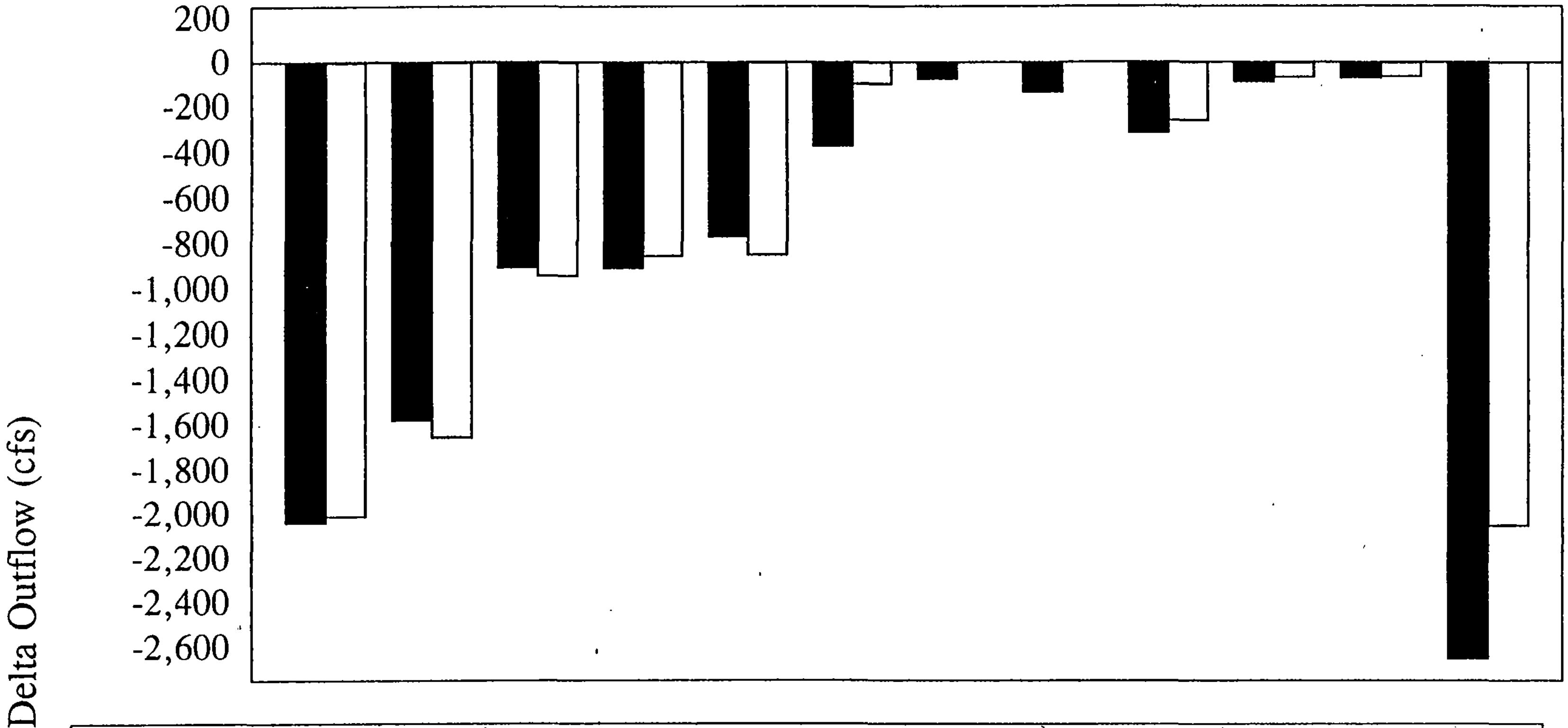
already strained by low flows, poor water quality, and high CVP/SWP entrainment rates. Delta outflow decreased by an average of 2,011 cfs, 1,653 cfs, 941 cfs, 853 cfs, 848 cfs, and 98 cfs in the October through March period (Figure 6).

Discharges from the Delta Wetlands islands would occur during critical rearing and emigration periods of the juvenile winter-run chinook salmon. These discharges to export at the CVP/SWP pumping plants will increase the reverse flows in Old and Middle rivers by up to 1,765, 1,161, 500, and 660 cfs during February, March, April, and May, respectively. These changes represent increases of 25 percent, 19 percent, 8 percent, and 10 percent compared to current conditions. Impacts from low river flows, poor water quality, and high CVP/SWP entrainment rates during drier water year types will be exacerbated by Delta Wetlands discharges for export.

b. Delta Smelt

Changes in Delta hydrodynamics resulting from the diversions shown in Table 2 during the period when adult delta smelt are migrating upstream into the Delta (December-March) and during portions of the critical spawning and rearing period for larval and juvenile delta smelt (February-June) will adversely affect the species. Decreases in Delta outflow, shifts in the position of X2, increases in export/inflow levels, and reduction in QWEST will reduce the survival of spawning, rearing, and emigrating juvenile fish. Existing reverse flows conditions in the lower San Joaquin River, Old River, and Middle River will be exacerbated by Delta Wetlands diversions. Natural transport flows and cues for larval and juvenile delta smelt and migrating adults will be adversely affected.

Lower survival rates are expected because fish are exposed to increased predation, higher water temperatures, unscreened diversions, poor water quality, reduced availability of food, and entrainment at the export facilities. Through reduced Delta outflow and decrease net westerly flow, Delta Wetlands diversions will degrade delta smelt spawning and rearing habitat in the Delta, degrade conditions for natural transport flows westward, and generally reduce delta smelt survival. During dryer water year types, Delta Wetlands diversions have an even greater potential for adversely affecting channel hydrodynamics and reducing delta smelt survival already strained by low flows, poor water quality, and high CVP/SWP entrainment rates. Discharges would occur during critical periods of adult upstream migration into the Delta for spawning, and during critical periods for larval and juvenile delta smelt.



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sept
BA ■	-2039	-1577	-902	-904	-767	-373	-75	-136	-315	-89	-72	-2651
ESA □	-2011	-1653	-941	-853	-848	-98	0	0	-261	-68	-66	-2055

Figure 6. California Endangered Species Act Biological Opinion for the Delta Wetlands Project. Average monthly changes in Delta outflow for a 70 year period. Minus values indicate outflow was decreased due to project operations. Values are shown for the BA and ESA Alternatives. Zero values were not factored into monthly averages. (Source: JSA)

Discharges for export will increase the reverse flows in Old and Middle rivers by up to 1,765, 1,161, 500, and 660 cfs during February, March, April, and May, respectively. These changes represent increases of 25, 19, 8, and 10 percent compared to current conditions. Impacts from low river flows, poor water quality, and high CVP/SWP entrainment rates during drier water year types will be exacerbated by Project discharges for export.

Indicators of adverse hydrodynamic conditions in the north and central Delta, the CDFP, showed increases of 37, 30, 42, 58, and 17 percent above baseline conditions during these same months. These adverse changes are directly linked to reduced survival of juvenile winter-run salmon and delta smelt.

Delta Wetlands will directly and indirectly reduce the survival of adult, larval and juvenile delta smelt in the Delta. Decreases in Delta outflow, higher net southerly flows in Old and Middle rivers, and decreases in QWEST adversely affect delta smelt primarily through increased entrainment into the central and south Delta waterways where they are subject to longer migration routes, increased predation, unscreened diversions, poor water quality, decreased westward flow cues, and losses at the CVP/SWP export facilities.

4. ENTRAINMENT IMPACTS

Figure 7 illustrates the results of the DeltaMOVE model for winter-run and delta smelt for the month of February. For the highest 10 years evaluated for the project as allowed by the federal opinions, winter-run chinook salmon mortality, measured by the entrainment index, increased between 4.3 and 13.2 compared with 0.5 and 15.6 for the project proposed in the Board's Biological Assessment.

For the highest 10 years evaluated for the project as allowed by the federal biological opinions, entrainment indices for larval delta smelt increased between 0.9 and 1.5 compared to 0.3 and 1.6 for the project proposed in the Board's Biological Assessment.

5. WATER QUALITY

Discharges would impact water quality by increasing water temperatures and decreasing dissolved oxygen. In April, May, and September Delta water quality conditions are often poorly suited for supporting rearing and migrating salmonids. At channel temperatures above 58 ° F, increases of more than 1° F in the channel can result in physiological sublethal stress, impair predation avoidance abilities, terminate smoltification, and cause migration delays or blockages (Boles 1982; Wedemeyer et al. 1980; and Zaugg and Adams 1972).

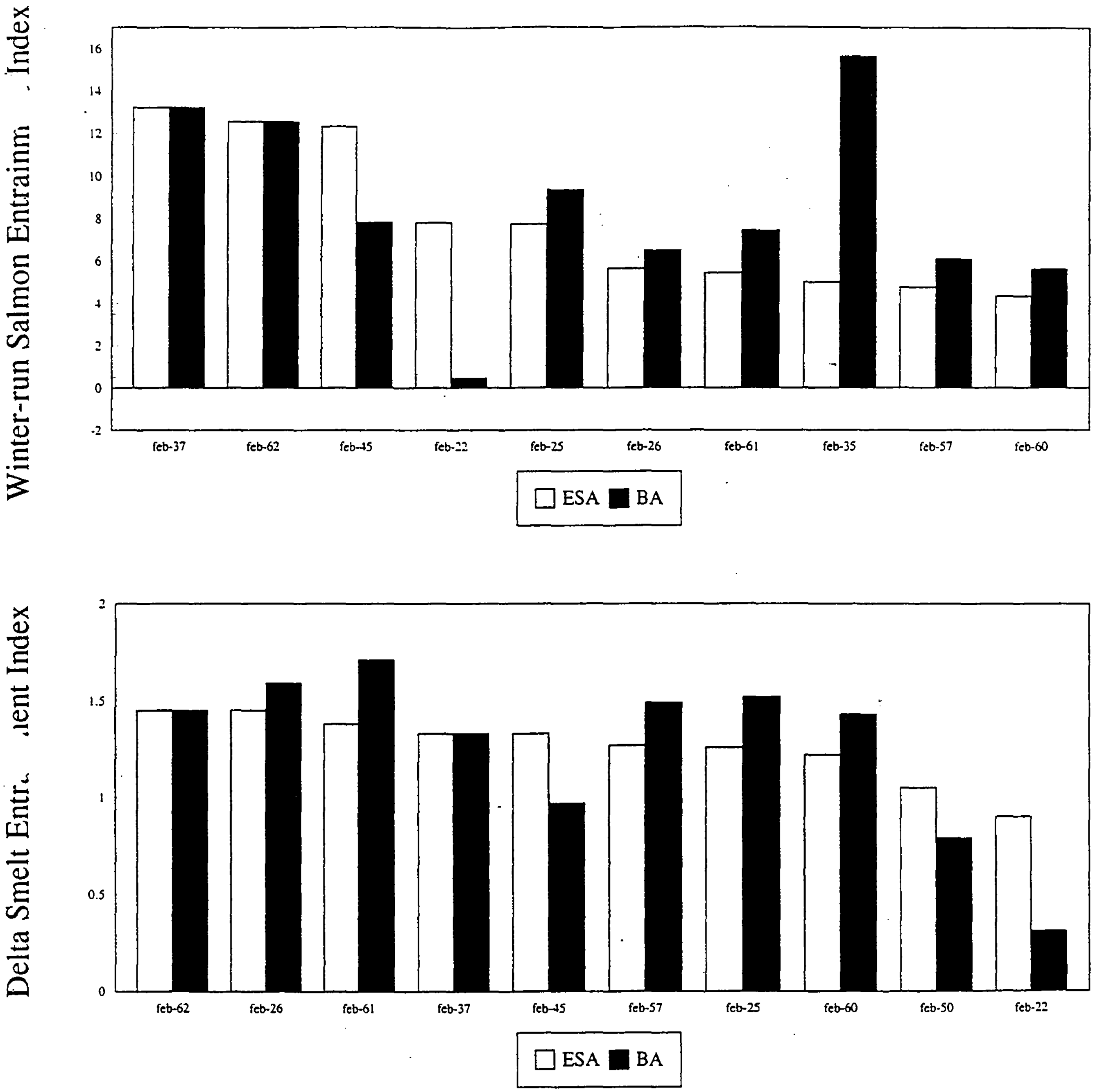


Figure 7. California Endangered Species Act Biological Opinion for the Delta Wetlands Project. February entrainment indices for winter-run Chinook salmon and delta smelt. Comparison between project proposed in the Board's BA and project under the federal biological opinions. Delta smelt indices are noted at the bottom, winter-run indices are noted at the top. Note: Scale used to present indices differs between the two species.

The extent of the risk posed by project discharges cannot be conclusively assessed without data such as reservoir island water temperatures, DO levels, and levels of biological oxygen demand, specific channel temperatures, tidal conditions, and net channel flows. Since these data were not provided during consultation, DFG biologists used the best available information to assess the impacts of the water quality criteria allowed in the federal biological opinions. Channel water impacts were estimated using calculations based on the same steady state model used by Delta Wetlands in support of its criteria. Modeling suggested that reservoir releases of as little as 900 cfs from a reservoir island when channel flow is about 3,800 cfs can overwhelm a channel's cross section and increase water temperatures by more than 2° F when reservoir temperature differences are as low as 10 ° F above the channel temperature.

In a recent review of thermal conditions in the Delta, Winternitz and Wadsworth (1997) summarized mean monthly water temperatures for 1996 at various sites within the Delta. The data demonstrate that existing conditions for winter-run chinook salmon in the Delta can already be thermally stressful. Data collected at five locations showed average monthly temperatures as high as 62 ° F in April and 67 ° F in May. June temperatures ranged from 67 to 74 ° F. In September, temperatures ranged from 68 to 74 ° F. In October, temperatures ranged from 63 to 68 ° F. The January 27, 1997 Final Operations Criteria (Attachment 2) included in the federal opinions may allow increases above these levels that would cause significant increased take of winter-run chinook salmon.

VII. ANALYSIS OF FEDERAL BIOLOGICAL OPINIONS

As discussed in Section III, CESA encourages coordination between State and federal agencies for consultations concerning projects that may affect species listed under ESA as well as CESA. The DFG has worked closely with the federal wildlife agencies. Through mid-1996, consultation between the DFG and the federal fish and wildlife agencies was cooperative and simultaneous. All three agencies jointly developed an "Aquatic Resources Management Plan" using the best scientific information available and the analytical tools in the Biological Assessment for the project. This plan formed the basis of discussions with Delta Wetlands and ultimately formed the foundation of the USFWS draft biological opinion. In mid-1996, consultation meetings began to focus on direct discussions between Delta Wetlands and the USFWS and NMFS. The DFG continued to attend those meetings, but the DFG's concerns were not directly discussed or otherwise addressed. Subsequently, pursuant to discussions between the federal agencies and Delta Wetlands, significant measures in the plan were modified or deleted. Elimination or modification of those measures with no alternative, equivalent protection, may result in inadequate protection of delta smelt or winter-run chinook salmon and the Project inadequately addressing take of delta smelt and winter-run.

At various times throughout the DFG's consideration of the Delta Wetlands Project, representatives from Natural Resources Consulting Scientists, HYA Consulting Engineers, and Delta Wetlands's legal representatives, the Ellison and Schneider Law Firm, as well as various technical and biological consultants, attended consultation meetings to discuss the effects of the Delta Wetlands Project on listed fish species and their habitat.

CESA requires the DFG to adopt a federal biological opinion as its written findings for a state lead agency's proposed project if it is possible to do so and would be consistent with CESA. The DFG here adopts, in part, the federal biological opinions prepared by the USFWS and NMFS for the Delta Wetlands Project. The DFG has determined that the project, if implemented according to the January 27, 1997 final operating criteria and federal biological opinions, would not jeopardize the continued existence of winter-run chinook salmon and delta smelt. The DFG hereby adopts the federal biological opinions insofar as they address jeopardy to winter-run chinook salmon and delta smelt. As further explained below, however, the DFG has determined that the federal biological opinions may not adequately minimize the adverse impacts of the incidental taking of winter-run chinook salmon and delta smelt, as provided in Section 2091. Consequently the DFG declines to adopt the federal biological opinions insofar as they adequately address the incidental taking of the winter-run chinook salmon; to do so would not be consistent with CESA. Specifically, the DFG's adoption of the federal biological opinions as its written findings regarding the incidental taking of winter-run chinook salmon and delta smelt for its consultation with the Board concerning the Delta Wetlands Project would conflict with Fish and Game Code §2052, 2055, and 2091. In order to adequately address take the DFG, therefore, adopts the final operating criteria dated January 27, 1997 which are contained in the federal biological opinions along with additional Reasonable and Prudent Measures contained in this Biological Opinion as necessary and appropriate to minimize the adverse effects of take of winter-run chinook salmon and delta smelt.

The federal biological opinions allow significant increased diversions and associated impacts for winter-run chinook salmon during the peak months of February and March when between 40 and 50 percent of the year's production can be located in the Delta and are vulnerable to project impacts. Impacts, using an indicator of adverse hydraulic conditions in the central Delta, may increase by up to 80 percent.

February and March are also critical months for delta smelt. Adults are entering the Delta for spawning and larval smelt are present in significant numbers. Ten and 25 percent of the total population of delta smelt are present in the Delta during those months respectively. Impacts, measured as changes in entrainment of larvae into Delta diversions associated with the Delta Wetlands Project, may increase by up to 75 percent.

During initial discussions among the State and federal fish and wildlife agencies, agency biologists agreed that a common goal was to ensure that significantly increased diversion impacts should be avoided in the February and March period. To achieve that goal, the USFWS recommended several operations criteria that were agreed to by Delta Wetlands and included in the Final Operations Criteria dated January 27, 1997. Unfortunately, the expected benefits may not be realized. Restrictions are so limited in duration (15 days) that in a given month, protection will be lost for that month when project diversions are allowed to immediately increase diversions when the 15 days have expired.

In addition, the federal opinions provide only minimal protection because the percentages allowed in those opinions are too high and, when the FMWT index is >239 project operations those limits can only be invoked for 15 of 120 days; the rest of the time there is no additional limit and, therefore, no protection. The limited number of days may provide little benefit in most years and implementation could be problematic. Agencies will be reluctant to invoke the limits early in the season and, therefore, if diversion opportunities do not occur in February or March no reductions will occur and project impacts will not be reduced.

Modeled benefits indicate that the measures were not successful in reducing impacts to the level necessary and appropriate to minimize the adverse impact of incidental taking. Modeling, furthermore, overestimated the benefits suggested by the modeling output since the results are derived from a monthly model which applies the measure for an entire month instead of the actual 15 days.

Project operations, allowed by the federal biological opinions during February and March, account for much of the remaining adverse impacts associated with the incidental take of winter-run chinook salmon and delta smelt.

The federal opinions contain only a small amount of environmental water. The expectation was that the fraction of water that was not to be exported would provide benefits at certain times and would help offset take of listed fish due to adverse hydraulic changes and flow patterns in Old and Middle rivers. Unfortunately, in 4 of 5 years the volume of discharges from the habitat islands will be nearly equal to the volume intended to reduce incidental take. Therefore, in most years, little or no water will be released from the reservoir islands to add to Delta outflow or contribute to offsetting adverse hydraulic conditions in order to reduce take.

The adverse impacts of take in October through June may not be adequately minimized with the avoidance or mitigation measures included in the project as allowed by the federal biological opinions.

DIFFERENCES BETWEEN FEDERAL OPINIONS AND DFG'S OPINION

Differences between the federal opinions and the DFG's CESA biological opinion include:

- The limits associated with higher delta smelt indices (>239) offer no significant reduction in the take of delta smelt and offer little or no take reduction for winter-run chinook salmon. While measures described in the federal opinions which are tied to lower delta smelt indices (<239) will reduce impacts below levels that were calculated by JSA for the federal biological opinions, effective protection will occur in only 1 in 5 years if the pattern established over the last 20 years is repeated (Attachment 6). Furthermore, since no relationship has been established between a given year's abundance of larval and juvenile delta smelt and a previous year's FMWT index, this increased level of protection will only rarely be provided when it is needed. The DFG, therefore, concludes that additional specific operational criteria during March are necessary and appropriate to minimize the adverse impacts of incidental taking.

- Measures described in the federal biological opinions for environmental water during discharges are inadequate to offset the unavoidable impacts associated with project operation. Furthermore, provisions to credit drainage from the habitat islands, reduces the value of releasing water from reservoir islands for environmental purposes to benefit listed fish. The resulting releases required in the federal biological opinions only infrequently result in benefits that can offset other project impacts. The DFG, therefore, concludes that additional provisions for environmental water are necessary and appropriate to minimize the adverse impacts of incidental taking.

- The federal biological opinions do not include adequate compensation for impacts to delta smelt rearing habitat caused by upstream shifts in X2 related to Project operations. The DFG, therefore, concludes that providing compensation through the restoration of rearing habitat is necessary and appropriate to minimize the adverse impacts of incidental take.

VIII. DFG FINDINGS

The DFG's CESA Biological Opinion is based, in part, on the following information: the Corps' and Board's June 21, 1995, Biological Assessment (Corps and Board 1995a); the draft Environmental Impact Report/Environmental Impact Statement for the Delta Wetlands Project (Corps and Board 1995b); numerous meetings between the DFG, USFWS, NMFS, Board, Corps, Delta Wetlands, and JSA; supplemental information and analyses provided to meeting participants; computer model simulations; existing literature on the life history of Listed Species and potential candidate species; and, personal communications with DFG species and water quality experts.

Pursuant to Fish & Game Code §2090, DFG finds and determines as follows:

1. Based on the best available scientific information, the DFG finds that the Project described in this Biological Opinion, including the Habitat Management Plan, and the measures in the attached federal biological opinions, would not jeopardize the continued

existence of the greater sandhill crane, Swainson's hawk, or other terrestrial Listed Species or result in the destruction or adverse modification of habitat essential to the continued existence of these species. This finding is specifically contingent on the Board requiring full implementation of and adherence to all provisions of the Habitat Management Plan, as proposed, as a condition of Delta Wetlands' water right permit.

2. Based on the best available scientific information, the DFG finds that the Project, as described in this biological opinion and the measures in the attached federal biological opinions would not jeopardize the continued existence of the winter-run chinook salmon and delta smelt and would not result in the destruction or adverse modification of habitat essential to the continued existence of these species.

3. Based on the best available scientific information, the DFG finds that the Project, as described in this Biological Opinion, along with the measures in the attached federal biological opinions, would result in the incidental take of individuals of the Listed Species such as giant garter snake, yellow-billed cuckoo, black rail, Swainson's hawk, greater sandhill crane, winter-run chinook salmon, and delta smelt. The adverse impacts of the taking of these species incidental to the Project will be minimized if the measures specified in Section IX-A are fully implemented and adhered to.

4. Based on the best available scientific information, the DFG finds that the protection, enhancement, and long-term management of suitable habitat for the Listed Species is essential to offset the Project's adverse impacts on the Listed Species.

As modified with the following Reasonable and Prudent Measures, the Delta Wetlands Project would not interfere with or foreclose opportunities to restore the ecological health of the estuary currently being pursued by the CALFED Bay-Delta Program.

The adverse impacts of the project on listed wildlife in the service areas of the SWP and CVP such as the San Joaquin antelope squirrel, giant kangaroo rat, Morro Bay kangaroo rat, Tipton kangaroo rat, and San Joaquin kit fox, would be reduced by implementing the DFG's recommendations in Section XIII-C.

IX. REASONABLE AND PRUDENT MEASURES

As described in Section III, where the DFG has made an incidental take finding, it must determine and specify to the State lead agency Reasonable and Prudent Measures that are necessary and appropriate to minimize the adverse impacts of the incidental taking.

If the project complies with the applicable measures specified by the DFG, taking that is incidental to the project is not prohibited by CESA. If the project does not comply with the

DFG's measures, take incidental to the project is prohibited by Fish & Game Code §2080.

Pursuant to Section 2093, the DFG has consulted with the Board and consistent with Section 2094, with the project proponent. Pursuant to Section 2091 the DFG has determined that the RPMs are necessary and appropriate to minimize the adverse impacts of incidental taking. The Board must require Delta Wetland to comply with the requirement of the RPMs.

It is the policy of the DFG to maintain the integrity of the December 14, 1994 Accord. Operations under the Accord represent the baseline below which jeopardy exists for the delta smelt and winter-run chinook salmon. Given the scientific and policy consensus on maintaining and improving biological protection during the February through June period, it is necessary to avoid or minimize any additional adverse impacts of take during those periods rather than attempt to mitigate for additional adverse impacts on the Listed Species. By increasing exports, the proposed Delta Wetlands Project could also undermine the biological protections for the November through January period contained in the 1995 WQCP, which assume existing diversion capacity. This period is important for yearling spring-run chinook salmon.

Pursuant to Fish and Game Code §2091, the DFG determines and specifies the following Reasonable and Prudent Measures for the Project that are necessary and appropriate to minimize the adverse impacts of the incidental taking of Listed Species. Any taking that is in compliance with the measures prescribed in this Biological Opinion is not prohibited by CESA.

The following describes the DFG's Reasonable and Prudent Measures for the Delta Wetlands Project and outlines how the project shall be managed to minimize the adverse impacts of the incidental taking of Listed Species. The Reasonable and Prudent Measures (RPMs) include:

- A measure that reduces entrainment of listed fish and reduces loss of fish due to the adverse effects of hydrodynamic changes on listed fish during project filling and during project discharges and rediversion at the State and Federal water export facilities.

- A measure that reduces take of listed fish by improving hydrodynamic conditions during periods critical to listed fish in the Estuary in order to offset unavoidable impacts during other periods of operation.

- Measures to ensure take of listed fish due to impacts on aquatic habitat are minimized.

- A measure related to fish screens to minimize take of listed fish.

- Measures that reduce take of terrestrial listed species by managing lands on Boudin Island and Holland Tract (Figure 8).

The RPMs focus on actions that directly avoid or reduce project impacts that result in take of winter-run chinook salmon and delta smelt. Project operations are modified to reduce take of listed fishery resources associated with water exports at key times to help offset some of the remaining, unavoidable losses that occur during project operations.

The RPMs can be implemented in a manner consistent with the intended purpose of the action and can be implemented consistent with the scope of the Board's legal authority and jurisdiction. In the DFG's view, the RPMs are necessary and appropriate to minimize the adverse impacts of incidental taking and will not require significant project modifications.

The RPMs are capable of being accomplished in a successful manner within a reasonable period of time, taking into account economic, environmental, social, and technological factors. Unless modified by the RPMs, the project will continue to cause significant adverse impacts to both delta smelt and winter-run. Hydrodynamic changes associated with the project, as proposed and allowed by the federal biological opinions, will degrade important ecosystem functions and Delta outflow, QWEST, and other important indicators of the environmental health of the Delta's aquatic ecosystem will be reduced.

The Accord set the new baseline from which the CALFED Bay-Delta Program could move forward in restoring the health of the estuary. The RPMs are protective of that baseline and the Delta's aquatic Listed Species and are consistent with the new paradigm that began with the 1994 Water Accord.

Delta Wetlands shall implement the following measures in addition to those listed in the final operations criteria dated January 27, 1997. In any instance where two or more conditions apply, the condition that is the most restrictive on Delta Wetlands Project operation shall control.

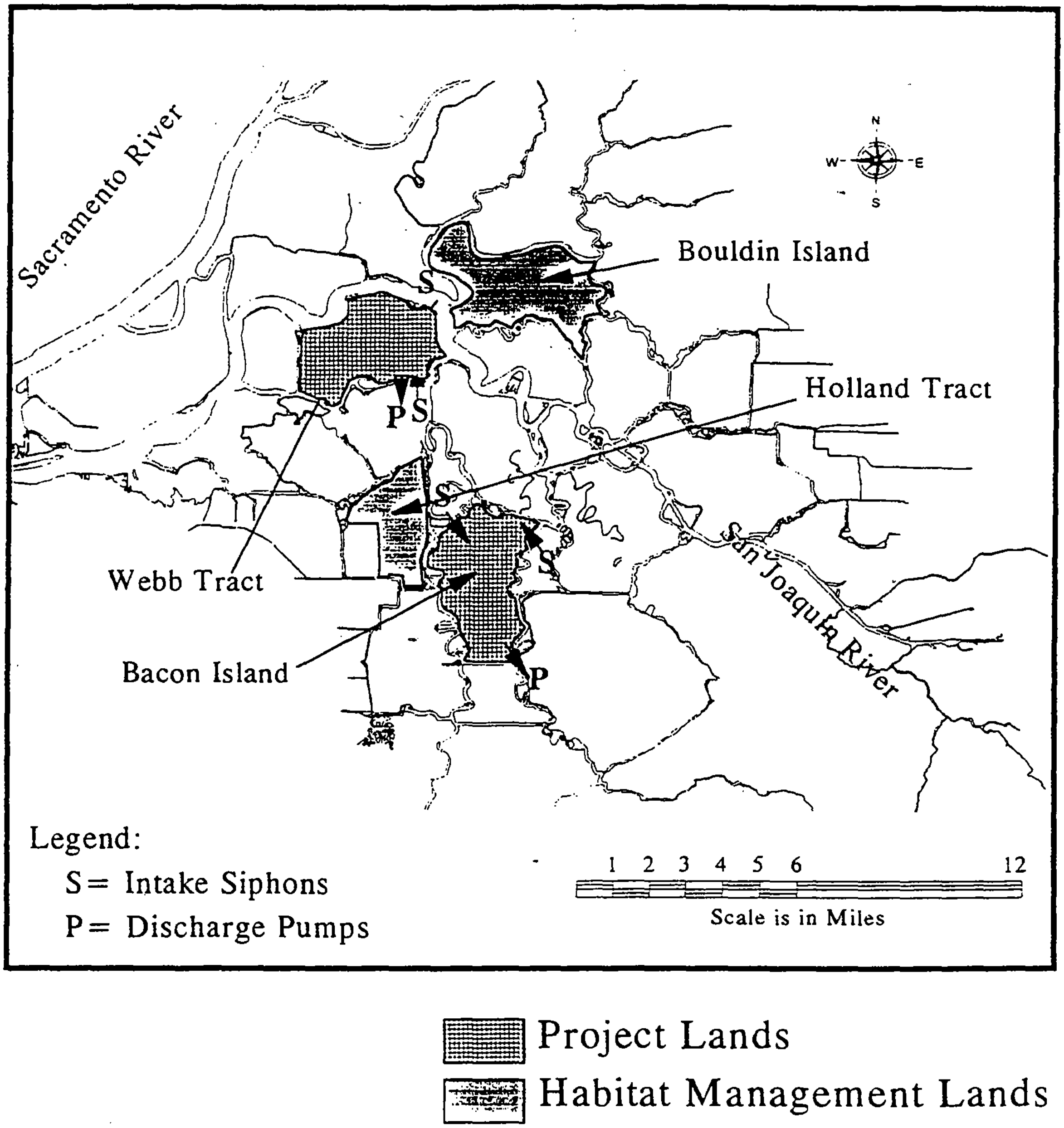


Figure 8. California Endangered Species Act Biological Opinion for the Delta Wetlands Project. Management Area.

A. REASONABLE AND PRUDENT MEASURES

Following are the DFG's Reasonable and Prudent Measures. They are comprised of measures that address both terrestrial and aquatic species and are necessary to minimize the adverse impacts of take of the Listed Species. In the absence of these measures unacceptably high levels of take would occur.

1.0 **March Restrictions:** This measure is necessary to minimize the adverse impacts of take of winter-run and delta smelt.

1.1 Delta Wetlands diversions to storage in the month of March shall be limited to a maximum diversion rate of 550 cfs unless the previous day's QWEST is positive and is calculated to remain positive during the current day's Delta Wetlands diversions to storage.

1.2 Diversions to storage during March shall occur through screened diversions in a manner that reduces the hydraulic effects in adjacent channels by spreading diversions among the project's intake siphons rather than maximizing diversions through the minimum number of siphons.

2.0 **Environmental Water Fund:** This measure is necessary to minimize the adverse impacts of take of winter-run and delta smelt.

2.1 An "Environmental Water Fund" (Fund) shall be established by Delta Wetlands. The Fund shall exclusively benefit and be controlled by the DFG. At the DFG's discretion, the Fund may be used to buy water each year, saved for use in drier years, or used for other environmental enhancement opportunities.

2.2 Funding shall be based on the amount of "Net Environmental Water" calculated using the criteria in RPM 2.4. Funds shall be provided by Delta Wetlands to the DFG on or before July 31 in any year in which there is Net Environmental Water. Concurrent with providing the funding, Delta Wetlands shall provide the DFG with a final report which displays the calculations used to determine the amount of Net Environmental Water.

2.3 Funds shall be provided by Delta Wetlands to the DFG at the rate of $50 per acre-foot in January 1998 dollars, adjusted for inflation as specified in this CESA Biological Opinion. The DFG shall deposit any money received from this RPM into the Fund.

2.4 The amount of "Net Environmental Water" that is calculated for the purpose of determining the amount of funds that Delta Wetlands provides the DFG for deposit into the Fund shall be calculated as follows:

2.4.1 A calculation shall be made of the volume of water diverted by Delta Wetlands that is equal to five (5) percent of all diversions to storage that occur from October 1 through March 31.

2.4.2 One-half of the net habitat island discharges shall be credited against the calculation in 2.4.1. The calculation of net habitat island discharges to determine the credit shall be made by subtracting total diversions onto the habitat islands from total discharges off of the habitat islands in the February through June period. Attachment 6 contains a table to illustrate the method.

2.4.3 Net Environmental Water shall be calculated by subtracting the amount of environmental water provided by Delta Wetlands' Discharge Measure 6 of the Project's January 27, 1997 Final Operations Criteria (FOC) and used by the DFG from the total amount of Environmental Water calculated in 2.4.1 and 2.4.2. Any positive value shall be used to calculate the amount of Delta Wetlands' funding obligation as described in 2.2 and 2.3.

2.4.4 The "Net Habitat Island Credit (HIC)" used in Delta Wetlands' Discharge Measure 6 of the Project's FOC shall be calculated by Delta Wetlands on a real-time basis in the February through June period. Delta Wetlands shall keep daily accounting of cumulative discharges off of and diversions onto the habitat islands as well as a cumulative total of discharges from the reservoir islands for export. A calculation shall be made daily of the amount of environmental water provided and available under Discharge Measure 6 of the FOC. This daily calculation shall be provided to the DFG within 48 hours.

2.4.5 The net habitat island discharges and net HIC used to define the potential amount of habitat island discharges that may be credited against the environmental water in this RPM and the environmental water in Discharge Measure 6 of the Project's January 27, 1997 FOC respectively shall be based on the actual measurement of the volume of water diverted and discharged at all habitat island intakes and drains. The final methodology for making and documenting these measurements shall be developed by Delta Wetlands after the issuance of the water rights permit and must be accepted, in writing, by the DFG prior to project operations. In the event the required measurements are not made, the net habitat island discharges and HIC shall be based on the water budget for the habitat islands contained in Table A1-8 of Appendix A-1 of the project's DEIR/EIR (included in Attachment 6 of this CESA Biological Opinion).

2.5 The Net Environmental Water, calculated in 2.4.1, 2.4.2, and 2.4.3 for the purpose of determining the amount of the funding obligation, combined with the environmental water provisions of the January 27, 1997 FOC shall not exceed 20 TAF in any water year.

2.6 Delta Wetlands shall, by the end of each March, provide DFG a report on the estimated amount of environmental water calculated for the year to date.

2.7 Delta Wetlands shall provide an initial installment of $300,000 for the Fund. That installment shall be provided to the DFG prior to the commencement of diversions to storage.

3.0 **Habitat Management Lands:** This measure is necessary to minimize the adverse impacts of take of Swainson's hawk and greater sandhill crane.

3.1 Delta Wetlands shall acquire, preserve, and enhance the Habitat Management (HM) lands as expressly provided for in the HMP as detailed in Attachment 3 of this CESA Biological Opinion. Delta Wetlands shall conduct the protection and enhancement activities with respect to the Swainson's hawk and greater sandhill crane described in the HMP as detailed in Attachment 3 of this CESA Biological Opinion and shall undertake the activities and management measures described in this paragraph.

3.2 Delta Wetlands shall acquire approximately 8,957 acres of HM lands on Bouldin Island and Holland Tract and, prior to project operations, transfer a non-assignable conservation easement interest in such lands to the DFG, by instruments substantially similar to the form of the conservation easements in Attachment 5 of this CESA Biological Opinion and mutually agreeable to Delta Wetlands and the DFG. It is the agreement and intention of the parties that Delta Wetlands shall under all circumstances, consistent with the requirements of this CESA Biological Opinion, have full management responsibility for HM lands and that the conservation easement conveyed with respect to such lands are in the nature of a restrictive covenant as authorized by section 815.1 of the California Civil Code.

3.3 With respect to any interest in real property transferred to the Department, all title documentation shall be approved as to form prior to acceptance by either the Fish and Game Commission or the DFG acting through the Wildlife Conservation Board. No approval shall be final until the lands or interests are accepted as to form by the Department of General Services, but, to the extent allowed by law, any delay in processing or acceptance by any state agency shall not give rise to or contribute to any breach by Delta Wetlands.

3.4 Delta Wetlands shall prohibit widespread use of rodenticide on all HM lands and Project lands. Squirrel and rodent control efforts shall be focused only in localized areas where needed to avoid public health problems (e.g., bubonic plague transmission in high-use recreation areas) or to prevent damage to building foundations, roadways, exterior levees, and other facilities. Control efforts shall emphasize non-toxic means (e.g., trapping); where localized rodenticide use is required, the poison least toxic to nontarget organisms shall be selected. All rodenticide use shall be conducted under the county permit system and all actual use shall be reported to the DFG on a quarterly basis. To the extent reasonably allowed under the circumstances, Delta Wetlands shall provide advance notice to the DFG of any use by Delta Wetlands of rodenticide on HM lands.

3.5 If, in the judgement of the Director of the DFG, the Plan or plan revisions, or a portion of the Plan or plan revisions, would result in adverse effects to the Swainson's hawk or greater sandhill crane not contemplated by the Biological Opinion, such Plan or plan revisions, or portion thereof, shall not be implemented without the approval of the DFG. If the Plan or plan revisions identify management measures that are inconsistent with management measures required by this CESA Biological Opinion, or conservation easements previously attached to HM lands and Project Lands, Delta Wetlands and the DFG may agree upon revisions or amendments to such instruments, and any revision or amendment to a conservation easement shall be recorded in the same manner as the conservation easement.

3.6 For the life of the Project, Delta Wetlands shall provide annually to the DFG upon issuance of the water right permit, the sum of SEVENTY-FIVE THOUSAND DOLLARS ($75,000.00) in January 1998 dollars adjusted for inflation as specified in this CESA Biological Opinion. Payments shall be made thereafter on or before July 1 of each subsequent year as a permanent support fund ("fund") which will be used by the DFG to monitor Delta Wetlands' management of the HM lands and Project Lands acquired and managed in accordance with this CESA Biological Opinion. A more detailed budget breakdown and explanation of the activities to be performed by the DFG are included in this Biological Opinion (Attachment 6).

4.0 **Aquatic Habitat Development Measures:** This measure is necessary to minimize the adverse impacts of take of delta smelt.

Delta Wetlands shall mitigate impacts on shallow shoal habitat in the delta smelt's rearing areas to offset impacts of moving X2 upstream in the February through June period. Funds in the Aquatic Habitat Restoration Fund (RPM 2.0) shall be used to restore and maintain at least 100 acres of shallow shoal/low elevation tidal wetland in the eastern Suisun Marsh and Bay or western Delta. The habitat acquired with Aquatic Habitat Restoration Fund money may be purchased from a mitigation bank or acquired and managed in an alternative ownership and management arrangement acceptable to DFG. DFG may not take fee title to such mitigation habitat.

5.0 **HMP Prerequisite for Project Operation:** This measure is necessary to minimize the adverse impacts of take of Swainson's hawk and greater sandhill crane.

In no case shall water be stored on Project Lands for purposes other than wetland habitat management prior to completion of the initial habitat island construction called for in the HMP. Furthermore, in no case shall water be stored on Project Lands for purposes other than wetland habitat management if the actions called for in the HMP are not being implemented.

6.0 **Aquatic Species Monitoring:** This measure is necessary to minimize the adverse impacts of take of winter-run and delta smelt.

6.1 All field sampling activity shall be performed in accordance with terms and conditions of appropriate DFG Scientific Collection Permits issued to personnel participating in project monitoring.

6.2 Monitoring programs shall be developed by the USFWS, NMFS, DFG, and Delta Wetlands as set forth in the Final Operations Criteria and Fish Monitoring Program dated January 27, 1997 (Attachment 2).

6.3 The designated representative of the DFG shall be notified within 24 hours *via* telephone, e-mail, and/or fax in the event that one (1) winter-run chinook salmon smolt (identified by daily size intervals), delta smelt, or splittail is collected during monitoring. Until further notice, the designated representative of the DFG is Mr. Frank Wernette with the Bay-Delta and Special Water Projects Division. Mr. Wernette may be reached by telephone at (209) 948-7800, e-mail fwernett@delta.dfg.ca.gov, and by facsimile at (209) 946-6355. Mr. Wernette's mailing address is 4001 N. Wilson Way, Stockton, CA 95205.

6.4 A weekly status report, presenting preliminary results of field fisheries collections and experimental investigations shall be prepared and distributed to all designated agency representatives throughout the duration of the field sampling program.

6.5 DFG personnel shall be permitted to observe all field and lab investigations associated with any monitoring project. All scientific data collected as part of the real time monitoring shall be provided, upon request, for independent review and analysis by the DFG.

7.0 **Management Measures and Monitoring of Greater Sandhill Cranes and Swainson's Hawks:** This measure is necessary to minimize the adverse impacts of take of Swainson's hawk and greater sandhill crane.

7.1 Monitoring of greater sandhill cranes and Swainson's hawks shall be conducted beginning prior to initial construction of the Habitat Management lands on Bouldin Island and Holland Tract and annually for five years after initial habitat island construction is completed. A specific monitoring plan shall be developed for these species consistent with the provisions of the HMP. If any inconsistencies between the following measures and the HMP exist, then the HMP shall control. Features of the plan shall include but not be limited to:

- Monitoring during September through March for greater sandhill cranes and March through September for the Swainson's hawk
- Numbers of birds seen
- Activity/behavior
- Habitat being used
- Mapping of roosting areas or nesting sites

7.2 To prevent disruption by Project construction and maintenance and reduce the potential for adverse impacts to Swainson's hawks during the breeding season, Delta Wetlands shall complete pre-construction and pre-maintenance surveys of potential nest trees within one-half mile of any propose work site.

7.3 Results of preconstruction surveys shall be submitted to the DFG within two weeks of their completion. A letter report and map addressing essential information (e.g., number of Swainson's hawks located in the Project area, their status, other identified activities) also shall be submitted. If no activity is identified during preconstruction surveys, a brief letter documenting this fact shall be submitted to the DFG.

7.4 Delta Wetlands shall prohibit widespread use of rodenticide on all HM lands and all Delta Wetlands Project lands. Rodent control efforts shall be focused only in localized areas where needed to prevent damage to exterior levees. Control efforts shall emphasize non-toxic means (e.g.. trapping): where localized rodenticide use is required, the poison least toxic to nontarget organisms shall be selected. All rodenticide use shall be conducted under the count, permit system and all actual use shall be reported to the DFG on a quarterly basis. To the extent reasonably allowed under the circumstances Delta Wetlands shall provide advance notice to the DFG of the use of rodenticide on HM lands.

7.5 Environmental monitors shall be on-site regularly during construction to monitor mitigation implementation. Environmental monitors shall regularly check to ensure that mitigation measures are being adhered to and that exclusion zones and fences are operative. The supervisor shall immediately contact the on-site biologist or environmental monitor regarding any incidents of non-compliance, who shall notify the DFG within 24 hours, followed by written notification within 3 working days, of any such incident.

7.6 In addition to described preconstruction and construction mitigation measures, Delta Wetlands Project shall implement guidelines adopted in its conceptual recreation plan to avoid impacts on listed species from recreational use and facility construction These measures include the following: conduct preconstruction surveys of potential and occupied habitat and undertake appropriate precautions during facility construction as outlined above, avoid constructing recreation facilities and trails within a 0.5 mile radius of an active Swainson's hawk nest.

8.0 Listed Plants:

In the event listed plants are found on the project islands the following measures shall be implemented prior to and during any future construction activities. If the construction is considered by the DFG to be minor, the DFG may waive the requirements of this RPM. If any inconsistencies between the following measures and the HMP exist, then the HMP shall control.

8.1 Floristic studies of the areas likely to be affected by the project shall be conducted according to the DFG's guidelines. These studies shall be carried out in the spring and summer when any rare plant species that may be present are likely to be evident and identifiable (see guidelines 4a and 4b). The Suisun Marsh aster, Rose mallow and Mason's lilaeopsis are often not identifiable before June.

8.2 If listed plant species are found on the project site, redesigning the project to avoid or minimize the impacts on these species shall be attempted. If impacts are unavoidable, a mitigation and monitoring plan which follows the enclosed format shall be developed. Mitigation options may involve restoring the rare plant population and associated habitat on- or off-site and providing for the long-term protection of the mitigation site.

8.3 All levee projects must be preceded by preparation and adoption of specific plans detailing the project impacts, mitigation and compensation measures that will reduce project impacts to result in no net loss of riparian, fishery, or wildlife habitat as per Sections 8610 and 8611 of the State Water Code. Monitoring plans to evaluate mitigation/compensation must be prepared and shall include remedial actions necessary if success criteria are not achieved. Annual reports shall be provided to the DFG.

9.0 **Yellow-billed Cuckoo:** This measure is necessary to minimize the adverse impacts of take of yellow-billed cuckoo, at such time as the yellow-billed cuckoo may be discovered on the project islands. The following measures shall be implemented prior to and during any future construction activities. If the construction is considered by the DFG to be minor, the DFG may waive the requirements of this RPM.

9.1 Tape recorded yellow-billed cuckoo (YBC) calls that successfully elicit vocalization by the YBC shall be used to survey construction sites and a 200 meter buffer prior to and during the nesting and rearing period of the YBC from June 1 - August 15. A minimum of 15 minutes of effort shall occur at each survey station. Survey stations shall not be located greater than 100 meters apart. Surveys shall be conducted twice weekly between 0700 and 1000 hours, at least 3 days apart, prior to any construction activities scheduled between June 1 and August 15. All surveys should extend 200 meters beyond the distal portions of the project site.

9.2 If survey results are positive, construction shall be avoided within 200 meters of nests, if located, or within 200 meters of survey stations where positive results were obtained until after August 15.

9.3 No construction is allowed between June 1 and July 20 in riparian areas exceeding 90 meters in width.

9.4 The DFG will concur with negative survey results under the following conditions:

9.4.1 At least 2 weeks of negative results from June 7 through 21 at dense riparian sites of 15 to 30 meters in width.

9.4.2 Riparian sites exceeding 30 meters, but less than 90 meters in width shall require negative results during the three survey weeks immediately preceding any construction proposed between July 1 and August 15.

9.4.3 Riparian areas exceeding 90 meters in width shall be surveyed weekly between June 7 and July 20. Construction scheduled after July 20 may proceed if all survey results are negative.

9.4.4 Sparse riparian areas less than 30 meters in width do not require surveys unless they are located within 200 meters of dense riparian habitat exceeding 30 meters in width.

10.0 Giant Garter Snake: This measure is necessary to minimize the adverse impacts of take of giant garter snake, at such time as the giant garter snake may be discovered on the project islands. The following measures shall be implemented prior to and during any future construction activities. If the construction is considered by the DFG to be minor, the DFG may waive the requirements of this RPM. During routine operation and maintenance activities the DFG may prescribe these measures unless the DFG concludes that those activities are minor and unlikely to affect the giant garter snake.

10.1 Localized construction and related impacts needed to reroute drainwater should be conducted in a manner that avoids take of any giant garter snakes present within the construction footprint. To avoid such take, all construction within suitable habitat should be conducted during the snake's active season (May 1 to October 1) rather than during the snake's winter dormancy period (October 1 to May 1) when giant garter snakes are wary and highly vagile during the active phase of their life cycle and able to move away from the localized disturbance of the construction sites, physical alterations should be scheduled during this time period. The small amount of temporary habitat disturbance is not expected to result in significant impacts provided these conservation measures are adopted.

10.2 The many procedures for maintaining the canals and ditches are, for the most part, compatible with GGS. Certain maintenance practices, are, however, detrimental to the GGS and its habitat and shall be avoided. The detrimental practices are: 1) lining the canals with cement or gunite and 2) excavating canals during the GGS dormant season (October 1-May 1). Spraying or otherwise removing the vegetation from the banks of the canals should be minimized.

10.3 Adverse impacts to the GGS during maintenance operations can be lessened by adhering to the HMP and to the following guidelines:

10.3.1 Excavate from only one side of the canal during a given year. Avoid excavating the banks above the high water level. Sides of any canals dedicated as emergent wetland habitats, shall be left undisturbed indefinitely.

10.3.2 Excavate the canals during the GGS active season. This is approximately May 1 to October 1.

10.3.3 Leave the vegetation on the tops and sides of the canals undisturbed.

10.3.4 Restrict auto traffic along the canals to maintenance or other official vehicles.

10.4 Other construction related avoidance measures include:

10.4.1 No grading, excavating, or filling may take place in or within 30 feet of existing GGS habitat from October 1 and May 1 unless authorized by the DFG.

10.4.2 Construction of replacement habitat may take place at any time of the year, but summer is preferred.

10.4.3 Dewatering of the existing habitat may begin any time after November 1, but must begin by April 1. All water must be removed from the existing habitat by April 15, or as soon after as weather permits, and the habitat must remain dry (no standing water) for 15 consecutive days after April 15 and prior to excavating or filling the dewatered habitat.

10.4.4 Any GGS surveys required by the DFG shall be completed to the satisfaction of the DFG prior to dewatering.

10.4.5 The DFG shall be notified when dewatering begins and when it is completed. The DFG will inspect the area to determine when the 15-day dry period may start. The DFG contact for inspection shall be Mr. Frank Wernette or his designee at (209) 948-7800, unless the DFG makes other arrangements.

11.0 Black Rail: This measure is necessary to minimize the adverse impacts of take of black rail, at such time as the of black rail may be discovered on the project islands. The following measures shall be implemented prior to and during any future construction activities. If the construction is considered by the DFG to be minor, the DFG may waive the requirements of this RPM.

11.1 Tidally influenced shoreline margins with bands of tules, cattails, phragmites, or pickled exceeding 3 meters in width must be surveyed using tape-recorded calls during the black rail breeding season (March 1 to June 30). Surveys shall be conducted between sunrise and 1000 hours. Recorded calls must be played three times at each station with 5 minute intervals for monitoring of responses. Calling stations shall not be further than 100 meters apart. Two surveys, separated by at least 2 days shall be conducted per week. The DFG will concur with negative results if a minimum of two survey weeks (4 surveys) with negative results are performed immediately prior to construction between March 15 and June 1. Negative survey results after June 1 or before March 1 are unacceptable.

11.2 No construction shall occur within 200 meters of survey stations where positive results were obtained between the period of March 15 and June 30 or until approved by the DFG. Compensation for habitat lost due to project impacts shall entail recreation of shoreline habitat or berm islands at sites acceptable to the DFG. Compensation shall occur at a 3 to 1 ratio for each site impacted by the project. This ratio is required to compensate for the time-lag required for restored habitats to mature.

11.3 The DFG is to be notified in writing within three working days of the finding of any dead or injured threatened or endangered species during construction, operation, or maintenance of the proposed facilities. Notification must include the date, time, and location of the incident or of the finding of a dead or injured animal, and any other pertinent information. The DFG contact for this information is the Bay-Delta and Special Water Projects Division at (209) 948-7800. Any endangered species found dead or injured must be turned over to the DFG for care or analysis.

12.0 **Fish Screens:** This measure is necessary to minimize the adverse impacts of take of winter-run chinook salmon and delta smelt.

Fish screens installed on existing and new diversions shall comply with the DFG's fish screen policy. A "Fish Screen Test Plan" and a "Fish Screen Maintenance Plan" shall be developed by Delta Wetlands as set forth in the Final Operating Criteria. Final plans shall be completed after the project is permitted and must be accepted, in writing, by the DFG.

13.0 **DFG notification and approval:**

Wherever the federal biological opinions require that the Corps, Board, or Delta Wetlands inform, notify, or obtain the approval of the USFWS or NMFS, the Corps, Board, or Delta Wetlands shall also inform, notify, or obtain the approval of the DFG, if the information, notification, or approval concerns the Listed Species. Where the DFG's approval is required, the DFG shall comply with the schedule or time constraints described in this

Biological Opinion.

14.0 Project representative:

At least thirty (30) days before initiating ground-disturbing activities, the Board, shall designate a representative responsible for communications with the DFG and for overseeing compliance with this Biological Opinion. The DFG shall be informed, in writing, of the representative's name, business address and telephone number, and shall be notified in writing if a substitute representative is designated.

15.0 Employee orientation:

The Board or its designee shall conduct an orientation program for all persons who will regularly work on-site during construction. The program shall consist of a brief presentation from a person knowledgeable about the biology of the Listed Species, the terms of this Biological Opinion, and of CESA. The education program shall include a discussion of the biology of the Listed Species, the habitat needs of these species, their status under CESA, and the Conservation Measures in this Biological Opinion. A fact sheet containing this information shall also be prepared and distributed. Upon completion of the orientation, employees shall sign a form stating that they attended the program and understand all Conservation Measures. These forms shall be filed at the Board's office and shall be accessible by the DFG.

16.0 Notification regarding dead, injured or entrapped animals:

If Delta Wetlands, its employees, contractors or agents kill or injure an individual of a Listed Species, or finds any such animal dead, injured, or entrapped, Delta Wetlands shall immediately notify the DFG. All reasonable efforts shall be made to allow any entrapped animals to escape. Any dead or injured animal shall be turned over to the DFG and a written report detailing the date, time, location and general description of the circumstances under which it was found must be submitted to the DFG no later than three business days following the incident.

17.0 Construction compliance inspections and reports:

During construction, compliance inspections shall be completed once a week and Delta Wetlands shall provide a monthly compliance report to the DFG. The inspections shall assess compliance with all RPMs in this Biological Opinion, specifically including the creation and maintenance of exclusion zones. Within forty-five (45) days of completing the Project, the Board shall provide to the DFG a final, post-construction compliance report. The report shall be prepared by a biologist knowledgeable of the biology of the

Listed Species and shall include the following: 1) construction dates; 2) verification that all RPMs were fully implemented; 3) identification of RPMs, if any, that were not fully implemented; 4) description of effects on Listed Species and Listed Species habitat; 5) any other pertinent information.

18.0 Access to Project site:

Delta Wetlands shall allow DFG representatives access to the Project site for purposes of monitoring compliance with the provisions of this Biological Opinion. The DFG will observe any reasonable access restrictions requested by the Board and Delta Wetlands.

19.0 Incidental Entrainment Compensation: This measure is necessary to minimize the adverse impacts of take of delta smelt.

In lieu of monitoring for the entrainment of eggs, larvae, and fry as described in Measure 7 on pages 14 and 15 of the Final Operating Criteria (Attachment 2), Delta Wetlands will provide $1.00 per acre foot of water diverted to storage during the specified period. All other provisions of Measure 7 shall apply. Funds derived from this RPM shall be provided to the DFG semi annually in any year the Project diverts to storage. Funds shall be provided on or before April 30 for the period January through March and on or before September 30 for the period June through August in any year in which compensation is required. In the event that the federal fish and wildlife agencies do not agree to waive sampling, the Incidental Entrainment Compensation provisions in the FOC shall remain as currently drafted and this RPM will not be imposed.

20.0 Aquatic Habitat Restoration Fund: This measure is necessary to minimize the adverse impacts of take of winter-run and delta smelt.

20.1 An "Aquatic Habitat Restoration Fund" shall be established by Delta Wetlands. This fund shall exclusively benefit and be controlled by the DFG. At the DFG's discretion, this fund may be used for environmental enhancement opportunities that benefit winter-run and delta smelt.

20.2 Delta Wetlands shall provide an initial installment of $700,000 for the "Aquatic Habitat Restoration Fund". That installment shall be provided to the DFG prior to the commencement of diversions to storage. This fund is intended to supplement funds received from other provisions in the Final Operating Criteria (Attachment 2) including Measure 3, Boat Wake Erosion on page 12; and, Measure 7, Incidental Entrainment Compensation on pages 14 and 15. The habitat acquired with Aquatic Habitat Restoration Fund money may be purchased from a mitigation bank or acquired and managed in an alternative ownership and management arrangement acceptable to DFG. DFG may not take fee title to such mitigation habitat.

X. IMPACTS OF THE PROPOSED PROJECT UNDER THE CESA BIOLOGICAL OPINION

Following is a description of the basis for the DFG's Biological Opinion and the rationale for the DFG'S Reasonable and Prudent Measures. It describes the effects of the proposed Delta Wetlands Project on listed fish species with implementation of the Reasonable and Prudent Measures contained in the CESA Biological Opinion.

A. OVERVIEW OF SIMULATED DELTA WETLANDS PROJECT OPERATIONS UNDER THE CESA BIOLOGICAL OPINION

The impacts of the project consistent with the Reasonable and Prudent Measures in the DFG's Biological Opinion is described below. The biological rationale for the Reasonable and Prudent Measures is also provided. The DFG used output from the model run completed by JSA for a suite of measures recommended by the DFG. Since the scope of measures has been reduced to only those that are included as RPMs in this Biological Opinion these data were interpreted carefully to estimate the reductions in take.

The RPMs will result in average annual Delta Wetlands diversions of approximately 191 TAF and average annual Delta Wetlands discharges to export of 153 TAF. The RPMs will also increase flows under certain hydraulic conditions through the release of water stored as environmental water pursuant to the Final Operating Criteria and as a result of flows acquired and released using funds in the Environmental Water Fund.

RPM 1.0 reduces project diversions by approximately 1 percent or 1 TAF.

The project operated as allowed by the CESA Biological Opinion RPMs will reduce the adverse impacts of the Delta Wetlands Project that remained under the federal biological opinions. Relative to conditions under the No-Project Alternative, operations under the RPMs will reduce the maximum monthly upstream shift of X2 in February through June. The remaining shift is offset by developing 100 acres of shallow water habitat.

B. ASSESSMENT OF NET PROJECT IMPACTS AND BENEFITS UNDER THE RPMS

A broad array of actions will help to contribute to reducing the adverse effects of take associated with the project and providing some aquatic improvements:

- Improvement in positive westerly flows (QWEST) in the February to April period to a level better than the No-Project condition in some years.
- Decrease in adverse flows toward the central and south Delta (CDFP) in March

through June from No-Project levels.

The CESA Biological Opinion provides more uniform protection even when FMWT indices are >239 and monitoring does not indicate delta smelt are present. This is of critical importance to providing adequate protection for both species, particularly winter-run chinook salmon. Based on the FMWT indices reported since 1967, less than 25 percent of the years would be affected by the index sensitive measures. Therefore, the additional protection offered when the FMWT is <239 would only be provided in 1 of 5 years.

C. GENERAL IMPACTS

Most of the impacts associated with the project as allowed by the federal biological opinions will remain. In the CESA Biological Opinion, however, the impacts of losses associated with increased entrainment due to project diversions and export of project discharges will be reduced by using the maximum rate at which funds are collected without the need for monitoring. Habitat developed with these funds will contribute to improving aquatic habitat conditions for the listed fish in the Delta.

D. OPERATIONAL IMPACTS

The CESA Biological Opinion will have a very small impact on Delta Wetlands operations. Project yield associated with the CESA Biological Opinion will be essentially as predicted for the project operated under the Final Operating Criteria.

E. FLOW AND HYDRODYNAMIC IMPACTS

1. WINTER- AND SPRING-RUN CHINOOK SALMON

Changes in Delta hydrodynamics resulting from project diversions during the critical rearing and migration period for juvenile winter-run chinook salmon is expected to be reduced. Diversions in March will be reduced under adverse negative QWEST conditions. Releases of environmental water associated with the Final Operating Criteria or purchased by the DFG using the Environmental Water Fund and released are likely to contribute to reducing the adverse effects of take of rearing and emigrating juvenile salmon. Existing reverse flows conditions in the lower San Joaquin River, Old River, and Middle River could be improved in drier conditions.

2. DELTA SMELT

Changes in Delta hydrodynamics resulting from project diversions during the period will be reduced under the CESA Biological Opinion. Many of the benefits described above will also apply to delta smelt. The uniform intake criteria in March will reduce the adverse effects on channel hydraulics in the vicinity of the intakes. This may reduce the likelihood of increased entrainment of larval and small juveniles into the diversions.

F. ENTRAINMENT

With the CESA Biological Opinion, project operations will be modified and the entrainment of winter-run and delta smelt will be reduced compared to existing conditions.

G. ECONOMIC FEASIBILITY

Reductions in project yield associated with the CESA Biological Opinion will have no significant affect on project feasibility. This is particularly true since effects on yield associated with the Final Operating Criteria are likely to be over-estimates since project yield can increase as storage capacity increases over time and because models used to estimated impacts were monthly models that could not take into account operational opportunities that were on a less than monthly basis. In addition, if the project is sold to the CVP or SWP, during reconsultation, opportunities could be explored to coordinate operations with the CVP and SWP which could increase yield while preserving environmental protection.

XI. BIOLOGICAL BASIS FOR THE REASONABLE AND PRUDENT MEASURES

Below, the DFG presents its biological basis for four of the Reasonable and Prudent Measures.

A. RPM 1.0: MARCH RESTRICTIONS

This measure reduces impacts on the critical rearing and migration period for juvenile winter-run. It will help reduce impacts during a critical spawning and rearing period for delta smelt and reduce impacts during times when the most vulnerable life stages of delta smelt are present. This measure minimizes the decreases in Delta outflow, increases in export/inflow levels, and reductions in QWEST that are likely to reduce the survival of rearing and emigrating juvenile fish.

This RPM reduces increased diversions and the associated fishery impacts during the peak month for winter-run chinook salmon (March) when nearly 50 percent of the year's production can be located in the Delta and vulnerable to project impacts. This RPM avoids the problem associated with the federal biological opinions of not providing adequate fishery protection in 4 out of 5 years because the FMWT index for delta smelt is >239.

March is also a critical months for delta smelt. Adults are entering the Delta for spawning and larval smelt are present in significant numbers. Twenty-five percent of the total population of delta smelt larvae are present in the Delta during March.

RESIDUAL IMPACTS

Adverse impacts associated with Delta Wetlands diversions and discharges may remain in the November through May period for winter-run juveniles, in the December through June period for adult delta smelt, and February through August period for juvenile delta smelt. Larval and juvenile delta smelt are flushed into eastern Suisun Bay by the end of August and removed from the most direct influence of the Delta Wetlands Project. Project operations will still result in negative impacts on QWEST in the November through February period. Therefore, unavoidable impacts on delta smelt and winter-run may remain. RPMs 2.0 and 20.0 will address those residual impacts.

B. RPM 2.0: ENVIRONMENTAL WATER FUND

Establishing an Environmental Water Fund and contributing funds based on five percent of the project diversions that occur in the October through March period is a key measure of the CESA Biological Opinion to minimize the adverse impacts of incidental taking and interacts with other protective measures in the CESA Biological Opinion and federal biological opinions so that the environmental baseline is not severely degraded by the Delta Wetlands Project. Requiring an initial deposit of $300,000 will help fund initial water acquisitions or environmental enhancement opportunities that will benefit winter-run and delta smelt.

The improvements resulting from controlled releases of water in the March through May period will reduce the level of take of listed species associated with water exports and increase survival sufficiently above current conditions to help offset unavoidable impacts associated with take during other months. Failure to include this measure will result in unacceptably high levels of take, in the serious degradation of the environmental baseline, and will be inconsistent with the Delta Accord.

Since significant adverse effects would remain for delta smelt and winter-run under the federal biological opinions, even with RPM 1.0 of the CESA Biological Opinion, maintaining the environmental baseline has been the DFG's position and is supported by the environmental community and sport fishing groups. This RPM allows resource agencies the ability to release a portion of the water back to the environment during critical periods to offset unavoidable losses at other times. While the amount dedicated with this project is not large in some years, in the DFG's opinion it is sufficient, in conjunction with the other RPMs, to minimize the adverse impacts of incidental taking pursuant to Section 2091.

In developing this RPM, the DFG based its rationale on a review of the project from the standpoint of the estimated water budget for the habitat islands displayed in Table A1-8 of

Appendix A in the DEIR/EIS. With that water budget, the DFG estimates that average annual funding for the Environmental Water Fund will range from approximately $200,000 to $300,000 in January 1998 dollars. These funds may be used to acquire water from water rights holders on tributaries to the Sacramento or San Joaquin rivers. Release of that water as specified by the DFG could provide significantly higher benefits to aquatic resources in the Delta compared to releases from the Delta Wetlands project islands. If the estimated water budget in the DEIR/EIS significantly underestimates actual discharges from the habitat islands, the amount credited against the Environmental Water Fund will be excessive and the expected benefit from this RPM may be degraded. The DFG may be required to reinitiate consultation depending on the extent of the difference between the information provided in the DEIR/EIS and actual operational experience following project implementation if the difference results in a significant additional adverse impact and significant degradation of this RPM to minimize the adverse impacts of take of winter-run and delta smelt.

C. RPM 4.0: AQUATIC HABITAT DEVELOPMENT MEASURES

When the mixing zone is located in Suisun Bay where there is extensive shallow water habitat within the euphotic zone (depths less than four meters), high densities of phytoplankton and zooplankton may accumulate (Arthur and Ball 1978, 1979, 1980) upon which juvenile delta smelt feed. The area immediately upstream of X2 is referred to as the "entrapment" zone, and concentrates nutrients and the food microorganisms upon which "rearing" delta smelt feed. Project operation is predicted to cause upstream shifts in X2. This shift will reduce the amount of suitable salinity habitat in the Suisun Bay area. The DFG finds that the acquisition, restoration, and management of 100 acres of shallow shoal/low elevation tidal wetland habitat will offset the adverse effects of this shift.

The federal biological opinions provide for offsetting this impact by securing an easement on 200 acres of shallow water aquatic habitat in the Delta. This may result in no new habitat being restored but simply an easement being provided on existing habitat. The net loss of habitat would remain.

Project construction activities such as the installation of siphons and pumps will impact water side habitat. Impacts have been estimated at 50 acres. Actual impacts should be measured during construction and mitigated using a 3:1 replacement ratio.

RESIDUAL IMPACT

In some years impacts on rearing habitat may be greater than the modeling suggests and the mitigation acreage defined in the RPM may not fully offset those impacts.

D. RPM 20.0: AQUATIC HABITAT RESTORATION FUND

Establishment of an "Aquatic Habitat Restoration Fund" and requiring an initial deposit of $700,000 will help fund environmental enhancement opportunities to benefit winter-run and delta smelt. This fund will be used to restore the 100 acres of aquatic habitat that is targeted to compensate impacts associated with Project induced upstream shifts in X2.

Money provided from Measure 3, Boat Wake Erosion on page 12 of the FOC and Incidental Entrainment Compensation on pages 14 and 15 of the FOC will also be deposited into this fund. Combining these funds will contribute to more efficient efforts to restore aquatic resources in the Bay-Delta. Collectively, these funds will be used to support projects that will increase survival of winter-run and delta smelt above base line levels to help offset unavoidable impacts associated with take caused by the project.

XII. SCOPE OF AUTHORIZATION

The RPMs described in the Biological Opinion are non-discretionary and the Board must, as a binding condition of Delta Wetlands' Water Right permit, require the Delta Wetlands Project to comply with the requirements of the RPMs in order for the take authorization in Section 2091 to apply. The Board has a continuing duty to regulate the activity that is covered by this incidental take statement. If the Board fails to: (1) require the applicant to adhere to the terms and conditions of the incidental take statement through enforceable terms that are added to the permit or grant document; and/or (2) retain oversight to ensure compliance with these terms and conditions, the protective coverage of Section 2091 may lapse.

XIII. ADDITIONAL CONSERVATION RECOMMENDATIONS

Under CESA, it is incumbent on all State agencies to seek to conserve endangered and threatened species. The following recommendations, while not required pursuant to Fish & Game Code §§2090-2092, are offered as additional conservation recommendations to be implemented by the SWRCB in furtherance of the purposes of CESA. The following recommendations have been made as more detailed CEQA mitigation recommendations during the water rights hearing. The biological basis for these recommendations were also provided in the water rights hearing.

A. FOOD HABITS ANALYSIS

The Board should encourage the Delta Wetlands Project to complete a food habits analysis of salmon caught during required sampling activities in order to better assess temperature effects on rearing and migrating juvenile salmon in the Delta.

B. WATER QUALITY

Delta Wetlands should operate in a manner which will ensure that discharges associated with the Delta Wetlands Project do not result in significant impacts on Listed Species in the Delta. Delta Wetlands should develop and implement a final monitoring program, in consultation with the DFG, which is accepted, in writing, by the DFG, USFWS, and NMFS prior to Delta Wetlands commencing operations.

C. RECOMMENDATIONS TO REDUCE IMPACTS IN PROJECT SERVICE AREAS

In order to minimize the incidental take of State listed species in the service areas receiving water from the Delta Wetlands Project, Delta Wetlands should annually provide the DFG with funds on the following schedule: Fifty cents per acre foot in those water years when Delta Wetlands exports between 25 and 50 thousand acre-feet of water; 75 cents per acre foot in those water years when Delta Wetlands exports are 50 to 100 thousand acre-feet of water; and, one dollar per acre foot in those water years when Delta Wetlands exports over 100 thousand acre-feet of water. All funds should be in Jan. 1997 dollars, adjusted for inflation as specified in this CESA Biological Opinion, and provided to the DFG by Jan. 1 following the subject water year in which the exports occurred. The DFG will deposit such funds in a special deposit account pursuant to Government Code Section 16370 for actions to mitigate impacts to Listed Species such as implementing Habitat Conservation Plans (HCP) pursuant to Section 10 of the Federal Endangered Species Act (FESA), Natural Community Conservation Plans (NCCP) pursuant to Fish and Game Code 2800, or other comprehensive area plans, approved by the USFWS and/or the DFG and purchasing of core conservation areas identified in those plans. This provision satisfies that portion of the Project's responsibility to address service area impacts. Obligations of project proponents whose projects induce or cause adverse land use changes in the service area will be addressed in Project specific consultations or through the mechanisms outlined in the applicable HCPs or NCCPs. The species covered by this recommendation shall be limited to those species identified for the service areas described in Attachment 4.

D. SPECIAL STATUS PLANTS

For special status plants that are not listed under CESA the following measures should be taken.

1. Floristic studies of the areas likely to be affected by the project should be conducted according to the DFG's guidelines. These studies should be carried out in the spring and summer when any rare plant species that may be present are likely to be evident and identifiable (see guidelines 4a and 4b). The Suisun Marsh aster, Rose mallow and Mason's lilaeopsis are often not identifiable

before June.

2. If listed plant species are found on the project site, redesigning the project to avoid or minimize the impacts on these species should be attempted. If impacts are unavoidable, a mitigation and monitoring plan which follows the enclosed format should be developed. Mitigation options may involve restoring the rare plant population and associated habitat on- or off-site and providing for the long-term protection of the mitigation site.

3. All levee projects should be preceded by preparation and adoption of specific plans detailing the project impacts, mitigation and compensation measures that will reduce project impacts to result in no net loss of riparian, fishery, or wildlife habitat as per Sections 8610 and 8611 of the State Water Code. Monitoring plans to evaluate mitigation/compensation should be prepared and should include remedial actions necessary if success criteria are not achieved. Annual reports should be provided to the DFG.

E. DIVERSION RECOMMENDATIONS

The Board should take actions that reduce adverse effects of diversions on Delta hydrodynamics in June and July, during periods of low San Joaquin River inflow as measured at Vernalis, and during the pulse flow period when flows in Middle and Old rivers are favorable for aquatic resources.

XIV. FUTURE CONSULTATION

Pursuant to Fish and Game Code §2090, if the RPMs identified in this Biological Opinion are not fully implemented and adhered to, or if the Project is substantially modified, further consultation with the DFG is required.

Re-initiation of formal consultation is required if: 1) the amount or extent of taking specified in any incidental take statement is exceeded; 2) new information reveals effects of the action that may affect listed species or habitat in a manner or to an extent not previously considered; 3) the action is subsequently modified in a manner that causes an effect to the listed species or its habitat that was not considered in the biological opinion; 4) there is a significant project modification; or 5) a new species is listed that may be affected by the action.

If the spring-run chinook salmon is ultimately listed by the California Fish and Game Commission, the Board, Delta Wetlands, or the current owner of the Project shall, pursuant to Section 2090 or in its absence 2081, initiate consultation with the DFG with regards to the spring-run chinook salmon.

XV. NOTICES

Notices and other communications regarding this Biological Opinion will be addressed as follows. Any funds provided to the DFG as a condition of the RPMs in this Biological Opinion shall be submitted to the DFG at the address below:

DFG	DIVISION CHIEF California Department of Fish and Game Bay-Delta and Special Water Projects Division 4001 North Wilson Way Stockton, California 95205
DELTA WETLANDS	DELTA WETLANDS 3697 Mt. Diablo Boulevard, Suite 100 Lafayette, California 94649
STATE WATER RESOURCES CONTROL BOARD	CHIEF, WATER RIGHTS DIVISION Water Resources Control Board 901 P Street Sacramento, California 95814

L. Ryan Broddrick, Chief Deputy Director
Department of Fish and Game

Date: [illegible]

XVI. ATTACHMENTS

ATTACHMENT 1: FEDERAL BIOLOGICAL OPINIONS

ATTACHMENT 2: FINAL OPERATIONS CRITERIA AND FISH MONITORING PROGRAM - JANUARY 27, 1997.

ATTACHMENT 3: TERRESTRIAL RESOURCES HABITAT MANAGEMENT PLAN (HMP)

ATTACHMENT 4: LIFE HISTORY OF STATE LISTED SPECIES; AND APPENDIX:

1. APPENDIX A - LISTED SPECIES IN THE PROJECT SERVICE AREAS

ATTACHMENT 5: CONSERVATION EASEMENTS

1. APPENDIX A- FORM OF CONSERVATION EASEMENT FOR HM LANDS ON BOULDIN ISLAND.
2. APPENDIX B- FORM OF CONSERVATION EASEMENT FOR HM LANDS ON HOLLAND TRACT.

ATTACHMENT 6: MISCELLANEOUS DATA AND INFORMATION FOR THE DELTA WETLANDS PROJECT BIOLOGICAL OPINION

XVII. REFERENCES

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ATTACHMENT 1

FEDERAL BIOLOGICAL OPINIONS

Attachment 1 of the California Endangered Species Act biological opinion is reproduced as Appendices D and E of this REIR/EIS.

ATTACHMENT 2

FINAL OPERATIONS CRITERIA

AND

FISH MONITORING PROGRAM

JANUARY 27, 1997

Attachment 2 of the California Endangered Species Act biological opinion is reproduced as Appendix B of this REIR/EIS.

ATTACHMENT 3

TERRESTRIAL RESOURCES HABITAT MANAGEMENT PLAN

Attachment 3 of the California Endangered Species Act biological opinion is Appendix G3, "Habitat Management Plan for the Delta Wetlands Habitat Islands", of the 1995 DEIR/EIS.

ATTACHMENT 4

LIFE HISTORY OF STATE LISTED SPECIES

ATTACHMENT 4

LIFE HISTORY SUMMARY

Delta Wetlands Inc. proposes to undertake a project that may cause the take of species of wildlife protected by the California Endangered Species Act, California Fish and Game Code §2050, *et seq.* ("CESA").

Life history information concerning the Federal Listed Species is contained in the federal biological opinions. This is a summary life history of the State Listed Species, including those that are federally listed or were previous candidates for listing.

LISTED SPECIES

Based on an assessment of the Project site and adjacent areas, the DFG has found that 27 of the species listed in Table 4-1 may use the project area, be affected by the Project, or the Project could provide habitat for their reestablishment. These species are the Swainson's hawk, greater sandhill crane, western yellow-billed cuckoo, willow flycatcher, giant garter snake, California black rail, bald eagle, American peregrine falcon, Aleutian Canada goose, loggerhead shrike, Sacramento River winter-run chinook salmon, splittail, delta smelt, Sacramento perch, spring-run chinook salmon, green sturgeon, longfin smelt, and riparian brush rabbit. Other State listed rare and State species of special concern include burrowing owl, tricolored blackbird, riparian wood rat, southwestern pond turtle, northwestern pond turtle, Mason's lilaeopsis, Delta tule pea, Rose mallow, and Suisun aster.

Table 4-1. California Endangered Species Act Biological Opinion for the Delta Wetlands Project-Life History Summary. Listed and Special Status Species.

Species	Status
Fish	
Splittail (*Pogonichthys macrolepidotus*)	FPT
Winter-run chinook salmon (*Oncorhynchus tshawytscha*)	FE,SE
Spring-run chinook salmon (*Oncorhynchus tshawytscha*)	SCT
Delta smelt (*Hypomesus transpacificus*)	FT,ST
Longfin smelt (*Spirinchus thaleichthys*)	1/
Sacramento perch (*Archoplites interruptus*)	1/
Tidewater goby (*Eucyclogobius newberryi*)	FE
Green sturgeon (*Acipenser medirostris*)	1/
Amphibians	
California red-legged frog (*Rana aurora draytonii*)	FT
California tiger salamander (*Ambystoma californiense*)	1/
Western spadefoot toad (*Scaphiophus hammondi*)	1/
Reptiles	
Giant garter snake (*Thamnophis couchii gigas*)	FT,ST
Northwesten pond turtle (*Clemmys marmorata marmorata*)	1/
Southwestern pond turtle (*Clemmys marmorata pallida*)	1/
San Francisco garter snake (*T. sirtalis tetrataenia*)	SE,FE
Birds	
California brown pelican (*Pelecanus occidentalis californicus*)	FE,SE
Bald eagle (*Haliaeetus leucocephalus*)	FE,SE
American peregrine falcon (*Falco peregrinus anatum*)	FE,SE
Aleutian Canada goose (*Branta canadensis leucopareia*)	FT
California black rail (*Laterallus jamaicensis coturniculus*)	1/,ST
Western snowy plover (*Charadrius alexandrinus nivosus*)	FT
California clapper rail (*Rallus longirostrus obsoletus*)	FE,SE
California least tern (*Sterna antillarum browni*)	FE,SE
Tricolored blackbird (*Agelaius tricolor*)	1/
Saltmarsh common yellow throat (*Geothylpis trichos sinuosa*)	1/
Suisun song sparrow (*Melospiza melodia maxillaris*)	1/
San Pablo song sparrow (*Melospiza melodia samuelis*)	1/
Swainson's hawk (*Buteo swainsoni*)	ST
Greater sandhill crane (*Grus canadensis tabida*)	ST
Bank swallow (*Riparia riparia*)	ST
Western yellow-billed cuckoo (*Coccyzus americanus occidentalis*)	SE,1/
Loggerhead shrike (*Lanius ludovicianus*)	1/
Willow Flycatcher (*Empidonax trailii*)	SE, 1/
Burrowing owl (*Athene cunicularia*)	SSC

Mammals

Suisun ornate shrew (*Sorex ornatus sinuosus*)	1/
Salt marsh harvest mouse (*Reithrodontomys raviventris*)	FE,SE
Yuma myotis/bat (*Myotis yumanensis*)	1/
Riparian woodrat (*Neotoma fuscipes riparia*)	1/
Riparian brush rabbit (*Sylvilagus bachmani riparius*)	SE
San Joaquin kit fox (*Vulpes macrotis mutica*)	ST,FE
Salt marsh wandering shrew (*Sorex vagrans halicoetes*)	1/

Plants

Rose mallow (*Hibiscus lasiocarpus*)	1/
Delta tule pea (*Lathyrus jepsonii var. jepsonii*)	1/
Suisun slough thistle (*Cirsium hydrophilum var. hydrophilum*)	FE
Suisun aster (*Aster lentus*)	1/
Mason's lilaeopsis (*Lilaeopsis masonii*)	1/,SR
Soft bird's beak (*Cordylanthus mollis ssp. mollis*)	FE, SR
Hispid bird's beak (*Cordylanthus mollis spp. hispidus*)	1/
Delta button-celery (*Eryngium racemosum*)	SE,1/
Salt marsh bird's beak (*Cordylanthus maritimus ssp maritimus*)	SE,FE
Contra Costa wallflower (*Erysimum capitatum ssp. angustatum*)	SE,FE
Antioch Dunes evening-primrose (*Oenothera deltoides spp. howellii*)	SE,FE
Pitkin Marsh Indian paintbrush (*Castilleja uliginosa*)	SE,1/
Slough thistle (*Cirsium crassicaule*)	1/
San Joaquin saltbush (*Atriplex joaquiniana*)	1/
California beaked-rush (*Rhynchospora californica*)	1/
Contra Costa goldfields (*Lasthenia conjungens*)	1/
Heart Scale (*Atriplex cordulata*)	1/
Tiburon Indian paint brush (*Castilleja affinis neglecta*)	1/
Contra Costa buckwheat (*Eriogonum truncatum*)	1/
Legenere (*Legenere limosa*)	1/
Northern California black-walnut (*Juglans californica var. hinksii*)	1/
Sanford's arrowhead (*Sagittaria sanfordii*)	1/
Gairdner's yampah (*Perideridia gairdneri ssp. gairdneri*)	1/
Fountain thistle (*Cirsium fontinale var. fontinale*)	SE,1/
Burke's goldfields (*Lasthania burkei*)	SE,1/
Mt. Hamilton thistle (*Cirsium fontinale var. campylon*)	1/
San Francisco gumplant (*Grindelia maritima*)	1/
Hairless popcorn flower (*Plagiobothrys glaber*)	1/
Bearded popcorn flower (*Plagiobothrys hystriculus*)	1/
Calistoga popcorn flower (*Plagiobothrys strictus*)	1/
Swamp sandwort (*Arenaria paludicola*)	1/
Showy indian clover (*Trifolium amoenum*)	1/
Sepastopol meadowfoam (*Limnanthes vinculans*)	SE,1/
Kenwood marsh checkerbloom (*Sidalcea oregana ssp. valida*)	SE,1/
Marin knotweed (*Polygonum marinense*)	1/
Palmate-bracted bird's beak (*Cordylanthus palmatus*)	FE
White sedge (*Carex albida*)	SE,1/
Pitkin marsh lily (*Lilium pardalinum ssp. pitkinense*)	SE,1/
Napa bluegrass (*Poa napensis*)	SE,1/

Insects

Lange's metalmark butterfly (*Apodemia mormo langei*)	FE
Valley elderberry longhorn beetle (*Desmocerus californicus dimorphus*)	FT
Sacramento anthicid beetle (*Anthicus sacramento*)	1/
Delta green ground beetle (*Elaphrus viridis*)	FT

Other Invertebrates

Longhorn fairy shrimp (*Branchinecta longiantenna*)	FE
California freshwater shrimp (*Syncaris pacifica*)	SE, FE
Conservancy fairy shrimp (*Branchinecta conservatio*)	FE
Vernal pool fairy shrimp (*Branchinecta lynchi*)	FT
California linderiella (*Linderiella occidentalis*)	FPE
Vernal pool tadpole shrimp (*Lepidurus packardi*)	FE

FE = Federal Endangered
FT = Federal Threatened
FPE = Federal Proposed Endangered
SCE = State Candidate Threatened
1/ = Former Federal Candidate
FPT = Federal proposed Threatened
SSC = Species of Special Concern
ST = State Threatened
SE = State Endangered
SR = State Rare

FISH

Splittail

The splittail is a native minnow that lives mostly in the slow-moving stretches of the Sacramento River up to the Red Bluff Diversion Dam, in the Delta, and in the Napa and Suisun marshes (Moyle 1976; DFG unpublished data). They have been found in Suisun Bay, San Pablo Bay, and Carquinez Strait (Moyle 1976). Turner (1966) reported finding them evenly distributed in the Delta, while a later study found them most abundant in the north and west Delta on flooded island areas in association with other native species (DFG 1987).

Splittail are tolerant of brackish water, being caught in salinities as high as 10-12 parts per thousand (ppt) or 15-18 mmhos EC (Moyle 1976). During spring, they congregate in dead-end sloughs of the marsh areas of the Delta, and Napa and Suisun marshes, to spawn over beds of aquatic or flooded terrestrial vegetation (Moyle 1976; DFG unpublished data). They have been observed to migrate up the Sacramento River and spawn at Miller Park.

The splittail commonly reach 12 to 16 inches in length (30-40 cm). It was formerly a commercially harvested fish but now is sometimes sought by recreational anglers in the Delta and Suisun Bay areas. The splittail is now a proposed threatened species. Figure 4-1 displays life history stages and the timing of those stages in the Delta in order to better assess how the Project affects this species.

Winter-Run Chinook Salmon

The Sacramento River winter-run chinook salmon is distinguishable from the other Sacramento River chinook races by the timing of its upstream migration and spawning season. Before construction of Shasta Dam in 1945, winter-run chinook salmon were reported to spawn in the upper reaches of the Little Sacramento, McCloud, and lower Pit rivers (Moyle et al. 1989). Specific data relative to the historic run sizes of winter-run chinook salmon prior to 1967 are anecdotal with some reports indicating runs that were substantially similar to or even larger than runs that occurred prior to the mid-1960s. Construction of Shasta Dam blocked access to all of the winter-run chinook salmon's historic spawning grounds.

Completion of the Red Bluff Diversion Dam (RBDD) in 1966 enabled escapement estimates of all salmon runs to the upper Sacramento River. The estimated numbers of winter-run chinook salmon passing the dam annually from 1967-1969 averaged 86,509 fish. During 1989, 1990, 1991, 1992, and 1993, however, the spawning escapement of winter-run chinook salmon past the dam was estimated at 547, 441, 191, 1,180, and 341 fish, respectively. The current population is thought to be dangerously low since spawning populations of 400 to

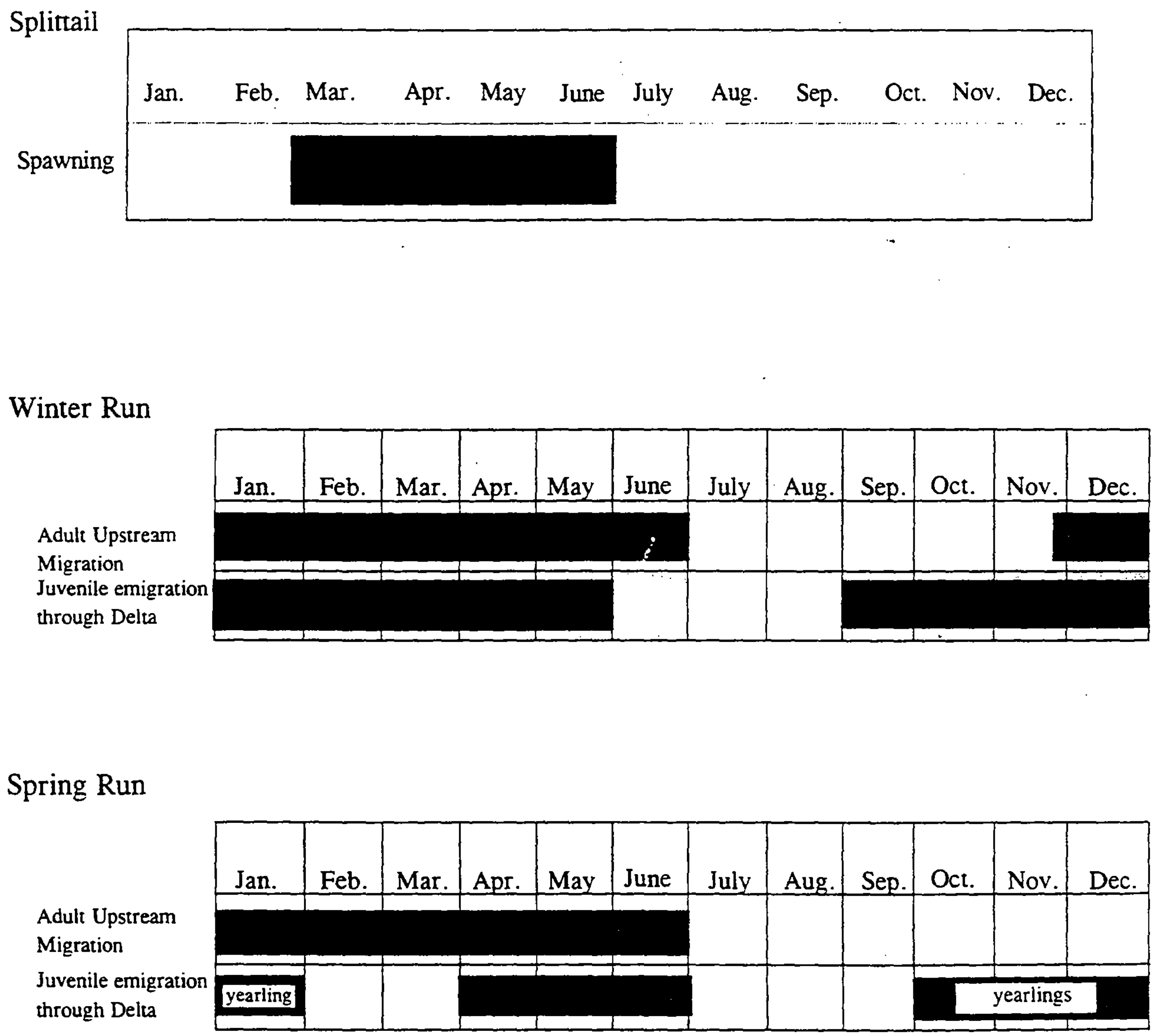

Figure 4-1. Life History of Splittail, Winter-run Chinook Salmon, and Spring-run Chinook Salmon.

1,000 fish are considered necessary to maintain genetic diversity in the winter-run chinook salmon population (52 FR 6041).

The first upstream adult migrants appear in the Sacramento-San Joaquin Delta during the early winter months (Skinner 1972), and move into the upper Sacramento River during December (Vogel and Marine 1991). Adult winter-run migrate to and hold in deep pools between RBDD and Keswick dam prior to initiating spawning activities. The arrival of winter-run chinook salmon in the spawning habitat typically peaks during March, but the peak may vary with river flow, water year type, and operation of the RBDD.

Eggs hatch after incubating about 40-60 days, depending on water temperature. Maximum survival of incubating eggs and preemergent fry occurs at water temperatures between 40 and 56 degrees Fahrenheit. Increased mortality of eggs and preemergent fry commences at 57.7 degrees Fahrenheit and reaches 100 percent at 62 degrees Fahrenheit (Boles 1988). Other potential sources of mortality during the incubation period include redd dewatering, insufficient oxygenation, physical disturbance, diseases, and water-borne contaminants.

Larval incubation lasts approximately 2-4 weeks, depending on water temperature. Emergence of the fry from the gravel begins during late June and continues through September.

The emigration of juvenile winter-run chinook salmon from the upper Sacramento River is highly dependent on individual behavior and streamflow conditions. Storm events can cause emigration of significant proportions of the juvenile population. Emigration past Red Bluff may occur as early as late July or August, generally peaks in September, and may continue through mid-March especially in drier years (Vogel and Marine 1991). During the combined periods of 1978-1979 and 1981-1989, an average of 60 percent of the total downstream emigration past RBDD occurred in September and October (Vogel and Marine 1991).

Numerous factors have contributed to the decline of the Sacramento River winter-run chinook salmon population. The principal factors thought to be responsible for this decline include blockage or interference with adult passage to suitable spawning and rearing areas in the upper Sacramento River (e.g., RBDD and Anderson-Cottonwood Irrigation District dam) temperature induced mortality during egg incubation and early fry development, entrainment of juveniles by water diversion, high levels of juvenile mortality due to downstream passage problems at the RBDD, and the diversion of out migrating juveniles from the Sacramento River into the central Delta via the Delta Cross Channel and other natural waterways where their survival is lower. Other factors that may have adverse effects on winter-run chinook salmon include toxic discharges (particularly from Iron Mountain Mine) and delays in adult migration through the Delta.

Data combined from trawling, seining and State and Federal water project fish salvage records in the Delta show that winter-run chinook salmon outmigrants occur from late September through June in the lower Sacramento River and Sacramento-San Joaquin Delta (Fisher 1993). In any one year, the actual arrival and residence time in the Delta is strongly influenced by the pattern of streamflows and turbidity events in the Sacramento River. The wide distribution of young winter-run chinook salmon throughout the lower Sacramento River and Delta from September through June indicates that juveniles rear in Delta waterways for extended periods of time.

Analysis of adult winter-run chinook salmon scales indicates that most juveniles enter saltwater at a length of 118 millimeters (DFG, unpublished data). Thus, the majority of winter-run chinook salmon juveniles are pre-smolts during the late fall and early winter months. They will undergo smoltification from January through April and are not likely to actively emigrate to the ocean until this time. Fall-run, in contrast, enter saltwater at a much smaller size, approximately 85 millimeters (DFG, unpublished data).

The operation of the intake to the Tracy Pumping Plant in the south Delta is a part of Central Valley Project (CVP) and the operation of the intake to the Harvey O. Banks Pumping Plant, also in the south Delta, is part of the State Water Project (SWP). The National Marine Fisheries Service (NMFS) issued a biological opinion with respect to CVP and SWP operations which prescribes reasonable and prudent measures to avoid jeopardy to winter-run chinook salmon from CVP and SWP operations (NMFS 1995). NMFS has also issued its biological opinion in May that the Delta Wetlands Project will not jeopardize the continued existence of the winter-run chinook salmon or result in the destruction or adverse modification of critical habitat (Attachment 1). Figure 4-1 displays life history stages and the timing of those stages in the Delta in order to better assess how the Project affects this species.

Spring-run Chinook Salmon

Spring-run chinook salmon were once the most abundant race of salmon in California's Central Valley, and one of the largest runs on the Pacific coast. Large spring-run populations occupied 26 streams in the Sacramento-San Joaquin drainage, principally in the middle reaches of the San Joaquin, Feather, Upper Sacramento, McCloud and Pit rivers and their tributaries. By 1992, however, wild spring-run populations were less than 0.5 percent of the historic runs which numbered up to a million fish (NHI 1994).

Overall population trends for spring run chinook salmon have been documented as declining for many decades. More than 20 historically large populations of spring-run salmon have been extirpated or reduced nearly to zero since 1940. The remnant wild spring-runs on Mill, Deer, Butte, and Big Chico creeks have Attachmented statistically significant declines over the same period.

Four tributaries to the Sacramento River, Mill, Deer, Chico, and Butte creeks, consistently support annual spawning populations of spring-run chinook salmon. Several other tributaries occasionally have spring-run salmon present or have recently supported small numbers of them. These tributaries include Antelope, Battle, Beegum, Clear, and South Fork Cottonwood creeks. Historically, spring-run salmon occupied the headwaters of all major river systems in California where natural barriers were absent. Spring-run salmon are known to have occurred in the San Joaquin, Merced (near Yosemite), Stanislaus, Tuolumne, Mokelumne, American, Yuba, Feather, McCloud, Pit, and upper Sacramento rivers. Most of the former spring-run habitat was eliminated by water development and dam construction, preventing access to the headwater areas. It is estimated that nearly 85 percent of the former salmon habitat was lost by 1928, primarily spring-run headwater habitat (NHI 1994).

Spring-run chinook salmon were heavily exploited by the early gill-net fishery in the Sacramento-San Joaquin Delta. A large canning industry, although short-lived, targeted spring-run salmon because of their superior condition when captured during their annual spawning run. Early reports by the California Fish Commissioners reported annual gill-net landings in excess of 700,000 spring-run salmon. Before completion of Friant Dam, nearly 50,000 spring-run salmon were counted on the San Joaquin River. As in the San Joaquin drainage, the Sacramento River populations were dramatically reduced following the construction of barrier dams in the 1940s. The most critical barriers were the closures of Shasta Dam on the Sacramento River in 1945 and Friant Dam on the San Joaquin River in 1948. The spring-run chinook salmon became extinct in the San Joaquin drainage and in the mainstem Sacramento River. Spring-run stocks are now limited to spawning in Mill and Deer creeks and possibly Big Chico, Butte and several other east valley creeks (NHI 1994). Spring-run salmon in the Feather and Sacramento rivers have become hybridized with fall-run salmon because of their forced coexistence below major reservoirs.

The majority of adult spring-run chinook salmon migrate into the Bay-Delta Estuary from mid-March though June. Some evidence from tagging studies indicates freshwater entry into the lower river may actually begin in mid-February. Both spring-run and winter-run migrate coincidentally, with each race segregating into separate holding and spawning areas apparently influenced by suitable water temperatures for spawning and reproductive success. No winter-run salmon migrate into Mill, Deer, Chico, or Butte creeks where summertime water temperatures are adequate for holding adults but lethal to incubating salmon eggs.

Spring-run spawning times have been poorly documented and reported as occurring at a variety of times. The most thorough record appears in the reports from the Baird Hatchery on the McCloud River. Adult spring-run salmon begin entering tributaries in early-March, continuing though April, and peaking in May. The upstream movement concludes by the end of June effectively isolating spring-run salmon in the headwater holding and spawning areas. Spawning takes place from mid-August to the mid-October. Recent spawning stock surveys in

Deer Creek have confirmed that the onset of spawning begins in late-August and continues to mid-October. There appears to be some variation in spawning times within different drainage, possibly related to water temperatures. Those populations spawning at higher elevations such as Mill and Deer creeks spawn approximately 3 weeks earlier than those in Butte and Chico creeks, where spawning activity is first noted in mid-September. Within Deer Creek, spawning begins first at upstream areas and occurs progressively later at lower elevations.

Additional complexity and variability of spring-run life history results from the different emergence times within different drainage. Early migration extending from early-December through June appears to be the dominate time of juvenile emigration in Butte and Chico creeks. However, some yearling salmon have been collected in January and February, which indicates some unknown portion of the juveniles over summer in the creeks to out migrate in the following fall. Yearling emigration from mid-October through March is significant in Mill and Deer creeks. The fall migration out of the drainage appears to respond to seasonal runoff events. Early season storms stimulate early outmigration (NHI 1994). In years of high late-spring runoff, coinciding with fry emergence, a large juvenile migration of age 0 fry is prompted similar to that observed in Butte Creek. Figure 4-1 displays life history stages and the timing of those stages in the Delta in order to better assess how the Project affects this species.

Delta Smelt

The delta smelt is a small, slender fish about 2-3 inches long endemic to the Sacramento-San Joaquin Estuary. Adult smelt spawn in freshwater, primarily in the channels and sloughs of the Delta (Moyle, et al. 1992). Adults begin migration to freshwater spawning areas during November through January. Recent SWP and CVP salvage data indicates salvage of adult delta smelt is highest in January and second highest in February.

During January through June, adhesive demersal eggs are spawned over aquatic vegetation, rocks, gravel, tree roots, and other submerged substrates (U.S. Fish and Wildlife Service 1993b). The eggs hatch within 9-14 days depending on water temperature and the buoyant larvae are carried by currents downstream to the upper end of the entrapment zone (EZ) i.e., the saltwater/freshwater interface of the Sacramento-San Joaquin Estuary.

Larvae and juvenile smelt generally rear in or upstream of the EZ (U.S. Fish and Wildlife Service 1993b). The EZ may be located in the channels of the Delta, in Suisun Bay, or further downstream, depending on the volume of Delta outflow. Location of the EZ in the Delta (i.e., reponding to Delta outflow less than about 10,000 cfs [Kimmerer 1992]) is believed to provide less favorable conditions than is provided when the location of the EZ is in Suisun Bay. The decline of the smelt population since 1983 may be associated with the occurrence of the EZ in the Delta channels, especially during the drought years 1987-1992 when monthly Delta outflow generally averaged less than 7,000 cfs during the spawning and rearing periods.

Recent SWP and CVP salvage data indicate salvage of young-of-the-year delta smelt is highest in June with July being the second highest.

The one-year life span and relatively low fecundity of delta smelt contribute to their vulnerability to extinction when population abundance is low. Factors that may reduce population abundance and drive the species toward extinction include (Moyle and Herbold 1989):

- reduced Delta inflow and outflow;
- extremely high Delta outflow (relatively rare flood events, i.e., 1983);
- entrainment in water diversions;
- perturbations to the smelt's food web (reduced abundance of phytoplankton and zooplankton, competition and predation by introduced species);
- presence of toxic substances (agricultural, industrial, and municipal discharges) in the smelt habitat; and
- loss of genetic integrity caused by reduced abundance of adult smelt.

The USFWS issued a biological opinion for the operation of the CVP and SWP, which prescribes reasonable and prudent alternatives to avoid jeopardy to delta smelt and Sacramento splittail from CVP and SWP operations (USFWS 1995). The USFWS issued its biological opinion in May 1997, that the Delta Wetlands Project will not jeopardize the continued existence of the delta smelt and Sacramento splittail or result in the destruction or adverse modification of their critical habitat (Attachment 1). Figure 4-2 displays life history stages and the timing of those stages in the Delta in order to better assess how the Project affects this species.

Longfin Smelt

The longfin smelt occurs from the Bay-Delta Estuary in California to Prince William Sound in Alaska. Longfin smelt is an euryhaline species with a 2-year life cycle. Spawning occurs in fresh water over sandy-gravel substrates, rocks, or aquatic plants. Spawning may take place as early as November and extend into June, although the peak spawning period is from February to April. After hatching, larvae move up into surface water and are transported downstream into brackish-water nursery areas. Delta outflow into Suisun and San Pablo bays has been positively correlated with longfin smelt recruitment because higher outflow increases larval dispersal and the area available for rearing. The longfin smelt diet consists of neomysids, although copepods and other crustaceans also are eaten. Longfin smelt are preyed upon by fishes, birds, and marine mammals (Federal Register Vol. 59 No. 4).

In the Bay-Delta Estuary, the decline in longfin smelt abundance is associated with freshwater diversion from the Delta. Longfin smelt may be particularly sensitive to adverse habitat alterations because their 2-year life cycle increases their likelihood of extinction after consecutive periods of reproductive failure due to drought or other factors. Relatively brief periods of reproductive failure could lead to extirpations (Federal Register Vol. 59 No. 4).

Although the southernmost populations of longfin smelt are declining, little or no population trend data are available for estuaries in Oregon and Washington. The listing of a Bay-Delta Estuary population segment is also not warranted at this time because that population does not seem to be biologically significant to the species as a whole, and may not be reproductively isolated (Federal Register Vol. 59 No. 4). Figure 4-2 displays life history stages and the timing of those stages in the Delta in order to better assess how the Project affects this species.

Sacramento Perch

The Sacramento perch is the only native Centrarchid west the Rocky Mountains. This species was once abundant in natural lakes, sloughs, and slow moving rivers of central California. The perch has been largely extirpated from the Delta, but surveys conducted by the DFG caught five Sacramento perch in Suisun Marsh from 1974 to 1979. In July of 1992, a DFG fishery biologist identified a Sacramento perch caught by an angler near Westgate Landing on the south fork of the Mokelumne River. Currently, in California, a viable native population of Sacramento perch exists in Clear Lake, Lake County. Introductions of Sacramento perch have occurred throughout the State in isolated farm ponds and reservoirs.

Sacramento perch can tolerate a wide range of water conditions, such as salinities of up to 17 ppt and water temperatures that exceed 77 °F. This adaptation is thought to have evolved in response to historical environmental fluctuations resulting from periods of flooding and drought. Throughout the Central Valley, the Sacramento perch inhabited sloughs, slow-moving rivers, and lakes that contained areas dominated by rooted emergent and submerged vegetation, which is critical for spawning and nursery habitat of young fish.

The decline of the Sacramento perch has been linked to several factors: competition with introduced species for food and spawning resources, predation by introduced species on eggs and young fish, and habitat alterations. The Sacramento perch's main competition comes from introduced species within its own family, such as black crappie, largemouth bass, small mouth bass, and bluegill. Competition may have forced the less aggressive Sacramento perch to utilize areas that are less suitable for spawning and feeding. When the perch is forced out of preferred habitats into areas that are less desirable, their reproductive success is limited. In Clear Lake, the

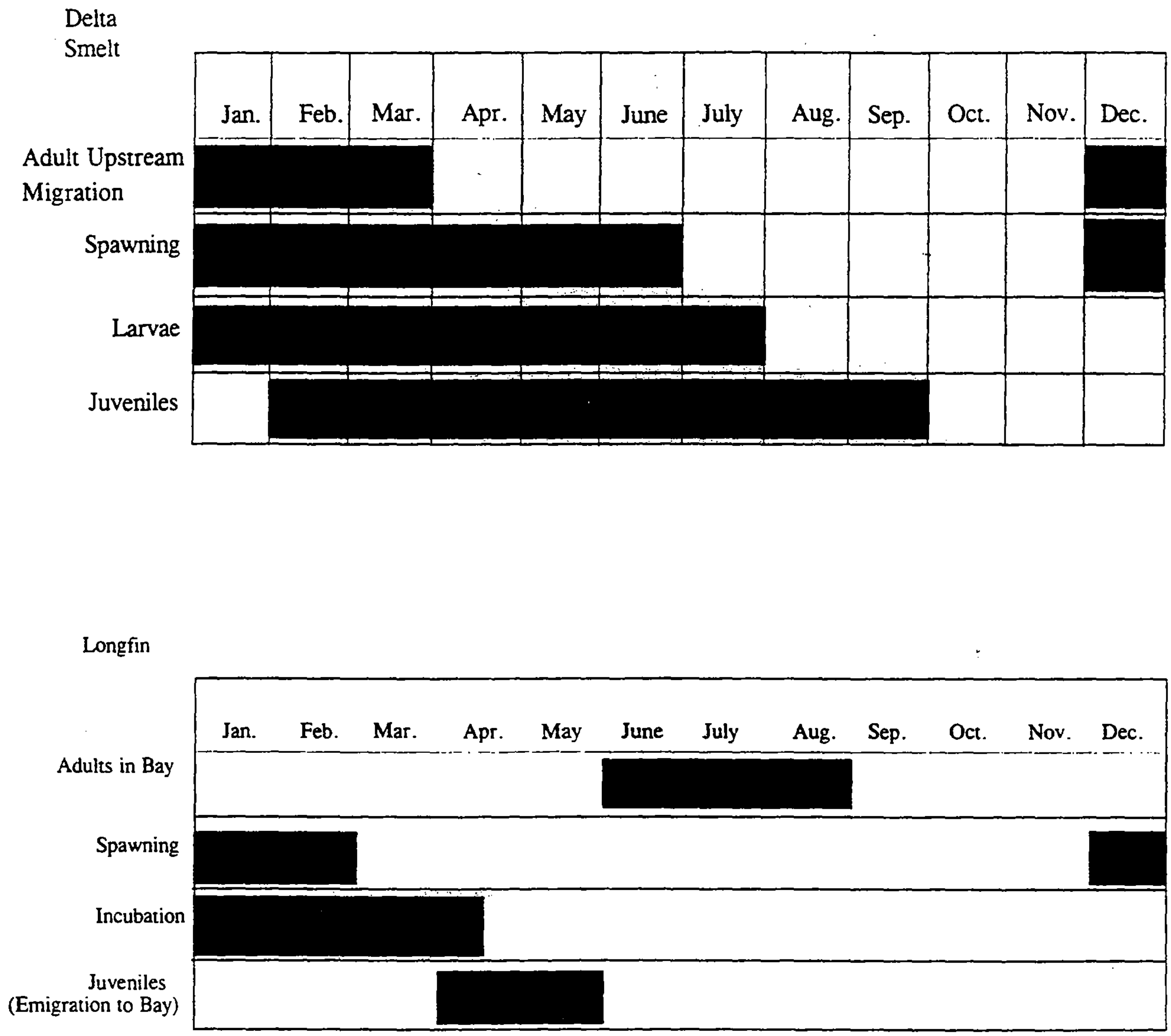

Figure 4-2. Life History of Delta Smelt and Longfin Smelt

Sacramento perch reproduction may be successful only when the population of black crappie is low. Moyle (1976) also reported that catfish and carp have been observed moving across spawning beds of the Sacramento perch eating deposited eggs. The introduction of these and other non-native species happened almost simultaneously with the occurrence of major habitat alterations in the Delta. Reduction in suitable habitat has occurred since the late-1800s when changes in the upstream hydraulic operations (dams, water diversions, and mining) altered the flow patterns of the Delta and its tributary streams. Construction of levees led to the loss of vast amounts of suitable spawning and nursery habitat in the Delta. Rip-rapping of channel and slough edges in the Delta further reduces the remaining habitat.

Stocking of Sacramento perch is currently limited to farm ponds and impoundments. Introductions into impoundments where other Centrarchid species are present have failed, and when stocked into impoundments where no other fish exist, they over-populate and growth becomes stunted (Moyle 1976).

Green Sturgeon

Green sturgeon have been taken in salt water from Ensenada, Mexico to the Bering Sea and Japan. They are found in the lower reaches of large rivers from the Sacramento-San Joaquin Delta northward, including the Eel, Mad, Klamath, and Smith rivers. Although spawning has not been confirmed in the Delta, juveniles are common in freshwater areas, especially in the summer. The diet of green sturgeon appears to consist primarily of neomysids and amphipods (Moyle 1976).

REPTILES

Giant Garter Snake

The giant garter snake is listed by the State of California as a threatened species. It is endemic to the Sacramento and San Joaquin valleys, where it presently occurs in a clumped distribution pattern from Butte to Fresno counties. It has be extirpated from the San Joaquin Valley south of Fresno County and has recently suffered serious declines in southern Sacramento County (Hansen and Brode 1980; Hansen 1982, 1986, 1988).

The original range of the GGS, as reported by Fitch (1940), was the floor of the Great Valley of California from Sacramento and Antioch southward to Buena Vista Lake. Fox (1951) indicated that intergrades between the GGS and a closely related subspecies, T. e.

The distribution of the GGS in the Sacramento Valley coincides for the most part with the major flood basins, including the American Basin, that historically formed along the Sacramento River.

Before reclamation was undertaken along the river, about 60 percent of the Sacramento Valley was subject to overflow which seasonally filled the broad, shallow flood basins. These basins supported heavy growths of tules. Today, only remnants of these once vast tules stands remain. The GGS inhabits sloughs, low gradient streams, and other waterways where it feeds on small fish and frogs. It finds shelter along banks and in adjacent uplands. It adapts well to man-made waterways as long as they have the primary requirements of (1) enough water during the active (summer) season to supply food and cover, (2) grassy banks for basking, (3) emergent vegetation for cover during the active season, and (4) high ground or uplands that provide cover and refuge from flood waters during the dormant (winter) season (Hanson 1988).

As a result of human activities, wetland habitats and GGS they once supported have been seriously depleted throughout the GGS's original range.

Housing, business, industrial, and recreational development have replaced GGS habitats with broad urban areas entirely unsuitable for these snakes. Wetlands have been drained and streams channelized, concreted, and even routed through underground pipes. Other habitats have been converted to landscaped green belts and managed as parks or other uses detrimental to GGS. Those GGS remaining in or near urban areas have been subjected to a host of hazards including loss of habitat, pollution, destruction of food sources, predation by native and introduced species and removal by amateur and commercial collectors.

While agriculture may benefit GGS under certain conditions by providing habitat and food along irrigation canals, many agricultural practices are detrimental to GGS.

GGS have been lost during tilling, grading, harvesting, and other operation of mechanical equipment within supporting habitats through direct physical injury and through exposure to predators and other stresses related to loss of shelter.

GGS habitats have lost their ability to support GGS when exposed to heavy grazing due to loss of protective plant cover (including tules). Soil compaction resulted in the destruction of underground and aquatic retreats such as rodent and crayfish burrows and other cracks and holes. Remaining GGS have been exposed to predators and other stresses related to loss of shelter.

GGS, functioning near the top of aquatic food chains, have been exposed to a wide array of chemical and other pest control measures. The effects of such measures as agricultural pest control and mosquito abatement (both of which applied large quantities of DDT and its successors within the habitats of GGS) remain unknown. Weed abatement and rodent control measures, especially along canal or other stream banks, has destroyed surface and underground shelter.

Human activities have resulted in widespread introductions of non-native species and redistribution of native species with the potential to compete with or prey on GGS. The terrestrial garter snake (TGS) and Valley garter snake (VGS) and a host of other animals such as skunks, raccoons, and housecats have been provided access to previously aquatic or semiaquatic environments through the conversion of these habitats to other uses.

Large predatory "gamefish" species have also been introduced into nearly all permanent freshwater environments within the Project Area. Since such aquatic predators did not previously occur here, these introductions affected GGS by preying on GGS and by competing with them for smaller forage fish. The tendency of these snakes to enter the water of forage or to escape enemies now places them at greater risk than previously.

GGS is an aquatic feeder specializing in ambushing fish underwater. It also readily takes larvae and young of the widely introduced bullfrog. A site must provide GGS protection (both in and out of water) from predation and other mortality factors during the active season. This shelter may take the form of vegetation or debris, or the burrows of rodents and crayfish.

Those sites that were populated by GGS provided access to upland retreats during runoff or flooding. Vegetation, burrows, and other shelter from predators at these upland retreats enhance the suitability of the site.

GGS bask during the active season in order to raise the body to activity temperatures. Basking may be an especially important aid to digestion, gestation, and healing and in rewarming the body following emersion in cool waters. While basking spots may be provided by vegetation and debris present within the habitat, dense overstories of riparian growth may block warming sunlight. Conversely, a lack of screening vegetation on a sunny stream bank exposes basking GGS to view by predators. If too few suitable basking spots are present in an otherwise favorable habitat, avian or other predators may concentrate their activates at those spots to the detriment of GGS.

Although the original GGS habitat within the Central Valley has largely been lost, man-made irrigation canals and ditches associated with rice farming and other agriculture now provide important habitat. GGS use the canals for year-round habitat and movement between major population centers. The GGS occurs in a wide variety of canals and ditches in the area. Some are densely vegetated with little disturbance and some have a dirt road along one or both sides. Most of these waterways are ideal for the GGS because they are too small to support large predatory fish, but large enough to provide adequate food and cover.

The rice fields provide important habitat during late summer, when the fields are flooded and contain large numbers of mosquitofish (*Gambusia affinis*), Pacific treefrogs (*Hyla regilla*) and other food items. This food source may be especially important to newborn GGS.

Northwestern Pond Turtle

The northwestern pond turtle occurs from the vicinity of the American River northward to the Columbia River. Within the Estuary, the northwestern pond turtle is found north of San Francisco Bay, while the southwestern pond turtle is found south of San Francisco Bay. These turtles, which are found in water that ranges from fresh to brackish to seawater, inhabits marshes, ponds, and small lakes with abundant vegetation, creeks, slow-moving streams, sloughs with riparian habitat, and irrigation ditches with emergent vegetation. Habitat requirements include well-vegetated backwater areas with logs for basking and open sunny slopes away from riparian zones for egg deposition. Western pond turtles nest up to 400 meters from and 60-90 meters above stream banks on sand banks along the courses of large rivers, or on hillsides in foothill regions. The turtles mate in April and May, and eggs are laid from June through August. The hatchlings overwinter in nests and emerge in March or April. Sexual maturity in pond turtles is thought to occur at about eight years and they may live for 30 to 40 years (DWR 1994, Jennings et al. 1992).

The continuing loss of suitable nesting habitat may result in inadequate reproduction rates in some areas. Extensive water diversion for agriculture and other purposes has led to the reduction of western pond turtle numbers in California. Dredging also destroys suitable habitat, as does the construction of dams and reservoirs.

Southwestern Pond Turtle

The southwestern pond turtle, previously a federal category 2 candidate species, ranges from San Francisco Bay south into northwest Baja California. It is restricted in its range to land west of the crest of the Sierra Nevada (Pritchard 1979, Behler and King 1979). It can be found from the Lower Sonoran into the Transition life-zones (Stebbins 1954).

The pond turtle is considered to be thoroughly aquatic in its habitat preference (Smith and Brode 1982). It selects quieter pools and backwaters in swifter streams. It has been seen in brackish water (Behler and King 1979, Stebbins 1954, Stebbins 1966, Pritchard 1979, Pope 1939). It is more common in areas with muddy or rocky bottoms that are overgrown with aquatic vegetation such as cattails, watercress, or water lilies. They use mudbanks, logs, and cattail mats for basking (Stebbins 1954, Stebbins 1966). Pond turtles seek deep water with masses of waterlogged leaves and brush for escape cover (Van Denburgh 1922).

The southwestern pond turtle is the most carnivorous member of the genus Clemmys (Smith and Brode 1982). Food consists of aquatic plants such as yellow pond lily pads (Stebbins 1954), insects such as aquatic beetles (Pope 1934), and carrion (Stebbins 1966).

Pond turtles hibernate in winter. The exact extent of the hibernation period varies with season, altitude, and latitude. It is active in March in southern California. Pond turtles hibernate in the mud of stream or pond bottoms (Pope 1939, Stebbins 1954).

Nesting in central California takes place in late April and May. Nesting sites are usually located in a sunny place near a pond, stream, or river, but nesting sites may also be in an open field or hillside hundreds of yards from water (Pope 1939, Stebbins 1954).

BIRDS

Bald Eagle

The bald eagle, a state- federally-listed endangered species, is a large brown bird of prey which, as an adult, has a white head and tail. The bald eagle occurs widely in North America and winters throughout most of California at lakes, reservoirs, river systems, interior and coastal wetlands, and some rangelands. The breeding range is mainly in mountainous habitat near reservoirs, lakes and rivers in the northern quarter of the State; some pairs also breed in southern California on Santa Catalina Island and mainland Santa Barbara County. The winter population appears to be stable, and the breeding population is increasing in number and range. The size of the winter population varies from year to year and may exceed 1,000 birds some winters (as in 1987-88). Eighty-three breeding pairs occupied breeding sits in 1989. The Pacific Bald Eagle Recovery Plan (1986) establishes geographical goals for population recovery. The multi-agency California Bald Eagle Working Team provides guidance to agencies and groups in management and research matters, and the team is preparing a management plan for bald eagles in California to assist in implementing the recovery plan. Many breeding territories are being maintained and protected under local management plans. Key winter habitats are receiving increasing attention in terms of population monitoring, site protection, and public viewing and education. Several entities, including Pacific Gas and Electric Company and U.S. Forest Service, are currently sponsoring intensive ecological studies. Other research efforts are under way on contaminants, human disturbance, and other issues that affect this species. Several bald eagle studies, including population restoration efforts on the Channel Island, have been supported with Tax Check-off funding assistance.

Bald eagles are occasional winter visitors in the Sacramento-San Joaquin Delta. The bald eagle is predominately a fish-eating bird, however, other prey items may include birds, amphibians, and reptiles. They forage over the lake and hunt from perches in trees along the shoreline, particularly where the banks are steep.

American Peregrine Falcon

This species nests in the Sierra Nevada, the mountains of northern California, and along the coast. It is found inland, during winter, throughout the Central Valley and occasionally on the Channel Islands. It migrates during the spring and fall throughout California. Riparian areas, and coastal and inland marshes are important year-round habitats, while breeding typically takes place in woodland, forest, and coastal habitats on cliffs.

It requires protected ledges for cover and preys upon many different bird species, up to the size of ducks. It utilizes cliffs in the vicinity of lakes, rivers or marshes. It stoops from flight to intercept flying prey.

This species is both state and federally listed endangered. Populations have been increasing in recent years. DFG researchers have recorded 106 breeding pairs in California in 1990. This species is highly susceptible to eggshell thinning induced by ingestion of DDT and its primary metabolite DDE. The low reproductive rates for the coastal population is probably due to heavier DDE loads received from migrant prey species. California has established several ecological reserves to protect peregrine nesting sites. The Predatory Bird Research Group (Santa Cruz, California) has operated a captive rearing program to help augment wild peregrine populations.

Aleutian Canada Goose

This subspecies of Canada goose breeds in the Aleutian Islands. Its main wintering grounds are in the Central Valley of California. This goose generally leaves the Aleutians in late-September for its southward migration. Following stops along the Oregon coast and the California coast above Crescent City, it arrives in the Central Valley from October to November. The geese use the Sacramento Valley marsh and agricultural areas in early winter. In December and January, Aleutians are typically found using suitable habitat in the upper San Joaquin Valley near Los Banos and south of Modesto. Use of Suisun Marsh by these birds is sporadic. Preferred foraging areas include lightly grazed pasture lands. Aleutians feed on green shoots and seeds of cultivated grains as well as wild grass and forbs. The return migration to the north occurs from late-February through April.

The Aleutian Canada goose was originally listed as endangered by the USFWS due to its severely depleted population. Nest predation in breeding areas was the principal cause. The sport hunting harvest of this reduced population exacerbated the decline. Recovery efforts focused on removal of predators from the breeding islands and hunting restrictions. The population has now rebounded from an estimated wintering population of 800 in the mid- 1970's to over 5,000 currently. As a result, the USFWS has recently down-listed this subspecies to threatened. Continued maintenance of suitable wintering habitat, including managed marsh and suitable agricultural lands, such as small grains and pasture, is important for the continuing recovery of this species.

The Aleutian Canada goose infrequently utilizes the areas that will be affected by the proposed project. The proposed standards include standards for the managed marsh in Suisun Marsh which are intended to maintain and improve habitat conditions, in part, for waterfowl.

California Black Rail

The California black rail is a rare year-long resident of tidal salt marshes and brackish and freshwater marshes in the San Francisco Bay area, Sacramento-San Joaquin Delta, coastal southern California at Morro Bay, the Salton Sea, and lower Colorado River area. Formerly a local resident in coastal lowland marshes from Santa Barbara County to San Diego, it still winters there rarely. Significant loss of saltwater, brackish, and freshwater wetland habitat has contributed to reduced populations. Extreme high tides in tidal marshes and water level fluctuations in freshwater marshes have disrupted nesting attempts. Loss of high marsh vegetation around San Francisco Bay has also eliminated the species as a breeder in the south bay (Manolis 1977).

Since black rails usually frequent upper marsh zones, during extreme high tides, they may depend on the zone where the upper marsh vegetation intergrades with peripheral, upland or freshwater marsh vegetation for cover.

Black rails are carnivorous. They glean and peck for a variety of arthropods (e.g., isopods and insects) from the surface of mud and vegetation.

Black rails occur most commonly in tidal saltmarshes dominated by pickleweed or brackish marshes supporting bulrushes, in association with pickleweed. In exclusively freshwater marshes where black rails occur, bulrushes and cattails are usually present.

Rail nests are concealed in dense marsh vegetation, such as pickleweed, near the upper limits of tidal flooding and consist of a loosely-made, deep cup which may be at ground level or elevated several inches high. The black rail is state listed threatened and was previously a federal candidate species.

Tricolored Blackbird

The tricolored blackbird is largely endemic to California but also occurs in extreme southern Oregon, western Nevada, and northwestern Baja California (Neff 1937). This species' historical breeding range in California included the Sacramento and San Joaquin Valleys and low foothills of the Sierra Nevada from Shasta County south to Kern County, along the coast from Sonoma County south to the Mexican border, and on the Modoc Plateau (Dawson 1923, Grinnel and Miller 1994).

Although tricolored blackbird populations have declined throughout their range, they continue to breed in the Central Valley up to the low foothills (DFG 1988), in coastal areas from Sonoma county south to Baja California, and on the Modoc Plateau south to the Honey Lake

Valley, Lassen County (Garrett and Dunn 1981, McCaskie et al. 1975a). A statewide survey conducted during 1968-1972 indicated that 78 percent of the 168 colonies located were in highly agricultural portions of the Central Valley (DeHaven et al. 1975a). Populations in this region may have declined by 50 percent from the 1940s (DeHaven et al. 1975a). Tricolored blackbird band recoveries suggest that wintering individuals may travel the entire length of the Central Valley, and from there into the San Francisco Bay-Delta area, the northeastern plateau region of California, and southern Oregon (Neff 1942, DeHaven et al. 1975b).

Nonbreeding tricolored blackbirds forage in large nomadic flocks and often mingle with other blackbirds (Orians 1980). During winter and fall, tricoloreds consume mostly weed seeds and waste grain (especially rice and water grass) from agricultural fields (Crase and DeHaven 1978).

Breeding tricolored blackbirds forage at freshwater marshes, wet pastures, margins of ponds, agricultural fields, barnyards, and feedlots (Beedy and Hayworth 1993). Although breeding tricoloreds may fly 2-4 miles from their colonies to seek food (Neff 1937, Orians 1961), they typically exploit locally abundant and changing food supplies and minimize the distance of their foraging flights (Crase and DeHaven 1977).

Breeding tricolored blackbirds forage opportunistically and glean insects and seeds from dry ground, flooded fields, mudflats, floating algal mats, and low vegetation; occasionally they hawk insects in midair (Beedy and Hayworth 1993). Breeding season foraging studies in Merced County showed that animal matter makes up about 91 percent of the food volume of nestlings and fledglings, 56 percent of the food of adult females, and 28 percent of adult males (Skorupa et al. 1980). The animal taxa most often consumed were beetles (63 percent), butterflies and moths (35 percent), and flies (14 percent). Plant foods eaten most often included oats (27 percent), chickweed (15 percent), and filaree (9 percent) (Skorupa et al. 1980).

Although the dietary water requirements of adult tricolored blackbirds are apparently unknown, observations suggest that breeding colonies need water on or near their colonies (Beedy 1989). Of seven colonies examined by Beedy and Hayworth (1993) , six were situated above standing water and one was within about 200 yards of a flowing canal.

Tricolored blackbirds nest in dense colonies in the vicinity of fresh water, especially in marshy areas with heavy growths of cattails (*Typha* spp) and tules (*Scirpus* spp.) (Grinnell and Miller 1944). In addition to these preferred nesting substrates, tricolored blackbirds also nest in other vegetation, such as willows (*Salix* spp), thistles (*Centaurea* spp.), mustard (*Brassica* spp.), nettles (*Urtica* spp), blackberries (*Rubus* spp.), salt cedar (*Tamarix* spp), giant cane (*Arundo donax*), wild grapes (*Vitus* spp.), and wild roses (*Rosa* spp.) (Neff 1937, DeHaven et al. 1975a, Hosea 1986). Proximity to productive foraging grounds such as flooded fields, margins of ponds, and grassy fields is also important in nest site selection (Grinnell and Miller 1944).

An important link in the tricolored blackbird nesting cycle is the availability of patchy, superabundant food supplies that may not be readily detected by humans. A lack of food may explain why many seemingly suitable habitats are unoccupied by tricoloreds. Thus, the quality, not only the extent, of habitat is of paramount importance (Beedy 1989).

Tricolored blackbirds typically initiate nest building in early or mid-April (Orians 1961), and breeding activity has been observed until early July (Beedy and Hayworth 1993). Rarely, tricolored blackbird populations have been observed nesting during October and November in the Sacramento Valley (Orians 1960, Payne 1969). Generally, nests are concentrated within a fraction of the total area available (Beedy 1989).

This species is the most intensely colonial of all North American passerines (Orians 1980) with as many as 20,000 nests located in an area of 10 acres or less (Dehaven et al. 1975a).

Within established nesting areas, tricolored blackbirds are extremely sensitive to predators, and even relatively minor disturbances can cause abandonment of entire colonies (Beedy 1989). Historical literature describes predation by mammals (Heerman 1853, Mailliard 1914, Evermann 1919) causing major nesting failures. Other observers have also reported massive tricolored blackbird nesting failures due to bird and mammal predators (Neff 1937, Lack and Emlen 1939), poisoning (McCabe 1934), and human disturbance (Beedy and Hayworth 1993).

Swainson's Hawk

The Swainson's hawk was described in early accounts as one of the most common raptors in California (Sharp 1902). The species occurred throughout much of lowland California, hunting in open grassland habitats and nesting along the edges of riparian forests or oak woodlands, or in isolated trees that were scattered across the valley savannas.

Pre-agricultural California supported abundant woodland and grassland habitats, particularly throughout the Central Valley. Since the mid-1800s, these native habitats have undergone a gradual conversion to agricultural uses. Today, native grassland habitats are much reduced in the state, and only remnants of the once vast riparian forests and oak woodlands still exist (Katibah 1983).

The effect of widespread loss of both nesting and foraging habitats on Swainson's hawks has been a significant reduction of the breeding range and the breeding population in California (Bloom 1980). The state currently supports an estimated 550 breeding pairs of Swainson's hawk, representing less than 10 percent of the historic population (California Department of Fish and Game 1988). To provide protection for the remaining population, the State of California listed the Swainson's hawk as a threatened species in 1983.

The largest segment of the California Swainson's hawk population exists in the Central Valley, where an estimated 440 pairs nest (California Department of Fish and Game 1988). Although agricultural conversion of native habitats was probably the primary factor responsible for initial Swainson's hawk declines in the state certain agricultural practices are largely responsible for maintaining current populations. The row, grain, and hay crop farming typical of the mid-section of the Central Valley is compatible with Swainson's hawk foraging habitat needs. The distribution of the Central Valley population is closely correlated with the distribution of these cropping patterns. This region of suitable agricultural foraging habitat is considered essential in maintaining the stability of the Central Valley Swainson's hawk population.

Swainson's hawks usually nest in large, mature trees. Native trees are almost always used, although nests have been found in eucalyptus (*Eucalyptus* sp.) trees and ornamental conifers. Tree species most commonly used in the Central Valley in decreasing order of frequency include valley oak (*Quercus lobata*), Fremont cottonwood (*Populus fremontii*), black walnut (*Juglans hindsii*), and willow (*Salix* sp.). Nests are usually of flimsy construction and often blow out of the nest tree during high winds, particularly during winter.

Although nest sites are not found exclusively in riparian habitat, more than 87 percent of the known nest sites in the Central Valley are within riparian systems (Schlorff and Bloom 1983, Estep 1984). Swainson's hawks also nest in roadside trees, isolated individual trees, small groves, and on the edges of remnant oak woodlands.

Swainson's hawks are highly traditional in their use of nesting territories, returning each year to the same nest tree or a tree nearby. Many nest sites in the Central Valley have been monitored annually since 1978, and a program of color banding nesting paries has been ongoing since 1986. These studies show a high degree of nest site and mate fidelity among pairs.

The Swainson's hawk is adapted to foraging in large, open plains and grasslands. In the Central Valley, however, virtually all native foraging habitat has been converted to agricultural uses, restricting Swainson's hawks to areas that support cropping patterns compatible with their foraging requirements. Both the abundance of prey populations and the accessibility of prey to foraging birds determine the suitability and quality of agricultural foraging habitat for Swainson's hawks. The many crop types grown in the Central Valley differ widely with respect to their foraging habitat suitability.

Swainson's hawks hunt aerially almost exclusively in the Central Valley, soaring from 100 to 300 feet above the ground while scanning for prey (Estep 1989). Foraging birds select fields that are most compatible with this type of foraging behavior (i.e., fields that are large, support low cover to provide access to the ground, and provide the highest densities of accessible prey). These habitats include hay and grain crops, lightly grazed pasture lands, and certain row crops, such as tomatoes and sugar beets. Fields lacking adequate prey populations, such as flooded rice fields, or those that are inaccessible to foraging birds, such as vineyards and orchards, are avoided.

Cropping patterns directly affect the foraging behavior, foraging range size, and ultimately the reproductive success of nesting Swainson's hawks. As crops mature, vegetative cover increase, which decreases prey accessibility; as a result foraging birds expand their ranges in search of fields that provide accessible prey. Foraging Swainson's hawks have been observed traveling more than 9 miles from their nest in search of prey (Estep 1989). Later in the season, as crops are harvested, foraging ranges decrease as prey become more accessible near the nest. Prey abundance has also increased by the time harvesting operations proceed. The result is that foraging ranges can fluctuate both seasonally, in response to changes in prey accessibility and abundance, and from year to year in response to changing cropping patterns. Overall foraging ranges (averaging 6,800 acres) ranks the habitat quality of various crops grown in the Central Valley as high, moderate, or low based on their value to foraging Swainson's hawks.

Corn and wheat, the primary crops grown in the central Delta, provide suitable foraging habitat for nesting Swainson's hawks. However, most of the crop types in the central Delta are suitable as foraging habitat only during part of the breeding season. The timing of corn and wheat planting and harvesting are complementary, providing suitable foraging habitat throughout most of the breeding season.

Both corn and wheat provide foraging habitat during the early part of the breeding season. Wheat fields become less suitable in April as the crop matures. Cornfields continue to be suitable for foraging through May. As cornfields mature, they also become unsuitable, but by late June to early July, wheat is harvested and harvested wheat fields again become suitable habitat. Thus, it is possible that suitable habitat is available to foraging Swainson's hawks on central Delta islands throughout most of the breeding season. The central Delta also supports other row, grain, and hay crops and pastures that attract foraging Swainson's hawks.

Swainson's hawks are known to nest in the central Delta and individuals are occasionally observed foraging on the central Delta islands, including the Project islands, during the breeding season, (Jones and Stokes Associates 1990a, Holt pers. comm.). Pairs that nest outside the Delta may also forage on Delta islands during certain times of the year, particularly during periods of harvest or during periods of foraging range expansion, which occurs when prey is limited near the nest (Estep 1989).

In general however, Swainson's hawks will limit their foraging movements to stay as close to the nest as possible. Thus, foraging frequency declines with distance from the nest. In most cases, nest sites are located near high-quality foraging habitat; thus, hawks will travel far from the nest only if necessary, based on both the crop patterns near the nest and availability of suitable habitat elsewhere.

Although an unusual occurrence at northern latitudes, the Delta is also used by Swainson's hawks during the winter. Swainson's hawks are migratory, and most spend winters in South America. Individuals, however, have been sighted during winter in the Delta over the last 10 years (Holt pers. comm.). In 1990-1991, a group of 29 adult Swainson's hawks was regularly observed on Bouldin Island and neighboring Venice Island for several weeks. These birds appeared to be attracted to the abundance of prey that resulted from the discing and flooding operations on the islands. A key roost area was a stand of eucalyptus trees across the Mokelumne River from Bouldin Island on neighboring Tyler Island, where the group roosted for several weeks.

The above information was taken into consideration when the DFG developed its mitigation guidelines for the Swainson's hawk.

Greater Sandhill Crane

The greater sandhill crane is the largest of four recognized subspecies of sandhill crane (Walkinshaw 1949). The greater sandhill crane is a wetland-associated bird, requiring marsh and meadow habitats during the breeding season, and shallow wet habitats for roosting during winter. This subspecies feeds primarily on invertebrates, roots, tubers, and certain cereal grains during the winter (Schlorff et al. 1983).

Four populations of greater sandhill crane are recognized: Eastern, Rocky Mountain, Colorado River Valley, and Central Valley. The Central Valley population nests from northeastern California to British Colombia (U.S. Fish and Wildlife Service 1978, Pogson and Lindstedt 1988). The entire Central Valley population, estimated at 3,400-6,000 individuals (California Department of Fish and Game 1989), winters in the Central Valley, along with the entire Pacific Flyway population of lesser sandhill crane (*Grus canadensis*) (Pogson et al. 1988).

Seven sites in the Central Valley are considered important wintering sites for the greater sandhill crane: Sacramento-San Joaquin River Delta, Chico, Butte Sink, Angel Slough, Modesto, Merced, and Pixley. The most important of these sites is the Sacramento-San Joaquin Delta, which supports as much 75 percent of the Central Valley population during late winter (Pogson and Lindstedt 1988).

Both roosting and foraging habitat are essential to Central Valley population during winter. Greater sandhill cranes congregate in communal roosts at night, and fly off each morning to forage in suitable fields, pastures, or other shallow wetland habitats. Most traditional foraging areas are near (within 2-3 miles) communal roost sites. Thus, the proximity of foraging habitat to communal roost sites is an important determinant of suitable wintering habitat.

Communal roost sites are typically large fields (100+ acres), flooded with one to ten inches of standing or slowly moving water, and with relatively low-relief shorelines (Pogson and Lindstedt 1988). Most roost sites in the Central Valley are on private duck clubs, and have been created to attract wintering waterfowl.

Foraging habitat for the Central Valley population varies at different locations in the Central Valley. The primary source of carbohydrates is cereal grains: waste corn in the Delta and Modesto regions and waste rice in the Sacramento Valley (Pogson and Lindstedt 1988). Cranes also forage on wheat sprouts in newly planted winter wheat fields and on sprouts, shoots, tubers, invertebrates, and seeds in fallow fields and in uncultivated habitats (field borders, levees, canal and irrigation ditch banks) (Pogson and Lidndstedt 1988).

Greater sandhill cranes begin arriving in the Central Valley in October. During winter, the distribution of the Central Valley population shifts as cranes move between the major wintering sites. Records from Pogson and Lindstedt (1988) and Department crane surveys indicate that populations in the Delta are relatively small in October (from zero to about 1,500 cranes) and begin increasing in mid-November to late November. The Delta population peaks in January and February (4,000-5,000 cranes) and declines sharply by March as cranes begin their northward migration.

The increased abundance of cranes in the Delta during January and February coincides with a decline in abundance in the Chico and Butte sink areas. Pogson and Lindstedt (1988) suggest that movement of the population from the northern Sacramento Valley to the Delta may be a traditional occurrence, possibly brought on by changes in food resources or roosting habitat availability. Thus, although greater sandhill cranes winter in the Delta form October through March, they occur in the greatest abundance toward the latter portion of the wintering season.

The central Delta and the Cosumnes and Mokelumne River floodplains provide habitat for the entire Delta wintering population (Pogson and Lindstedt 1988). Delta islands considered important greater sandhill crane winter foraging and roosting habitat include Staten Island, Tyler Island, Brack Tract, and Canal Ranch. Other Delta Islands considered crane winter foraging acres include Grand Island, Terminous Tract, New Hope Tract, and Bouldin Island (Pogson and Lindstedt 1988). Cranes also use Webb Tract extensively. Isolated records of cranes suggest that cranes may also forage on adjacent Delta islands such as Bacon Island and Holland Tract.

Cranes occur primarily on suitable roosting habitat and adjacent suitable foraging areas. Roost sites are limited in the central Delta, although cornfields and wheat fields and other crane foraging habitats are abundant. Thousands of lesser and greater sandhill cranes converge each evening on the few available roost sites in the Delta provided by private duck clubs. Two important roost sites, Woodbridge Ecological Reserve and the Robin Bell property, are owned by the Department solely for the management of greater sandhill cranes.

Western Yellow-Billed Cuckoo

The California yellow-billed cuckoo, a California-listed endangered species, is a subspecies of the yellow-billed cuckoo. The species was once common in the Western states but has been extirpated from much of its previous range including southern British Columbia, Washington, Oregon, Idaho, Utah, and Nevada (Laymon and Halterman 1987).

The cuckoo usually arrives in California in June and departs by late August or early September to winter in South America. It is considered an uncommon to rare summer resident of valley foothill and desert riparian habitats in scattered locations throughout California (Zeiner et al. 1990).

The yellow-billed cuckoo inhabits deciduous riparian thickets or forests with dense, low-level or understory foliage adjacent to slow-moving watercourses, backwaters, or seeps. Willow and cottonwood are usually dominant components of the vegetation. Within the Sacramento Valley, the cuckoo may also utilize adjacent orchards; along the Colorado River, they may inhabit mesquite thickets when willow is absent (Zeiner et al. 1990).

The cuckoo typically nests in sites with at least some willow, a dense understory of foliage, high humidity, and wooded foraging sites greater than 25 acres in area (Gaines 1977). Most eggs are laid mid-June to Mid-July with the clutch size averaging 3-4 eggs (Bent 1964).

Surveys conducted in California in 1977 estimated between 122 and 163 breeding pairs. Surveys conducted again in 1986 and 1987 estimated between 30 to 33 pairs (Laymon and Halterman 1988). This represents a 73 to 82 percent decline which is attributed to loss of riparian habitat.

Loggerhead Shrike

Typical loggerhead shrike nesting habitat is an open field with a few trees, open woodlands, or scrub. They breed over most of North America from central Canada south to southern Mexico. The loggerhead shrike winters throughout most of the breeding range, but retreats somewhat from Canada. The loggerhead shrike feeds mostly on large insects and other land invertebrates, and also on mice, birds, lizards, and carrion. Its survival is jeopardized by habitat destruction and exposure to pesticides, and possibly from impact with cars on roads within nesting and hunting territories (Erlich et al. 1992).

The loggerhead shrike has been observed in the eastern and western Suisun Marsh. They utilize a number of different habitat types in the marsh including open fields, wetlands, uplands, and open woodlands (Brenda Grewell, DWR, pers. comm., December 1994).

Willow Flycatcher

The willow flycatcher, a state-listed endangered species, was formally a common summer resident throughout California. The breeding range of the willow flycatcher extended wherever extensive willow thickets occurred. The species has now been eliminated as a breeding bird from most of its former range in California. Only five populations of significance remain in isolated meadows of the Sierra Nevada and along the Kern, Santa Margarita, San Luis Rey, and Santa Ynez rivers in southern California. The smallest of these consisted of about six pairs and the largest about 44 pairs. The total population estimate for California is about 200 pairs of willow flycatchers. A survey conducted in late summer 1991 on Department-owned willow riparian habitat at Red Lake, Alpine County, indicated that a significant breeding population exists there. Further study is planned.

The loss of riparian habitat is the principal reason for the decline of California's willow flycatcher population land contraction of the species' range. Impacts to habitat and breeding birds associated with livestock grazing have also been implicated in the decline of the species. Nest parasitism by brown-headed cowbirds (*Molothrus sp.*) may have contributed significantly to population reductions.

More than a decade ago, the Department designated the willow flycatcher a "Bird Species of Special Concern" of highest priority. This finding prompted several years of Department studies to further assess the status of willow flycatchers in California. Reports from the Pacific Coast and Southwest resulted in addition of the willow flycatcher to the National Audubon Society's Blue List of declined bird species in 1980 and 1986. In 1984, the willow flycatcher was added to the U.S. Forest Service, Region 5 (most comprised of the State of California) Sensitive Species list. The USFWS has also designated the willow flycatcher as a sensitive species for Region 1 (Washington, Idaho, Oregon, California, and Nevada) based on significant declines in this region. The Southwestern willow flycatcher (*E.T. extimus*), with small populations in southern California, was proposed for listing as endangered by the USFWS on July 21, 1993.

Burrowing Owl

The burrowing owl, a California species of special concern, is a year round resident of open, dry grassland and desert habitats and can also be found in grass, forb and open shrub stages of pinyon-juniper and ponderosa pine habitats. It was formerly common in appropriate habitats throughout the state, excluding the humid northwest coastal forests and high mountains. The population of these owls has markedly decreased in recent decades due to conversion of grassland to agriculture, and poisoning of ground squirrels (Zeiner et al. 1990).

The burrowing owl's diet consists mainly of insects but will consume small mammals, reptiles, birds, and carrion. It hunts from a perch, but also hovers, hawks, dives, and hops after prey on the ground (Zeiner et al. 1990).

This owl usually nests in bare, level ground in abandoned burrows of ground squirrels or other small mammals (Verner and Boss 1980). In soft soils it may dig its own burrows and in areas where animal burrows are scarce it may use pipes, culverts, and nest boxes (Robertson 1929). The nest chamber is typically lined with excrement, pellets, debris, grass, feathers, but on occasion it may be unlined.

Throughout the day the burrowing owl moves its perching location to thermoregulate. In the early morning hours it perches in open sunlight and as the warms it will move to the shade or into the burrow (Coulombe 1971.)

Breeding occurs from March through August, with peak in April and May. Clutch size ranges between 2-10 eggs with an average of 5-6. The young emerge from the burrow at about 2 weeks of age and are able to fly by about 4 weeks. The burrowing owl is semicolonial and probably the most gregarious owl in North America.

MAMMALS

Riparian Woodrat

The riparian woodrat, a subspecies of the dusky-footed woodrat, is a California Species of Special Concern and previously a Federal Category 2 Candidate. The historic range of the riparian woodrat occupied the native riparian forests within the natural floodplain along the northern portion of the San Joaquin River and its tributaries from Stanislaus County to the Delta. This type of habitat had a brushy understory associated with the forest and adjacent upland areas suitable for cover and retreat from annual floods (Orr 1940). This historic range is nearly identical to the historic range of the riparian brush rabbit (Larsen 1993). Currently, the riparian woodrat and the riparian brush rabbit are known to occur only in CMSP, San Joaquin County, along the Stanislaus River (Williams and Basey 1986).

The riparian woodrat is declining in population size and appears to be in jeopardy (Williams 1986) due to loss of habitat. This loss is primarily due to the completion of dams on the main tributaries to the lower San Joaquin River system which has reduced the frequency and severity of flooding. Prior to construction of dams and levees, much of the land that periodically flooded was used as pasture and was uneven in topography with some ground remaining above typical flood levels. These higher areas contained numerous patches of shrubs and trees and probably provided refuge during flooding events. Virtually all areas outside of flood-control levees now have been cleared, leveled, and planted as orchards, vineyards, or annual row crops.

The riparian woodrat lodge is constructed of sticks and other litter in tree cavities, snags, logs, or downed woody material.

Riparian Brush Rabbit

There are 13 recognized subspecies of brush rabbit, and eight of these occur in California. Riparian brush rabbits, a subspecies of the brush rabbit, are small brownish cottontail-like rabbits with a white belly, relatively short ears and a small inconspicuous tail. The hind legs are short and hind feet are slender and not covered with long or dense hair. The white belly and ventral tail hairs are gray near the skin, and the ears lack dark areas at the tips (Orr 1940, Ingles 1965, Chapman 1974). Adults are about 13 inches long (300-375 mm). The riparian brush rabbit can be distinguished from other subspecies by its relatively pale color, gray sides and darker back (Orr 1935)., its restricted range and habit requirements, and its skull characteristics. When looking down at the head from above, their cheeks protrude outward rather than being strait or curving inward as in other subspecies (Orr 1935, 1940).

The riparian brush rabbit was first described by Orr in 1935 with the type locality designated as the west side of the San Joaquin River, two miles north of Vernalis, Stanislaus County, California.

Riparian brush rabbits forage on herbaceous vegetation, including grasses, sedges, clover, forbs, shoots, and leaves within or very close to brushy cover, usually along trails, fire breaks, or at the edge of brushy areas. They seldom venture more than several meters from brushy cover, and do not forage in large open areas. Foraging activity occurs during the early morning and early evening hours (Larsen 1993).

Home ranges are generally small, and are located within and usually shaped by the extent of available brushy areas. The average home range size has been estimated as 957 m^2 for males and 244 m^2 for females. Female home ranges overlapped slightly at the edges, but the core areas did not overlap. Brushy clumps smaller than 450 m^2 are rarely occupied (Larsen 1993). At Caswell Memorial State Park (CMSP), the overall population density of riparian brush rabbits at carrying capacity is estimated to be three animals per hectare (3/ha).

The breeding season of riparian brush rabbits in CMSP occurs from January to May. The gestation period is about 27 days, and three to four young are born in a shallow burrow or cavity lined with grasses and fur and covered by a plug of residual vegetation. The young have fine thin hair and their eyes are closed. They are nursed only at night, and after about 10 days their eyes open. They remain in the nest for about two weeks and continue to nurse for two more weeks after that. The young do not become reproductively active until the following breeding season. Adult females can breed again shortly after birth of a litter. They have about three to four litters during the season, with an average of nine to 16 young produced per female per year. Five out of six rabbits (*Sylvilagus* sp.) do not survive until the next breeding season, so population turnover is rapid (Larsen 1993).

The habits of dispersal are generally unknown. It is assumed that animals may travel a very short distance if necessary to find a suitable unoccupied home range within riparian habitat during the breeding season. They are closely restricted to dense brushy cover and probably are unable or unwilling to disperse through large open areas, so the riparian brush rabbit population is confined to the CMSP. Animals that are displaced farther than 350 m from their home range have extreme difficulty returning to their original territory (Larsen 1993).

Riparian brush rabbits are preyed upon by various native raptorial and carnivorous species that normally occur within the riparian habitat, such as hawks, owls, foxes, and snakes. They are also susceptible to predation by feral dogs and cats. During chance environmental events resulting in flooding or wildlife, they can suffer direct mortality.

The riparian brush rabbit is strictly associated with San Joaquin Valley riparian forests with dense brushy understory. The habitat was found within the floodplain on the valley floor in northern San Joaquin Valley. The original forest and floodplain have been cleared, altered, and degraded. The wholesale destruction of this essential habitat has resulted in the disappearance of the riparian brush rabbit from all but a very tiny portion of its historic range (Williams 1986, 1988, and 1993; Williams and Basey 1986; Basey 1990).

Riparian brush rabbits occupied the native riparian forest within the natural floodplain along the northern portion of the San Joaquin River and its tributaries from Stanislaus County to the Delta (Orr 1940). During historical times, this area had ample brushy understory associated with the forest and suitable upland areas for cover and retreat from annual floods. The riparian brush rabbit occurred within suitable habitat throughout this area (Larsen 1993).

All evidence indicates that riparian brush rabbits are now completely dependent on the remaining suitable habitat in CMSP. Recent surveys along rivers within the historic range were conducted by Williams and Basey (1986) and Basey (1990) and concluded that no riparian brush rabbits were found anywhere outside CMSP. A current census of the riparian rush rabbit population was conducted during January 1993 in CMSP by Williams (1993). The current population size is 213 to 312 individuals. The population is presently at carrying capacity at the CMSP due to the recent drought conditions. Based on the estimated historic abundance, there is only 0.23% of the original population still surviving.

During the mid 1970s and 1980s, this population drastically dropped yearly to a low of 10 to 20 individuals during flooding. In one year during the 1970s, the survivors were removed from trees and shrubs by CMSP personnel in boats and released on solid ground (Williams and Basey 1986, Basey 1990).

The major cause of decline for the riparian brush rabbit in California has been the destruction, fragmentation, and degradation of the San Joaquin Valley native riparian forest habitat within their historic range (Williams and Basey 1986, Basey 1990). In addition, the remaining riparian habitat is severely fragmented, highly disturbed, regularly subjected to prolonged flooding, and thus, is not likely to provide adequate support for viable populations of riparian brush rabbits. Even if there were suitable habitat areas, it is not possible for the animals to disperse from the Park to these fragments of habitat on their own (Larsen 1993).

Riparian brush rabbits are strictly confined to areas with dense brushy and herbaceous ground cover within riparian forests. They seldom venture more than one to two meters from brushy cover. Some large shrubs, small bushy trees, large trees, and snags must be present, along with brushy areas that are at least 460 m^2 in size and some raised areas with appropriate cover. Open areas and areas subject to prolonged flooding, where ground cover and litter are regularly removed and willows predominate, are not typically used by riparian brush rabbits.

Typical vegetation forming essential habitat within the riparian forest for riparian brush rabbits includes Wild Rose (*Rosa* sp.), Coyote Brush (*Baccharis* sp.), Blackberries (*Rubus* sp), Elderberries (*Sambucus* sp.). Wild Grape (*Vitus californicus*), Box Elder (*Acer negundo*), Valley Oak (*Quercus lobata*), and Cottonwoods (*Populus* sp).

Within the historic range of riparian brush rabbits, prior to any attempts to reestablish populations, extensive habitat restoration must be undertaken. This will require construction of mounds, revegetation with native habitat, and provision of cover on flood levees to provide protection during flooding. Cover must be maintained at a height of at least 21 cm for riparian brush rabbits (Williams 1988, 1993).

PLANTS

Rose Mallow

The habitat of the rose mallow includes river banks and freshwater marsh. The range extends along Butte Creek and the Sacramento River and adjoining sloughs from Butte County to the Delta and to San Joaquin County. The species is common in the south and central Delta: Middle River islands, Woodward Canal, West Canal, Old River near Coney Island, Grant Line Canal, and Bacon Island. In the Delta, it is confined to freshwater marsh habitat on remnant berm islands. It is associated with tules, willows, button willow, and other marsh and riparian species on heavy silt, clay, or peat soils (DWR 1992).

Its range has been diminished by channelization and draining of wetlands. In the southern Delta, levee maintenance, bank erosion, and island submergence have led to the loss of some populations of California hibiscus. Increases in channel water salinity may also pose a threat to this freshwater species. Competition from an invasive introduced iris may displace the hibiscus. The scarcity of remaining habitat prompted the special status (DWR 1992a).

Delta Tule Pea

This climbing perennial herb was distributed historically throughout many San Francisco Bay and Delta marshlands, with additional populations known from San Benito, Fresno, and Tulare counties (Broich, Oregon State University, pers. comm.). Because of widespread habitat losses from the filling and diking of wetlands, its current distribution is largely restricted to fresh and brackish tidal wetlands bordering San Pablo and Suisun bays and tidal wetlands in the Delta. It was previously a federal candidate species.

Its current geographical range is from the Napa River to the Stockton area (CNPS 1977d). Several populations have been found in various localities of the San Joaquin Valley, although placement of these specimens in this subspecies has been questioned (Hitchcock 1952). A closely related subspecies, *L. jepsonii* ssp. *californicus*, is common along waterways throughout the State. It is distinguished from the Delta tule-pea by the presence of small hairs on most of the plant parts (Munz and Keck 1968).

CNPS (1977d) lists marsh lands, on drier ground, as habitat of this subspecies. It is found among tule stands in the western Suisun Marsh and Delta where in occasionally forms dense tangled masses. Most of the occurrences listed in the data base computer search had habitat descriptions such as "edge of slough" or "along river bank", implying areas of tidal influence.

All of the populations of the Delta tule-pea noted during field surveys in Suisun Marsh localities were confined to the edges and water side of levees (sometimes the crest) of tidally influenced streams. Drainage of marshy areas and salinity changes are considered as endangerment factors (CNPS 1977d).

Suisun Aster

This robust, perennial herb, 1-2 meters tall, is known from various areas throughout Suisun Marsh and the Sacramento-San Joaquin Delta. It typically occurs along tidal sloughs in salt to brackish marshes and was previously a federal candidate species.

Mason's Lilaeopsis

Mason's lilaeopsis is a member of the carrot family (Apiaceae), the fourth largest family of flowering plants in California. In 1979, Mason's lilaeopsis was listed as "rare" by DFG. It was previously a federal candidate for listing. In addition, Mason's lilaeopsis is in the inventory of rare and endangered plants of the California Native Plant Society (Smith and York 1984) in which it is listed as a plant of "highest priority".

Mason's lilaeopsis is a low-growing perennial that appears grass-like at a distance. The leaves are reduced to hollow, obscurely septate, cylindrical phyllodes that are produced in short tufts 1.5-7 cm long and less than 1 mm wide. Flowering branches (peduncles) are shorter than the leaves. The inflorescence is a simple umbel producing 3-8 flowers.

Mason's lilaeopsis is known from a minimum of 39 sites according to information from the California Natural Diversity Data Base (CNDDB). The overall distribution of the plant includes Contra Costa, Napa, Solano, Sacramento, and San Joaquin counties.

The plant is restricted to the tidal zone and grows in disturbed muddy banks and flats and occasionally on rotting wood. Measurements taken of population positions on exposed banks determined that they occur in the zone between 16 and 36 inches (40 and 90 cm) above the high and low tide equilibrium point (i.e., above the zero flood level). The highest densities of plants were found to occur at 30 to 32 inches (75-80 cm) above tidal equilibrium.

The formation of habitat is primarily due to natural disturbance of riparian or marsh vegetation as a result of bank failure and erosion. The plants appear to colonize new habitat both vegetatively and by seed deposition. Entire plants of Mason's lilaeopsis were observed floating in the Delta sloughs suggesting that vegetative reproduction and the formation of clonal populations may be important in colonization. The rhizomatous nature of Mason's lilaeopsis allows it to reproduce vegetatively. It is likely that some populations are composed mostly of clones from individuals that initially colonized the habitat.

The plants grow successfully in the shade of riparian shrubs, such as willows (*Salix* spp.), and in full sunlight. No correlation between riparian or marsh species was observed for plant association preference of Mason's lilaeopsis. The associated species were a function of local habitat conditions. Highly-disturbed, steeply-sloping levees supported herbaceous perennial associates. Older levees with more gentle slopes and small islands supported riparian shrubs and non-levied areas consisted primarily of tule and cattail marshlands. Mason's lilaeopsis is rarely observed in association with rock revetment under conditions when siltation occurs in a manner that provides a suitable substrate.

The habitat of Mason's lilaeopsis is generally considered transient. The rate of habitat formation, colonization, and eventually loss varies as a function of bank stability. Steep levee banks are unstable and the viability of a population of Mason's lilaeopsis may be as short as one year after colonization. More stable situations, such as those on riparian islands, may support a population for over 20 years based on historical information obtained from topographic maps of islands in the sloughs. In summer, habitat viability is directly related to the level of human development with levied banks having low viability.

While little data are available on channel water salinity requirements, evidence suggests populations are restricted to the fresher portion of the Napa River and locations west of Martinez in the Suisun Bay area and Sacramento-San Joaquin Delta. Threats to this species are primarily related to dredging, levee construction and riprapping.

SPECIAL STATUS SPECIES IN PROJECT SERVICE AREAS

A wide variety of special status plants and animals are found in the potential service areas of the Project. Appendix A of this Attachment lists those species and their location. The DFG's Annual Status Report on Threatened Species in California and the DFG's Wildlife Habitat Relationship Species Accounts can be used as more detailed references for these species. The habitats, by service area, are listed below. Impacts to these habitats facilitated by the delivery of water from the Delta Wetlands Project will affect the species listed in Appendix A.

San Joaquin Valley Service Area

Valley-foothill grassland, blue oak-foothill pine woodland, chaparral, interior Coast Range saltbush scrub, valley sink scrub, valley saltbush scrub, valley freshwater marsh, northern claypan vernal pool, and various riparian habitats, including riparian forest, woodland, and scrub (Hansen 1993).

Central Coast Service Area

Cropland, wetland, estuary, marine habitat, riparian habitat, oak woodland, grassland, oak-foothill pine woodland, and chaparral (San Luis Obispo County 1994).

Coastal strand and marine habitats, chaparral, coastal scrub, grassland, oak woodland, pinyon-juniper woodland, conifer forest, riparian forest and woodlands, and freshwater marsh (Santa Barbara County 1994).

Cropland, riparian habitat, dune habitat, marine, grassland, coastal sage scrub, chaparral, oak woodland, pinyon-juniper woodland, conifer forest, coastal wetlands, lagoons, and subalpine forest (Ventura County 1988).

South Coast Service Area

Subalpine conifer forest, lodgepole pine forest, white fir forest, Jeffrey pine forest, pinyon-juniper woodland, montane hardwood-conifer forest, montane hardwood forest, oak woodland, oak-foothill pine woodland, eucalyptus habitat, riparian habitat, Joshua tree woodland, alpine dwarf scrub, chaparral, chamise-redshank chaparral, coastal scrub, desert wash, desert scrub, alkali desert scrub, annual grassland, cropland, pasture, fresh emergent wetland, riverine, and open water habitats, including lacustrine and marine (Mayer and Laudenslayer 1988).

Cropland, grassland, oak woodland, pine-fir forest, chaparral, juniper-pinyon woodland, woodland-chaparral, coastal sage scrub, riparian habitat, marsh, seasonal marsh, and open water habitats associated with lakes, bays, and reservoirs (San Diego County 1993).

Grassland, coastal sage scrub, chaparral, oak savanna, southern oak woodland-forest, riparian woodland-forest, conifer-woodland-forest, marsh, and cropland (Orange County 1984).

Southern Deserts Service Area

Chaparral, coastal sage scrub, deciduous woodlands, grasslands, wetlands, oak woodlands, conifer forest, pebble or pavement plans, white fir woodland, pinyon/juniper woodlands, Mojave desert scrub, saltbrush scrub, alkali sinks, sand dunes (San Bernardino County March 1989).

Subalpine conifer forest, lodgepole pine forest, white fir forest, Jeffrey pine forest, ponderosa pine forest, pinyon-juniper woodland, montane hardwood-conifer forest, montane hardwood forest, oak woodland, eucalyptus habitat, riparian habitat, palm oasis, Joshua tree woodland, alpine dwarf scrub, chaparral, chamise-redshank chaparral, coastal scrub, desert succulent scrub, desert wash, desert scrub, alkali desert scrub, annual grassland, fresh emergent wetland, pasture, riverine, lacustrine, orchard, and cropland (Mayer and Laudenslayer 1988).

Desert scrub, succulent scrub, sand dune habitat, pinyon-juniper woodland, mixed chaparral, montane hardwood conifer forest, alkali desert scrub, cropland, freshwater/saltwater marsh, desert riparian habitat, and desert wash (Imperial County 1993).

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APPENDIX A

STATE-LISTED ENDANGERED OR THREATENED SPECIES IN SERVICE AREAS OF THE DELTA WETLANDS PROJECT THAT COULD BE DIRECTLY OR INDIRECTLY AFFECTED BY THE PROPOSED DELTA WETLANDS PROJECT.

STATE-LISTED ENDANGERED OR THREATENED SPECIES AND SPECIAL STATUS SPECIES IN SERVICE AREAS OF THE DELTA WETLANDS PROJECT THAT COULD BE DIRECTLY OR INDIRECTLY AFFECTED BY THE PROPOSED DELTA WETLANDS PROJECT.

BIRDS

Species	Status
1. California condor *Gymnogyps californianus*	SE, FE
2. Bald eagle *Haliaeetus leucocephalus*	SE, FT
3. American peregrine falcon *Falco peregrinus anatum*	SE, FE
4. Light-footed clapper rail *Rallus longirostris levipes*	SE, FE
5. California least tern *Sterna antillarum browni*	SE, FE
6. Least Bell's vireo *Vireo bellii pusillus*	SE, FE
7. Belding's savannah sparrow *Passerculus sandwichensis beldingi*	SE, 1/
8. California brown pelican *Pelecanus occidentalis californicus*	SE, FE
9. California horned lark *Eremophila alpestris actia*	1/
10. Ferruginous hawk *Buteo regalis*	1/
11. Mountain plover *Charadrius montanus*	1/

Species	Status
12. Southwestern willow flycatcher *Empidonax traillii extimus*	FPE
13. California gnatcatcher *Polioptila californica*	FT
14. Southern California rufous-crowned sparrow *Aimophila ruficeps canescens*	1/
15. Bell's sage sparrow *Amphispiza belli belli*	1/

MAMMALS

Species	Status
1. San Joaquin antelope squirrel *Ammospermophilus nelsoni*	ST, 1/
2. Mohave ground squirril *Spermophilus mohavensis*	ST
3. Morro Bay kangaroo rat *Dipodomys heermanni morroensis*	SE, FE
4. Giant kangaroo rat *Dipodomys ingens*	SE, FE
5. Stephens' kangaroo rat *Dipodomys stephensi*	ST, FE
6. Fresno kangaroo rat *Dipodomys nitratoides exilis*	SE, FE
7. Tipton kangaroo rat *Dipodomys nitratoides nitratoides*	SE, FE
8. San Joaquin kit fox *Vulpes macrotis mutica*	ST, FE
9. Townsend's western big-eared bat *Plecotus townsendii townsendii*	1/

10. Greater western mastiff bat
Eumops perotis californicus 1/

11. Short nosed kangaroo rat
Dipodomys nitratoides brevinasus 1/

12. California leaf-nosed bat
Macrotus californicus 1/

13. Arizona myotis
Myotis lucifugus occultus 1/

14. California mastiff bat
Eumops perotis californicus 1/

15. San Diego black-tailed jackrabbit
Lepus californicus bennettii 1/

16. San Bernardino flying squirrel
Glaucomys sabrinus californicus 1/

17. Dulzura (California) pocket mouse
Chaetodipus californicus femoralis 1/

18. Northwestern San Diego pocket mouse
Chaetodipus fallax fallax 1/

19. San Bernardino Merriam's kangaroo rat
Dipodomys merriami parvus 1/

20. Tehachapi pocket mouse
Perognathus alticola inexpectatus 1/

21. Yuma mountain lion
Felis concolor browni 1/

FISHES

Species	Status
1. Unarmored threespine stickleback *Gasterosteus aculeatus williamsoni*	SE, FE
2. Mohave tui chub *Gila bicolor mohavensis*	SE, FE

AMPHIBIANS

Species	Status
1. Tehachapi slender salamander *Batrachoceps stebbinsi*	ST
2. Foothill yellow-legged frog *Rana boylii*	1/

REPTILES

Species	Status
1. Coachella Valley fringe-toed lizard *Uma inornata*	SE, FT
2. Blunt-nosed leopard lizard *Gambelia silus*	SE, FE
3. Alameda whipsnake *Masticophis lateralis euryxanthus*	ST, FPE
4. Giant garter snake *Thamnophis couchii gigas*	ST, FT
5. Southern rubber boa *Charina bottae umbratica*	ST, 1/

6. San Diego horned lizard *Phrynosoma coronatum blainvillii*	1/
7. Southern sagebrush lizard *Sceloporos graciosus vadenburgianus*	1/
8. Coastal western whiptail *Cnemidophorus tigris multiscutatus*	1/
9. Coastal rosy boa *Lichamura trivirgata rosafusca*	1/
10. San Bernardino ringneck snake *Diadophis punctatus modestus*	1/
11. California mountain kingsnake *Lampropeltis zonata pulchra*	1/
12. Northern red diamond rattlesnake *Crotalus ruber ruber*	1/

INSECTS

Species	Status
1. San Joaquin dune beetle *Coelus gracilis*	1/
2. Ciervo aegialian scarab beetle *Aegialia concinna*	1/

PLANTS

Species	Status
1. Succulent owl's-clover *Orthocarpus campestris* var *succulentus*	SE, 1/
2. Hairy Orcutt grass *Orcuttia pilosa*	SE, FPE

3.	San Joaquin Valley Orcutt grass *Orcuttia inaequalis*	SE, FPE
4.	Colusa grass *Neostapfia colusana*	SE, FPT
5.	Merced clarkia *Clarkia lingulata*	SE , 1/
6.	Coastal Dunes milk vetch *Astragalus tener* var *titi*	SE, 1/
7.	Slender-horned spineflower *Centrostegia leptoceras*	SE, FE
8.	Nevin's barberry *Mahonia nevinii*	SE, 1/
9.	Thread-leaved brodiaea *Brodiaea filifolia*	SE, 1/
10.	Santa Ana River woollystar *Eriastrum densifolium* ssp. *sanctorum*	SE, FE
11.	Bakersfield saltbush *Atriplex tularensis*	SE, 1/
12.	Tulare pseudobahia *Pseudobahia peirsonii*	SE, FPE
13.	Hearst's manzanita *Arctostaphylos hookeri* ssp. *hearstiorum*	SE, 1/
14.	Indian knob mountainbalm *Eriodictyon altissimum*	SE, FPE
15.	Nipoma mesa lupine *Lupinus nipomensis*	SE, 1/
16.	Sacramento Orcutt grass *Orcuttia viscida*	SE, FPE
17.	Crampton's tuctoria *Tuctoria mucronata*	SE, FE

18. Indian Valley brodiaea
Brodiaea coronaria ssp. *rosea* — SE, 1/

19. Kaweah brodiaea
Brodiaea insignis — SE, 1/

20. Striped adobe lily
Fritillaria striata — ST, 1/

21. Pitkin Marsh Indian paintbrush
Castilleja uliginosa — SE, 1/

22. Slough thistle
Cirsium crassicaule — 1/

23. Dunn's mariposa lily
Calochortus dunnii — SR, 1/

24. Conejo buckwheat
Eriogonum crocatum — SR, 1/

25. Mexican flannelbush
Fremontodendron mexicanum — SR, 1/

26. Santa Susana tarplant
Hemizonia minthornii — SR, 1/

27. Santa Ynez false-lupine
Thermopsis macrophylla var *aqnina* — SR, 1/

28. Parish's checkerbloom
Sidalcea hickmanii ssp. *parishii* — SR, 1/

29. Red rock tarplant
Hemizonia arida — SR, 1/

30. Dwarf goldenstar
Bloomeria humilis — SR, 1/

31. Hearst's ceanothus
Ceanothus hearstiorum — SR, 1/

32. Maritime ceanothus
Ceanothus maritimus — SR, 1/

33. Pismo clarkia	*Clarkia speciosa* ssp. *immaculata*	SR, FPE
34. Dudley's lousewort	*Pedicularis dudleyi*	SR, 1/
35. Adobe sanicle	*Sanicula maritima*	SR, 1/
36. Cuesta Pass checkerbloom	*Sidalcea hickmanii* ssp. *anomala*	SR, 1/
37. Recurved larkspur	*Delphinium recurvatum*	1/
38. California jewelflower	*Caulanthus californicus*	SE, FE

SE = State endangered; ST = State threatened; FE = Federally endangered;
1/ = Previous Federal candidate species FPE = Federally proposed endangered;
FPT = Federally proposed threatened; FT = Federally threatened; SR = State rare

FW98g771.wpd/cf

ATTACHMENT 5

CONSERVATION EASEMENTS

RECORDING REQUESTED BY:
Delta Wetlands Properties
3697 Mt. Diablo Boulevard
Suite 100
Lafayette, California 94549
Attention: Project Director

MAIL TO:
Delta Wetlands Properties
3697 Mt. Diablo Boulevard
Suite 100
Lafayette, California 94549
Attention: Project Director

Space Above Line for Recorder's Use Only

CONSERVATION EASEMENT DEED

THIS CONSERVATION EASEMENT DEED is made this _____day of ________________, 19___ by Delta Wetlands ("Grantor"), in favor of THE STATE OF CALIFORNIA ("Grantee"), acting by and through its Department of Fish and Game, a subdivision of the California Resources Agency, with reference to the following facts:

RECITALS

A. Grantor is the sole owner in fee simple of certain real property located on Bouldin Island in the County of San Joaquin, State of California, more particularly described in Exhibit "A" attached hereto and incorporated by this reference (the "Property");

B. The Property possesses wildlife and habitat values (collectively, "Conservation Values") of great importance to Grantee, the people of the State of California;

C. The Property provides high quality habitat for wintering wildlife such as ducks, geese, and swans, upland game birds, wintering and resident songbirds, and small mammals, and habitat for special status species such as the Swainson's hawk and greater sandhill crane;

D. The Department of Fish and Game has jurisdiction, pursuant to the Fish and Game Code Section 1802, over the conservation, protection, and management of fish, wildlife, native plants and the habitat necessary for biologically sustainable populations of those species, and the Department of Fish and Game is authorized to hold easements for these purposes pursuant to Civil Code Section 815.3, Fish and Game Code Section 1348, and other provisions of California law; and

E. This Conservation Easement provides mitigation for certain impacts of the Delta Wetlands Project located in the counties of Contra Costa and San Joaquin, State of California, pursuant to a California Endangered Species Act Biological Opinion dated August 6, 1998 and Habitat Management Plan, dated September 1995.

COVENANTS, TERMS, CONDITIONS AND RESTRICTIONS

In consideration of the above recitals and the mutual covenants, terms, conditions, and restrictions contained herein, and pursuant to California law, including Civil Code Section 815, *et seq.*, Grantor hereby voluntarily deeds and conveys to Grantee a conservation easement in perpetuity over the Property.

1. Purpose. The purpose of this Conservation Easement is to provide protection of the Conservation Values of the Property, to prevent any use of the Property that will significantly impair or interfere with the Conservation Values of the Property, to improve, preserve, and protect wintering waterfowl habitat and habitat for resident and migratory songbirds in order to offset a portion of the loss of wintering waterfowl and resident and migratory songbird habitat values, caused by the Delta Wetlands Project in the Sacramento-San Joaquin Delta. Towards that end, it is the Grantor's intention that this Conservation Easement will confine the use of the Property to such activities, including without limitation, those involving the preservation and enhancement of native species and their habitat in a manner consistent with the habitat conservation purposes of this Conservation Easement and the use of the Property for the production of crops, recreation, hunting and wildlife habitat management practices as set forth herein and contained in the Habitat Management Plan (HMP), dated September 1995 which are consistent with the maintenance and protection of wintering waterfowl and resident and migratory songbird habitat.

2. Grantee's Rights. To accomplish the purposes of this Conservation Easement, Grantor hereby grants and conveys the following rights to Grantee by this Conservation Easement Deed:

(a) To preserve and protect the conservation values of the Property;

(b) To enter upon the Property at reasonable times in order to monitor Grantor's compliance with and to otherwise enforce the terms of this Conservation Easement and for scientific research and interpretive purposes by Grantee or its designees, provided that Grantee shall not unreasonably interfere with Grantor's use and quiet enjoyment of the Property;

(c) To prevent any activity on or use of the Property that is inconsistent with the purposes of this Conservation Easement and to require the restoration of such areas or features of the Property that may be damaged by any act, failure to act, or any use that is inconsistent with the purposes of this Conservation Easement;

(d) All present and future development rights except as described in the DEIR/EIS.

3. Prohibited Uses. Any activity on or use of the Property inconsistent with the purposes of this Conservation Easement is prohibited. Without limiting the generality of the foregoing, the following uses by Grantor, Grantor's agents, and third parties, are expressly prohibited:

(a) Any activity that, in Grantee's reasonable judgment, would have an adverse impact on the Conservation Easement or materially affects the protections of the HMP, except as otherwise expressly provided herein.

(b) The division, subdivision or de facto subdivision of the Property, without the prior written consent of Grantee.

(c) Conversion of any portion of the Property into asparagus, vineyards, or orchards.

(d) Any agricultural practice not expressly permitted herein or in the HMP which physically impedes the use of the Property by wildlife particularly waterfowl, including, but not limited to, the use of trellises or plastic mulching, and the use of any devices intended to harass or injure waterfowl. The term "agricultural practice" does not include any practice related to the hunting activities permitted herein.

(e) The filling, excavating, extracting, dredging, mining, drilling for or removal of topsoil, sand, gravel, rock, geothermal resources, oil, gas, hydrocarbons, minerals, or other materials on or below the surface of the Property that are inconsistent with the HMP or materially affect the protections of the HMP, except such filling and removal of materials from the surface as may be permitted hereunder in connection with the provisions of the HMP.

(f) The building of roads or trails, that are inconsistent with the HMP or materially affect the protections of the HMP.

(g) The operation of any motorcycles, trail bikes or other motor-driven or motor-powered land vehicles off existing roads, that are inconsistent with the HMP or materially affect the protections of the HMP.

(h) The disposal or dumping of agrichemicals, biocides, trash, garbage or other unsightly, offensive or toxic material.

(i) The construction or placement of any buildings, mobile homes, camping facilities, fences, signs, billboards or commercial advertising material or any other structures of any kind, unless such structure replaces a preexisting structure of similar size, bulk, and height except as described in the DEIR/EIS.

(j) The use or storage of biocides and/or other agrichemicals, in a manner inconsistent with the HMP .

(k) The introduction of exotic plant or animal species, that are inconsistent with the HMP or materially affect the protections of the HMP.

(l) Any alteration or manipulation of natural water courses which might, in the Grantee's judgment, materially adversely affect the Conservation Easement except for customary Reclamation District activities.

(m) The installation of utility structures or lines, except as permitted in the HMP or as described in the DEIR/EIS.

(n) Livestock grazing in the habitat areas.

4. Grantor's Duties. Grantor shall undertake all reasonable actions to prevent the unlawful entry and trespass by persons whose activities may degrade or harm the conservation values of the Property. In addition, Grantor shall undertake all necessary actions to perfect Grantee's rights under section 2 of this Conservation Easement, including but not limited to, Grantee's water rights.

5. Reserved Rights. Grantor reserves to itself, and to its personal representatives, heirs, successors, and assigns, all rights accruing from its ownership of the Property, including the right to engage in or to permit or invite others to engage in all uses of the Property that are consistent with the purposes of this Conservation Easement.

6. Grantee's Remedies. If Grantee determines that Grantor is in violation of the terms of this Conservation Easement or that a violation is threatened, Grantee shall give written notice to Grantor of such violation and demand in writing the cure of such violation. If Grantor fails to cure the violation within fifteen (15) days after receipt of said written notice and demand from Grantee, or said cure reasonably requires more than fifteen (15) days to complete and Grantee fails to begin the cure within the fifteen (15) day period or fails to continue diligently to complete the cure, Grantee may bring an action at law or in equity in a court of competent jurisdiction to enforce compliance by Grantor with the terms of this Conservation Easement, to recover any damages to which Grantee may be entitled for violation by Grantor of the terms of this Conservation Easement, to enjoin the violation, *ex parte* as necessary, by temporary or permanent injunction without the necessity of proving either actual damages or the inadequacy of otherwise available legal remedies, or for other

equitable relief, including, but not limited to, the restoration of the Property to the condition in which it existed prior to any such violation or injury. Without limiting Grantor's liability therefor, Grantee may apply any damages recovered to the cost of undertaking any corrective action on the Property.

If Grantee, in its sole discretion, determines that circumstances require immediate action to prevent or mitigate significant damage to the conservation values of the Property, Grantee may pursue its remedies under this paragraph without prior notice to Grantor or without waiting for the period provided for cure to expire. Grantee's rights under this paragraph apply equally to actual or threatened violations of the terms of this Conservation Easement. Grantor agrees that Grantee's remedies at law for any violation of the terms of this Conservation Easement are inadequate and that Grantee shall be entitled to the injunctive relief described in this section, both prohibitive and mandatory, in addition to such other relief to which Grantee may be entitled, including specific performance of the terms of this Conservation Easement, without the necessity of proving either actual damages or the inadequacy of otherwise available legal remedies. Grantee's remedies described in this section shall be cumulative and shall be in addition to all remedies now or hereafter existing at law or in equity, including but not limited to, the remedies set forth in Civil Code Section 815, *et seq.*, inclusive.

If at any time in the future Grantor or any subsequent transferee uses or threatens to use such lands for purposes inconsistent with this Conservation Easement, notwithstanding Civil Code Section 815.7, the California Attorney General or any entity or individual with a justiciable interest in the preservation of this Conservation Easement has standing as interested parties in any proceeding affecting this Conservation Easement.

6.1 Costs of Enforcement. Any costs incurred by Grantee in enforcing the terms of this Conservation Easement against Grantor, including, but not limited to, costs of suit and attorneys' fees, and any costs of restoration necessitated by Grantor's violation or negligence under the terms of this Conservation Easement shall be borne by Grantor.

6.2 Grantee's Discretion. Enforcement of the terms of this Conservation Easement by Grantee shall be at the discretion of Grantee, and any forbearance by Grantee to exercise its rights under this Conservation Easement in the event of any breach of any term of this Conservation Easement by Grantor shall not be deemed or construed to be a waiver by Grantee of such term or of any subsequent breach of the same or any other term of this Conservation Easement or of any of Grantee's rights under this Conservation Easement. No delay or omission by Grantee in the exercise of any right or remedy upon any breach by Grantor shall impair such right or remedy or be construed as a waiver.

6.3 Acts Beyond Grantor's Control. Nothing contained in this Conservation Easement shall be construed to entitle Grantee to bring any action against Grantor for any injury to or change in the Property resulting from causes beyond Grantor's control, including, without limitation, fire, flood, storm, and earth movement, or from any prudent action taken by Grantor under emergency conditions to prevent, abate, or mitigate significant injury to the Property resulting from such causes.

6.4 Department of Fish and Game Right of Enforcement. All rights and remedies conveyed to Grantee under this Conservation Easement Deed shall extend to and are enforceable by the Department of Fish and Game.

7. Fences, Gates and Other Protective Measures. Grantor shall take proper action to install and/or maintain adequate measures to protect the conservation values of the Property, including but not limited to, fences, gates, canals, ditches, and levees.

8. Access. This Conservation Easement does not convey a general right of access to the public.

9. Costs and Liabilities. Grantor retains all responsibilities and shall bear all costs and liabilities of any kind related to the ownership, operation, upkeep, and maintenance of the Property.

9.1 Taxes. Grantor shall pay before delinquency all taxes, assessments, fees, and charges of whatever description levied on or assessed against the Property by competent authority (collectively "taxes"), including any taxes imposed upon, or incurred as a result of, this Conservation Easement, and shall furnish Grantee with satisfactory evidence of payment upon request.

9.2 Hold Harmless. Grantor shall hold harmless, indemnify, and defend Grantee and its, directors, officers, employees, agents, contractors, and representatives (collectively "Indemnified Parties") from and against all liabilities, penalties, costs, losses, damages, expenses, causes of action, claims, demands, or judgments, including without limitation, reasonable attorneys' fees, arising from or in any way connected with: (1) injury to or the death of any person, or physical damages to any property, resulting from any act, omission, condition, or other matter related to or occurring on or about the Property, regardless of cause, unless due to the negligence of any of the Indemnified Parties; (2) the obligations specified in Sections 4, 9, and 9.1; and (3) the existence or administration of this Conservation Easement.

9.3 Condemnation. The purposes of the Conservation Easement are presumed to be the best and most necessary public use as defined at Civil Procedure Code Section 1240.680 notwithstanding Civil Procedure Code Sections 1240.690 and 1240.700.

10. Assignment. This Conservation Easement is transferable, but Grantee may assign its rights and obligations under this Conservation Easement only to an entity or organization authorized to acquire and hold conservation easements pursuant to Civil Code Section 815.3. Grantee shall require the assignee to record the assignment in the county where the property is located.

11. Subsequent Transfers. Grantor agrees to incorporate the terms of this Conservation Easement in any deed or other legal instrument by which Grantor divests itself of any interest in all or a portion of the Property, including, without limitation, a leasehold interest. Grantor further agrees to give written notice to Grantee of the intent to transfer of any interest at least fifteen (15) days prior to the date of such transfer. Grantee shall have the right to prevent subsequent transfers in which prospective subsequent claimants or transferees are not given notice of the covenants, terms, conditions and restrictions of this Conservation Easement. The failure of Grantor or Grantee to perform any act provided in this section shall not impair the validity of this Conservation Easement or limit its enforceability in any way.

12. Notices. Any notice, demand, request, consent, approval, or communication that either party desires or is required to give to the other shall be in writing and be served personally or sent by first class mail, postage prepaid, addressed as follows:

To Grantor:

Delta Wetlands Properties
3697 Mt. Diablo Boulevard
Suite 100
Lafayette, California 94549
Attention: Project Director

To Grantee:

California Department of Fish and Game
Bay-Delta and Special Water Projects Division
4001 North Wilson Way
Stockton, California 95205

General Counsel
Department of Fish and Game
Legal Affairs Division
1416 Ninth Street, 12th Floor
Sacramento, California 95814-2090

or to such other address as either party shall designate by written notice to the other. Notice shall be deemed effective upon delivery in the case of personal delivery or, in the case of delivery by first class mail, five (5) days after deposit into the United States mail.

13. Extinguishment. This Conservation Easement may be extinguished by Grantor and Grantee by mutual written agreement upon the request of either party only after the requesting party acquires and records a perpetual conservation easement in the name of the State of California at an alternative location, which provides conservation values that satisfy the specific mitigation purposes of this Conservation Easement as stated in Paragraph E.

14. Amendment. This Conservation Easement may be amended by Grantor and Grantee by mutual written agreement. Any such amendment shall be consistent with the purposes of this Conservation Easement and, except as provided in Section 13, shall not affect its perpetual duration. Any such amendment shall be recorded in the official records of San Joaquin County, State of California.

15. General Provisions.

(a) Controlling Law. The interpretation and performance of this Conservation Easement shall be governed by the laws of the State of California.

(b) Liberal Construction. Any general rule of construction to the contrary notwithstanding, this Conservation Easement shall be liberally construed in favor of the deed to effect the purpose of this Conservation Easement and the policy and purpose Civil Code Section 815, *et seq*. If any provision in this instrument is found to be ambiguous, an interpretation consistent with the purposes of this Conservation Easement that would render the provision valid shall be favored over any interpretation that would render it invalid.

(c) Severability. If a court of competent jurisdiction voids or invalidates on its face any provision of this Conservation Easement Deed, such action shall not affect the remainder of this Conservation Easement Deed. If a court of competent jurisdiction voids or invalidates the application of any provision of this Conservation Easement to Deed to a person or circumstance, such action shall not affect the application of the provision to other persons or circumstances.

(d) Entire Agreement. This instrument sets forth the entire agreement of the parties with respect to the Conservation Easement and supersedes all prior discussions, negotiations, understandings, or agreements relating to the Conservation Easement. No alteration or variation of this instrument shall be valid or binding unless contained in an amendment in accordance with Section 14.

(e) No Forfeiture. Nothing contained herein will result in a forfeiture or reversion of Grantor's title in any respect.

(f) Successors. The covenants, terms, conditions, and restrictions of this

Conservation Easement Deed shall be binding upon, and inure to the benefit of, the parties hereto and their respective personal representatives, heirs, successors, and assigns and shall continue as a servitude running in perpetuity with the Property.

(g) Termination of Rights and Obligations. A party's rights and obligations under this Conservation Easement terminate upon transfer of the party's interest in the Conservation Easement or Property, except that liability for acts or omissions occurring prior to transfer shall survive transfer.

(h) Captions The captions in this instrument have been inserted solely for convenience of reference and are not a part of this instrument and shall have no effect upon construction or interpretation.

(i) Counterparts. The parties may execute this instrument in two or more counterparts, which shall, in the aggregate, be signed by both parties; each counterpart shall be deemed an original instrument as against any party who has signed it. In the event of any disparity between the counterparts produced, the recorded counterpart shall be controlling.

IN WITNESS WHEREOF Grantor and Grantee have entered into this Conservation Easement the day and year first above written.

GRANTOR:
Delta Wetlands Properties
3697 Mt. Diablo Boulevard
Suite 100
Lafayette, California 94549
Attention: Project Director

BY:__________________________
Authorized Representative

Approved as to form:

BY:__________________________
LINUS MASOUREDIS, General Counsel
California Department of Fish and Game

CERTIFICATE OF ACCEPTANCE

This is to certify that the interest in real property conveyed by the Conservation Easement Deed by __________________________, dated __________, to the State of California, grantee, acting by and through its Department of Fish and Game (the "Department"), a governmental agency (under Government Code section 27281), is hereby accepted by the undersigned officer on behalf of the Department, pursuant to authority conferred by resolution of the California Fish and Game Commission on

________________.

GRANTEE:
STATE OF CALIFORNIA, by and through,
DEPARTMENT OF FISH AND GAME

By: ____________________________
Title: ___________________________
Authorized Representative
Date: ___________________________

RECORDING REQUESTED BY:
Delta Wetlands Properties
3697 Mt. Diablo Boulevard
Suite 100
Lafayette, California 94549
Attention: Project Director

MAIL TO:
Delta Wetlands Properties
3697 Mt. Diablo Boulevard
Suite 100
Lafayette, California 94549
Attention: Project Director

Space Above Line for Recorder's Use Only

CONSERVATION EASEMENT DEED

THIS CONSERVATION EASEMENT DEED is made this _____day of ________________, 19____ by Delta Wetlands ("Grantor"), in favor of THE STATE OF CALIFORNIA ("Grantee"), acting by and through its Department of Fish and Game, a subdivision of the California Resources Agency, with reference to the following facts:

RECITALS

A. Grantor is the sole owner in fee simple of certain real property located on Holland Tract in the County of Contra Costa, State of California, more particularly described in Exhibit "A" attached hereto and incorporated by this reference (the "Property");

B. The Property possesses wildlife and habitat values (collectively, "Conservation Values") of great importance to Grantee, the people of the State of California;

C. The Property provides high quality habitat for wintering wildlife such as ducks, geese, and swans, upland game birds, wintering and resident songbirds, and small mammals, and habitat for special status species such as the Swainson's hawk and greater sandhill crane;

D. The Department of Fish and Game has jurisdiction, pursuant to the Fish and Game Code Section 1802, over the conservation, protection, and management of fish, wildlife, native plants and the habitat necessary for biologically sustainable populations of those species, and the Department of Fish and Game is authorized to hold easements for these purposes pursuant to Civil Code Section 815.3, Fish and Game Code Section 1348, and other provisions of California law; and

E. This Conservation Easement provides mitigation for certain impacts of the Delta Wetlands Project located in the counties of Contra Costa and San Joaquin, State of California, pursuant to a California Endangered Species Act Biological Opinion dated August 6, 1998 and Habitat Management Plan, dated September 1995.

COVENANTS, TERMS, CONDITIONS AND RESTRICTIONS

In consideration of the above recitals and the mutual covenants, terms, conditions, and restrictions contained herein, and pursuant to California law, including Civil Code Section 815, *et seq.*, Grantor hereby voluntarily deeds and conveys to Grantee a conservation easement in perpetuity over the Property.

1. Purpose. The purpose of this Conservation Easement is to provide protection of the Conservation Values of the Property, to prevent any use of the Property that will significantly impair or interfere with the Conservation values of the Property, to improve, preserve, and protect wintering waterfowl habitat and habitat for resident and migratory songbirds in order to offset a portion of the loss of wintering waterfowl and resident and migratory songbird habitat values, caused by the Delta Wetlands Project in the Sacramento-San Joaquin Delta. Towards that end, it is the Grantor's intention that this Conservation Easement will confine the use of the Property to such activities, including without limitation, those involving the preservation and enhancement of native species and their habitat in a manner consistent with the habitat conservation purposes of this Conservation Easement and the use of the Property for the production of crops, recreation, hunting and wildlife habitat management practices as set forth herein and contained in the Habitat Management Plan (HMP), dated September 1995 which are consistent with the maintenance and protection of wintering waterfowl and resident and migratory songbird habitat.

2. Grantee's Rights. To accomplish the purposes of this Conservation Easement, Grantor hereby grants and conveys the following rights to Grantee by this Conservation Easement Deed:

(a) To preserve and protect the conservation values of the Property;

(b) To enter upon the Property at reasonable times in order to monitor Grantor's compliance with and to otherwise enforce the terms of this Conservation Easement and for scientific research and interpretive purposes by Grantee or its designees, provided that Grantee shall not unreasonably interfere with Grantor's use and quiet enjoyment of the Property;

(c) To prevent any activity on or use of the Property that is inconsistent with the purposes of this Conservation Easement and to require the restoration of such areas or features of the Property that may be damaged by any act, failure to act, or any use that is inconsistent with the purposes of this Conservation Easement;

(d) All present and future development rights except as described in the DEIR/EIS.

3. Prohibited Uses. Any activity on or use of the Property inconsistent with the purposes of this Conservation Easement is prohibited. Without limiting the generality of the foregoing, the following uses by Grantor, Grantor's agents, and third parties, are expressly prohibited:

(a) Any activity that, in Grantee's reasonable judgment, would have an adverse impact on the Conservation Easement, except as otherwise expressly provided herein.

(b) The division, subdivision or de facto subdivision of the Property, without the prior written consent of Grantee.

(c) Conversion of any portion of the Property into asparagus, vineyards, or orchards.

(d) Any agricultural practice not expressly permitted herein or in the HMP which physically impedes the use of the Property by wildlife particularly waterfowl, including, but not limited to, the use of trellises or plastic mulching, and the use of any devices intended to harass or injure waterfowl. The term "agricultural practice" does not include any practice related to the hunting activities permitted herein.

(e) The filling, excavating, extracting, dredging, mining, drilling for or removal of topsoil, sand, gravel, rock, geothermal resources, oil, gas, hydrocarbons, minerals, or other materials on or below the surface of the Property that are inconsistent with the HMP or materially affect the protections of the HMP, except such filling and removal of materials from the surface as may be permitted hereunder in connection with the provisions of the HMP.

(f) The building of roads or trails, that are inconsistent with the HMP or materially affect the protections of the HMP.

(g) The operation of any motorcycles, trail bikes or other motor-driven or motor-powered land vehicles off existing roads, that are inconsistent with the HMP or materially affect the protections of the HMP.

(h) The disposal or dumping of agrichemicals, biocides, trash, garbage or other unsightly, offensive or toxic material.

(i) The construction or placement of any buildings, mobile homes, camping facilities, fences, signs, billboards or commercial advertising material or any other structures of any kind, unless such structure replaces a preexisting structure of similar size, bulk, and height except as described in the DEIR/EIS.

(j) The use or storage of biocides and/or other agrichemicals, in a manner inconsistent with the HMP .

(k) The introduction of exotic plant or animal species, except as provided in the HMP.

(l) Any alteration or manipulation of natural water courses which might, in the Grantee's judgment, materially adversely affect the Conservation Easement except for customary Reclamation District activities.

(m) The installation of utility structures or lines, except as permitted in the HMP or as described in the DEIR/EIS.

(n) Livestock grazing in the habitat areas.

4. Grantor's Duties. Grantor shall undertake all reasonable actions to prevent the unlawful entry and trespass by persons whose activities may degrade or harm the conservation values of the Property. In addition, Grantor shall undertake all necessary actions to perfect Grantee's rights under section 2 of this Conservation Easement, including but not limited to, Grantee's water rights.

5. Reserved Rights. Grantor reserves to itself, and to its personal representatives, heirs, successors, and assigns, all rights accruing from its ownership of the Property, including the right to engage in or to permit or invite others to engage in all uses of the Property that are consistent with the purposes of this Conservation Easement.

6. Grantee's Remedies. If Grantee determines that Grantor is in violation of the terms of this Conservation Easement or that a violation is threatened, Grantee shall give written notice to Grantor of such violation and demand in writing the cure of such violation. If Grantor fails to cure the violation within fifteen (15) days after receipt of said written notice and demand from Grantee, or said cure reasonably requires more than fifteen (15) days to complete and Grantee fails to begin the cure within the fifteen (15) day period or fails to continue diligently to complete the cure, Grantee may bring an action at law or in equity in a court of competent jurisdiction to enforce compliance by Grantor with the terms of this Conservation Easement, to recover any damages to which Grantee may be entitled for violation by Grantor of the terms of this Conservation Easement, to enjoin the violation, *ex parte* as necessary, by temporary or permanent injunction without the necessity of proving either actual damages or the inadequacy of otherwise available legal remedies, or for other equitable relief, including, but not limited to, the restoration of the Property to the condition in which it existed prior to any such violation or injury. Without limiting Grantor's liability

therefor, Grantee may apply any damages recovered to the cost of undertaking any corrective action on the Property.

If Grantee, in its sole discretion, determines that circumstances require immediate action to prevent or mitigate significant damage to the conservation values of the Property, Grantee may pursue its remedies under this paragraph without prior notice to Grantor or without waiting for the period provided for cure to expire. Grantee's rights under this paragraph apply equally to actual or threatened violations of the terms of this Conservation Easement. Grantor agrees that Grantee's remedies at law for any violation of the terms of this Conservation Easement are inadequate and that Grantee shall be entitled to the injunctive relief described in this section, both prohibitive and mandatory, in addition to such other relief to which Grantee may be entitled, including specific performance of the terms of this Conservation Easement, without the necessity of proving either actual damages or the inadequacy of otherwise available legal remedies. Grantee's remedies described in this section shall be cumulative and shall be in addition to all remedies now or hereafter existing at law or in equity, including but not limited to, the remedies set forth in Civil Code Section 815, *et seq.*, inclusive.

If at any time in the future Grantor or any subsequent transferee uses or threatens to use such lands for purposes inconsistent with this Conservation Easement, notwithstanding Civil Code Section 815.7, the California Attorney General or any entity or individual with a justiciable interest in the preservation of this Conservation Easement has standing as interested parties in any proceeding affecting this Conservation Easement.

6.1 Costs of Enforcement. Any costs incurred by Grantee in enforcing the terms of this Conservation Easement against Grantor, including, but not limited to, costs of suit and attorneys' fees, and any costs of restoration necessitated by Grantor's violation or negligence under the terms of this Conservation Easement shall be borne by Grantor.

6.2 Grantee's Discretion. Enforcement of the terms of this Conservation Easement by Grantee shall be at the discretion of Grantee, and any forbearance by Grantee to exercise its rights under this Conservation Easement in the event of any breach of any term of this Conservation Easement by Grantor shall not be deemed or construed to be a waiver by Grantee of such term or of any subsequent breach of the same or any other term of this Conservation Easement or of any of Grantee's rights under this Conservation Easement. No delay or omission by Grantee in the exercise of any right or remedy upon any breach by Grantor shall impair such right or remedy or be construed as a waiver.

6.3 Acts Beyond Grantor's Control. Nothing contained in this Conservation Easement shall be construed to entitle Grantee to bring any action against Grantor for any injury to or change in the Property resulting from causes beyond Grantor's control, including, without limitation, fire, flood, storm, and earth movement, or from any prudent action taken by Grantor under emergency conditions to prevent, abate, or mitigate significant injury to the

Property resulting from such causes.

6.4 Department of Fish and Game Right of Enforcement. All rights and remedies conveyed to Grantee under this Conservation Easement Deed shall extend to and are enforceable by the Department of Fish and Game.

7. Fences, Gates and Other Protective Measures. Grantor shall take proper action to install and/or maintain adequate measures to protect the conservation values of the Property, including but not limited to, fences, gates, canals, ditches, and levees.

8. Access. This Conservation Easement does not convey a general right of access to the public.

9. Costs and Liabilities. Grantor retains all responsibilities and shall bear all costs and liabilities of any kind related to the ownership, operation, upkeep, and maintenance of the Property.

9.1 Taxes. Grantor shall pay before delinquency all taxes, assessments, fees, and charges of whatever description levied on or assessed against the Property by competent authority (collectively "taxes"), including any taxes imposed upon, or incurred as a result of, this Conservation Easement, and shall furnish Grantee with satisfactory evidence of payment upon request.

9.2 Hold Harmless. Grantor shall hold harmless, indemnify, and defend Grantee and its, directors, officers, employees, agents, contractors, and representatives (collectively "Indemnified Parties") from and against all liabilities, penalties, costs, losses, damages, expenses, causes of action, claims, demands, or judgments, including without limitation, reasonable attorneys' fees, arising from or in any way connected with: (1) injury to or the death of any person, or physical damages to any property, resulting from any act, omission, condition, or other matter related to or occurring on or about the Property, regardless of cause, unless due to the negligence of any of the Indemnified Parties; (2) the obligations specified in Sections 4, 9, and 9.1; and (3) the existence or administration of this Conservation Easement.

9.3 Condemnation. The purposes of the Conservation Easement are presumed to be the best and most necessary public use as defined at Civil Procedure Code Section 1240.680 notwithstanding Civil Procedure Code Sections 1240.690 and 1240.700.

10. Assignment. This Conservation Easement is transferable, but Grantee may assign its rights and obligations under this Conservation Easement only to an entity or organization authorized to acquire and hold conservation easements pursuant to Civil Code Section 815.3. Grantee shall require the assignee to record the assignment in the county where the property is located.

11. Subsequent Transfers. Grantor agrees to incorporate the terms of this Conservation Easement in any deed or other legal instrument by which Grantor divests itself of any interest in all or a portion of the Property, including, without limitation, a leasehold interest. Grantor further agrees to give written notice to Grantee of the intent to transfer of any interest at least fifteen (15) days prior to the date of such transfer. Grantee shall have the right to prevent subsequent transfers in which prospective subsequent claimants or transferees are not given notice of the covenants, terms, conditions and restrictions of this Conservation Easement. The failure of Grantor or Grantee to perform any act provided in this section shall not impair the validity of this Conservation Easement or limit its enforceability in any way.

12. Notices. Any notice, demand, request, consent, approval, or communication that either party desires or is required to give to the other shall be in writing and be served personally or sent by first class mail, postage prepaid, addressed as follows:

To Grantor:

Delta Wetlands Properties
3697 Mt. Diablo Boulevard
Suite 100
Lafayette, California 94549
Attention: Project Director

To Grantee:

California Department of Fish and Game
Bay-Delta and Special Water Projects Division
4001 North Wilson Way
Stockton, California 95205

General Counsel
Department of Fish and Game
Legal Affairs Division
1416 Ninth Street, 12th Floor
Sacramento, California 95814-2090

or to such other address as either party shall designate by written notice to the other. Notice shall be deemed effective upon delivery in the case of personal delivery or, in the case of delivery by first class mail, five (5) days after deposit into the United States mail.

13. Extinguishment. This Conservation Easement may be extinguished by Grantor and Grantee by mutual written agreement upon the request of either party only after the requesting party acquires and records a perpetual conservation easement in the name of the State of California at an alternative location, which provides conservation values that satisfy the specific mitigation purposes of this Conservation Easement as stated in Paragraph E.

14. Amendment. This Conservation Easement may be amended by Grantor and Grantee by mutual written agreement. Any such amendment shall be consistent with the purposes of this Conservation Easement and, except as provided in Section 13, shall not affect its perpetual duration. Any such amendment shall be recorded in the official records of Contra Costa County, State of California.

15. General Provisions.

(a) Controlling Law. The interpretation and performance of this Conservation Easement shall be governed by the laws of the State of California.

(b) Liberal Construction. Any general rule of construction to the contrary notwithstanding, this Conservation Easement shall be liberally construed in favor of the deed to effect the purpose of this Conservation Easement and the policy and purpose Civil Code Section 815, *et seq.* If any provision in this instrument is found to be ambiguous, an interpretation consistent with the purposes of this Conservation Easement that would render the provision valid shall be favored over any interpretation that would render it invalid.

(c) Severability. If a court of competent jurisdiction voids or invalidates on its face any provision of this Conservation Easement Deed, such action shall not affect the remainder of this Conservation Easement Deed. If a court of competent jurisdiction voids or invalidates the application of any provision of this Conservation Easement to Deed to a person or circumstance, such action shall not affect the application of the provision to other persons or circumstances.

(d) Entire Agreement. This instrument sets forth the entire agreement of the parties with respect to the Conservation Easement and supersedes all prior discussions, negotiations, understandings, or agreements relating to the Conservation Easement. No alteration or variation of this instrument shall be valid or binding unless contained in an amendment in accordance with Section 14.

(e) No Forfeiture. Nothing contained herein will result in a forfeiture or reversion of Grantor's title in any respect.

(f) Successors. The covenants, terms, conditions, and restrictions of this Conservation Easement Deed shall be binding upon, and inure to the benefit of, the parties hereto and their respective personal representatives, heirs, successors, and assigns and shall continue as a servitude running in perpetuity with the Property.

(g) Termination of Rights and Obligations. A party's rights and obligations under this Conservation Easement terminate upon transfer of the party's interest in the Conservation Easement or Property, except that liability for acts or omissions occurring prior to transfer shall survive transfer.

(h) Captions The captions in this instrument have been inserted solely for convenience of reference and are not a part of this instrument and shall have no effect upon construction or interpretation.

(i) Counterparts. The parties may execute this instrument in two or more counterparts, which shall, in the aggregate, be signed by both parties; each counterpart shall be deemed an original instrument as against any party who has signed it. In the event of any disparity between the counterparts produced, the recorded counterpart shall be controlling.

IN WITNESS WHEREOF Grantor and Grantee have entered into this Conservation Easement the day and year first above written.

GRANTOR:
Delta Wetlands Properties
3697 Mt. Diablo Boulevard
Suite 100
Lafayette, California 94549
Attention: Project Director

BY:__________________________
Authorized Representative

Approved as to form:

BY:__________________________
LINUS MASOUREDIS, General Counsel
California Department of Fish and Game

CERTIFICATE OF ACCEPTANCE

This is to certify that the interest in real property conveyed by the Conservation Easement Deed by ________________________, dated _________, to the State of California, grantee, acting by and through its Department of Fish and Game (the "Department"), a governmental agency (under Government Code section 27281), is hereby accepted by the undersigned officer on behalf of the Department, pursuant to authority conferred by resolution of the California Fish and Game Commission on

________________.

GRANTEE:
STATE OF CALIFORNIA, by and through,
DEPARTMENT OF FISH AND GAME

By: ________________________
Title: ________________________
Authorized Representative
Date: ________________________

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ATTACHMENT 6

MISCELLANEOUS DATA AND INFORMATION FOR THE DELTA WETLANDS PROJECT BIOLOGICAL OPINION

METHOD USED TO CALCULATE HABITAT ISLAND DISCHARGE CREDITS FOR RPM 2.4.2 IN THE DFG'S CESA BIOLOGICAL OPINION

	February	March	April	May	June	Total
Discharges off of the Habitat Islands(TAF)[1/]	2.3	2.2	0.7	0.3	0	5.5
Diversions onto the Habitat Islands(TAF)[2/]	1.1	0	0	0.4	3.0	-4.5
					Net Habitat Island Discharges (TAF)	1TAF

CESA HABITAT ISLAND CREDIT = $\frac{1\ \text{TAF}}{2}$ = 0.5 TAF

1/ If discharges in the February through June period are less than shown, the HIC may be decreased.

2/ If diversions in the February through June period are less than shown, the HIC may increased.

ILLUSTRATIONS OF METHOD USED TO CALCULATE THE NET HABITAT ISLAND CREDIT (HIC) AND AVAILABLE FOC ENVIRONMENTAL WATER

Example 1 (using operations model output for 1971)[A]

	Dec.	Jan.	Feb.	March	April	May	June
10 % of discharges for export (TAF)	0	0	9.5	0	0.2	0	0
Cumulative Discharges	0	0	9.5	9.5	9.7	9.7	0
Discharge off of the habitat islands (TAF)	N/A	N/A	2.3	2.2	0.7	0.3	0
Diversions onto the habitat islands (TAF)	N/A	N/A	1.1	0	0	0.4	3.0
Net Cumulative HIC (TAF) [1]	0	0	1.2	3.4	4.1	4.0	-3.0 [3]
Cumulative FOC Environmental Water Available (TAF) [2]	0	0	8.3	6.1	5.6	0	0 [4]
FOC Environmental Water Released (TAF)	0	0	0	0	0	5.7	0

[A] For the purpose of this example any FOC environmental water available in May will be released in May.

5.7 TAF would be released in May

Example 2 (using operations model output for 1932)[B/]

	Dec.	Jan.	Feb.	March	April	May	June
10 % of discharges for export (TAF)	0	0	0	6.5	1.2	0	0
Cumulative Discharges	0	0	0	6.5	7.7	7.7	0
Discharge off of the Habitat Islands(TAF)	N/A	N/A	2.3	2.2	0.7	0.3	0
Diversions onto the Habitat Islands(TAF)	N/A	N/A	1.1	0	0	0.4	3.0
Net Cumulative HIC (TAF) [1/]	0	0	1.2	3.4	4.1	4.0	-3.0[3/]
Cumulative FOC Environmental Water Available (TAF) [2/]	0	0	0	3.1	3.6	0	0 [4/]
FOC Environmental Water Released (TAF)	0	0	0	0	0	3.7	0

[B/] For the purpose of this example any FOC environmental water available in May will be released in May.

3.7 TAF would be released in May

Example 3 (using operations model output for 1954)[c]

	Dec.	Jan.	Feb.	March	April	May	June
10 % of discharges for export (TAF)	3.4	0	0	0	0	1.1	0.2
Cumulative Discharges	3.4	3.4	3.4	3.4	3.4	4.5	0.2
Discharge off of the Habitat Islands(TAF)	N/A	N/A	2.3	2.2	0.7	0.3	0
Diversions onto the Habitat Islands(TAF)	N/A	N/A	1.1	0	0	0.4	3.0
Net Cumulative HIC (TAF) [1/]	0	0	1.2	3.4	4.1	4.0	3.0[3/]
Cumulative FOC Environmental Water Available (TAF) [2/]	3.4	3.4	2.2	0	0	0	0 [4/]
FOC Environmental Water Released (TAF)	0	0	0	0	0	0.5	0.2

[c/] For the purpose of this example any FOC environmental water available in May will be released in May and any FOC environmental water available in June will be released in June.

0.5 TAF would be released in May and 0.2 TAF in June

Example 4 (using operations model output for 1964)[D/]

	Dec.	Jan.	Feb.	March	April	May	June
10 % of discharges for export (TAF)	6.2	0	0.7	0	1.2	0.9	0
Cumulative Discharges	6.2	6.2	6.9	6.9	8.1	0.9	0
Discharge off of the Habitat Islands(TAF)	N/A	N/A	2.3	2.2	0.7	0.3	0
Diversions onto the Habitat Islands(TAF)	N/A	N/A	1.1	0	0	0.4	3.0
Net Cumulative HIC (TAF) [1/]	0	0	1.2	3.4	4.1	-0.1	-3.0[3/]
Cumulative FOC Environmental Water Available (TAF) [2/]	6.2	6.2	5.7	3.5	0	0	0 [4/]
FOC Environmental Water Released (TAF)	0	0	0	0	4.0	0.9	0

D/ For the purpose of this example any FOC environmental water available in April will be released in April and any FOC environmental water available in May will be released in May.

<u>4.0 TAF</u> would be released in April and <u>0.9 TAF</u> in May

---

1/ Value displayed is the monthly net HIC quantity. Actual net HIC quantity will be calculated on a cumulative daily basis from February through June. Once the HIC is applied toward discharges to calculate cumulative FOC environmental water, the calculations of discharges off of and onto the habitat islands will start at zero until applied again or June 30 of the water year, whichever occurs first.

2/ Value displayed is the cumulative FOC environmental water available at the end of the month, assuming no releases are made. Actual amount available will be determined on a daily basis.

3/ If the cumulative net flow quantity over the February through June period is less than zero, the amount of FOC Environmental Water available is not affected.

4/ FOC Environmental Water, if available in June, will need to be released in June rather than being made available for the following month since any FOC Environmental Water not used by June 30 in any water year must be returned to Delta Wetlands.

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UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Southwest Region
501 West Ocean Boulevard, Suite 4200
Long Beach, California 90802-4213
TEL (310) 980-4000; FAX (310) 980-4018

F/SW03:GRS

OCT 26 1995

Mr. Jim Monroe
Chief, Sacramento/San Joaquin Delta Offices
Department of the Army
U. S. Army Engineer District, Sacramento
Corps of Engineers
1325 J Street
Sacramento, California 95814-2922

Dear Mr. Monroe:

Thank you for providing the National Marine Fisheries Service (NMFS) with the opportunity to comment on the Biological Assessment (BA) entitled: "Impacts of the Delta Wetlands Project on Fish Species."

General Comments on the Project Description

The Delta Wetlands (DW) project description outlines a wide range of project flexibility from providing DW discharge for export at the State Water Project (SWP) and Central Valley Project (CVP) to providing DW discharge for Delta outflow. Phrases such as "DW could choose", or "uncertain at times", or "most likely", or "may be sold or used" are used frequently in the BA's description of project operations. Specific operations in any particular water year are vague. Potential effects to the endangered Sacramento River winter-run chinook salmon could also range widely from beneficial to adverse depending on project operations and the destination of DW discharges.

The BA describes the DW project as designed to operate within the objectives of the State Water Resources Control Board (SWRCB) 1995 Water Quality Control Plan (WQCP) developed for the SWP and CVP. However, project alternative 1 requires a modification to the total delta inflow formula and project alternative 2 requires an exemption from the WQCP "percent inflow" export limit. The 1995 WQCP was developed to address the permits and licenses of the Bureau of Reclamation (Bureau) and the California Department of Water Resources (DWR) to appropriate water. Since the DW project falls outside the scope of the existing water right and the normal coordinated operation of the CVP and SWP, the SWRCB may choose to set additional or alternative terms and conditions upon diversions and discharges by the DW project.

Although the SWP and CVP export facilities are described as integral components of the DW project, the Bureau and DWR have not participated in the development of the project proposal or committed to the purchase of DW discharges. Thus, incorporation of DW project operations into SWP/CVP operations is unclear and uncertain at present. NMFS will require more specific information regarding CVP and SWP operations from the Bureau and DWR to fully assess the potential effects of DW project water that is sold or "wheeled" through the existing Delta export facilities.

General Comments on the Impact Assessment for Winter-run Chinook

The BA relies on the use of a mortality index to evaluate the potential effects of Delta flow diversions and patterns on survival of juvenile winter-run chinook salmon during migration through the Delta. In the "Impacts Assessment" section of the BA, mortality values are presented several times without being referred to as indices. It is important to note that the values generated by the Jones & Stokes model are not predictive of actual levels of mortality and that these indices are valid for comparison purposes only.

In addition, the mortality indices generated by the Jones & Stokes model may significantly underestimate the level of mortality for several reasons:

1) The model assumes that juvenile salmon that continue down the Sacramento River below Georgiana Slough are not affected by DW or SWP/CVP operations. Fisheries investigations by the U.S. Fish and Wildlife Service have shown that juvenile salmon released in the Sacramento River at Ryde and in the lower San Joaquin River at Jersey Point are effected by SWP/CVP export operations. Therefore, the population at risk is likely to exceed the levels evaluated in the model because the geographic area of influence is broader than the area identified in the model.

2) The mortality model assumes all juvenile salmon are actively migrating through the Delta to the sea without regard to their time of arrival. By doing so, the model does not address the cumulative effects on rearing juvenile salmon. Juvenile winter-run chinook salmon which arrive in the Delta during the fall and early winter months are likely to reside in Delta waterways for several months. These fish will be subject to any and all adverse conditions created by DW operations until they undergo smoltification and emigration from the Delta during the early spring. The model may significantly underestimate mortality rates by assuming all fish in the area of risk have been entrained or emigrated after 10 days.

3) The Jones & Stokes model assumes the Delta Cross Channel gates are closed continuously from November 1 through late May.

The 1995 WQCP provides for a total of 45 days of gate closure between November 1 and January 31. Thus, the number of fish which are diverted off the Sacramento River into the central Delta and subsequently lost due to project operations will be greater than estimated in the EA.

4) The DeltaSOS model simulates monthly DW operations and Delta hydrological conditions. However, daily conditions can vary widely from the monthly averages generated by the model. Juvenile chinook salmon will be responding to the daily and, even, hourly hydrological conditions in Delta. Large losses of fish may occur during brief periods of adverse hydrological conditions.

<u>Specific Comments</u>

Page 1-3, Delta Export Demands, 2nd paragraph. At this time, the buyers or potential uses of the DW water are unknown, making the project description incomplete and analysis of the project effects difficult.

Page 1-3, Delta Water Quality Needs, 1st paragraph. Although the EA indicates the DW project could increase the supply of high-quality water for environmental benefits including Delta outflow, this type of operational scenario is not described in project Alternatives 1 or 2.

Page 2-6, Habitat Island Diversions and Discharges. It is unclear if habitat island water diversions and discharges are designed to operate within the 1995 WQCP or any other operational criteria.

Page 5-16, Cumulative Impacts, 2nd paragraph. Pursuant to the February 12, 1993, biological opinion issued by NMFS for winter-run chinook salmon, the Bureau maintains suitable habitat conditions (e.g. temperatures and flow) in the upper Sacramento River and a minimum carryover storage level in Shasta Reservoir. Thus, upstream conditions in the Sacramento River are likely to improve, rather than deteriorate, in future years for winter-run chinook salmon.

Page 5-16, Cumulative Impacts, 4th paragraph. The DW project could also result in reservoir water stored for a reduced period of time. Reservoir releases may increase earlier in the season, because DW water would be available for use later in the year. Reduced reservoir levels over the summer and fall months could result in adverse temperature conditions for spawning salmon and steelhead trout.

Page 5-16, Summary of Potential Fishery Effects of the DW Project, Beneficial Effects, Foregone agricultural diversions. There is little overlap between the timing of the juvenile winter-run chinook salmon outmigration and the irrigation season for Delta agriculture. Thus, there would be little benefit for winter-run chinook salmon associated with the elimination of these diversions.

Summary

The information provided in the BA is inadequate for the completion of formal section 7 consultation with NMFS for the endangered winter-run chinook salmon. However, meetings between my staff, Jones & Stokes, and the DW project have provided a significant amount of new information which should facilitate the successful completion of consultation. NMFS will continue to work with the DW project and their consultants to clarify the project description and further assessment of potential project effects on the endangered winter-run chinook salmon.

If you have any questions about these comments please call Ms. Penny Ruvelas at (707) 578-7513.

Sincerely,

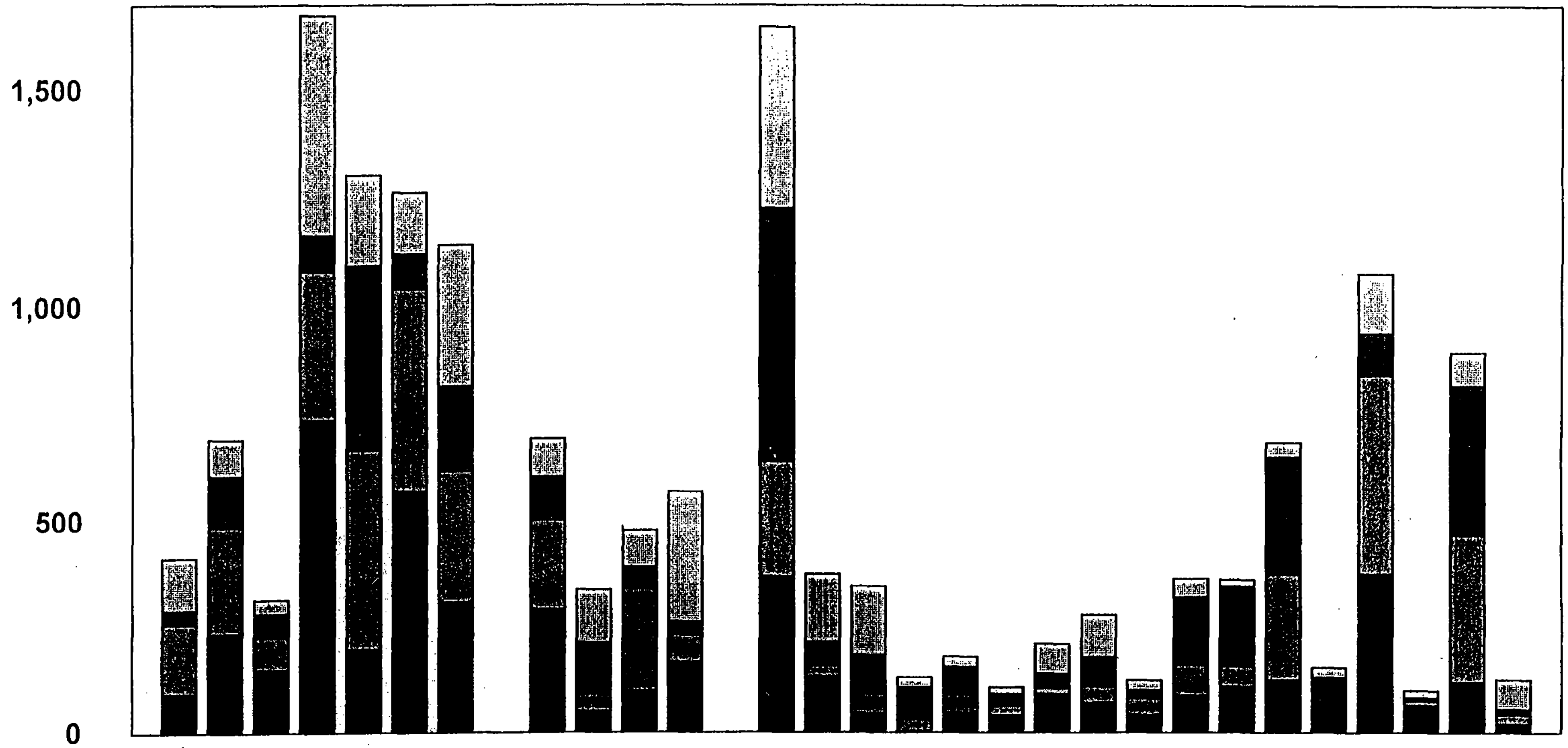
for [signature]

Hilda Diaz-Soltero
Regional Director

cc: Robert Pine, USFWS
Debra McKee, CDFG
Dale Sweetman, CDFG
Ken Bogdan, Jones and Stokes Associates

TOTAL P.05

Delta Smelt Fall Midwa Trawl Abundance Index



Year	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81
Sep	93.4	234.7	149.8	741.6	197.4	571.6	307.9		290.5	49.8	97.5	166.9		368.6	132.4
Oct	165.2	253.4	76.8	343.0	473.1	472.0	312.4		213.7	42.2	242.5	64.7		273.7	27.3
Nov	31.1	119.9	55.3	83.1	427.7	81.1	198.2		102.3	120.9	51.7	31.1		586.2	54.2
Dec	125.2	88.7	33.7	509.9	207.7	142.3	327.4		91.3	125.0	87.8	308.9		422.9	161.1
Index	414.9	696.7	315.6	1677.6	1305.9	1267.0	1145.9	0.0	697.8	337.9	479.5	571.6	0.0	1651.4	375.0

Year	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96
Sep	44.8	2.1	47.0	40.7	92.1	71.0	41.6	88.1	109.5	125.9	71.5	375.7	64.8	120.4	20.6
Oct	47.4	28.0	43.7	23.6	15.1	39.6	40.7	74.7	49.7	249.2	3.5	470.0	11.8	349.6	23.0
Nov	91.8	77.9	66.6	28.0	33.8	69.5	19.1	157.9	187.6	279.0	57.5	94.3	6.8	350.6	13.1
Dec	162.0	24.3	24.2	16.9	70.9	100.1	24.8	45.5	16.6	35.0	24.3	139.4	17.8	78.1	71.6
Index	346.0	132.3	181.5	109.2	211.9	280.2	126.2	366.2	363.4	689.1	156.8	1079.4	101.2	898.7	128.3

1/17/97

Table A1-8. Estimated Monthly Water Budget Terms for DW Islands

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Annual Total (inches)	Contributing Area (acres)	Annual Volume (TAF)
DW Project Islands Intensified Agricultural Use															
Rainfall (inches)	0.8	2.2	2.6	3.2	2.5	2.7	1.2	0.4	0.1	0.1	0.1	0.4	16.3	17,000	23
Soil moisture (inches)	4.0	5.1	7.1	8.0	8.0	8.0	6.5	4.0	4.0	4.0	4.0	4.0			
Lowlands evapotranspiration (inches)	1.4	1.1	0.6	0.7	1.5	2.1	2.7	3.8	4.9	5.8	4.3	2.3	31.2	17,000	44
Seepage (inches)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	12.0	17,000	17
Salt leaching water (inches)	0.0	0.0	2.0	2.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.0	17,000	9
Applied water (inches)	1.2	0.0	0.0	0.0	0.0	0.0	0.0	1.9	9.5	11.3	8.3	3.9	36.1	17,000	51
Drainage water (inches)	1.6	1.0	1.0	4.6	4.0	3.6	1.0	1.9	5.8	6.7	5.2	2.9	39.2	17,000	56
DW Project Islands Wildlife Habitat Use															
Water and marsh (acres)	1,060	1,060	1,060	1,060	1,060	1,060	1,060	1,060	1,060	1,060	1,060	1,060			
Flooded area (acres)	2,000	3,400	5,000	4,500	4,300	1,400	500	0	0	0	0	1,200			
Irrigated area (acres)	5,000	3,600	2,000	2,500	2,700	5,600	6,500	7,000	7,000	7,000	7,000	5,800			
Rainfall (inches)	0.8	2.2	2.6	3.2	2.5	2.7	1.2	0.4	0.1	0.1	0.1	0.4	16.3		
Water evaporation (inches)	3.7	1.7	0.9	1.0	1.9	3.4	5.1	6.9	7.9	9.0	8.0	5.9	55.4		
Lowlands evapotranspiration (inches)	1.4	1.1	0.6	0.7	1.5	2.1	2.7	3.8	4.9	5.8	4.3	2.3	31.2		
Soil moisture	4.0	5.1	7.1	8.0	8.0	8.0	6.5	4.0	4.0	4.0	4.0	4.0			
Seepage volume (TAF)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5			6
Change in flooded volume (TAF)	0.8	1.4	1.6	(0.5)	(0.2)	(2.9)	(0.9)	(0.5)	0.0	0.0	0.0	1.2			0
Net evaporation (TAF)	1.0	(0.2)	(0.9)	(1.3)	(0.5)	(0.1)	0.5	1.1	3.5	4.1	3.1	2.0			12
Applied water (TAF)	1.9	1.7	1.9	0.2	1.1	0.0	0.0	0.4	3.0	3.6	2.6	2.7			19
Drainage water (TAF)	0.6	1.0	1.7	2.5	2.3	2.2	0.7	0.3	0.0	0.0	0.0	0.0			11

Notes: Flooded depth is assumed to average 1 foot.
Drainage is assumed to be at least 50% of previous month's flooded volume for circulation.
Long-term average monthly rainfall is assumed; variations from year to year will occur.
Soil moisture is assumed to supply water for evapotranspiration or store excess rainfall.
Rainfall plus seepage plus applied water minus the change in soil moisture minus evaporation minus ET will equal the drainage.

Appendix D. National Marine Fisheries Service Biological Opinion

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Southwest Region
501 West Ocean Boulevard, Suite 4200
Long Beach, California 90802-4213
TEL (310) 980-4000; FAX (310) 980-4018
F/SW03:PR

MAY 7 1997

Mr. Jim Monroe
Chief, Sacramento/San Joaquin Delta Office
Corps of Engineers
1325 J Street
Sacramento, California 95814-2922

Dear Mr. Monroe:

Please find enclosed the National Marine Fisheries Service's (NMFS) final biological opinion and draft conference opinion concerning the effects of the proposed construction and operation of the Delta Wetlands (DW) project (PN 190109804) on the endangered Sacramento River winter-run chinook salmon and proposed Central Valley Steelhead Evolutionarily Significant Unit (ESU), respectively. Please note that these two opinions have been combined into a single document.

The biological and draft conference opinions conclude that the Corps of Engineers' issuance of a Department of Army permit for the DW project is not likely to jeopardize the continued existence of the Sacramento River winter-run chinook salmon or the Central Valley Steelhead ESU which is proposed as endangered. The biological opinion also concludes that the proposed project will not result in the adverse modification of winter-run chinook salmon critical habitat. However, because NMFS believes there will be some incidental take of winter-run chinook salmon as a result of project operations, an incidental take statement is also attached to the biological opinion. This take statement includes several reasonable and prudent measures that NMFS believes are necessary and appropriate to reduce, minimize, and monitor project impacts. Terms and conditions to implement the reasonable and prudent measures are presented in the take statement and must be adhered to in order for incidental take to be authorized. The take statement also addresses the incidental take of Central Valley ESU Steelhead, however, the prohibitions against take in section 9 of the Endangered Species Act do not apply to a proposed species. In the event of a listing, the incidental take statement included in this document will apply to the Central Valley Steelhead ESU.

Please note that the incidental take statement does not provide incidental take authorization for the re-diversion of Delta Wetlands discharges by other parties including the Delta pumping plants operated by the Central Valley Project (CVP) or the State Water Project (SWP). The operations of these facilities and the related incidental take of winter-run chinook salmon are already covered under the CVP-OCAP biological opinion issued by NMFS to the Bureau of Reclamation (Bureau). I expect that the Bureau and the Department of Water Resources will follow their general practice of coordinating with NMFS to assess the potential effects of the transfer of DW water through their project facilities on the endangered winter-run chinook salmon to determine whether the projects will be able to comply with the requirements of the CVP-OCAP opinion (as amended) on project operations.

Finally, the biological and conference opinions also provide several advisory conservation recommendations for winter-run chinook salmon and the Central Valley Steelhead ESU that include the use of levee maintenance procedures that will increase or enhance the quantity and quality of riparian habitat, and studies designed to explore juvenile salmonid rearing and migratory behaviors in the Sacramento/San Joaquin Delta.

If you have questions concerning the final biological and draft conference opinions or incidental take statements, please contact Ms. Penny Ruvelas at (707) 575-6062.

Sincerely,

WTHogarth

William T. Hogarth, Ph.D.
Acting Regional Administrator

Enclosure

cc: Michael Thabault, USFWS, Sacramento
D. McKee, CDFG, Sacramento
Frank Wernette, CDFG, Stockton

BIOLOGICAL AND CONFERENCE OPINIONS

Agency: Sacramento District, U.S. Army Corps of Engineers.

Activity: Delta Wetlands (PN 190109804)

Consultation Conducted By: Southwest Region, National Marine Fisheries Service.

Date Issued: MAY 7 1997

I. BACKGROUND

The U.S. Army Corps of Engineers (USACE) first requested formal consultation pursuant to section 7 of the Endangered Species Act with the National Marine Fisheries Service (NMFS) on the Delta Wetlands Project (DW) in January, 1991. However, concerns with the 1991 DW proposal resulted in its withdrawal for revision by the project proponents.

A biological assessment (BA) for the revised DW proposal was prepared by Jones & Stokes Associates (JSA) and submitted to NMFS on June 21, 1995. Formal consultation for the endangered winter-run chinook salmon was initiated by the USACE with NMFS on July 10, 1995. The draft environmental impact report and environmental impact statement (DEIR/EIS) for the revised DW proposal was released on September 11, 1995.

Early in the consultation period, questions about DW and the interrelated and interdependent water export operations at the Federal Central Valley Project (CVP) and State Water Project (SWP) were raised by the U.S. Fish and Wildlife Service (FWS), the California Department of Fish and Game (CDFG), and NMFS. As proposed by DW, the CVP and SWP pumping plants in Sacramento-San Joaquin Delta would increase water exports from the Delta above current levels. However, the U.S. Bureau of Reclamation (Reclamation) and the California Department of Water Resources (DWR) were not participants in this section 7 consultation and consistency with the existing biological opinions for CVP/SWP issued by NMFS (2/13/93 and amended 5/95) and FWS (3/6/95) was unclear. To address this issue, the USACE, NMFS, FWS, and DW agreed at a meeting on February 1, 1996 that the consultation would: (1) assess the construction and operation of all DW facilities, (2) assess the diversion of water from, and discharge of water to, adjacent waterways within the Delta, and (3) assess reasonably foreseeable impacts resulting from CVP/SWP export operations associated with DW discharges. However, it was also agreed that the incidental take of listed species at the CVP/SWP facilities would be addressed and authorized through the existing biological opinions issued to Reclamation and DWR for the long-term operations of the CVP/SWP.

Based on discussion and analysis during 1995 and early 1996 consultation meetings, the DW project proposal was further revised to include measures to reduce potential adverse effects to listed species. This mitigation plan was submitted to NMFS and FWS by the USACE on February 20, 1996, and NMFS issued a draft biological opinion based on this mitigation plan to the USACE on June 28, 1996.

In response to the March 29, 1996 draft FWS biological opinion and reasonable and prudent alternative for the listed delta smelt and proposed Sacramento splittail, DW requested that the USACE delay their comments on the NMFS and FWS draft biological opinions until agreement regarding the operations of the DW project could be reached. On May 13, 1996, The USACE requested that NMFS and FWS deliver their final biological opinions 60 days after the receipt of USACE comments on the draft biological opinions. These comments were delayed to explore other operational scenarios that would not jeopardize a listed species.

On September 12, 1996, the USACE requested formal conferencing on the impacts of the DW project on the proposed as endangered Central Valley Evolutionarily Significant Unit (ESU) steelhead trout. This biological opinion for the endangered winter-run chinook salmon contains the conference opinion on impacts to the Central Valley steelhead.

Further discussions on potential measures to avoid or reduce impacts to listed species continued until early February, 1997, resulting in an operations matrix of measures to reduce impacts to listed species. On February 21, 1997, the USACE transmitted their formal comments on the NMFS draft biological opinion and DW's proposed mitigation measures to reduce impacts to listed species, thereby starting the 60-day clock for delivery of the final opinion.

II. PROPOSED ACTIVITY

DW proposes a water storage project on four islands within the Sacramento-San Joaquin Delta: Bacon Island, Webb Tract, Bouldin Island, and Holland Tract. Bacon Island, Webb Tract, and Bouldin Island are owned by DW. Holland Tract is partially owned by DW. Bacon Island and Webb Tract will be managed as "reservoir islands". Surplus Delta inflows, transferred water, or banked water would be diverted by siphon onto the two reservoir islands for later sale and/or release for Delta export or to meet Bay-Delta estuary water quality or flow requirements. Bouldin Island and Holland Tract will be managed as "habitat islands" through wetland creation and wildlife habitat management. DW currently does not have a water right to implement the proposed activity. The State Water Resources Control Board (SWRCB) will issue its determination for such a water right following issuance of the final biological opinions on the proposed DW project.

Portions of the habitat islands will be flooded to shallow depths during the winter to attract wintering waterfowl and support private hunting clubs. Reservoir island operations may include shallow-water management during periods of non-storage at the discretion of DW and incidental to the proposed project.

Reservoir Islands

DW will undertake its diversion and discharge operations pursuant to the "final operations criteria" which are set out in Appendix 1. Bacon Island and Webb Tract will be managed for year-round water storage. Two intake siphon stations and one discharge pumping station will be constructed along the perimeter of each reservoir island.

Each reservoir island will be designed for water storage levels up to a maximum pool elevation of +6.0 feet relative to mean sea level. The implementation of the final operations criteria, water availability, permit conditions, and requirements of the California Department of Water Resources Division of Safety of Dams may limit storage capacities and may result in a final storage elevation of less than +6 feet. The +6.0 feet pool elevation provides an initial estimated combined capacity of 238 thousand acre-feet (TAF) for Bacon Island (118 TAF) and Webb

Tract (120 TAF). The total physical storage capacity of the islands may increase over time as a result of soil subsidence. Subsidence normally occurs at a rate of 2 to 3 inches per year. Due to the replacement of agriculture operations with water storage operations, this subsidence is estimated to occur at approximately 0.5 inches per year, resulting in an increase in combined storage capacity to 260 TAF in 50 years.

Diversion operations. Water diversions onto the reservoir islands would occur when there is surplus water in the Delta under the requirements of the State Water Resource Control Board's (SWRCB) 1995 Water Quality Control Plan (WQCP). This surplus water is defined as the amount of water remaining within the specified export/inflow ratio for that month after all other WQCP requirements have been met and all senior water rights have been appropriated within these WQCP requirements and permitted pumping capacities. This would occur when two conditions are met: (1) all Delta outflow requirements are met and the export limit is exceeded; and (2) water that is available and is allowable for export is not being exported by the CVP and SWP pumps. For purposes of modeling, the second condition is assumed to occur only when water that is allowable for export exceeds the permitted pumping rate. However, the CVP and SWP may not be pumping at capacity because of low demands during the winter, and under these conditions the DW project will still be able to divert water for storage.

Because the reservoir islands will be managed for possible year round storage of water, there may be years during which multiple diversion and subsequent discharges of the reservoirs may occur. The reservoir islands will be filled, drawn down, and refilled in years when the operations criteria, water availability and demands allow. Multiple storage would generally occur during years of moderate precipitation. This management scenario depends on the availability of surplus water early in the year, and a demand for the water to allow an early discharge of the reservoir, followed by another period of available surplus water.

During years of low water demand, water would remain in the reservoirs at the end of the water year (i.e., September 30). Under the DW project, water could remain on a reservoir island for release in subsequent years. Carry-over storage would generally occur during wet years with low demand.

Any diversion of water by DW will be controlled by its final operations criteria. These criteria set variable diversion rates and conditions based on a number of factors including: location of X2; delta smelt Fall Midwater Trawl Index values; and availability percentages applied to the total surplus water available, the previous day's net Delta outflow, and San Joaquin River inflow. These requirements are described in Appendix 1.

The timing and volume of diversions onto the reservoir islands will depend on how much water flowing through the Delta is not put to a reasonable beneficial use by senior water-right holders or is not required for environmental protection. A procedure for coordinating daily DW project diversions with CVP and SWP operations will be established to ensure that DW project diversions capture only available Delta flows, satisfy 1995 State Water Quality Control Board (SWQCB) water quality objectives, and maximize efficiency of DW project water storage operations.

Diversion rates of water onto reservoir islands would vary with pool elevation and water availability. The initial diversion rate for each water year is limited to a combined maximum of 5,500 cfs for a five-day period. Thereafter, the maximum rate of diversions onto either Webb Tract or Bacon Island would be 4,500 cfs (9 TAF per day) at the time diversion begin (i.e., when the head differential between channel water elevation and the island bottom is greatest). The diversion rate would be reduced as reservoirs fill and head differentials diminish. The combined maximum daily average rate of diversion for all islands (including diversions to habitat islands) will not exceed 9,000 cfs. The proposed maximum average monthly diversion rate will be 4,000 cfs.

Discharge operations. Export of DW project water would mainly take place at the CVP and SWP pumps. Discharges of water from the DW project islands would occur when the CVP/SWP pumping plants are not pumping at full capacity. DW discharge for export at the CVP/SWP would be regulated in a manner that the CVP/SWP export limits, as defined by the WQCP, are not exceeded. Actual timing and volume of discharges from the reservoir islands will depend on periods of demand, Delta regulatory limitations, and CVP/SWP export pumping capacities. For the purposes of this biological opinion, discharges from the DW project islands are not counted as inflow to the Delta, as defined by the 1995 WQCP. Treatment of DW discharges as Delta inflow will constitute new information and may require further consultation.

Discharge of DW project water will occur pursuant to DW's final operations criteria as set out in Appendix 1. Stored water will be discharged from reservoir islands during periods of demand, subject to Delta regulatory limitations and export pumping capacities. Discharges will be pumped at a combined maximum daily average of 6,000 cfs per reservoir island. Combined monthly average reservoir island discharge will be up to 4,000 cfs. Pump stations will discharge under the surface of receiving channel water.

DW's final criteria have several limitations on discharge operations, including: no discharges for export from Webb Tract from January through June; limiting discharges from Bacon Island from April through June to 50% of San Joaquin River flows at Vernalis; and percentage limitations on discharges from February through July based on unused export capacity at the CVP/SWP pumps.

Shallow Water Management. Incidental to project operations and at times when water is not being stored, the project may include shallow water management on Bacon Island and Webb Tract to enhance forage and cover for wintering waterfowl. From September through May, reservoir islands may be flooded to shallow depths (approximately 1 foot of water per acre of wetland) to create habitat, typically 60 days after reservoir drawdown. During years of late reservoir drawdown, additional time may be necessary before shallow flooding begins to allow seed crops to mature. Once shallow water flooding for wetland management occurs, water will be circulated through a system of inner levees until deep flooding occurs or through April or May. If reservoir islands are not deeply flooded by April or May, water in seasonal wetlands will be drawn down in May, and if no water is available for storage, island bottoms will remain dry until September when the cycle may be repeated. DW project water used for shallow water flooding in April and May may be available for sale.

Siphon Station Design. Two new siphon stations for water diversions will be installed along the perimeter of each reservoir island. Each station would consist of 16 siphon pipes, each 36 inches in diameter. Screens to prevent entrainment of fish in diversions will be installed around the intake end of each existing and new siphon pipe. The individual siphons will be placed at least 40 feet apart to incorporate fish screen requirements. Existing reservoir island siphons may be used to create shallow water wetland habitat. In-line booster pumps will be available on the reservoir islands to supplement siphon capacity during the final stages of reservoir filling.

Pump Station Design. One discharge pump station will be located on each reservoir island. Webb Tract will have 32 new pumps and Bacon Island will have 40 new pumps, each with 36-inch-diameter pipes discharging to adjacent Delta channels. Typical spacing of the pumps will be 25 feet on center. An assortment of axial-flow and mixed-flow pumps will be used to accommodate a variety of head conditions through drawdown. Actual discharge rates for each pump will vary with pool elevations. As water levels decrease on the islands, the discharge rate of each pump will decrease. Existing pump stations on the islands may be modified and used when appropriate to help with dewatering or for water circulation to improve water quality. Pump station pipes will discharge underwater to adjacent Delta channels through a 3-foot by 10-foot expansion chamber, protected by guard piles adjacent to the expansion chambers and including riprap on the channel bottom to protect against erosion.

Levee Improvements and Maintenance. Exterior levees on the reservoir islands will be improved to bear the stress and potential erosion caused by interior island water storage and drawdown. The perimeter levees on reservoir islands will be raised and widened to hold water at a maximum elevation of +6 feet. Levee improvements will be designed to meet or exceed criteria for levees outlined in DWR Bulletin 192-82. Levee design will address control of wind and wave erosion through placement of rock revetment on levee slopes, and control of project-related seepage through an extensive monitoring and control system. Maintenance activities would include, but are not limited to, placement of fill material, placement or installation of erosion protection material, reshaping or grading of fill material, herbicide application, selective burning, and regrading or patching of the levee road surface.

Exterior levees on all four islands will be buttressed and improved as described here. In addition, an inner levee system will be constructed and maintained within the islands. This system will consist of a series of low-height levees and connecting waterways, to facilitate the management of shallow water during periods of non-storage. The inner levees will be broad, earthen structures similar those currently in place on existing farm fields.

Habitat Islands

As proposed, Bouldin Island and Holland Tract would be dedicated to management for wildlife and wetland habitat values to offset impacts to terrestrial wildlife and wetlands resulting from operations of the two reservoir islands. A variety of habitats will be created or protected to provide foraging and breeding habitats for a wide range of wildlife and waterfowl species. DW will not discharge for export or rediversion any water from the habitat islands.

Wetland management on the habitat islands will require grading areas, re-vegetating, and diverting water. Improvements will be made to existing pump and siphon facilities, and to perimeter levees, including levee buttressing to meet DWR's recommended standards for levee stability and flood control. No new siphon or pump stations will be constructed on habitat islands. Recreation facilities will be constructed on perimeter levees. Routine levee maintenance activities would not differ from current practices including replenishing riprap, placing fill material, grading, disking, mowing, selectively burning, controlling rodents, and installing rock revetment.

Diversions and Discharges. Bouldin Island and Holland Tract will be managed for improvement and maintenance of wetland and wildlife values through use of a Habitat Management Plan (HMP). The HMP was primarily developed (and finalized in the early 1990s) by CDFG and DW to address project effects on waterfowl. The timing and volume of diversions onto the habitat islands will depend on the needs of wetland and wildlife habitats. Wetland diversions will typically begin in September, and water will be circulated throughout the winter. Existing siphons will be used for diversions to the habitat islands. Fish screens will be installed on all siphons used for diversions.

The maximum rate of proposed diversions onto Holland Tract and Bouldin Island will be 200 cfs per island. Diversions onto the habitat islands will not cause the combined daily average maximum diversion rate of 9,000 cfs for all four project islands to be exceeded. Water will be applied to the habitat islands for management in each month of the year to maintain acreages of open water, perennial wetlands, flooded seasonal wetlands, and irrigated croplands specified in the HMP. On an annual basis, approximately 19 TAF will be diverted onto the habitat islands.

Water will be discharged from the habitat islands based on wetland and wildlife management needs. Typically, water will be drawn down by May and the habitat islands will remain dry until September, except for permanently watered areas and other areas maintained for wetland vegetation. Existing pumps will be used for discharges and for water circulation on the habitat islands. If new appropriative water rights are approved for water diverted onto the islands for wetland and wildlife management needs, water may be sold when it is discharged, provided conflicts do not arise with the HMP. For the purposes of this biological opinion, habitat island discharges shall be treated as not available for sale, export, or rediversion. Sale, export, or rediversion of habitat island discharges will constitute new information and may require further consultation.

Operation and Maintenance. Operation and maintenance activities will include: (1) siphon and pump unit operations and routine maintenance; (2) management of habitat areas, including (but not limited to) the control of undesirable plant species, the maintenance or modification of inner levees, and water circulation in ditches, canals, open water, and shallow flooded habitats to facilitate flooding and drainage; (3) fish screen maintenance and monitoring during water diversions for habitat maintenance; (4) wildlife and habitat monitoring under the HMP; (5) perimeter levee inspections and maintenance; (6) aircraft operations for seeding, fertilizing, etc.; (7) operation of recreational facilities using seasonal workers; and (8) monitoring and enforcement of hunting restrictions.

Recreation facilities

DW proposes to construct 11 recreational facilities on each reservoir island and 10 new recreation facilities on Bouldin

Island and 6 new recreation facilities on Holland Tract. Specific types of facilities have not been described by DW. Each recreational facility will be constructed on approximately 5 acres and will include vehicle and boat access. A total of 1200 boat docks and 1472 piles will be placed around exterior island levees in association with the recreation facilities and siphon/pumping stations. The Bouldin Island airstrip will be available for use by hunters and other recreationalists to fly to the island.

Fish Screens

For all four islands, fish screens will be installed around the intake of each existing and new siphon to prevent entrainment and impingement of all adult and most juvenile fish that are present in the Delta. The DW fish screens will maintain a 0.2 fps approach velocity for diversions. The average approach velocity will decrease rapidly as the islands are filled because of decreases in siphon head differential. The preliminary fish screen design consists of a barrel-type screen on the inlet side of each siphon with a hinged flange connection at the water surface (for cleaning). Each siphon opening will be enclosed by a stainless steel, woven wire mesh consisting of seven openings per inch in a screen of 0.035-inch-diameter number 304 stainless steel wire with a pore diagonal of 0.1079 inch. Siphon pipes, with their individual screen modules, will be spaced approximately 40 feet apart on center. Final design elements and installation guidelines will be subject to approval by the USACE and SWRCB with concurrence by USFWS, DFG and NMFS.

III. LISTED AND PROPOSED SPECIES

Sacramento River Winter-run Chinook Salmon

The Sacramento River winter-run chinook salmon (Oncorhynchus tshawytscha) is a unique population of chinook salmon in the Sacramento River. It is distinguishable from the other three Sacramento chinook runs by the timing of its upstream migration and spawning season. NMFS listed winter-run chinook salmon as threatened under emergency provisions of the Endangered Species Act (ESA) in August 1989, and formally listed the species in

November 1990. The State of California listed winter-run chinook as endangered in 1989 under the California State Endangered Species Act. On January 4, 1994, NMFS reclassified the winter-run chinook as an endangered species (59 FR 440). On June 16, 1993, NMFS designated critical habitat for the winter-run chinook from Keswick Dam (Sacramento River mile 302) to the Golden Gate Bridge in San Francisco Bay (58 FR 33212).

Prior to construction of Shasta and Keswick Dams in 1945 and 1950, respectively, winter-run chinook were reported to spawn in the upper reaches of the Little Sacramento, McCloud, and lower Pit Rivers (Moyle et al. 1989). Specific data relative to the historic run sizes of winter-run chinook prior to 1967 are sparse and anecdotal. Numerous fishery researchers have cited Slater (1963) to indicate that the winter-run chinook population may have been fairly small and limited to the spring-fed areas of the McCloud River before the construction of Shasta Dam. However, recent CDFG research in California State Archives has cited several fisheries chronicles that indicate the winter-run chinook salmon population may have been much larger than previously thought. According to these qualitative and anecdotal accounts, winter-run chinook salmon reproduced in the McCloud, Pit and Little Sacramento Rivers and may have numbered over 200,000 (Rectenwald 1989).

Completion of the Red Bluff Diversion Dam (RBDD) in 1966 enabled accurate estimates of all salmon runs to the upper Sacramento River based on fish counts at the fish ladders. These annual fish counts document the dramatic decline of the winter-run chinook population. The estimated number of winter-run chinook passing the dam from 1967 to 1969 averaged 86,509. During 1990, 1991, 1992, 1993, 1994, and 1995, the spawning escapement of winter-run chinook past the dam was estimated at 441, 191, 1,180, 341, 189, and 1,361 adults, respectively.

The first winter-run chinook salmon upstream migrants appear in the Sacramento-San Joaquin Delta during the early winter months (Skinner 1972). On the upper Sacramento River, the first upstream migrants appear during December (Vogel and Marine 1991). The upstream migration of winter-run chinook typically peaks during the month of March, but may vary with river flow, water-year type, and operation of the RBDD. Keswick Dam completely blocks any further upstream migration, forcing adults to migrate to and hold in deep pools downstream, before initiating spawning activities.

Since the construction of Shasta and Keswick dams, winter-run chinook spawning has primarily occurred between RBDD and Keswick Dam. The spawning period of winter-run chinook generally extends from mid-April to mid-August with peak activity occurring in June (Vogel and Marine 1991). Aerial survey of spawning redds have been conducted annually by the CDFG since 1987. These surveys have shown that the majority of winter-run chinook spawning in the upper Sacramento River occurs between the upper Anderson Bridge at RM 284 and the Anderson-Cottonwood Irrigation District Dam at RM 298. However, some winter-run chinook may also spawn below Red Bluff (RM 245) in some years. In 1988, for example, winter-run chinook redds were observed as far downstream as Woodson Bridge (RM 218).

Winter-run chinook eggs hatch after an incubation period of about 40-60 days depending on ambient water temperatures. Maximum survival of incubating eggs and pre-emergent fry occurs at water temperatures between 40° F and 56° F. Mortality of eggs and pre-emergent fry commences at 57.5° F and reaches 100 percent at 62° F (Boles 1988). Other potential sources of mortality during the incubation period include redd dewatering, insufficient oxygenation, physical disturbance, and water-borne contaminants.

The pre-emergent chinook salmon fry remain in the redd and absorb the yolk stored in their yolk-sac as they grow into fry. This period of larval incubation lasts approximately 2 to 4 weeks depending on water temperatures. Emergence of the fry from the gravel begins during late June and continues through September. The fry seek out shallow, nearshore areas with slow current and good cover, and begin feeding on small terrestrial and aquatic insects and aquatic crustaceans. As they grow to 50 to 75 mm in length, the juvenile salmon move out into deeper, swifter water, but continue to use available cover to minimize the risk of predation and reduce energy expenditure.

The emigration of juvenile winter-run chinook from the upper Sacramento River is highly dependent on streamflow conditions and water year type. Once fry have emerged, storm events may cause en masse emigration pulses. Thus, emigration past Red Bluff may begin as early as July, generally peaks in September, and can continue until mid-March in drier years (Vogel and Marine 1991). Data combined from 1981-1992 trapping and seining efforts show that winter-run chinook emigrants occur between early July and early May from Keswick to Princeton (RM 302 to RM 158). Emigration monitoring of Glenn Colusa Irrigation District (GCID) at RM 206 shows that juvenile winter-run chinook migrate past GCID as early as mid-July and may continue through April (HDR Engineering Inc., 1993).

In the Sacramento-San Joaquin Delta, juvenile winter-run chinook generally occur from December through April as evidenced from trawling, seining, and CVP/SWP fish salvage data (CDFG 1993a). Low to moderate numbers of juvenile winter-run chinook may occur in the fall, or later in the spring depending on the water year type. Smolt outmigration typically occurs from late January through April (Stevens 1989, Perry 1992).

In an estuarine environment such as the Delta, juvenile chinook salmon forage in intertidal and shallow subtidal areas, such as marshes, mudflats, channels, and sloughs. These habitats provide protective cover and a rich food supply (McDonald 1960, Dunford 1975). The distribution of the juvenile fish appears to change tidally in an estuarine environment. Juvenile chinook have been observed moving with the flood tide from deeper tidal channels into the tidally flooded nearshore areas for feeding (Healy 1991, Levy and Northcote 1981, Levings 1982). With the receding tide these juveniles retreat back into tidal channels. Large fry and smolts tend to congregate in the surface waters of main and subsidiary sloughs and channels, moving into shallow subtidal areas only to feed (Allen and Hassler 1986).

Optimal water temperatures for the growth of juvenile chinook salmon in an estuary are 54-57°F (Brett 1952). In Suisun and San Pablo Bays water temperatures reach 54°F by February in most years. Other Delta waters do not reach 54°F until March. The specific cues that trigger juvenile chinook salmon to migrate from the Sacramento-San Joaquin Estuary are not well understood, but water temperatures of 59°F and higher have been observed to induce migration in Northwest estuaries (Dunford 1975, Reimers 1973: cited from Cannon 1981). High river flows in the winter and early spring assist juvenile fish migrate downstream to the estuary, while positive outflow from the Delta improves juvenile survival and migration to the ocean.

Proposed Central Valley Steelhead ESU

On May 20, 1993, NMFS announced that it would conduct a status review to identify all coastal steelhead ESU(s) within California, Oregon and Washington and to determine whether any of these ESU(s) warranted listing under the ESA (58 FR 29390). Subsequently, on February 16, 1994 NMFS received a petition from the Oregon Natural Resources Council and 15 co-petitioners to list all steelhead (or specific ESUs, races or stocks) within California, Oregon, Washington and Idaho. On August 9, 1996, NMFS proposed the listing of 10 ESUs within California, Oregon, Washington, and Idaho (61 FR 41541). Within California, all six ESUs have been proposed for listing under the ESA. Threatened status has been proposed for the Klamath Mountains Province and Northern California ESUs. Endangered status has been proposed for the Central California Coast, South/Central California Coast, Southern California, and Central Valley ESUs.

Steelhead (Oncorhynchus mykiss) are considered to have the greatest diversity of life history patterns of any Pacific salmonid species, including varying degrees of anadromy and plasticity of life history patterns between generations (Barnhart 1986). Biologically, steelhead can be divided into two basic run-types, based on the state of sexual maturity at the time of river entry and duration of spawning migration. The stream-maturing type, often referred to as summer steelhead, enters fresh water in a sexually immature condition and requires several months in freshwater to mature and spawn. The ocean-maturing type, or winter steelhead, enters fresh water with well-developed gonads and spawns shortly thereafter (Barnhart 1986).

The Sacramento and San Joaquin Basins may once have had multiple runs of steelhead of both winter and summer types. However, through hatchery practices and modifications to the natural hydrology of the systems caused by large-scale water projects, most of the runs throughout the system have been extirpated, and the remaining runs are commonly thought to be winter steelhead only. Previous run size estimates of greater than 10,000 fish in the upper Sacramento River were reported in the late 1960's. Currently, run sizes in the upper Sacramento River are approximately 1,500 fish. In the San Joaquin Basin, small populations may remain in the Mokelumne, Tuolomne and Stanislaus Rivers. Steelhead primarily utilize the habitats in the upper tributaries of rivers. Many of these areas are no longer accessible to steelhead due to the major dams built in many of the lower river reaches throughout the valley. Over 95% of the habitat formerly available to steelhead migrants has been lost due to these barriers.

In the Sacramento-San Joaquin Delta, the CVP and SWP pumping plants have a serious effect on the habitat conditions available to migrating steelhead. Reverse flows delay migrating adults and juveniles. Juveniles are entrained into Clifton Court Forebay, where predation and entrainment may result in tremendous mortalities.

In the Central Valley ESU, spawning migrations may occur throughout the year with seasonal peaks of activity. Adult steelhead enter fresh water from July through May, with two peaks in September and February. Spawning occurs between November and June with peak activity in January and February. Steelhead are iteroparous, meaning that they do not always die after spawning like other Pacific salmon. However, more than two spawning migrations appears to be unusual. Iteroparous steelhead are predominantly female (McEwan and Jackson 1996). Most of the natural production of steelhead within the Central Valley ESU occurs in Antelope, Deer and Mill Creeks which are tributaries to the upper Sacramento River below the RBDD. The American, Feather, Yuba, and possibly the Mokelumne Rivers also have naturally spawning populations.

Steelhead spawn in cool, clear streams featuring suitable gravel size, depth, and current velocity. Intermittent streams may be used for spawning (Barnhart 1986; Everest 1973). Steelhead eggs generally incubate between February and June (Bell 1991), and fry typically emerge from the gravel 2 to 3 weeks after hatching (Barnhart 1996). After emergence, steelhead fry usually inhabit shallow water along perennial stream banks. Older fry establish territories which they defend. The majority of steelhead in their first year of life occupy riffles, although some larger fish inhabit pools or deeper runs. Juvenile steelhead feed on a wide variety of aquatic and terrestrial insects, and emerging fry are sometimes preyed upon by older juveniles. Juvenile steelhead live in freshwater for between one and four years (usually two years in the Pacific Southwest) and then become smolts and migrate to the sea from November through May with peaks in March, April and May. The smolts can range from 14 to 21 cm in length. Steelhead spend between one and four years in the ocean (usually two years in the Pacific Southwest) (Barnhart 1986).

Water temperatures affect all metabolic and reproductive activities of the fish, including growth, swimming ability, and the ability to capture and assimilate food. Productive steelhead streams should have summer temperatures in the 10 to 15 degrees Celsius range, with an upper limit of 20 degrees Celsius. Steelhead have difficulty extracting oxygen from water which is above 21 degrees Celsius (69.8 degrees Fahrenheit) in temperature, regardless of the amount of oxygen available (Hooper 1973). Bell (1973) listed 23.9 degrees Celsius (75 degrees Fahrenheit) as the upper lethal limit of steelhead. Juvenile steelhead smoltification abruptly ceased when temperatures increased to 14 to 18 degrees Celsius (57.2 to 64.4 degrees Fahrenheit) (Wagner 1974, Kerstetter and Keeler 1976).

Environmental Baseline

Sacramento-San Joaquin Delta. The Sacramento River Basin provides approximately 75% of the water flowing into the Delta (DWR 1993). With the completion of upstream reservoir storage projects, the Sacramento River, San Joaquin River, and Delta waterways are now highly regulated systems, such that the current seasonal distribution of flows differs from historical patterns. The magnitude and duration of peak flows during the winter and spring are reduced by water impoundment in upstream reservoirs. Instream flows during the summer and early fall months have increased over historic levels for deliveries of municipal and agricultural water supplies. Overall, water management now reduces natural variability by creating more uniform flows year-round.

To a great extent, streamflow volume and runoff patterns regulate the quality and quantity of habitat available to juvenile salmonids. Salmon are highly adapted to seasonal changes in flow. Increased stream flows in the fall and winter stimulate juvenile salmonid downstream migration, improve rearing habitat, and improve smolt survival to the ocean. Changes in runoff patterns from upstream reservoir storage, and changes in natural flow patterns in Delta waterways from CVP/SWP pumping in the south Delta have adversely affected Central Valley salmonids, including winter-run chinook salmon and Central Valley ESU steelhead, through reduced survival of juvenile fish.

Juvenile salmon migrate downstream from their upper river spawning and nursery grounds to lower river reaches and the Delta prior to entering the ocean as smolts. Historically, the tidal marshes of the Delta provided a highly productive estuarine environment for juvenile anadromous salmonids. During the course of their downstream migration, juvenile winter-run chinook and steelhead utilize the Delta's estuarine habitat for seasonal rearing, and as a migration corridor to the sea. Since the 1850's, reclamation of Delta islands for agricultural purposes caused the cumulative loss of 94 percent of the Delta's tidal marshes (Monroe and Kelly 1992).

In addition to the degradation and loss of estuarine habitat, downstream migrant juvenile salmon in the Delta are currently subject to adverse conditions created by water export operations at the CVP/SWP. Specifically, juvenile salmon are adversely affected by: (1) water diversion from the mainstem Sacramento River into the Central Delta via the manmade Delta Cross Channel, Georgiana Slough, and Three-mile Slough; (2) upstream or reverse flows of water in the lower San Joaquin River and southern Delta waterways; and (3) entrainment at the CVP/SWP export facilities and associated problems at Clifton Court Forebay. In addition, salmonids are exposed to increased water temperatures from late spring through early fall in the lower Sacramento and San Joaquin River reaches and the Delta. These temperature increases are primarily caused by the loss of riparian shading and thermal inputs from municipal, industrial, and agricultural discharges.

Diversion into the Central and South Delta. Juvenile salmon emigrating from spawning and rearing areas in the Sacramento River may be diverted into the interior Delta through the manmade Delta Cross Channel, Georgiana Slough, or Three-Mile Slough. Fisheries investigations by Schaffter (1980) and Vogel et al. (1988) suggest winter-run chinook salmon juveniles are diverted in proportion to flow into the central Delta at the Delta Cross Channel.

Studies conducted using fall-run chinook salmon smolts have demonstrated substantially higher mortality rates for those fish passing into the interior Delta (USFWS 1990; USFWS 1992). The increased mortality rates reflect increased susceptibility to predation, delays in migration, exposure to increased water temperatures, and increased susceptibility to entrainment losses at the CVP/SWP export pumps and other water diversion locations within the Delta.

Reverse Flows. Channel hydrodynamics in the lower San Joaquin River and other southern Delta waterways are altered by CVP/SWP water export operations in the south Delta. CVP/SWP pumping can change the net flow in these channels from a westward direction to an eastward direction, particularly during periods of drought and high pump rates. When present, these 'reverse' flows move the net flow of water east up the San Joaquin River and then south towards the CVP/SWP export facilities, via Old and Middle Rivers. In general, magnitude of reverse flow increases with the rate of export pumping. Although the mechanism is not well understood, juvenile salmon frequently pass with the net flow of water into a complex network of channels leading to the CVP/SWP water export facilities in the south Delta. Indirect losses of juvenile salmon are thought to occur in these southern Delta channels through predation, disorientation, and delayed out-migration. Direct losses to predation and entrainment are known to occur in Clifton Court Forebay and at the CVP/SWP pumping plants.

Entrainment at CVP/SWP and Clifton Court Forebay. The CVP and SWP Delta pumping plants presently have maximum capacities of 4,600 cfs and 10,300 cfs, respectively. However, the State's existing COE permit generally restricts the SWP's level of pumping by limiting the monthly maximum average inflow into Clifton Court Forebay to 6,680 cfs. Both projects operate fish collection facilities within the intake channels of their canals using a louver system which resembles venetian blinds and acts as a behavioral barrier. Although the slots are wide enough for fish to enter, approximately 75 percent of the chinook salmon encountering the louvers sense the turbulence and move along the face of the louvers to enter the bypass system. The remaining 25 percent are lost to the pumping plant and canal. Additional losses occur inside the fish screening facilities from predation to striped bass and other predators. Significant handling and trucking losses also occur during the process used to transport salvaged fish to a release site in the western Delta.

Clifton Court Forebay is a 31 TAF regulating reservoir at the pump intake to the SWP's California Aqueduct. The forebay is operated to minimize water level fluctuations at the intake by draining water through open gates at high tide and closing the gates at low tide. When the gates are opened, inflow can exceed 20,000 cfs for a short time and then decreases as the water levels inside and outside the forebay reach equilibrium. Within the forebay, juvenile salmon are subject to severe predation loss. In a series of investigations by CDFG, predation loss rates of marked hatchery fall-run salmon released in Clifton Court Forebay during April, May, and June ranged from 63 to 97 percent.

Delta Water Quality. Increased water temperatures, insufficient dissolved oxygen, and contaminants have degraded the aquatic habitat quality of rearing and migrating salmonids. Discharges from industrial and agricultural sources have led to increased water temperatures and contaminant levels. Water temperatures typically exceed 60 or 66 degrees Fahrenheit from April through September. Contaminants such as mercury from mine discharges may be well above 'safe' levels for beneficial uses in the Delta. Dissolved oxygen (DO) levels are affected by municipal, industrial, and agricultural discharges. Salmonids function normally at DO levels of 7.75 mg/L and may exhibit distress symptoms at 6.0 mg/L (Reiser and Bjornn 1979). Low dissolved oxygen levels impair metabolic rates, growth, swimming ability, and the overall survival of young salmonids.

Current Operations Under the Bay-Delta Accord and 1995 WQCP. Significant actions to protect beneficial uses in the Delta were initiated by a three-year agreement between the Federal government, State of California, water users, and environmental interests in the Bay-Delta Accord of December 15, 1994 (Accord). Through the Accord and the 1995 WQCP, water quality objectives for the protection of fish and wildlife have been established for the following parameters: dissolved oxygen, salinity, Delta outflow, river flows, export limits, and Delta Cross Channel gate operation. An "operations" group (CALFED Ops Group)coordinates CVP/SWP project operations, using current biological and hydrological information for management of water quality, endangered species, and the Central Valley Project Improvement Act. Water quality objectives and criteria established by the Accord are based on historical operations of the CVP/SWP and the life history needs of the fish species affected by Delta water operations. The combined effect of these various criteria seems to have improved the environmental baseline of the Delta to a level which provides adequate protection for the conservation of listed species and critical habitat.

For the purposes of this biological opinion, the No-Project Alternative includes water project operations in the Central Valley Basin as defined by the 1995 WQCP and 1994 Accord.

IV. ASSESSMENT OF IMPACTS

The DW project operations are likely to adversely effect the endangered winter-run chinook salmon and the proposed as endangered Central Valley steelhead, and diminish some of the fisheries habitat benefits gained in the Bay-Delta Accord. Juvenile winter-run chinook salmon and steelhead will be adversely affected through reduced Delta outflow, higher reverse flows in central and south Delta waterways, and entrainment in local diversions of the central and southern Delta, and entrainment at the CVP/SWP pumping plants. Impacts to winter-run chinook salmon and steelhead are expected to occur during the filling of the reservoir and habitat islands (diversions), and during the discharge of water from the islands for subsequent export at the CVP/SWP pumping plants or habitat island drawdowns. Some construction related impacts may occur, but are likely to be minor in nature.

Hydrologic data discussed in the assessment of impacts which follows were provided by JSA. The results of JSA's computer model analyses were provided to NMFS in a December 20, 1996 memorandum analyzing the proposed operations matrix and the no-project alternative, or baseline condition. These databases are used in the following assessment which focuses on the months of September through May to evaluate impacts to winter-run chinook salmon and steelhead.

A. Diversion Operations

Effects on Winter-run Chinook Salmon

The DW project proposal relies on diversion of 'surplus' Delta inflows during the winter and early spring months. DW project operations during the months of September through May coincide with the presence of winter-run chinook salmon in the Delta.

The inflow-export criteria[1] established by the Accord were developed to replace and lead to, at minimum, equivalency with the historic QWEST[2] criteria for protection of juvenile winter-run chinook salmon. Historic Delta inflows from upstream rivers and existing CVP/SWP operations under the inflow-export criteria were simulated by computer models to aid in the QWEST equivalency determination. In addition to the Accord's water quality criteria, the NMFS assessment and equivalency determination during the development of the Accord assumed the CVP and SWP exports were limited by: (1) current CVP/SWP pumping plant capacities, (2) existing Corps permits, (3) south of Delta storage capacity, (4) the independent operation of the CVP/SWP pumping plants under their existing State water rights, and (5) inflow originating from upstream sources. These limits on export and the Accord's criteria resulted in Delta conditions which are frequently above the minimum WQCP standards.

As proposed, DW diversion operations will frequently reduce Delta outflow. The decrease in outflow may reach an average daily maximum rate of 9,000 cfs and an average monthly maximum rate of 4,000 cfs. Delta outflows would be reduced by 5 percent or greater in approximately 10 percent of the simulated years (1922-1991) with a maximum reduction in outflow of 25 percent. On an annual basis, DW diversions would directly decrease outflow by a mean of 192 TAF and a maximum of 490 TAF. In comparison, the CVP and SWP export an average of 6.1 million acre feet per year. Water diversions to the DW islands will increase the percent of inflow diverted in all months of the year.

Project water diversions will also directly reduce the net western flow of freshwater in the central Delta (QWEST). Reduced QWEST in the central Delta will be in direct proportion to the DW

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1 The Accord established inflow-export limits for the CVP/SWP pumping plants as 65 percent in September, October, November, December and January, 35-45 percent in February, and 35 percent in March, April and May.

2 QWEST is the calculated estimate of the net flow from the central Delta to the western Delta. It represents the sum of the flows in the lower San Joaquin River, False River, and Dutch Slough. Negative QWEST values mean 'reverse flow', or net flow from the western Delta into the central Delta.

diversion rate. DW diversions will also directly increase the net reverse flows down Old and Middle rivers between Webb Tract and Bacon Island by a maximum of 4,500 cfs.

Analysis of DW diversion opportunities shows that diversions on to the reservoir islands can occur as much as 36 percent of the time simulated during September through May. Table 1 presents the number of years by month over the 70 year modeled simulation that DW was able to divert water onto the reservoir islands and the monthly average maximum diversion rate. Most DW diversion events occur in October through February.

Table 1. Diversion frequency during the 70 year modeled simulation and maximum diversion rates (cfs) (from JSA 1996).

	Diversions (years out of 70)	Average Maximum Rates of Diversion (cfs)
September	8	4,000
October	21	3,871
November	29	4,000
December	28	3,871
January	45	3,600
February	40	4,000
March	39	1,144
April	0	0
May	0	0

These changes in Delta hydrodynamics during the critical rearing and emigration period for juvenile winter-run chinook salmon is expected to adversely affect the species. Decreases in Delta outflow, increases in export-inflow levels, and reductions in QWEST are likely to reduce the survival of rearing and emigrating juvenile fish. Existing reverse flow conditions in the lower San Joaquin River, Old River, and Middle River will be exacerbated by DW diversions. Natural flow cues for emigrating winter-run chinook salmon smolts and migrating adults will be adversely affected. The number and rate of juvenile winter-run chinook salmon drawn from their typical migration route into central and southern Delta waterways is also likely to increase.

Once in the complex configuration of waterways in the central and southern Delta, fish are subjected to a variety of adverse conditions that decrease their chances for survival (FWS 1987). Lower survival rates are expected due to the longer migration route, where fish are exposed to increased predation, higher water temperatures, unscreened agricultural diversions, poor water quality, reduced availability of food, and entrainment at the CVP/SWP export facilities. Through reduced Delta outflow and decreases in net westerly flow, DW diversion operations are expected to degrade chinook salmon rearing habitat in the Delta, degrade conditions for natural smolt outmigration stimulus and seaward orientation, and generally reduce smolt survival. During dry and critical water years, DW diversions have an even greater potential for adversely affecting channel hydrodynamics and reducing winter-run chinook salmon survival already strained by low flows, poor water quality, and high CVP/SWP entrainment rates.

Fish screens installed on all DW intakes are expected to adequately prevent the direct entrainment of juvenile winter-run chinook salmon onto DW reservoir and habitat islands. Eliminating existing unscreened diversions on DW reservoir and habitat islands is expected to provide a minor project benefit to winter-run chinook salmon. However, the benefits attributable to foregone unscreened agricultural diversions is small, because the timing of current agricultural diversions has little overlap with the seasonal presence of juvenile winter-run chinook salmon.

Effects on Proposed Central Valley Steelhead ESU

Impacts to Central Valley ESU steelhead trout are expected to be similar to impacts experienced by winter-run chinook salmon in the months of November through May. The level of impacts may be reduced from winter-run impact levels due to the older age and larger size of steelhead juveniles rearing and emigrating through the Delta.

B. Discharge Operations

Effects on Winter-run Chinook Salmon

As currently proposed, DW's discharge operations rely on the CVP/SWP pumping plants in the south Delta to transport project water to potential buyers. Export of DW discharges by the CVP/SWP is expected to increase winter-run chinook salmon losses in the Delta through entrainment, predation, and diversion with the net flow down Old and Middle rivers.

During DW discharge operations, water will be released from the reservoir islands to Delta waterways for re-diversion at the CVP/SWP pumping plants. Water released from the habitat islands will not be available for rediversion or export and should add to Delta outflow, providing some benefit to Delta species if the habitat island releases occur during favorable aquatic habitat conditions in the Delta. CVP/SWP export rates are expected to increase above baseline levels as a result of reservoir island releases. The frequency of CVP/SWP operations approaching or reaching maximum inflow-export levels will increase.

Analysis of DW discharge opportunities shows that discharges from the reservoir islands generally occur 14 percent of the simulated time from September through May. Most of these discharge events occur in April and May. Table 2 presents the number of years by month over the 70-year modeled simulation that DW was able to discharge water from the reservoir islands and the monthly average maximum discharge rate. Annual discharges from the DW reservoir islands range from zero to 306 TAF, with an average annual diversion of 154 TAF. Most annual DW discharge events occur in April through September.

Table 2. Discharge frequency during the 70 year modeled simulation and maximum discharge rates (cfs) (JSA 1996).

	Discharges (years out of 70)	Maximum Rates of Discharge (cfs)
September	15	1,777
October	8	962
November	5	743
December	6	1,758
January	2	956
February	5	1,742
March	4	1,088
April	20	450
May	29	599

Discharges from the DW reservoir islands would occur during critical rearing and emigration periods of the juvenile winter-run chinook salmon. These discharges to export at the CVP/SWP pumping plants will increase the reverse flows in Old and Middle rivers by an average maximum of 1765, 1161, 500, and 660 cfs during February, March, April, and May, respectively, or by 25 percent, 19 percent, 8 percent, and 10 percent over average baseline conditions. Winter-run chinook salmon typically undergo smoltification during the months of February through April. Winter-run chinook smolts emigrating in the Central Delta may have difficulty following net flows to the ocean under these conditions. Proposed discharge prohibitions for Webb Tract in January through June should minimize potential adverse affects to emigrating juveniles from increased reverse flows that might have occurred between Webb Tract and Bacon Island in the absence of discharge prohibitions. Additionally, DW opportunities for discharge to export at the CVP/SWP pumping plants increase during some dry and critical water year types. Impacts from low river flows, poor water quality, and high CVP/SWP entrainment rates during dry and critical water years will be exacerbated by DW discharges for export.

Discharges from the habitat islands may also supply Delta channels with prey organisms of the winter-run chinook salmon, increasing food availability and benefitting rearing juveniles. Potential impacts from dissolved oxygen level reductions caused by high biological oxygen demand of the release water are addressed below.

Effects on Proposed Central Valley Steelhead ESU

Impacts to Central Valley ESU steelhead trout are expected to be similar to impacts experienced by winter-run chinook salmon in the months of November through May. Steelhead smolts pass through the Delta in peak numbers during March, April, and May. The level of impacts may be reduced from winter-run impact levels due to the older age and larger size of steelhead juveniles rearing and emigrating through the Delta.

C. Combined DW Operations Impacts to Baseline Conditions

Effects on Winter-run Chinook Salmon

Combined operations of the DW project include diversions of water onto, and discharges of water from, the reservoir and habitat islands. Since DW proposes to operate alternatively between diversions and discharges within a season, combined DW project operations and its effects on channel hydrodynamics must be assessed for periods of juvenile winter-run chinook salmon rearing and emigration.

Analysis provided by JSA indicates that many of the flow variables important to juvenile salmon survival in the Delta, such as outflow, QWEST, and flows in Old and Middle rivers are often negatively affected by DW operations.

Decreases in QWEST and outflow from baseline conditions in December through February by 1,000 cfs or greater occurred 14 to 20 percent of the time modeled (JSA 1996). Increases in QWEST and outflow values during February through May also occurred. These increases were generally less than 100 cfs, however there were several instances where the increases exceeded 100 cfs.

The combined effects of DW diversions onto Bacon Island and discharges from both reservoir islands increase the net southerly flow in the Old and Middle rivers north of the export facilities. Increased reverse flows occurred from January through May with 40 and 55 percent of DW operations resulting in increased reverse flows in April and May. Reverse flows in Old and Middle rivers increased by greater than 1,000 cfs during DW operations 6.0, 4.0, and 1.5 percent of the time in December, February, and March, respectively. DW operations in December showed an incremental improvement to reverse flow conditions in Old and Middle Rivers during 35 percent of DW operations. It is also important to consider that the JSA operations model simulates monthly average DW operations and monthly average Delta hydrological conditions. Daily conditions can vary widely from the monthly averages generated by the model and include other significant variables such as tidal fluctuations.

The combined operation of DW water diversions onto the reservoir islands, discharges into adjacent Delta waterways, and the subsequent export of DW water at the CVP/SWP pump plants is expected to directly and indirectly reduce the survival of juvenile winter-run chinook salmon in the Delta. Decreases in Delta outflow, higher net southerly flows in Old and Middle rivers, and decreases in QWEST adversely affect winter-run chinook salmon primarily through increased entrainment into the central and southern Delta waterways where they are subject to longer migration routes, increased predation, unscreened diversions, poor water quality, decreased westward flow cues, and losses at the CVP/SWP export facilities.

Appendix 2 shows average monthly values for CVP/SWP export levels, QWEST, Delta outflow, and Old and Middle Rivers flows for baseline and DW operations conditions. These values are generated from the DeltaSOS monthly modeling simulation results provided by JSA.

Effects on Proposed Central Valley Steelhead ESU

Impacts to Central Valley ESU steelhead trout are expected to be similar to impacts experienced by winter-run chinook salmon in the months of November through May. The level of impacts may be reduced from winter-run impact levels due to the older age and larger size of steelhead juveniles rearing and emigrating through the Delta.

D. Specific Criteria Impacts

Effects on Winter-run Chinook Salmon

The following discusses the effects of specific proposed operational criteria on winter-run chinook salmon. These measures have been proposed by DW to minimize project impacts to the winter-run chinook salmon.

In general, most of the operational criteria proposed by DW for minimizing impacts do reduce the potentially significant adverse effects the project would have on the winter-run chinook salmon. Reductions in the rate and volume of diversions, required X2 positions for diversion initiation, and diversion prohibitions or limitations during sensitive periods all contribute to reduced degradation of the existing environmental baseline. Limiting diversions to a certain percentage of the Delta outflow in critical emigration months may provide significant reductions in the level of impact that would otherwise occur in critical or dry water year types.

Webb Tract discharge prohibitions from January through June avoid significant impacts to aquatic habitat quality in the Webb Tract vicinity that would have occurred during peak winter-run chinook salmon juvenile presence months. Habitat island releases, which are not available for export or rediversion, should benefit juveniles present in the vicinity, provided the existing hydrologic conditions allow for proper environmental cues to emigrating salmonids.

Fish screens installed on all of the project intakes should eliminate entrainment of winter-run chinook salmon onto the project islands. The proposed fish screens will have a maximum approach velocity of 0.2 feet per second, which surpasses the NMFS screening criterion for screens to protect anadromous salmonids. Final screen designs have yet to be reviewed by NMFS fish passage engineers.

Creating 200 acres of delta smelt rearing habitat and the replacement of lost aquatic habitat, due to construction related impacts, at a 3:1 ratio should also provide usable rearing habitat for salmonid juveniles. However, lost riparian and shaded riverine aquatic habitat (SRA), discussed below, is not currently mitigated. Proposed June through November construction windows will minimize construction related impacts to winter-run chinook salmon.

Measures proposed by DW for years in which the Fall Midwater Trawl Index of the delta smelt is less than 239 are more restrictive than the measures analyzed in this opinion, providing substantial reductions in project effects to winter-run chinook salmon and steelhead when they are implemented. However, for the purposes of making determinations as to whether the DW project is likely to jeopardize the winter-run chinook salmon, only the 'base case' scenario of proposed operational criteria has been assessed.

Effects on Proposed Central Valley Steelhead ESU

Impacts and benefits to Central Valley ESU steelhead trout are expected to be similar to impacts and benefits experienced by winter-run chinook salmon in the months of November through May. The level of impacts may be reduced from winter-run impact levels due to the older age and larger size of steelhead juveniles rearing and emigrating through the Delta.

E. Water Quality

Effects on Winter-rurn Chinook Salmon

Potential water quality impacts from DW project releases off of the reservoir and habitat islands include increased water temperatures and decreased dissolved oxygen(DO) levels. The months of April, May, and September often have Delta water quality conditions that are not suitable for salmonid rearing and migratory behaviors. DW proposes to increase water temperatures by a maximum of four degrees Fahrenheit when channel temperatures are between 55 and 66 degrees Fahrenheit and by a maximum of two degrees Fahrenheit when channel temperatures are 66 to 77 degrees Fahrenheit. At channel temperatures above 60 degrees, increases of up to four degrees Fahrenheit across the entire channel may cause physiological sublethal stress effects, impair predation avoidance abilities, terminate smoltification, and cause migration delays or blockages (Boles 1988, Brett 1982, Wedemeyer et al. 1980, Zaugg and Adams 1972). Higher temperatures decrease aquatic habitat productivity, while nutritive needs of salmonids increase. Impacts to salmonids may decrease if temperature changes affect only a portion of the channel, thereby allowing for avoidance of increased temperature plumes. Impacts to salmonids can be avoided if release-water temperatures are less than or equal to channel temperatures.

Island releases that cause local dissolved oxygen levels to drop below 6.0 mg/L may also cause sublethal physiological impacts to emigrating salmonids. Reiser and Bjornn (1979) found that salmonids exhibit various distress symptoms at 6.0 mg/L. Low dissolved oxygen levels impair metabolic rates, growth, swimming ability, and the overall survival of young salmonids. DW proposes to prohibit discharges when the island water DO is below 6.0 mg/L. Additionally, DW proposes to prohibit discharges that will cause a DO drop in the receiving water to below 5.0 mg/L. Localized DO drops to 5.0mg/L may adversely affect rearing and emigrating juveniles if the drop affects the entire channel cross-section. Impacts to salmonids may be decreased if effects are temporary in nature or affect only a portion of the channel, thereby allowing for avoidance of decreased DO areas.

Effects on Proposed Central Valley Steelhead ESU

Impacts to Central Valley ESU steelhead trout are expected to be similar to impacts experienced by winter-run chinook salmon in the months of November through May. The level of impacts may be reduced from winter-run impact levels due to the older age and larger size of steelhead juveniles rearing and emigrating through the Delta.

F. Levee Maintenance

Effects on Winter-run Chinook Salmon

While losses of low salinity or freshwater habitat from levee failure may be reduced through improved levee protection, maintenance of levees on the habitat and reservoir islands may result in damage or loss of riparian vegetation. Shaded riverine aquatic cover (SRA), or the zone of overhanging riparian vegetation along the stream banks, provides temperature moderation, protective cover, and allochthonous materials and energy input to the stream. It provides food and habitat for invertebrates that in turn become prey of salmonids and other fish. Removal of this vegetation, or large reductions in the quality and quantity of SRA vegetation eliminates these inputs from the stream and estuary. Juvenile winter-run chinook salmon rearing or emigrating through areas that have suffered vegetation losses may be at a greater risk of predation, increased physiological stress from lack of cover and high temperatures, and have reduced food availability.

Permanent losses to this habitat are expected to occur during normal levee construction and maintenance if methods such as grading, riprap placement, herbicide application, selective burning and mowing are used. Approximately 152 acres of exterior levee slopes around the reservoir islands will be improved and maintained to protect the water storage capabilities of the islands. If strict vegetation control methods are used, existing vegetation on the project's 152 acres of levees may be permanently lost.

Effects on Proposed Central Valley Steelhead ESU

Impacts to Central Valley ESU steelhead trout are expected to be similar to impacts experienced by winter-run chinook salmon in the months of November through May. The level of impacts may be reduced from winter-run impact levels due to the older age and larger size of steelhead juveniles rearing and emigrating through the Delta.

G. Recreation Facilities, Siphon Stations and Pumping Stations

Effects on Winter-run Chinook Salmon

Construction activities at the recreation and siphon/pump facilities may temporarily affect juvenile winter-run chinook salmon through disturbance or degradation of water quality. Boat wakes may increase levee erosion (increasing levee maintenance) and raise local turbidity levels. Increased inputs of oil and gasoline from increased boat traffic and storage will continue to degrade the water quality within the channels and reservoirs. Permanent impacts to winter-run chinook salmon rearing habitat may occur through destruction of shallow water vegetated habitat and the creation of predator habitat under docks and around siphon/pump station pilings. DW proposes to limit their construction activities to June through November to minimize construction related impacts to juvenile salmonids.

Effects on Proposed Central Valley Steelhead ESU

Impacts to Central Valley ESU steelhead trout are expected to be similar to impacts experienced by winter-run chinook salmon in the months of November through May. The level of impacts may be reduced from winter-run impact levels due to the older age and larger size of steelhead juveniles rearing and emigrating through the Delta.

H. Delta Smelt Monitoring

Effects on Winter-run Chinook Salmon

DW proposes a sampling program in the vicinity of their reservoir islands from December through August to monitor the presence of delta smelt. Presence of delta smelt triggers 50 percent reductions in diversion and discharge activities on the reservoir islands. The sampling program may incidentally capture juvenile winter-run chinook salmon depending on gear types and sampling methodologies used. The final monitoring plan will be developed after issuance of this biological opinion.

Effects on Proposed Central Valley Steelhead ESU

Impacts to Central Valley ESU steelhead trout are expected to be similar to impacts experienced by winter-run chinook salmon in the months of November through May. The level of impacts may be reduced from winter-run impact levels due to the older age and larger size of steelhead juveniles rearing and emigrating through the Delta.

I. Interrelated and Interdependent Effects: CVP/SWP operations

Effects on Winter-run Chinook Salmon

Modeling of CVP/SWP operations in coordination with DW discharge operations was performed by JSA with a Delta operations model (DeltaSOS). These results are presented in the BA and DEIR/EIS. While the DeltaSOS model uses results from the CVP/SWP operations model (DWRSIM), an integrated analysis of DW project operations with the participation of Reclamation (CVP) and DWR (SWP) has not been performed to date. Concern has been expressed that DW's analysis has not integrated some important components of CVP/SWP operations. Specifically, the re-operation of upstream reservoirs has the potential to adversely affect winter-run chinook salmon in the Sacramento River.

Although project proponents stated during consultation that they do not anticipate DW operations will result in the re-operation of upstream CVP and SWP reservoirs, NMFS and the CVP/SWP water projects believe the potential does exist. In commenting on the DEIR/EIS, DWR expressed concern with JSA's model analysis for DW, because: (1) the DeltaSOS model does not have the ability to account for upstream and downstream reservoir storage, and (2) there has been no consideration for real-time operational adjustments for reducing incidental take of ESA listed fish (DWR 1995).

Potential adverse affects to winter-run chinook salmon from re-operating upstream reservoirs relate primarily to upper Sacramento River instream flow levels and water temperature control. Releases from Shasta and Trinity reservoirs could be reduced if DW discharges replace a portion of water exports at the Delta pumping plants. Flow reductions which approach or meet minimum instream flows in the upper Sacramento River are likely to result in the stranding of juvenile fish in side channels with shallow inverts and broad, flat-gradient, near-shore areas. Temperature control operations could be adversely effected by re-operation of upstream reservoirs. Re-scheduling of CVP water deliveries may occur with the availability of additional DW water supplies to the south of Delta water users. The re-scheduling of CVP deliveries could alter seasonal reservoir storage levels and adversely effect temperature control operations designed to protect incubating winter-run chinook eggs and larvae. However, it must be noted that significant re-operation of the CVP or SWP will result in the re-initiation of consultation on these projects with Reclamation and DWR.

Effects on Proposed Central Valley Steelhead ESU

The re-operation of upstream reservoirs has the potential to adversely affect steelhead in the Sacramento, San Joaquin, Mokelumne, Tuolomne and Stanislaus Rivers. Impacts to Central Valley ESU steelhead trout are expected to be similar to impacts experienced by winter-run chinook salmon in the months of November through May. The level of some impacts may be reduced from winter-run impact levels due to the older age and larger size of steelhead juveniles rearing and emigrating through the Delta.

Summary of Impacts: Winter-run Chinook Salmon and Proposed Central Valley Steelhead ESU

DW project operations will diminish many of the fisheries benefits gained in the Bay-Delta Accord and adversely affect the endangered winter-run chinook salmon and Central Valley ESU steelhead. As proposed, the DW project will operate frequently during the peak months of adult and juvenile winter-run chinook salmon and steelhead presence in the Delta. These fish will be adversely affected through reduced Delta outflow, reduced QWEST, increased reverse flows in central and south Delta waterways, and increased entrainment into the central and southern Delta. Higher rates of juvenile fish loss at the CVP/SWP pumping plants are expected. Impacts are expected to be greatest during below normal, dry, and critical water years.

The changes in Delta hydrodynamics as a result of DW operations are expected to increase entrainment of juvenile winter-run into the interior Delta and reduce their survival rates. Lower survival rates are expected due to the longer migration route where fish are exposed to increased predation, higher water temperatures, unscreened agricultural diversions, poor water quality, reduced availability of food, and entrainment at the CVP/SWP export facilities. Through reduced Delta outflow and reductions in net westerly flow, DW diversion operations are expected to degrade chinook salmon and steelhead trout rearing habitat in the Delta, degrade conditions for proper smolt outmigration stimulus and seaward orientation, and generally reduce smolt survival.

Fish screens will reduce direct entrainment of juvenile winter-run chinook salmon and steelhead trout onto the DW project islands; however, the screens have no effect upon the indirect impacts resulting from the hydrological changes described above.

Finally, due to the uncertainty of CVP/SWP operational changes in response to the availability of DW project water, it is not possible to fully assess the impacts to winter-run chinook salmon and steelhead trout resulting from potential re-operation of upstream reservoirs.

V. CONCLUSIONS

Sacramento River Winter-run Chinook Salmon

Based on the best available information and the analysis in this biological opinion, it is NMFS's biological opinion that the proposed construction and operation of the DW water storage project is not likely to jeopardize the continued existence of the winter-run chinook salmon or result in the adverse modification of winter-run chinook salmon critical habitat.

Proposed Central Valley Steelhead ESU

Based on the best available information and the analysis in this conference opinion, NMFS's has concluded that the proposed construction and operation of the DW water storage project is not likely to jeopardize the continued existence of the proposed Central Valley steelhead ESU.

VI. CONSERVATION RECOMMENDATIONS

Section 7(a)(1) of the ESA directs Federal agencies to utilize their authorities to further the purposes of the ESA by carrying out conservation programs for the benefit of endangered and threatened species. These "conservation recommendations" include discretionary measures that the USACE can take to minimize or avoid adverse effects of a proposed action on a listed species or critical habitat or regarding the development of information. In addition to the terms and conditions of the Incidental Take Statement, the NMFS provides the following conservation recommendations that would reduce or avoid adverse impacts on the Sacramento River winter-run chinook salmon and Central Valley ESU steelhead:

1) The USACE should encourage the use of levee maintenance designs that would increase and enhance the quantity and quality of riparian and shaded riverine aquatic (SRA) habitat.

2) The USACE should support, through funding and other means, studies which evaluate juvenile salmonid rearing and migratory behavior in the Sacramento/San Joaquin Delta, including the effects of various water management operations on juvenile survival and behavior.

VII. REINITIATION OF CONSULTATION

Reinitiation of formal consultation is required if there is discretionary Federal involvement or control over the action and if (1) the amount or extent of taking specified in any incidental take statement is exceeded; (2) new information reveals effects of the action that may affect listed species or critical habitat in a manner or to an extent not previously considered; (3) the action is subsequently modified in a manner that causes an effect to the listed species that was not considered in the biological opinion; or (4) a new species is listed or critical habitat designated that may be affected by the action.

The USACE may ask NMFS to adopt the conference opinion incorporated in this document as a biological opinion if the Central Valley ESU steelhead is listed. This request must be in writing. If NMFS reviews the action and finds that there have been no significant changes in the actions planned or in the information used during the conference, NMFS will adopt the conference opinion on the project and no further section 7 consultation will be necessary, unless one or more of the reinitiation requirements described above apply.

INCIDENTAL TAKE STATEMENT

Section 7 (b)(4) of the ESA provides for the issuance of an incidental take statement for the agency action if the biological opinion concludes that the proposed action is not likely to jeopardize the continued existence of a listed species or result in the destruction or adverse modification of critical habitat. In such a situation, NMFS will issue an incidental take statement specifying the impact of any incidental taking of endangered or threatened species, providing for reasonable and prudent measures that are necessary to minimize impacts, and setting forth the terms and conditions with which the action agency must comply in order to implement the reasonable and prudent measures. Incidental takings resulting from the agency action, including incidental takings caused by activities authorized by the agency, are authorized under the incidental take statement only if those takings are in compliance with the specified terms and conditions.

This incidental take statement is applicable to the construction and operations of the Delta Wetlands (DW) project as described in the biological assessment submitted on June 21, 1995, the draft environmental impact report/environmental impact statement issued on September 11, 1995, and as modified by the February 21, 1997, letter and proposed operations matrix from the USACE to the National Marine Fisheries Service (NMFS).

Sacramento River winter-run chinook salmon

The construction and proposed operations of the DW project are expected to result in the incidental take of winter-run chinook salmon. In-water and streambank construction activities will adversely affect winter-run chinook by destruction of riparian vegetation and disturbances from operation of construction equipment. Operation of the DW project will adversely affect hydrodynamic and habitat conditions for rearing and emigrating juvenile winter-run chinook salmon in the interior Delta. DW operations are expected to reduce the survival of juvenile winter-run chinook in the Delta through reduced Delta outflow, reduced QWEST, increased reverse flows in central and south Delta waterways, and increased entrainment into the central and southern Delta. Higher rates of juvenile fish loss at the

CVP/SWP pumping plants are expected. Impacts are expected to be greatest during below normal, dry, and critical water years.

The magnitude of winter-run chinook salmon incidental take associated with construction and operation of the DW project cannot be accurately quantified since: (1) the timing of construction and specific location of some of the facilities is uncertain, (2) the adequacy of the screen design and maintenance procedures are uncertain, (3) the variability and uncertainty in the winter-run chinook salmon population size, run size, and the timing of the downstream migration, and (4) an integrated analysis of DW project operations with the participation of the U.S. Bureau of Reclamation and the California Department of Water Resources has not been performed.

Proposed Central Valley Steelhead ESU

The construction and proposed operations of the DW project are expected to result in the incidental take of Central Valley ESU steelhead. In-water and streambank construction activities will adversely affect steelhead through destruction of riparian vegetation and disturbances from operation of construction equipment. Operation of the DW project will adversely affect hydrodynamic and habitat conditions for rearing and emigrating juvenile steelhead in the interior Delta. DW operations are expected to reduce the survival of juvenile winter-run chinook in the Delta through reduced Delta outflow, reduced QWEST, increased reverse flows in central and south Delta waterways, and increased entrainment into the central and southern Delta. Higher rates of juvenile fish loss at the CVP/SWP pumping plants are expected. Impacts are expected to be greatest during below normal, dry, and critical water years.

The magnitude of Central Valley ESU steelhead incidental take associated with construction and operation of the DW project cannot be accurately quantified since: (1) the timing of construction and specific location of some of the facilities is uncertain, (2) the adequacy of the screen design and maintenance procedures are uncertain, (3) the variability and uncertainty in the steelhead population size, run size, and the timing of the downstream migration, and (4) an integrated analysis of DW project operations with the participation of the U.S. Bureau of

Reclamation and the California Department of Water Resources has not been performed.

Reasonable and Prudent Measures: Winter-run Chinook Salmon

The NMFS believes the following reasonable and prudent measures are necessary and appropriate to minimize the incidental take of winter-run chinook salmon caused by DW.

1. Measures shall be taken to reduce the extent of entrainment and predation during DW diversion operations through the use of properly designed fish screens.

2. Measures shall be taken to reduce degradation of Delta habitat during construction, operation, and maintenance activities.

3. Measures shall be taken to reduce impacts to juvenile winter-run chinook salmon from discharge monitoring activities.

4. Measures shall be taken to monitor DW operations and Delta hydrologic conditions.

In order to be exempt from the prohibitions of Section 9 of the ESA, the USACE is responsible for DW compliance with the following terms and conditions that implement the reasonable and prudent measures described above:

1. Measures shall be taken to reduce the extent of entrainment and predation during DW diversion operations through the use of properly designed fish screens.

Terms and conditions:

a) The USACE shall ensure the final fish screen design and construction schedule is submitted to NMFS Southwest Region for review and acceptance prior to construction. At least 90 percent of the design shall be submitted to NMFS at least two months prior to the completion of the design process.

b) The USACE shall ensure that a hydraulic monitoring program for evaluating the performance of the fish screens and conformance with NMFS criteria is submitted to NMFS Southwest Region for review at least two months prior to the start of operations.

c) The USACE shall ensure the fish screens are adequately operated and maintained by submitting to NMFS a proposed operations and maintenance plan which includes:

(1) periodic underwater inspections;
(2) periodic hydraulic measurements;
(3) periodic assessment of screen performance - component reliability, component durability, and screen-cleaning system effectiveness.

d) The USACE shall ensure that DW annually submits a log record to NMFS Southwest Region that documents compliance with measures 1-3 above.

2. **Measures shall be taken to reduce degradation of Delta habitat during construction, operation, and maintenance activities.**

Terms and conditions:

a) Riparian vegetation and/or SRA lost or damaged during construction or maintenance shall be mitigated by adherence to the "Guidelines for Revegetation" in Appendix 3.

b) Levee maintenance and bank protection activities shall adhere to the material guidelines described in Appendix 4.

c) Steel pilings and sheetpile may not be treated with chemical antifouling products.

d) Wood piles, or wood cores within concrete piles, may not be creosote-treated wood or chromated copper arsenate pressure-treated wood.

3. **Measures shall be taken to reduce impacts to juvenile winter-run chinook salmon from discharge monitoring activities.**

Terms and conditions:

a) Captured chinook salmon shall be handled with extreme care and kept in cool local water to the maximum extent possible during the sampling and processing procedures. Artificial slime products or anesthetics may be used to reduce physiological or osmotic stress. Chinook salmon handled out-of-water for the purpose of recording biological information shall be anesthetized, when necessary, to prevent mortality. Anesthetized fish shall be allowed to recover (e.g. in a recovery bucket) before being released. Fish that are simply counted shall remain in water but do not need an anesthetic. All captured salmonids shall be returned to the water as soon as possible.

b) With gear that capture a mixture of species, chinook salmon shall be removed, processed first and returned to the water as soon as possible.

c) Identification of the listed juvenile fish authorized to be captured and handled by this permit shall be based on NMFS-approved size criteria until other identification methods are formally approved by NMFS.

d) The following information shall be collected on each fish identified as a winter-run chinook salmon in the field:

(1) Location of capture, including nearshore habitat type and water stage;

(2) Date and time of capture;

(3) Fork length; and

(4) Fish condition, including abrasions, or other obvious injuries or scale losses.

This information shall be submitted to NMFS as a part of the weekly reports described below.

e) Any winter-run chinook salmon mortalities shall be placed in labeled whirl-pak bags and promptly frozen. Labels shall include the date/location of capture and the fork length of the fish. NMFS shall be notified as soon as possible of any winter-run chinook salmon mortalities.

f) An annual report of DW operations shall include:

(1) a description of the total number of winter-run chinook salmon taken, the manner of take, and the dates and locations of take, the condition of winter-run chinook salmon taken, the disposition of winter-run chinook salmon in the event of mortality, and a brief narrative of the circumstances surrounding injuries or mortalities;

(2) This report shall be submitted to the addresses given below.

4. Measures shall be taken to monitor DW operations and Delta hydrologic conditions.

Terms and conditions:

a) The USACE shall ensure that DW develops a comprehensive monitoring plan designed to collect the hyrologic and project operational information described below in (1)-(6). This monitoring plan shall be submitted to NMFS Southwest Region for review and approval prior to its implementation. The results of this monitoring program will be used to determine if the DW project is affecting winter-run chinook salmon to an extent not previously considered. The USACE, in coordination with DW, shall provide weekly monitoring reports of diversions and discharges to NMFS. These reports shall include the following information:

(1) daily diversions at each intake siphon station on the reservoir and habitat islands;

(2) daily discharges at each discharge station on the reservoir and habitat islands;

(3) daily amount of DW discharged water exported at the CVP and SWP pumping plants;

(4) daily average QWEST;

(5) net flow in cfs in the Old and Middle rivers north of the CVP/SWP pumping plants; and

(6) daily receiving water temperature and dissolved oxygen conditions and resultant changes to those conditions from DW discharges.

b) The USACE in coordination with DW shall summarize the above weekly reports into an annual report of the DW project operations and Delta hydrological conditions for the previous water year (July 1-June 30) for submittal to NMFS by September 30 of each year.

c) All weekly and annual reports shall be submitted by mail or fax to:

(1) Administrator, Southwest Region, NMFS
501 West Ocean Boulevard, Suite 4200
Long Beach, California, 90802
Fax: 562/980-4047

(2) Ms. Penny Ruvelas
NMFS, Santa Rosa Field Office
777 Sonoma Ave, Room 325
Santa Rosa, California, 95404
Fax: 707/578-3435

Reasonable and Prudent Measures: Proposed Central Valley Steelhead ESU

The NMFS believes the following reasonable and prudent measures are necessary and appropriate to minimize the incidental take of Central Valley ESU steelhead caused by DW.

The prohibitions against taking species found in section 9 of the ESA do not apply to the proposed Central Valley ESU steelhead until this species is listed. However, NMFS advises the USACE to consider implementing the following reasonable and prudent measures. If this conference opinion is adopted as a biological opinion following a listing, these measures, with their implementing terms and conditions, will be nondiscretionary.

1. Measures shall be taken to reduce the extent of entrainment and predation during DW diversion operations through the use of properly designed fish screens.

2. Measures shall be taken to reduce degradation of Delta habitat during construction, operation, and maintenance activities.

3. Measures shall be taken to reduce impacts to juvenile steelhead from discharge monitoring activities.

4. Measures shall be taken to monitor DW operations and Delta hydrologic conditions.

In order to be exempt from the prohibitions of Section 9 of the ESA, the USACE is responsible for DW compliance with the following terms and conditions that implement the reasonable and prudent measures described above:

1. **Measures shall be taken to reduce the extent of entrainment and predation during DW diversion operations through the use of properly designed fish screens.**

Terms and conditions:

a) The USACE shall ensure the final fish screen design and construction schedule is submitted to NMFS Southwest Region for review and acceptance prior to construction. At least 90 percent of the design shall be submitted to NMFS at least two months prior to the completion of the design process.

b) The USACE shall ensure that a hydraulic monitoring program for evaluating the performance of the fish screens and conformance with NMFS criteria is submitted to NMFS Southwest Region for review at least two months prior to the start of operations.

c) The USACE shall ensure the fish screens are adequately operated and maintained by submitting to NMFS a proposed operations and maintenance plan which includes:

(1) periodic underwater inspections;
(2) periodic hydraulic measurements;
(3) periodic assessment of screen performance - component reliability, component durability, and screen-cleaning system effectiveness.

d) The USACE shall ensure that DW annually submits a log record to NMFS Southwest Region that documents compliance with measures 1-3 above.

2. **Measures shall be taken to reduce degradation of Delta habitat during construction, operation, and maintenance activities.**

Terms and conditions:

a) Riparian vegetation and/or SRA lost or damaged during construction or maintenance shall be mitigated by adherence to the "Guidelines for Revegetation" in Appendix 3.

b) Levee maintenance and bank protection activities shall adhere to the material guidelines described in Appendix 4.

c) Steel pilings and sheetpile may not be treated with chemical antifouling products.

d) Wood piles, or wood cores within concrete piles, may not be creosote-treated wood or chromated copper arsenate pressure-treated wood.

3. **Measures shall be taken to reduce impacts to juvenile steelhead from discharge monitoring activities.**

Terms and conditions:

a) Captured steelhead shall be handled with extreme care and kept in cool local water to the maximum extent possible during the sampling and processing procedures. Artificial slime products or anesthetics may be used to reduce physiological or osmotic stress. Steelhead handled out-of-water for the purpose of recording biological information shall be anesthetized, when necessary, to prevent mortality. Anesthetized fish shall be allowed to recover (e.g. in a recovery bucket) before being released. Fish that are simply counted shall remain in water but do not need an anesthetic. All captured salmonids shall be returned to the water as soon as possible.

b) With gear that capture a mixture of species, steelhead shall be removed, processed first and returned to the water as soon as possible.

c) The following information shall be collected on each fish identified as a steelhead in the field:

(1) Location of capture, including nearshore habitat type and water stage;

(2) Date and time of capture;

(3) Fork length; and

(4) Fish condition, including abrasions, or other obvious injuries or scale losses.

This information shall be submitted to NMFS as a part of the weekly reports described below.

d) Any steelhead mortalities shall be placed in labeled whirl-pak bags and promptly frozen. Labels shall include the date/location of capture and the fork length of the fish. NMFS shall be notified as soon as possible of any steelhead mortalities.

e) An annual report of DW operations shall include:

(1) a description of the total number of steelhead taken, the manner of take, and the dates and locations of take, the condition of steelhead taken, the disposition of steelhead in the event of mortality, and a brief narrative of the circumstances surrounding injuries or mortalities;

(2) This report shall be submitted to the addresses given below.

4. Measures shall be taken to monitor DW operations and Delta hydrologic conditions.

Terms and conditions:

a) The USACE shall ensure that DW develops a comprehensive monitoring plan designed to collect the hyrologic and project operational information described below in (1)-(6). This monitoring plan shall be submitted to NMFS for review and approval prior to its implementation. The results of this monitoring program will be used to determine if the DW project is affecting Central Valley ESU to an extent not previously considered. The USACE, in coordination with DW, shall provide weekly monitoring reports of diversions and discharges to NMFS. These reports shall include the following information:

(1) daily diversions at each intake siphon station on the reservoir and habitat islands;

(2) daily discharges at each discharge station on the reservoir and habitat islands;

(3) daily amount of DW discharged water exported at the CVP and SWP pumping plants;

(4) daily average QWEST;

(5) net flow in cfs in the Old and Middle rivers north of the CVP/SWP pumping plants.

b) The USACE in coordination with DW shall summarize the above weekly reports into an annual report of the DW project operations and Delta hydrological conditions for the previous water year (July 1-June 30) for submittal to NMFS by September 30 of each year.

c) All weekly and annual reports shall be submitted by mail or fax to:

(1) Administrator, Southwest Region, NMFS
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(2) Ms. Penny Ruvelas
NMFS, Santa Rosa Field Office
777 Sonoma Ave, Room 325
Santa Rosa, California, 95404
Fax: 707/578-3435

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Appendix 1. Proposed mitigation package for impacts to listed species from the proposed operations of the DW project.

This narrative reflects final operations criteria for the Delta Wetlands (DW) project that would take the place of the operations criteria previously proposed by Jones & Stokes Associates on March 1, 1996. These operations criteria are intended to ensure that the DW project operations do not jeopardize the continued existence of delta smelt, Sacramento splittail, winter-run chinook salmon, or steelhead trout. DW expects that non-listed species will also benefit from these criteria and such criteria will replace the related mitigation measures for fishery impacts proposed in the context of the CEQA/NEPA process.

Under these operations criteria, DW will be consistent with, and in many instances, exceed the conditions set forth in the State Water Resources Control Board's (SWRCB) 1995 Water Quality Control Plan for the Bay-Delta estuary. These revised operations criteria set forth multi-layered diversion and discharge parameters. In the instance where two or more conditions apply, the condition that is the most restrictive on DW operations will control.

Additional restrictions apply if the Fall Mid-Water Trawl (FMWT) index shows a significant decline in delta smelt abundance. The FMWT Index refers to the most current four month (Sep-Dec) FMWT index in place at the time of the intended diversion. A diversion prior to January can utilize either the previous year's FMWT Index or the partial FMWT Index for the months available, whichever is greater. Any changes in the FMWT Index calculation methodology will be adjusted so that the FMWT Index values applied herein can continue to be the standard for DW operations criteria.

A delta smelt Fall Mid-Water Trawl index measurement of less than 84 (FMWT<84) is new information under the reinitiation regulations (50 C.F.R. § 402.16) and may require reinitiation of the USFWS biological opinion. [#26,45][3]

The following text represents the final language for replacement of Term I of the USFWS draft biological opinion: [#1]

> DW will not enter into any contractual agreement(s) which would provide for the export of more than 250,000 AF of DW water on a yearly (calendar year) basis. This provides for, but is not limited to, the following types of transfers: a c-user, short-term, opportunistic water transfer; a long-term water transfer; and any other such agreement, or contract for sale or transfer which is consistent with the March 6, 1995 biological opinion on the CVP/SWP, the SWRCB's 1995 Water Quality

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[3] The number(s) in brackets are provided as a reference to the DW ESA Matrix which summarizes the final operations criteria as compared to the March 1, 1996 JSA proposed terms.

Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (1995 WQCP), and the improved environmental baseline established under the March 6, 1995, CVP/SWP Section 7 consultation performed in conjunction with implementation of the *Principles for Agreement on Bay-Delta Standards Between the State of California and the Federal Government* (Bay-Delta Agreement). If such agreement(s) were determined to result in an adverse effect to delta smelt, delta smelt critical habitat or the Sacramento splittail in a manner or to an extent not previously identified, the contractual agreement(s) would be subject to some level of further environmental review.

Diversion Measures

DW shall limit diversions to the four project islands as set forth in the following measures:

1. In the period from September through November, DW shall not undertake its initial diversion to storage for the current water year until X2 is located at or downstream of Chipps Island. If DW's initial diversion to storage has not taken place by November 30, 1996, DW shall not undertake its initial diversion to storage for the current water year until X2 is located at or downstream of Chipps Island for a period of ten (10) consecutive days. After the initial X2 condition is met, diversions shall be limited to a combined maximum rate of 5,500 cfs for five consecutive days. Information documenting achievement of the X2 condition and resultant operational changes shall be submitted to the CDFG, USFWS, and NMFS within 24 hours of implementation of operational changes. [#2, 3, 4]

   The location of X2 shall be defined as the average daily location of a surface water salinity of 2.64 EC, determined by interpolating the average daily surface EC measurements at existing Bay-Delta monitoring stations. Should this traditional X2 methodology be replaced, superseded, or become otherwise unavailable, DW shall follow whatever equivalent practice is developed, subject to approval of the resources agencies and notice to the responsible agencies.

2. In the period from September through March, DW shall not divert water to storage when X2 is located upstream (east) of the Collinsville salinity gauge. When the delta smelt Fall Mid-Water Trawl index is less than 239 (FMWT<239), DW shall not divert water to storage when X2 is located upstream of a point 1.4 kilometers west of the Collinsville salinity gauge. [#5, 6, 7, 19]

3. In the period from October through March, DW shall not divert water to storage if the effect of DW diversions would cause an upstream shift in the X2 location in excess of 2.5 km. The resultant shift in X2 shall be determined by a comparison of the modeled estimates of the X2 location outflow, with and without the DW project, using a mathematical model, e.g., Kimmerer and Monismith equation. [#8, 9]

4. In the period from April through May, DW shall not divert water to storage. If the delta smelt Fall Mid-Water Trawl index is less than 239 (FMWT<239), DW shall not divert water for storage from February 15 through June 30. [#10, 20]

5. DW diversions to storage shall be limited to the following percentage of available surplus water as derived pursuant to the 1995 WQCP (e.g., E/I ratio, outflow). [#13]

Table 1: Surplus Availability

Month	FMWT>239	FMWT<239
October	90%	90%
November	90%	90%
December	90%	90%
January	90%	90%
February 1-14	75%	75%
February 15-28	75%	NA
March	50%	NA
April	NA	NA
May	NA	NA
June	50%	NA
July	75%	75%
August	90%	90%
September	90%	90%

6. DW diversions to storage shall not exceed a percentage of the previous day's net Delta outflow rate (cfs), as set forth in the following table: [#11, 23]

Table 2: Outflow Diversion Limit

Month	Percent Outflow [(1)]	
	FMWT>239	FMWT<239
October	25%	25%
November	25%	25%
December	25%	25%
January	15%	15%
February 1-14	15%	15%
February 15-28	15%	NA
March	15%	NA
April	NA	NA
May	NA	NA
June	25%	NA
July	25%	25%
August	25%	25%
September	25%	25%

(1) The percent of Delta outflow is calculated without consideration of DW diversions; therefore, the calculation could use the previous day's actual Delta outflow added to the previous day's DW diversions to yield an outflow value that would not include DW operations.

7. In the period from December through March, DW diversions to storage shall not exceed the percentage of the previous day's San Joaquin River inflow rate (cfs) for the maximum number of days, as set forth in the following table: [#12, 24]

Table 3: SJR Diversion Limit

Month	Percent SJR Inflow [(1)]	
	FMWT > 239	FMWT < 239
Application [(2)]	15 days	30 days
December	125%	125%
January	125%	100%
February 1 - 14	125%	50%
February 15 - 28	125%	NA
March	50%	NA

(1) The percent of SJR inflow is calculated from the previous day's inflow at Vernalis.

(2) The application of the SJR diversion limit is subject to a specific election on the part of the responsible fishery agencies for a maximum number of days, as specified above. The election to invoke the SJR diversion limit shall be based upon available monitoring data (e.g., project specific monitoring, MWT data).

8. DW shall implement a monitoring program to minimize or avoid adverse impacts of DW diversions to storage, as set forth below: [#15, 16, 21, 22]

a. DW shall implement a monitoring program in accordance with the attached "Delta Wetlands Fish Monitoring Program."

b. DW shall provide daily in-channel monitoring from December through August during all diversions to storage, except as provided below.

c. DW shall provide daily on-island monitoring from January through August during all diversions to storage, except as provided below.

d. Monitoring shall not be required at a diversion station if the total diversion rate at the station is less than 50 cfs and the maximum fish screen approach velocity is less than 0.08 fps (e.g., topping-off).

e. DW shall reduce the diversions at a diversion station to 50% of the previous day's diversion rate during the presence of delta smelt. Should delta smelt be detected on the first day of diversions to storage, the diversion rate shall be immediately reduced to 50%. This reduced diversion rate will remain in place until the monitoring program no longer detects a presence of delta smelt at the diversion station. For the purpose of this mitigation measure, delta smelt presence is defined as a two-day running average in excess of one (1) delta smelt per day at any reservoir diversion station. The definition of presence may be revisited from time to time as new information or monitoring techniques become available.

9. During periods when the DCC gates are closed for fisheries protection purposes, between November 1 and January 31, and the inflow into the Delta is less than or equal to 30,000 cfs, DW shall restrict diversions onto the reservoir islands to a combined instantaneous maximum of 3,000 cfs. When the DCC gates are closed for fishery protection purposes and the inflow into the Delta is between 30,000 and 50,000 cfs, DW shall restrict diversions onto the reservoir islands to a combined instantaneous maximum of 4,000 cfs. At Delta inflows greater than 50,000 cfs, DW diversions shall not be restricted by the closure of the DCC for fishery protection purposes. For purposes of this provision, Delta inflow is defined in accordance with the 1995 WQCP. [#17]

10. Nothing in measures 1 through 9 above shall limit DW from diverting water onto Bacon Island and Webb Tract from June through October in order to offset actual reservoir losses of water stored on those islands, hereafter referred to as "topping-off" reservoirs. Daily topping-off diversions shall be subject to the following conditions: [#18, 25]

    a. Topping-off diversions shall not exceed the maximum diversion rate (cfs) and maximum monthly quantity (TAF) listed in below:

Table 4: Maximum Topping-Off Diversion Rates

Month	Jun	Jul	Aug	Sep	Oct
Maximum diversion rate (cfs)	215	270	200	100	33
Maximum monthly quantity (TAF)	13	16	12	6	2

    b. Topping-off diversions shall occur through screened diversions with approach velocities less than 0.10 fps.

    c. A mechanism acceptable to USFWS, NMFS, and CDFG shall be devised and used by DW to document actual reservoir losses.

    d. The maximum topping-off diversion rates shown above shall be further limited by diversions onto the habitat islands. The maximum topping-off diversion rate and quantity shall be reduced by an amount equal to the habitat island diversions during the same period.

Discharge Measures

Delta Wetlands (DW) shall limit discharges from the four project islands as set forth in the following measures:

1. In the period from April through June, DW shall limit discharges for export or rediversion from Bacon Island to one-half (50%) of the San Joaquin River inflow measured at Vernalis. [#34]

2. In the period from January through June, DW shall not discharge for export or rediversion from Webb Tract. [#33]

3. DW shall not discharge for export or rediversion any water from the habitat islands. [#41]

4. In the period from February through July, DW discharges for export shall be limited to the following percentage of the available unused export capacity at the CVP and SWP facilities as derived pursuant to the 1995 WQCP. [#35, 36]

Table 5: Export Availability

Month	Bacon	Webb
February	75%	NA
March	50%	NA
April	50%	NA
May	50%	NA
June	50%	NA
July	75%	75%

6. DW shall provide a quantity of "environmental water" for release as additional Delta outflow, as set forth in the following terms and conditions: [#38, 42]

a. DW shall provide a quantity of environmental water equal to 10% of all discharges for export that occur in the period from December through June. If the delta smelt Fall Mid-Water Trawl index is less than 239 (FMWT<239), this environmental water percentage shall be increased to 20% of all discharges for export that occur in the period from December through June.

b. Environmental water shall be released between February and June of the same water year as the discharge for export that generated the water and may not be banked for future use in subsequent water years.

c. Habitat island discharges may be credited toward the environmental water quantities required above, if:

I. habitat island discharges occur between February and June;
ii. habitat island discharge credits are limited to the net flow quantity (e.g., habitat discharge minus habitat diversion);
iii. habitat island discharges occur during a period of time when 75% of the spacial distribution of the delta smelt population is located downstream of the discharge location, where the determination of spacial distribution is based on the most recent distribution data available (e.g., IEP);
iv. the habitat island discharge rate does not vary on a daily basis more than 1% of the average gross flow rate in the adjacent channel, either upstream or downstream, when delta smelt are spawning in the area;
v. DW makes a best effort to minimize fluctuations in daily discharge rates;
vi. and the habitat island discharges are consistent with the HMP.

d. Environmental water, less habitat island discharge credits, shall be discharged at the discretion of USFWS, NMFS and CDFG to maximize fishery benefits. Coordination of these discharges shall be performed by the CDFG Bay-Delta office.

7. DW shall implement a monitoring program to minimize or avoid adverse impacts of DW discharges for export, as set forth below: [#39, 40, 43, 44]

a. DW shall implement a monitoring program in accordance with the attached "Draft Proposed Delta Wetlands Fish Monitoring Program."

b. DW shall provide daily in-channel monitoring from April through August during all discharges for export, except as provided below.

c. Monitoring shall not be required if the total discharge for export rate is less than 50 cfs.

d. DW shall reduce the discharge for export rate to 50% of the previous day's diversion rate during the presence of delta smelt. Should delta smelt be detected on the first day of discharges for export, the discharge rate shall be immediately reduced to 50%. This reduced diversion rate will remain in place until the monitoring program no longer detects a presence of delta smelt at the in-channel sampling sites. For the purpose of this mitigation measure, delta smelt presence is defined as a two-day running average in excess of one (1) delta smelt per day at the Old and Middle River sampling sites. The definition of presence may be revisited from time to time as new information or monitoring techniques become available.

e. DW shall provide for this monitoring either by contributing financial support commensurate with the proportionate share of DW exports to the Bay/Delta monitoring programs, or when no other monitoring is being conducted at appropriate sites, DW shall provide for direct monitoring in river channels as described above.

Other Measures

1. Fish screen design: [#49]

The DW fish screens will be generally consistent with the design presented in the DEIR/EIS except that DW shall maintain a 0.2 fps approach velocity for diversions. Final design elements and installation guidelines will be subject to approval by the responsible agencies with concurrence by the resource agencies. Final design, including a monitoring program to evaluate performance criteria will be submitted for approval at least 90 days prior to commencing operations.

2. Rearing and Spawning Habitat. [#50, 51]

Prior to construction, DW will secure a perpetual conservation easement (easement) for 200 acres of shallow-water aquatic habitat not currently protected by easement or covenant. The easement shall fully protect in perpetuity the shallow-water aquatic habitat. A management plan for the easement area shall be developed for the habitat covered by the easement, and shall be incorporated as an exhibit to the easement.

Additionally, DW shall provide to the USFWS documentation that there is adequate financing for the perpetual management of the habitat protected by the conservation easement consistent with the terms of this biological opinion and the management plan including that (1) adequate funds for the management of habitat in perpetuity protected by the conservation easement have been transferred to an appropriate third-party, and (2) the third party has accepted the funds and (3) such funds have been deposited in an interest-bearing account intended for the sole purpose of carrying out the purposes of this easement.

The easement (along with a title report for the easement area) and management plan shall be approved by the USFWS prior to recordation. After approval, the easement and management plan shall be recorded in the appropriate County Recorders Office(s). A true copy of the recorded easement shall be provided to the USFWS within 30 days after recordation.

3. Boat Wake Erosion [#53]

DW shall contribute $100 per year for each net additional berth beyond pre-project conditions added to any of the four project islands. These funds shall be in January 1996 dollars and shall be adjusted annually for inflation.

4. Aquatic Habitat [#54]

The actual impact to aquatic habitat acreage for construction and operation of siphon and pumping facilities and waterside boat docks shall be verified prior to construction and mitigation shall take place on a 3:1 basis.

5. Temperature Limits [#55]

DW shall implement a temperature program to minimize or avoid adverse impacts of DW discharges for export, as set forth below:

a. DW shall not discharge reservoir water for export if the temperature differential between the discharge and the adjacent channel temperature is greater than or equal to 20°F.

b. If the natural receiving water temperature of the adjacent channel is greater than or equal to 55°F and less than 66°F, DW discharges for export shall not increase the channel temperature by more than 4°F.

c. If the natural receiving water temperature of the adjacent channel is greater than or equal to 66°F and less than 77°F, DW discharges for export shall not cause an increase of more than 2°F.

d. If the natural receiving water temperature of the adjacent channel is greater than or equal to 77°F, DW discharges for export shall not cause an increase of more than 1°F.

e. DW shall develop temperature monitoring and implementation plans to ensure that the project does not adversely impact the channel temperature levels as described above. The monitoring plan shall include reservoir and channel temperature monitoring. The monitoring and implementation plans shall be completed after the project is permitted, but at least 90 days prior to project operations. The plans shall be submitted to the responsible agencies for approval with the concurrence of the resource agencies.

6. DO Limits [#56]

DW shall implement a dissolved oxygen (DO) program to minimize or avoid adverse impacts of DW discharges for export, as set forth below:

a. DW shall not discharge reservoir water for export if the discharge DO level is less than 6.0 mg/l without authorization from the resource agencies and notice to the responsible agencies.

b. DW shall not discharge reservoir water for export if the discharge would cause channel water DO levels to fall below 5.0 mg/l.

c. DW shall develop DO monitoring and implementation plans to ensure that the project does not adversely impact the channel DO levels as described above. The monitoring plan shall include reservoir and channel DO monitoring. The monitoring and implementation plans shall be completed after the project is permitted, but at least 90 days prior to project operations. The plans shall be submitted to the responsible agencies for approval with the concurrence of the resource agencies.

7. Incidental Entrainment Compensation [#57]

Certain life stages of key fish species may not be effectively screened during periods of diversions for storage. DW will, therefore, sample DW diversions during the periods specified below and compensate for losses to selected target fish. DW diversions onto the reservoir islands will be sampled for egg, larval, and juvenile life stages of the selected target fish. Those losses will be mitigated using a formula which ties measured losses with mitigation as specified below.

This provision covers entrainment of non-listed species, as well as, delta smelt and splittail (that are, respectfully, listed and candidate species). Coverage of non-listed species is intended as a CEQA/NEPA mitigation measure and is only included here for ease of understanding.

Should on-island monitoring detect the presence of eggs, larvae, and juveniles during the months specified in the incidental entrainment monitoring guidelines, DW shall provide monetary compensation for incidental entrainment, as set forth in the following tables:

Table 6: Incidental Entrainment Monitoring Guidelines

Species and Life Stages	Jan	Feb	Mar	Jun	Jul	Aug
Striped Bass						
larvae and juveniles				X	X	X
American Shad						
larvae and juveniles				X	X	X
Delta Smelt						
larvae	X	X	X	X	X	
juveniles		X	X	X	X	X
Splittail						
larvae	X	X	X	X	X	X
juveniles		X	X	X	X	X
Longfin Smelt						
eggs and larvae	X	X	X			
juveniles	X	X	X	X	X	X

Table 7: Incidental Entrainment Compensation

Measured Density	Mitigation/TAF
10-999 eggs, larvae, and juveniles/AF	$500
1,000-5,000 eggs, larvae, and juveniles/AF	$750
>5,000 eggs, larvae, and juveniles/AF	$1,000

Should DW be unable to perform on-island monitoring, the maximum mitigation compensation will be assumed, unless waived or modified by the responsible agencies, with concurrence of the resource agencies. Funds are in January 1996 dollars and shall be adjusted annually for inflation. Monetary reimbursement shall be deposited into a mitigation fund on a semi-annual basis. The use of the mitigation funds shall be at the discretion of the resource agencies (e.g., CDFG Bay-Delta office) but shall be used to the fullest extent possible to plan and implement actions that improve habitat for the target species in the Estuary.

8. Construction Period [#60]

All construction activities taking place in the tidal waters of the adjacent channels or impacting a tidal water habitat shall occur between June and November.

Appendix 2. Baseline and DW operations conditions, September through May, 70 year simulation (JSA 1996).

		CVP/SWP export levels	QWEST	Delta Outflow	Old and Middle Rivers flow
September	Baseline	7147	-540	4951	-6660
	DW	7411	-800	4691	-6924
October	Baseline	8695	-456	7578	-9300
	DW	9019	-1062	6972	-9355
November	Baseline	9107	-3212	11287	-7597
	DW	9127	-3902	10597	-7616
December	Baseline	10138	-1848	22257	-8216
	DW	10229	-2241	21864	-8307
January	Baseline	11025	570	34981	-8176
	DW	11226	0.1	34410	-8197
February	Baseline	10487	4011	47215	-6861
	DW	10568	3542	46746	-6950
March	Baseline	9420	3450	38703	-6252
	DW	9456	3423	38676	-6288
April	Baseline	6666	3614	25665	-6219
	DW	6753	3655	25707	-6306
May	Baseline	6191	1914	17458	-6418
	DW	6314	1950	17494	-6540

Appendix 3. Guidelines for Revegetation of Woody Riparian and Shaded Riverine Aquatic Habitat.

NMFS anticipates that adherence to these guidelines will result in 'no net loss' of riparian vegetation or SRA habitat within the project area.

1. All remaining, natural woody riparian or SRA habitat shall be avoided or preserved to the maximum extent practicable.

2. Re-planting ratios for woody riparian and SRA shall replace lost habitat at 3:1.

3. Species chosen for replanting should reflect native species lost during the permitted activity or native species usually found in the riparian and SRA zones of the project location.

4. Plantings should be done during the optimal season for the species being planted. Therefore, completion of the entire mitigation plan may not occur at the same time as the permitted activity.

5. Maintenance plans for revegetated sites should continue for at least three growing seasons to allow the vegetation to establish.

6. Remediation plans should be prepared in the event of a planting failure.

Appendix 4. Material Guidelines for Levee Maintenance and Bank Stabilization Projects.

These guidelines should be applied to all bank stabilization and levee maintenance projects.

1. No petroleum products such as asphalt may be used.

2. Concrete or other similar rubble shall be free of trash or reinforcement steel.

3. If anchoring and stabilizing fabrics (geotextiles, armorflex, etc.,) are used, they shall be slit in appropriate locations to allow for plant root growth.

4. No fill material other than clean, silt-free gravel or river rock shall be allowed to enter the live stream.

5. When possible, hard points, fish groins, or tethered trees should be incorporated into the levee or bank protection design.

Appendix E. U.S. Fish and Wildlife Service Biological Opinion

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Sacramento Fish and Wildlife Office
2800 Cottage Way, Room W-2605
Sacramento, CA 95825-1846

IN REPLY REFER TO:
1-1-00-I-1573

April 26, 2000

Tom Coe, Chief
Sacramento/San Joaquin Delta Office
U.S. Army Corps of Engineers
Sacramento District
1325 J Street
Sacramento, California 95814-2922

Subject: Adoption of Sacramento Splittail Conference Opinion for the Formal Programmatic Consultation and Conference on the proposed Delta Wetlands project (1-1-97-F-76) as a Biological Opinion

Dear Mr. Coe:

The U.S. Fish and Wildlife Service (Service) received your request, dated November 22, 1999, to adopt the conference opinion on the Delta Wetlands project (1-1-97-F-76) for the Sacramento splittail (*Pogonichthys macrolepidotus*) (splittail) as a biological opinion. As stated in your letter, no changes in circumstances or in the proposed project are anticipated that would alter the conclusions regarding the splittail. Therefore, we adopt your conference opinion as a biological opinion.

Please contact Stephanie Brady or Ken Sanchez of my staff at (916) 414-6625, if you have questions regarding this response.

Sincerely,

Karen J. Miller

Karen J. Miller
Chief, Endangered Species Division

United States Department of the Interior

FISH AND WILDLIFE SERVICE

Ecological Services
Sacramento Field Office
3310 El Camino, Suite 130
Sacramento, California 95821-6340

IN REPLY REFER TO:

1-1-97-F-76

May 6, 1997

Mr. Jim Monroe
Chief, Sacramento/San Joaquin Delta Office
U.S. Army Engineer District, Sacramento
Corps of Engineers
1325 J Street
Sacramento, California 95814-2922

Subject: Formal Consultation and Conference on the Army Corps Public Notice Number 190109804 for the Delta Wetlands Project, Contra Costa and San Joaquin Counties, California

Dear Mr. Monroe:

This is in response to your March 5, 1997, letter requesting reinitiation of formal consultation with the U.S. Fish and Wildlife Service (Service) pursuant to section 7(a)(2) of the Endangered Species Act of 1973, as amended (Act). This document represents the Service's biological opinion on the effects of the Department of the Army Public Notice Number 190109804 for the Delta Wetlands Project (DW) on the delta smelt (*Hypomesus transpacificus*).

This biological opinion addresses effects of DW on the delta smelt. On January 6, 1994, a proposed rule to list the Sacramento splittail (*Pogonichthys macrolepidotus*) as a threatened species (Service 1994a) was published in the **Federal Register**. On December 19, 1994, a final rule designating critical habitat for the delta smelt was published (Service 1994c). This biological opinion also incorporates a conference opinion prepared pursuant to 50 CFR §402.10, which addresses project effects on the proposed threatened Sacramento splittail, and a biological opinion on delta smelt critical habitat. Should the Sacramento splittail become listed, the Army Corps of Engineers (Corps) may request that the Service adopt the conference opinion incorporated in this consultation as a biological opinion issued through formal consultation. If a review of the proposed action indicates that there have been no significant changes in the action as planned, or in the information used during the conference, the Service will adopt the conference opinion as the biological opinion and no further section 7 consultation will be necessary. Insignificant project effects occur on the bald eagle (*Haliaeetus leucocephalus*), California clapper rail (*Rallus longirostris obsoletus*), salt marsh harvest mouse (*Reithrodontomy raviventris*), valley elderberry longhorn beetle (*Desmoceros californiacus dimorphus*), and giant garter snake (*Thamnophis gigas*).

Pursuant to 50 CFR §402.08, the Corps and the permit applicant have agreed to name Jones and Stokes Associates, Incorporated (JSA), as the designated non-

Federal representative for purposes of preparing and assisting in the evaluation of the biological assessment. Representatives from the Service, Corps, National Marine Fisheries Service (NMFS), California Department of Fish and Game (DFG), California State Water Resources Control Board (SWRCB), Natural Resources Consulting Scientists, HYA Consulting Engineers, Ellison and Schneider Law Firm, Kemper Insurance (project financier), JSA, and Delta Wetlands Corporation (DWC) have met since October 1993 to discuss the effects of the proposed project on listed fish species. DW does not have a water right: Issuance of the water right will be determined by the SWRCB after the delta smelt and winter-run chinook salmon biological opinions have been issued. A summary of significant events resulting from these meetings and related Federal actions affecting the development of the proposed project follows:

1. At a July 7, 1994, meeting, it was determined that to mitigate for project effects for delta smelt adaptive management should be used. Adaptive management uses real-time monitoring to avoid or minimize operational effects on delta smelt.

2. On September 2, 1994, DWC transmitted a draft fish monitoring proposal to facilitate use of adaptive management.

3. On December 15, 1994, the Bay-Delta Accord (Accord) was signed (see Appendix 1 for Accord CVP and SWP operations relevant to DW).

4. On March 6, 1995, the Service issued a delta smelt biological opinion for the operation of the Central Valley Project (CVP) and State Water Project (SWP)(Service 1995) that implemented relevant sections of the Accord.

5. At the May 3, 1995, meeting, the loss of listed fish due to conveyance of DW water at the CVP and SWP pumping plants was discussed. A suggested method for covering this "take" was to reinitiate the delta smelt and winter-run chinook salmon consultations on the operation of the CVP and SWP.

6. On May 17, 1995, NMFS issued a winter-run chinook salmon biological opinion for the operation of the CVP and SWP (NMFS 1995).

7. On October 3, 1995, DFG transmitted a draft proposal to avoid or minimize DW effects using both rigid measures such as a QWEST (defined as the calculated flows on the San Joaquin River as measured at Vernalis and used as measurement of reverse flows caused by south Delta pumping) criteria, complete diversion curtailment in certain months, and adaptive management measures.

8. On October 24, 1995, DWC responded with a counter proposal that included adaptive management measures.

9. On November 28, 1995, the Service, NMFS, DFG, and other interested parties met to develop a coordinated proposal to reduce project effects on listed and non-listed Delta fish species.

10. On December 7, 1995, a draft "Delta Wetlands Aquatic Resources Management Plan" was transmitted to DWC by DFG that combined avoidance and minimization measures recommended by the Service, NMFS, and DFG to minimize effects on delta smelt, winter-run chinook salmon, and several non-listed species. Adaptive management measures were used in this document.

11. On March 29, 1996, the Service's Portland Regional Office transmitted a draft jeopardy biological opinion to the Sacramento Corps District Engineer.

12. On June 28, 1996, NMFS transmitted a draft non-jeopardy biological opinion to the Corps.

13. On May 10, 1996 (1-1-96-I-936), the Service responded to nine questions posed by DWC.

14. On August 5, 1996 (1-1-96-I-1087), the Service responded to 37 additional questions posed by JSA and transmitted by the Corps.

15. On March 5, 1997, the Corps reinitiated consultation with the Service and provided comments on the Service's draft jeopardy biological opinion and a proposed mitigation matrix to avoid or minimize adverse project effects.

16. Discussions between the Service and DWC concerned the draft jeopardy biological opinion's treatment of DW discharges in relation to the export/inflow ratio implemented in the March 6 delta smelt biological opinion and operations of the CVP and SWP pumps. As a result of those discussions, DWC transmitted to the Service an October 18, 1996, issue letter which set out the following agreement:

   - DWC does not intend to seek a SWRCB ruling on whether DW discharges should be included as inflow for purposes of calculating the export/inflow ratio during its water rights hearing.

   - DW discharges for export will be limited so as to not cause total exports at the SWP and CVP pumping plants in the South Delta to exceed the export/inflow ratio as defined by the SWRCB.

   - While reserving its right to take a position before the SWRCB, if a proceeding to reconsider the export/inflow ratio is initiated, the Service will not take a position or impose a condition within DWC's final biological opinion that would preclude DW discharges from being considered as inflow under the export/inflow ratio should the SWRCB make such a determination.

The following sources of information were used to develop this biological opinion: (1) November 8, 1994, site visit to project area; (2) June 21, 1995, Biological Assessment: "Impacts of the Delta Wetlands Project on Fish Species"; (3) administrative draft Environmental Impact Report and Environmental Impact Statement (EIR/EIS) for DW; (4) March 5, 1997, Corps letter containing DW mitigation operations matrix; (5) various meetings with DWC, JSA, Ellison and Schneider and the Corps; (6) telephone discussions with the Corps; (7) references cited in this biological opinion; and (8) unpublished information in Service files. A complete administrative record of this consultation is contained at the Service's Sacramento Field Office.

BIOLOGICAL OPINION

Description of the Proposed Action

Project Overview.

The purpose of DW is to divert surplus Delta inflows, transferred water, or banked water for later sale and/or release for Delta export or to meet Bay-Delta estuary (Estuary) water quality or flow requirements. Additionally, DW will provide for managed wetlands, wildlife habitat, and recreational uses. DWC currently does not have a water right to implement the proposed action. The SWRCB will issue its determination for such a right following issuance of biological opinions on the proposed DW project by the Service and NMFS.

DW involves water storage on four islands in the Delta (Figure 1). The proposed project involves the potential year-round diversion and storage of water on two "reservoir" islands, Bacon Island and Webb Tract (Figure 2). It also involves the seasonal diversion and use of water for wildlife management and wetland creation on two "habitat" islands, Bouldin Island and Holland Tract (Figure 2). Bacon Island, Webb Tract, and Bouldin Island are wholly owned by DWC. Holland Tract is partially owned by DWC.

DWC intends to implement a habitat management plan on the two habitat islands. Water from these islands may also be used for the same purposes as water released from the reservoir islands. DWC will improve levees on all four islands and install additional siphons and water pumps on the reservoir islands. Inner levee systems would also be installed on both the reservoir and habitat islands for wetland management and shallow-water control.

DW will undertake its diversion and discharge operations pursuant to the "final operations criteria" which are set out in Appendix 2. DW would divert water onto the reservoir islands during periods of availability throughout the year and discharge it from the islands into Delta channels during any period of demand, subject to Delta regulatory limitations and channel and pump capacities. Export of DW water would mainly take place at the CVP and SWP pumps. DW would divert water onto the habitat islands for wetland and wildlife habitat creation and management. Wetland diversions would most likely begin in September and water would be circulated throughout the winter. Habitat island water discharges would be scheduled to maintain wetland and wildlife values. Portions of the habitat islands and the reservoir islands, if not used for water storage, may be flooded to shallow depths during the winter to attract wintering waterfowl and support private hunting clubs. Reservoir island operations may include shallow-water management during periods of non-storage at the discretion of DWC and incidental to the proposed project.

DW Operations

1. DW water may be purchased to supply water for export to the SWP, CVP, and third-party purchasers that use SWP or CVP facilities for transport of water ("wheeling"). Estimated mean annual DW project water available for export would be approximately 154,000 acre-feet (TAF) (JSA 1996).

2. DW project water may be purchased to improve Delta water quality; it may be of higher quality for urban and agricultural use with respect to temperature, turbidity, oxygen, dissolved metals and organics, and nutrient contents.

3. DW water may be purchased to meet environmental flow requirements. Flows having the greatest effect on Delta biological resources are: (1) Delta inflow; (2) flows from the Sacramento River through the Delta Cross Channel; (3) reverse flows caused by water project and local agricultural diversions; (4) agricultural return flows; (5) Delta outflow and salinity; and (6) transport flows.

4. DW reservoir islands may be used for wetland habitat management during periods of non-storage. Diversions would typically begin after September 1, and wetland habitats would be flooded as storage water becomes available.

Specific Operation of the Reservoir Islands

As noted above, Bacon Island and Webb Tract would be managed for water storage pursuant to DW's final operations criteria. Facilities that would be needed for these proposed water storage operations include intake siphon stations to divert water onto the reservoir islands, and pump stations to discharge stored water from the islands. DWC proposes to construct two intake siphon stations on each reservoir island with 16 new siphons each, for a total of 64 siphons. One discharge pump station with 32 new pumps would be installed on Webb Tract and a pump station with 40 pumps installed on Bacon Island, for a total of 72 new pumps.

Storage Capacity. The two reservoir islands will be designed for water-storage levels up to a maximum pool elevation of +6 feet relative to mean sea level. This provides a total estimated initial capacity of 238 TAF, allocated between Bacon Island and Webb Tract at 118 TAF and 120 TAF, respectively. Water availability, permit conditions, and requirements of the California Department of Water Resources (DWR) Division of Safety of Dams may limit storage capacities and may result in a final storage elevation of less than +6 feet.

The total physical storage capacity of the reservoir islands may increase over the life of the project as a result of soil subsidence (caused by oxidation of peat soil). Subsidence on the reservoir islands is currently estimated to average two to three inches per year and is thought to be caused by agricultural operations. With water storage operations replacing agricultural operations, the rate of subsidence on the reservoir islands is expected to be greatly reduced. DWC estimates that the reservoir islands could subside at a rate of approximately 0.5 inches per year, which includes sedimentation due to filling. Thus, the reservoir storage capacity could increase by nine percent in 50 years, increasing total storage capacity of the reservoir islands to 260 TAF.

Multiple Storage. The reservoir islands will be filled, drawn down, and refilled in years when water availability, demands, and operational criteria contained in Appendix 2 allow. These years are classified as multiple storage years. Multiple storage would generally occur during years of moderate precipitation. This management scenario depends on the availability of surplus water early in the year and a demand for the water to allow an early discharge of the reservoir followed by another period of available surplus water.

Carry-Over Storage. During years of low water demand, water would remain in the reservoirs at the end of the water year (*i.e.*, September 30), and thus could be released in subsequent years. Carry-over storage would generally occur during wet years with low demand.

Diversions. DW diversions for storage would occur only when the volume of allowable water for export (*i.e.*, the lesser amount specified by the export limits and the amount of available water) is greater than the permitted pumping rate of State and Federal export pumps and when the conditions in Appendix 2 are met. The former condition would occur when two conditions are met: (1) all Delta outflow requirements are met and the export limit is exceeded; and (2) water that is available and is allowable for export is not being exported by the CVP and SWP pumps. For purposes of modeling these alternatives, the second condition is assumed to occur only when water that is allowable for export exceeds the permitted pumping rate. However, the CVP and SWP may not be pumping at capacity because of low demands during the winter, and under these conditions DW will still be able to divert water for storage.

Any diversion of water by DW will be controlled by its final operations criteria shown in Appendix 2. These criteria set variable diversion rates and conditions based on a number of factors including: (1) location of X2; (2) Fall Midwater Trawl Survey (FMWT) index values; and (3) availability percentages applied to the total surplus water available, the previous day's net Delta outflow, and San Joaquin River inflow.

The timing and volume of diversions onto the reservoir islands will depend on how much water flowing through the Delta is not put to a reasonable beneficial use by senior water-right holders or is not required for environmental protection. A procedure for coordinating daily DW diversions with CVP and SWP operations will be established to ensure that DW diversions capture only available Delta flows, satisfy 1995 State Water Quality Control Plan (SWQCP) water quality objectives, and maximize DW water storage efficiency.

Diversion rates of water onto reservoir islands would vary with pool elevation and water availability. The maximum rate of diversions possible onto either Webb Tract or Bacon Island would be 4,500 cfs (9 TAF per day) at the time diversions begin (*i.e.*, when the head differential between channel water elevation and the island bottom is greatest) with decreases occurring from intake screening criteria and operational criteria in Appendix 2. The diversion rate also would be reduced as reservoirs fill and head differentials diminish. The combined maximum daily average rate of diversion for all islands (including diversions to habitat islands) will not exceed 9,000 cfs.

Discharges. Releases from DW would be exported by the CVP and SWP pumps when an unused capacity within the permitted pumping rate exists. DW discharges will be allowed to be exported in any month subject to the limitations described below. The project will operate in the context of existing Delta facilities, demand for export, and operating constraints as defined in Appendix 2. Export of DW discharges is limited by the 1995 SWQCP Delta outflow requirements, the Corps permitted combined pumping rate of the export pumps, and the delta smelt and winter-run salmon biological opinions for operation of the CVP and SWP.

Timing of Discharges. Discharge of DW project water will occur pursuant to DW's final operations criteria as set out in Appendix 2. Stored water will be discharged from reservoir islands during periods of demand, subject to 1995 SWQCP Delta outflow requirements, the Corps permitted combined pumping rate of the export pumps, and the delta smelt and winter-run salmon biological opinions for operation of the CVP and SWP.

The final operations criteria set out several limitations on discharge operations, including:

1. no discharges for export from Webb Tract from January through June;

2. limiting discharges from Bacon Island from April through June during the San Joaquin River pulse flow interval and peak delta smelt period of downstream movement to 50 percent of San Joaquin River flows at Vernalis (*i.e.*, if Vernalis flow is 1,000 cfs, then maximum Bacon Island discharge of 500 cfs); and

3. percentage limitations of unused export capacity at the CVP and SWP pumps for DW discharges from February through July.

Shallow-water Management. Incidental to project operations and at times when water is not being stored, the project may include shallow-water management on Bacon Island and Webb Tract to enhance forage and cover for wintering waterfowl. From September through May, reservoir islands may be flooded to shallow depths (approximately one acre-foot of water per acre of wetland) for creation of habitat, typically 60 days after reservoir drawdown. During years of late reservoir drawdown, additional time may be necessary before shallow flooding begins to allow seed crops to mature. Once shallow water flooding for wetland management occurs, water will be circulated through the system of inner levees until deep flooding occurs or through April or May. If reservoir islands are not deeply flooded by April or May, water in seasonal wetlands will be drawn down in May, and if no water is available for storage, island bottoms will remain dry until September when the cycle will potentially be repeated. DW water used for shallow water flooding in April and May may be available for sale.

Siphon Station Design. Two new siphon stations for water diversions would be installed along the perimeter of each reservoir island. Each station would consist of 16 siphon pipes, each 36 inches in diameter. Screens to prevent entrainment of fish in diversions will be installed around the intake end of each existing and new siphon pipe. The individual siphons will be placed at least 40 feet apart to incorporate fish screen requirements. Existing reservoir island siphons may be used to create shallow-water wetland habitat. In-line booster pumps will be available on the reservoir islands to supplement siphon capacity during the final stages of reservoir filling.

Pump Station Design. One discharge pump station will be located on each reservoir island. Webb Tract will have 32 new pumps and Bacon Island will have 40 new pumps, each with 36-inch-diameter pipes discharging to adjacent Delta channels. Typical spacing of the pumps will be 25 feet on center. An assortment of axial-flow and mixed-flow pumps will be used to accommodate a variety of head conditions throughout drawdown. Actual rates of discharge for each pump will vary with pool elevations. As water levels decrease on the islands, the discharge rate of each pump will decrease. Existing pump stations on the islands may be modified and used when appropriate to help with dewatering or for water circulation to improve water quality. Pump station pipes will discharge underwater to adjacent Delta channels through a 3-foot by 10-foot expansion chamber, protected by guard piles adjacent to the expansion chambers and including riprap on the channel bottom to protect against erosion.

Levee Improvements and Maintenance. Exterior levees on the reservoir islands will be improved to bear the stresses and potential erosion of interior island water storage and drawdown. The perimeter levees on reservoir islands will be raised and widened to hold water at a maximum elevation of +6 feet. Levee improvements will be designed to meet or exceed criteria for levees outlined in DWR Bulletin 192-82. Levee design will address control of wind and wave erosion through placement of a rock revetment on levee slopes, and control of project-related seepage through an extensive monitoring and control system.

Exterior levees on all four islands will be buttressed and improved as described for Webb Tract and Bacon Island. In addition, an inner levee system will be constructed and maintained on the bottom of the islands. This system will consist of a series of low-height levees and connecting waterways, and will facilitate the management of shallow water during periods of non-storage. The inner levees will be broad, earthen structures similar to structures currently in place on existing farm fields.

<u>Specific Operation of the Habitat Islands</u>

Bouldin Island and Holland Tract would be managed for wetland and wildlife habitats. An incidental operation of the habitat islands will involve the sale or use of water drained from the islands. Wetland management on the habitat islands will require grading areas, re-vegetating, and diverting water. Improvements will be made to existing pump and siphon facilities, and to perimeter levees, including levee buttressing to meet DWR's recommended standards for levee stability and flood control. No new siphon or pump stations will be constructed on habitat islands. Recreation facilities will be constructed on perimeter levees.

Diversions and Discharges. Bouldin Island and Holland Tract will be managed for improvement and maintenance of wetland and wildlife values through use of a Habitat Management Plan (HMP). The HMP was primarily developed (and finalized in the early 1990s) by DFG and DWC to address project effects on waterfowl. The timing and volume of diversions onto the habitat islands will depend on the needs of wetland and wildlife habitats. Wetland diversions will typically begin in September, and water will be circulated throughout the winter. Existing siphons will be used for diversions to the habitat islands. Fish screens will be installed on all siphons used for diversions.

The maximum rate of proposed diversions onto Holland Tract and Bouldin Island will be 200 cfs per island. Diversions onto the habitat islands will not cause the combined daily average maximum diversion rate of 9,000 cfs for all four project islands to be exceeded. Water will be applied to the habitat islands for management in each month of the year to maintain acreages of open water, perennial wetlands, flooded seasonal wetlands, and irrigated croplands specified in the HMP. On an annual basis, approximately 19 TAF will be diverted onto the habitat islands.

Water will be discharged from the habitat islands based on wetland and wildlife management needs. Typically, water will be drawn down by May and the habitat islands will remain dry until September, except for permanently watered areas and other areas maintained for wetland vegetation. Existing pumps will be used for discharges and for water circulation on the habitat islands. If new appropriative rights are approved for water diverted onto the islands for wetland and wildlife management needs, water may be sold when it is discharged, provided conflicts do not arise with the HMP.

Recreation Facilities. Recreation facilities on the habitat islands will be similar to those described above for the reservoir islands. Consistent with the HMP, up to 10 new recreation facilities will be constructed on Bouldin Island, and six new recreation facilities on Holland Tract. New boat docks will accommodate more than 1,200 vessels at final build-out. The Bouldin Island airstrip will be available for use by hunters and other recreationists.

Operation and Maintenance. Operation and maintenance activities will include: (1) siphon and pump unit operations and routine maintenance; (2) management of habitat areas, including (but not limited to) the control of undesirable plant species, the maintenance or modification of inner levees, and water circulation in ditches, canals, open water, and shallow flooded habitats to facilitate flooding and drainage; (3) fish screen maintenance and monitoring during water diversions for habitat maintenance; (4) wildlife and habitat monitoring under the HMP; (5) perimeter levee inspections and maintenance; (6) aircraft operations for seeding, fertilizing, *etc.*; (7) operation of recreational facilities using seasonal workers; and (8) monitoring and enforcement of hunting restrictions.

Fish Screens

Fish screens will be installed around the intake of each existing and new siphon to prevent entrainment and impingement of most adult and juvenile fish that are present in the Delta. DW fish screens shall not exceed a 0.2 fps approach velocity for diversions. The average approach velocity will decrease rapidly as the islands are filled because of decreases in siphon head differential. The preliminary fish screen design consists of a barrel-type screen on the inlet side of each siphon with a hinged flange connection at the water surface (for cleaning). Each siphon opening will be enclosed by a stainless steel, woven wire mesh consisting of seven openings per inch in a screen of 0.035-inch-diameter number 304 stainless steel wire with a pore diagonal of 0.1079 inches. Siphon pipes, with their individual screen modules, will be spaced approximately 40 feet apart on center. Final design elements and installation guidelines will be subject to approval by the Corps, SWRCB, the Service, DFG, and NMFS.

Operations to Mitigate Project Effects

The Corps formally transmitted modifications to DW project operations to the Service on March 5, 1997 (Corps 1997). The intent of these changes, which are described in detail in Appendix 2, was to mitigate project effects on listed and proposed fish species and critical habitat. The revisions to the proposed action addressed: (1) diversion criteria; (2) discharge to export criteria; (3) discharge limits based on temperature and dissolved oxygen criteria; and (4) compliance and coordination with CVP and SWP Delta operations.

Introduction. This narrative reflects final operations criteria for the DW that would take the place of the operations criteria previously proposed by JSA on March 1, 1996. These operations criteria are intended to ensure that the DW project operations do not jeopardize the continued existence of delta smelt, Sacramento splittail, winter-run chinook salmon, or steelhead trout. DW expects that non-listed species will also benefit from these criteria and such criteria will replace the related mitigation measures for fishery impacts proposed in the context of the CEQA/NEPA process.

Under these operations criteria, DW will not be inconsistent with conditions set forth in the March 6, 1995, delta smelt biological opinion (Appendix 1) or the SWRCB 1995 WQCP for the Bay-Delta estuary. These revised operations criteria set forth multi-layered diversion and discharge parameters. In the instance where two or more conditions apply, the condition that is the most restrictive on DW operations will control.

Additional restrictions apply if the delta smelt FMWT index declines to less than 239. The FMWT index refers to the most current four month (Sep-Dec) FMWT index in place at the time of the intended diversion. A diversion prior to January can utilize either the previous year's FMWT index or the partial FMWT index for the months available, whichever is greater. Any changes in the FMWT index calculation methodology will be adjusted so that the FMWT index values applied herein can continue to be the standard for DW operations criteria.

A delta smelt FMWT index measurement of less than 84 (FMWT<84) is new information under the reinitiation regulations (50 C.F.R. § 402.16) and requires reinitiation of this biological opinion. [#26,45][1]

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[1] The number(s) in brackets are provided as a reference to the DW ESA Matrix which summarizes the final operations criteria as compared to the March 1, 1996, JSA proposed terms.

The following enables DW to conform with water transfer criteria set forth in the Service's March 6, 1995 CVP/SWP delta smelt biological opinion (see Appendix 3 for water transfer language from March 6 biological opinion):

> DW will not enter into any contractual agreement(s) which would provide for the export of more than 250,000 AF of DW water on a yearly (calendar year) basis. This provides for, but is not limited to, the following types of transfers: a c-user, short-term, opportunistic water transfer; a long-term water transfer; and any other such agreement, or contract for sale or transfer which is consistent with water transfer language in the March 6, 1995, biological opinion on the CVP/SWP (Appendix 3), the SWRCB's 1995 WQCP for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (1995 WQCP), and the improved environmental baseline established under the March 6, 1995, CVP/SWP delta smelt biological opinion (Appendix 1). If such agreement(s) were determined to result in an adverse effect to delta smelt, delta smelt critical habitat or the Sacramento splittail in a manner or to an extent not previously identified, the contractual agreement(s) would be subject to some level of further environmental review.

Diversion Measures. DW shall limit diversions to the four project islands as set forth in the following measures:

1. In the period from September through November, DW shall not undertake its initial diversion to storage for the current water year until X2 is located at or downstream of Chipps Island. For example, if DW's initial diversion to storage has not taken place by November 30, 1997, DW shall not undertake its initial diversion to storage for the current water year until X2 is located at or downstream of Chipps Island for a period of ten (10) consecutive days. After the initial X2 condition is met, diversions shall be limited to a combined maximum rate of 5,500 cfs for five consecutive days. Information documenting achievement of the X2 condition and resultant operational changes shall be submitted to the Service, DFG, and NMFS within 24 hours of implementation of operational changes. [#2, 3, 4]

   The location of X2 shall be defined as the average daily location of a surface water salinity of 2.64 EC, determined by interpolating the average daily surface EC measurements at existing Bay-Delta monitoring stations. Should this traditional X2 methodology be replaced, superseded, or become otherwise unavailable, DW shall follow whatever equivalent practice is developed, subject to approval of the resources agencies and notice to the responsible agencies.

2. In the period from September through March, DW shall not divert water to storage when X2 is located upstream (east) of the Collinsville salinity gauge. When the delta smelt FMWT index is less than 239 (FMWT<239), DW shall not divert water to storage when X2 is located upstream of a point 1.4 kilometers west of the Collinsville salinity gauge. [#5, 6, 7, 19]

3. In the period from October through March, DW shall not divert water to storage if the effect of DW diversions would cause an upstream shift in the X2 location in excess of 2.5 km. The resultant shift in X2 shall be determined by a comparison of the modeled estimates of the X2 location outflow, with and without the DW project, using a mathematical model, *e.g.*, Kimmerer and Monismith equation. [#8, 9]

4. In the period from April through May, DW shall not divert water to storage. If the previous year's delta smelt FMWT index is less than 239 (FMWT<239), DW shall not divert water for storage from February 15 through June 30. [#10, 20]

5. DW diversions to storage shall be limited to the following percentage of available surplus water as derived pursuant to the 1995 WQCP (*e.g.*, export/inflow ratio, outflow). [#13]

Table 1: Surplus Availability

Month	FMWT>239	FMWT<239
October	90%	90%
November	90%	90%
December	90%	90%
January	90%	90%
February 1-14	75%	75%
February 15-28	75%	NA
March	50%	NA
April	NA	NA
May	NA	NA
June	50%	NA
July	75%	75%
August	90%	90%
September	90%	90%

6. DW diversions to storage shall not exceed a percentage of the previous day's net Delta outflow rate (cfs), as set forth in the following table: [#11, 23]

Table 2: Outflow Diversion Limit

Month	Percent Outflow [1]	
	FMWT>239	FMWT<239
October	25%	25%
November	25%	25%
December	25%	25%
January	15%	15%
February 1-14	15%	15%
February 15-28	15%	NA
March	15%	NA
April	NA	NA
May	NA	NA
June	25%	NA
July	25%	25%
August	25%	25%
September	25%	25%

(1) The percent of Delta outflow is calculated without consideration of DW diversions; therefore, the calculation could use the previous day's actual Delta outflow added to the previous day's DW diversions to yield an outflow value that would not include DW operations.

7. In the period from December through March, DW diversions to storage shall not exceed the percentage of the previous day's San Joaquin River inflow rate (cfs) for the maximum number of days, as set forth in the following table: [#12, 24]

Table 3: SJR Diversion Limit

Month	Percent SJR Inflow [1]	
	FMWT > 239	FMWT < 239
Application [2]	15 days	30 days
December	125%	125%
January	125%	100%
February 1 - 14	125%	50%
February 15 - 28	125%	NA
March	50%	NA

(1) The percent of SJR inflow is calculated from the previous day's inflow at Vernalis.

(2) The application of the SJR diversion limit is subject to a specific election on the part of the responsible fishery agencies for a maximum number of days, as specified above. The election to invoke the SJR diversion limit shall be based upon available monitoring data (*e.g.*, project specific monitoring, FMWT data).

8. DW shall implement a monitoring program to minimize or avoid adverse effects of DW diversions to storage, as set forth below: [#15, 16, 21, 22]

   a. DW shall implement a monitoring program in accordance with the attached, "Delta Wetlands Fish Monitoring Program" (Appendix 4).

   b. DW shall provide daily in-channel monitoring (Appendix 4 for description of monitoring) from December through August during all diversions to storage, except as provided below.

   c. DW shall provide daily on-island monitoring (Appendix 4 for description of monitoring) from January through August during all diversions to storage, except as provided below.

   d. Monitoring shall not be required at a diversion station if the total diversion rate at the station is less than 50 cfs and the maximum fish screen approach velocity is less than 0.08 fps (*e.g.*, topping-off).

   e. DW shall reduce the diversions at a diversion station to 50 percent of the previous day's diversion rate during the presence of delta smelt. Should delta smelt be detected on the first day of diversions to storage, the diversion rate shall be immediately reduced to 50 percent of the current day's diversion rate. This reduced diversion rate will remain in place until the monitoring program no longer detects a presence of delta smelt at the diversion station. For the purpose of this mitigation measure, delta smelt presence is defined as a two-day running average in excess of one (1) delta smelt per day at any reservoir diversion station. The definition of presence may be revisited from time to time as new information or monitoring techniques become available.

9. During periods when the Delta Cross Channel (DCC) gates are closed for fisheries protection purposes, between November 1 and January 31, and the inflow into the Delta is less than or equal to 30,000 cfs, DW shall restrict diversions onto the reservoir islands to a combined instantaneous maximum of 3,000 cfs. When the DCC gates are closed for fishery protection purposes and the inflow into the Delta is between 30,000 and 50,000 cfs, DW shall restrict diversions onto the reservoir islands to a combined instantaneous maximum of 4,000 cfs. At Delta inflows greater than 50,000 cfs, DW diversions shall not be restricted by the closure of the DCC for fishery protection purposes. For purposes of this provision, Delta inflow is defined in accordance with the 1995 WQCP. [#17]

10. Nothing in measures 1 through 9 above shall limit DW from diverting water onto Bacon Island and Webb Tract from June through October in order to offset actual reservoir losses of water stored on those islands, hereafter referred to as "topping-off" reservoirs. Daily topping-off diversions shall be subject to the following conditions: [#18, 25]

    a. Topping-off diversions shall not exceed the maximum per island diversion rate (cfs) and maximum monthly quantity (TAF) listed below for both islands:

Table 4: Maximum Topping-Off Diversion Rates

Month	Jun	Jul	Aug	Sep	Oct
Maximum diversion rate (cfs)	215	270	200	100	33
Maximum monthly quantity (TAF)	13	16	12	6	2

    b. Topping-off diversions shall occur through screened diversions with approach velocities less than 0.10 fps.

    c. A mechanism acceptable to the Service, NMFS, and DFG shall be devised and used by DW to document actual reservoir losses.

    d. The maximum topping-off diversion rates shown above shall be further limited by diversions onto the habitat islands. The maximum topping-off diversion rate and quantity shall be reduced by an amount equal to the habitat island diversions during the same period.

Discharge Measures. DW shall limit discharges from the four project islands:

1. In the period from April through June, DW shall limit discharges for export or rediversion from Bacon Island to one-half (50 percent) of the San Joaquin River inflow measured at Vernalis. [#34]

2. In the period from January through June, DW shall not discharge for export or rediversion from Webb Tract. [#33]

3. DW shall not discharge for export or rediversion any water from the habitat islands. [#41]

4. From February through July, DW discharges for export shall be limited to the following percentage of the available unused export capacity at the CVP and SWP facilities as derived pursuant to the 1995 WQCP. [#35, 36]

Table 5: Export Availability

Month	Bacon	Webb
February	75%	NA
March	50%	NA
April	50%	NA
May	50%	NA
June	50%	NA
July	75%	75%

6. DW shall provide a quantity of "environmental water" for release as additional Delta outflow: [#38, 42]

   a. DW shall provide a quantity of environmental water equal to 10 percent of all discharges for export that occur in the period from December through June. If the delta smelt FMWT index is less than 239 (FMWT<239), this environmental water percentage shall be increased to 20 percent of all discharges for export that occur in the period from December through June.

   b. Environmental water shall be released between February and June of the same water year as the discharge for export that generated the water and may not be banked for future use in subsequent water years.

   c. Habitat island discharges may be credited toward the environmental water quantities required above, if:

      i. habitat island discharges occur between February and June;

ii. habitat island discharge credits are limited to the net flow quantity (*e.g.*, habitat discharge minus habitat diversion);

iii. habitat island discharges occur during a period of time when 75 percent of the spacial distribution of the delta smelt population is located downstream of the discharge location, where the determination of spacial distribution is based on the most recent distribution data available (*e.g.*, IEP);

iv. the habitat island discharge rate does not vary on a daily basis more than 1 percent of the average gross flow rate in the adjacent channel, either upstream or downstream, when delta smelt are spawning in the area;

v. DW makes a best effort to minimize fluctuations in daily discharge rates;

vi. and the habitat island discharges are consistent with the HMP.

d. Environmental water, less habitat island discharge credits, shall be discharged at the discretion of the Service. NMFS and DFG to maximize fishery benefits. Coordination of these discharges shall be performed by the DFG Bay-Delta office.

7. DW shall implement a monitoring program to minimize or avoid adverse effects of DW discharges for export, as set forth below: [#39, 40, 43, 44]

a. DW shall implement a monitoring program in accordance with the attached, "Draft Proposed Delta Wetlands Fish Monitoring Program" (Appendix 4).

b. DW shall provide daily in-channel monitoring from April through August during all discharges for export, except as provided below.

c. Monitoring shall not be required if the total discharge for export rate is less than 50 cfs.

d. DW shall reduce the discharge for export rate to 50 percent of the previous day's diversion rate during the presence of delta smelt. Should delta smelt be detected on the first day of discharges for export, the discharge rate shall be immediately reduced to 50 percent. This reduced diversion rate will remain in place until the monitoring program no longer detects a presence of delta smelt at the in-channel sampling sites. For the purpose of this mitigation measure, delta smelt presence is defined as a two-day running average in excess of one (1) delta smelt per day at the Old and Middle River sampling sites. The definition of presence may be revisited from time to time as new information or monitoring techniques become available.

e. DW shall provide for this monitoring either by contributing financial support commensurate with the proportionate share of DW exports to the Bay/Delta monitoring programs, or when no other monitoring is being conducted at appropriate sites, DW shall provide for direct monitoring in river channels as described above.

Other Measures:

1. Fish screen design: [#49]

The DW fish screens will be generally consistent with the design presented in the DEIR/EIS except that DW shall not exceed a maximum of 0.2 fps approach velocity for diversions. Final design elements and installation guidelines will be subject to approval by the regulatory agencies including the Service, Corps, DFG, SWRCB, and NMFS. Final design, including a monitoring program to evaluate performance criteria will be submitted for approval at least 90 days prior to commencing operations.

2. Rearing and Spawning Habitat. [#50, 51]

Prior to construction, DW will secure a perpetual conservation easement (easement) for 200 acres of shallow-water aquatic habitat not currently protected by easement or covenant. The easement shall fully protect in perpetuity the shallow-water aquatic habitat. A management plan for the easement area shall be developed for the habitat covered by the easement, and shall be incorporated as an exhibit to the easement.

The easement (along with a title report for the easement area) and management plan shall be approved by the Service prior to recordation. After approval, the easement and management plan shall be recorded in the appropriate County Recorders Office(s). A true copy of the recorded easement shall be provided to the Service within 30 days after recordation.

Additionally, DW shall provide to the Service documentation that there is adequate financing for the perpetual management of the habitat protected by the conservation easement consistent with the terms of this biological opinion and the management plan including that (1) adequate funds for the management of habitat in perpetuity protected by the conservation easement have been transferred to an appropriate third-party, (2) the third party has accepted the funds, and (3) such funds have been deposited in an interest-bearing account intended for the sole purpose of carrying out the purposes of this easement.

3. Boat Wake Erosion [#53]

DWC shall contribute $100 per year to DFG for each net additional berth beyond conditions existing at the time of issuance of this biological opinion added to any of the four project islands. These funds shall be in January 1996 dollars and shall be adjusted annually for inflation.

4. Aquatic Habitat [#54]

The actual effect to aquatic habitat acreage for construction and operation of siphon and pumping facilities and waterside boat docks shall be surveyed prior to construction and submitted to the Service, NMFS, the Corps, DFG, and the SWRCB, and mitigation shall take place on a 3:1 basis after approval by the Service, NMFS, the Corps, DFG, and the SWRCB.

5. Temperature Limits [#55]

DW shall implement a temperature program to minimize or avoid adverse effects of DW discharges for export (see Appendix 4 for details of program):

a. DW shall not discharge reservoir water for export if the temperature differential between the discharge and the adjacent channel temperature is greater than or equal to 7^0 C.

b. If the natural receiving water temperature of the adjacent channel is greater than or equal to 13^0 C and less than 19^0 C, DW discharges for export shall not increase channel temperature by more than 3^0 C.

c. If the natural receiving water temperature of the adjacent channel is greater than or equal to 19^0 C and less than 25^0 C, DW discharges for export shall not cause an increase of more than 1^0 C.

d. If the natural receiving water temperature of the adjacent channel is greater than or equal to 25^0 C, DW discharges for export shall not cause an increase of more than 0.5^0 C.

e. DW shall develop temperature monitoring and implementation plans to ensure that the project does not adversely affect channel temperature levels as described above. The monitoring plan shall include reservoir and channel temperature monitoring. The monitoring and implementation plans shall be completed after the project is permitted, but at least 90 days prior to start of project operations. The plans shall be submitted to the responsible agencies for approval with the concurrence of the resource agencies.

6. DO Limits [#56]

DW shall implement a dissolved oxygen (DO) program to minimize or avoid adverse effects of DW discharges for export (see Appendix 4 for details of program):

a. DW shall not discharge reservoir water for export if the discharge DO level is less than 6.0 mg/l without authorization from the resource agencies and notice to the responsible agencies.

b. DW shall not discharge reservoir water for export if the discharge would cause channel water DO levels to fall below 5.0 mg/l.

c. DW shall develop DO monitoring and implementation plans to ensure that the project does not adversely affect the channel DO levels as described above. The monitoring plan shall include reservoir and channel DO monitoring. The monitoring and implementation plans shall be completed after the project is permitted, but at least 90 days prior to project operations. The plans shall be submitted to the Service, NMFS, the Corps, DFG, and SWRCB for approval.

7. Incidental Entrainment Compensation Provided to DFG [#57]

Certain life stages of key fish species may not be effectively screened during periods of diversions for storage. DW will, therefore, sample DW diversions during the periods specified below and compensate for losses to selected target fish. DW diversions onto the reservoir islands will be sampled for egg, larval, and juvenile life stages of the selected target fish. Those losses will be mitigated using a formula which ties measured losses with mitigation as specified below.

This provision covers entrainment of non-listed species, as well as, delta smelt and splittail (that are, respectively, listed and proposed species).

Should on-island monitoring detect the presence of eggs, larvae, and juveniles during the months specified in the incidental entrainment monitoring guidelines, DW shall provide monetary compensation to DFG for incidental entrainment, as set forth in the following tables:

Table 6: Incidental Entrainment Monitoring Guidelines

Species and Life Stages	Jan	Feb	Mar	Jun	Jul	Aug
Striped Bass						
larvae and juveniles				X	X	X
American Shad						
larvae and juveniles				X	X	X
Delta Smelt						
larvae	X	X	X	X	X	
juveniles		X	X	X	X	X
Splittail						
larvae	X	X	X	X	X	X
juveniles		X	X	X	X	X
Longfin Smelt						
eggs and larvae	X	X	X			
juveniles	X	X	X	X	X	X

Table 7: Incidental Entrainment Compensation Provided to DFG

Measured Density	Mitigation/TAF
10-999 eggs, larvae, and juveniles/AF	$500
1,000-5,000 eggs, larvae, and juveniles/AF	$750
>5,000 eggs, larvae, and juveniles/AF	$1,000

Should DW be unable to perform on-island monitoring, the maximum mitigation compensation will be assumed, unless waived or modified by the responsible agencies, with concurrence of the resource agencies. Funds are in January 1996 dollars and shall be adjusted annually for inflation. Monetary reimbursement shall be deposited into a mitigation fund on a semiannual basis. The use of the mitigation funds shall be at the discretion of the state agencies but shall be used to plan and implement actions that improve habitat for the target species in the Estuary.

8. Construction Period [#60]

All construction activities taking place in the tidal waters of the adjacent channels or affecting a tidal water habitat shall occur between June 1 and November 1.

Status of the Species

<u>Delta smelt</u>

The delta smelt was federally listed as a threatened species on March 5, 1993, (58 **FR** 42:12854-12864). Please refer to Service (1993, 1994a, 1994c) and DWR and Reclamation (1994) for additional information on the biology and ecology of the delta smelt. The delta smelt is a slender-bodied fish with a steely blue sheen on the sides and seems almost translucent (Moyle 1976). The delta smelt, which has a lifespan of one year, has an average length of 60 to 70 mm (about 2 to 3 inches) and is endemic to Suisun Bay upstream of San Francisco Bay through the Delta in Contra Costa, Sacramento, San Joaquin, and Solano counties, California. Historically, the delta smelt is thought to have occurred from Suisun Bay upstream to at least the city of Sacramento on the Sacramento River and Mossdale on the San Joaquin River (Moyle *et al*. 1992, Sweetnam and Stevens 1993). The delta smelt is an euryhaline species (tolerant of a wide salinity range) that spawns in fresh water and has been collected from estuarine waters up to 14 parts per thousand (ppt) salinity (Moyle *et al*. 1992). For a large part of its annual life span, this species is associated with the freshwater edge of the mixing zone (saltwater-freshwater interface and also called X2), where the salinity is approximately 2 ppt (Ganssle 1966, Moyle *et al*. 1992, Sweetnam and Stevens 1993).

The delta smelt is adapted to living in the highly productive Estuary where salinity varies spatially and temporally according to tidal cycles and the amount of freshwater inflow. Despite this tremendously variable environment, the historical Estuary probably offered relatively constant suitable habitat conditions for delta smelt, because they could move upstream or downstream with the mixing zone (Moyle, pers. comm., 1993). The final rule to list the delta smelt as threatened describes in detail the factors that have contributed to this species' decline (Service 1993).

Shortly before spawning, adult delta smelt migrate upstream from the brackish-water habitat associated with the mixing zone to disperse widely into river channels and tidally-influenced backwater sloughs (Radtke 1966, Moyle 1976, Wang 1991). Migrating adults with nearly mature eggs were taken at the CVP's Tracy Pumping Plant from late December 1990 to April 1991 (Wang 1991). Spawning locations appear to vary widely from year to year (DWR and Reclamation 1993). Sampling of larval delta smelt in the Delta suggests spawning has occurred in the Sacramento River, Barker, Lindsey, Cache, Georgiana, Prospect, Beaver, Hog, and Sycamore sloughs, in the San Joaquin River off Bradford Island including Fisherman's Cut, False River along the shore zone between Frank's and Webb tracts, and possibly other areas (Dale Sweetnam, DFG, pers. comm., Wang 1991). Delta smelt also may spawn north of Suisun Bay in Montezuma and Suisun sloughs and their tributaries (Meng, Service, pers. comm., Sweetnam, DFG, pers. comm.).

Delta smelt spawn in shallow, fresh, or slightly brackish water upstream of the mixing zone (Wang 1991). Most spawning occurs in tidally-influenced backwater sloughs and channel edgewaters (Moyle 1976, Wang 1986, 1991, Moyle *et al.* 1992). Although delta smelt spawning behavior has not been observed in the wild (Moyle *et al.* 1992), the adhesive, demersal eggs are thought to attach to substrates such as cattails, tules, tree roots, and submerged branches (Moyle 1976, Wang 1991).

The spawning season varies from year to year and may occur from late winter (December) to early summer (July). Moyle (1976) collected gravid adults from December to April, although ripe delta smelt were most common in February and March. In 1989 and 1990, Wang (1991) estimated that spawning had taken place from mid-February to late June or early July, with peak spawning occurring in late April and early May. A recent study of delta smelt eggs and larvae (Wang and Brown 1994 as cited in DWR and Reclamation 1994) confirmed that spawning may occur from February through June, with a peak in April and May. Spawning has been reported to occur at about 7° to 15° C. Results from a University of California at Davis (UCD) study (Cech and Swanson 1995) indicate that although delta smelt tolerate a wide range of temperatures (<8° C to >25° C), warmer water temperatures restrict their distribution more than colder water temperatures.

Laboratory observations indicate that delta smelt are broadcast spawners that spawn in a current, usually at night, distributing their eggs over a local area (Lindberg 1992 and Mager 1993 as cited in DWR and Reclamation 1994). The eggs form an adhesive foot that appears to stick to most surfaces. Eggs attach singly to the substrate, and few eggs were found on vertical plants or the sides of a culture tank (Lindberg 1993 as cited in DWR and Reclamation 1994).

Delta smelt eggs hatched in 9 to 14 days at temperatures from 13° to 16° C during laboratory observations in 1992 (Mager 1992 as cited in Sweetnam and Stevens 1993). In this study, larvae began feeding on phytoplankton on day four, rotifers on day six, and *Artemia* nauplii at day 14. In laboratory studies, yolk-sac fry were found to be positively phototaxic, swimming to the lightest corner of the incubator, and negatively buoyant, actively swimming to the surface. The post-yolk-sac fry were more evenly distributed throughout the water column (Lindberg 1992 as cited in DWR and Reclamation 1994). After hatching, larvae and juveniles move downstream toward the mixing zone where they are retained by the vertical circulation of fresh and salt waters (Stevens *et al.* 1990). The pelagic larvae and juveniles feed on zooplankton. When the mixing zone is located in Suisun Bay where there is extensive shallow-water habitat within the euphotic zone (depths less than four meters), high densities of phytoplankton and zooplankton may accumulate (Arthur and Ball 1978, 1979, 1980). In general, estuaries are among the most productive ecosystems in the world (Goldman and Horne 1993). Estuarine environments produce an abundance of fish as a result of plentiful food and shallow, productive habitat.

Delta smelt swimming behavior. Observations of delta smelt swimming in the swimming flume and in a large tank show that these fish are unsteady, intermittent, slow-speed swimmers (Swanson and Cech 1995). At low velocities in the swimming flume (<3 body lengths per second), and during spontaneous, unrestricted swimming in a 1-meter tank, delta smelt consistently swam with a "stroke and glide" behavior. This type of swimming is very efficient; Weihs (1974) predicted energy savings of about 50 percent for "stroke and glide" swimming compared to steady swimming. However, the maximum speed delta smelt are able to achieve using this preferred mode of swimming, or gait, was less than three body lengths per second, and the fish did not readily or spontaneously swim at this or higher speeds (Swanson and Cech 1995). Juvenile delta smelt proved stronger swimmers than adults. Forced swimming at these speeds in a swimming flume was apparently stressful; the fish were prone to swimming failure and extremely vulnerable to impingement. Unlike fish for which these types of measurements have been made in the past, delta smelt swimming performance was limited by behavioral rather than physiological or metabolic constraints (*e.g.*, metabolic scope for activity; Brett 1976).

<u>Delta Smelt Critical Habitat</u>

Please refer to Service (1994c) for additional information on delta smelt critical habitat. In determining which areas to designate as critical habitat, the Service considers those physical and biological features that are essential to a species' conservation and that may require special management considerations or protection (50 CFR §424.12(b)).

The Service is required to list the known primary constituent elements together with the critical habitat description. Such physical and biological features include, but are not limited to, the following:

1. space for individual and population growth, and for normal behavior;

2. food, water, air, light, minerals, or other nutritional or physiological requirements;

3. cover or shelter;

4. sites for breeding, reproduction, rearing of offspring, germination, or seed dispersal; and

5. generally, habitats that are protected from disturbance or are representative of the historic geographical and ecological distributions of a species.

In designating critical habitat, the Service identified the following primary constituent elements essential to the conservation of the delta smelt: physical habitat, water, river flow, and salinity concentrations required to maintain delta smelt habitat for spawning, larval and juvenile transport, rearing, and adult migration. Critical habitat for delta smelt is contained within Contra Costa, Sacramento, San Joaquin, Solano, and Yolo counties (Figure 3b).

Spawning habitat. Specific areas that have been identified as important delta smelt spawning habitat include Barker, Lindsey, Cache, Prospect, Georgiana, Beaver, Hog, and Sycamore sloughs and the Sacramento River in the Delta, and tributaries of northern Suisun Bay (Figure 3b).

Larval and juvenile transport. Adequate river flow is necessary to transport larvae from upstream spawning areas to rearing habitat in Suisun Bay and to ensure that rearing habitat is maintained in Suisun Bay (Figure 3a). To ensure this, X2 must be located westward of the confluence of the Sacramento-San Joaquin Rivers, located near Collinsville (Confluence), during the period when larvae or juveniles are being transported, according to historical salinity conditions (Figure 3c). X2 is important because the "entrapment zone" or zone where particles, nutrients, and plankton are "trapped," leading to an area of high productivity, is associated with its location. Habitat conditions suitable for transport of larvae and juveniles may be needed by the species as early as February 1 and as late as August 31, because the spawning season varies from year to year and may start as early as December and extend until July.

Rearing habitat. An area extending eastward from Carquinez Straits, including Suisun, Grizzly, and Honker bays, Montezuma Slough and its tributary sloughs, up the Sacramento River to its confluence with Three Mile Slough, and south along the San Joaquin River including Big Break, defines the specific geographic area critical to the maintenance of suitable rearing habitat (Figure 3b). Three Mile Slough represents the approximate location of the most upstream extent of historical tidal incursion. Rearing habitat is vulnerable to impacts from the beginning of February to the end of August.

Adult migration. Adequate flow and suitable water quality are needed to attract migrating adults in the Sacramento and San Joaquin river channels and their associated tributaries, including Cache and Montezuma sloughs and their tributaries (Figure 3b). These areas are vulnerable to physical disturbance and flow disruption during migratory periods.

The Service's 1994 and 1995 biological opinions provided for larval and juvenile transport flows, rearing habitat, and protection from entrainment for upstream migrating adults (Service 1994b, 1995).

Sacramento Splittail

Please refer to Service (1994a, 1994d, 1995) and DWR and Reclamation (1994) for additional information on the biology and ecology of the Sacramento splittail. The Sacramento splittail is a large cyprinid that can reach greater than 12 inches in length (Moyle 1976). Adults are characterized by an elongated body, distinct nuchal hump, and a small blunt head with barbels usually present at the corners of the slightly subterminal mouth. This species can be distinguished from other minnows in the Central Valley of California by the enlarged dorsal lobe of the caudal fin. Sacramento splittail are a dull, silvery-gold on the sides and olive-grey dorsally. During the spawning season, the pectoral, pelvic and caudal fins are tinged with an orange-red color. Males develop small white nuptial tubercles on the head.

Sacramento splittail are endemic to California's Central Valley where they were once widely distributed in lakes and rivers (Moyle 1976). Historically, Sacramento splittail were found as far north as Redding on the Sacramento River and as far south as the site of Friant Dam on the San Joaquin River (Rutter 1908). Rutter (1908) also found Sacramento splittail as far upstream as the current Oroville Dam site on the Feather River and Folsom Dam site on the American River. Anglers in Sacramento reported catches of 50 or more Sacramento splittail per day prior to damming of these rivers (Caywood 1974). Sacramento splittail were common in San Pablo Bay and Carquinez Strait following high winter flows up until about 1985 (Messersmith 1966, Moyle 1976, and Wang 1986 as cited in DWR and Reclamation 1994).

In recent times, dams and diversions have increasingly prevented upstream access to large rivers and the species is restricted to a small portion of its former range (Moyle and Yoshiyama 1989). Sacramento splittail enter the lower reaches of the Feather (Jones and Stokes 1993) and American rivers (Charles Hanson, State Water Contractors, *in litt.*, 1993) on occasion, but the species is now largely confined to the Delta, Suisun Bay, and Suisun Marsh (Service 1994a). Stream surveys in the San Joaquin Valley reported observations of Sacramento splittail in the San Joaquin River below the mouth of the Merced River and upstream of the confluence of the Tuolumne River (Saiki 1984 as cited in DWR and Reclamation 1994).

Sacramento splittail are long-lived, frequently reaching five to seven years of age. Generally, females are highly fecund, producing more than 100,000 eggs each year (Daniels and Moyle 1983). Populations fluctuate annually depending on spawning success. Spawning success is highly correlated with freshwater outflow and the availability of shallow-water habitat with submersed, aquatic vegetation (Daniels and Moyle 1983). Sacramento splittail usually reach sexual maturity by the end of their second year at a size of 180 to 200 mm. There is some variability in the reproductive period since older fish reproduce before younger individuals (Caywood 1974). The largest recorded Sacramento splittail have measured between 380 and 400 mm (Caywood 1974, Daniels and Moyle 1983). Adults migrate into fresh water in late fall and early winter prior to spawning. The onset of spawning is associated with rising temperature, lengthening photoperiod, seasonal runoff, and possibly endogenous factors from the months of March through May, although there are records of spawning from late January to early July (Wang 1986). Spawning occurs in water temperatures from 9° to 20° C over flooded vegetation in tidal freshwater and euryhaline habitats of estuarine marshes and sloughs and slow-moving reaches of large rivers. The eggs are adhesive or become adhesive soon after contacting water (Caywood 1974, and Bailey, University of California at Davis, pers. comm. 1994 as cited in DWR and Reclamation 1994). Larvae remain in shallow, weedy areas close to spawning sites and move into deeper water as they mature (Wang 1986).

Sacramento splittail are benthic foragers that feed on opossum shrimp, although detrital material makes up a large percentage of their stomach contents (Daniels and Moyle 1983). Earthworms, clams, insect larvae, and other invertebrates are also found in the diet. Predators include striped bass and other piscivores. Sacramento splittail are sometimes used as bait for striped bass.

Sacramento splittail can tolerate salinities as high as 10 to 18 ppt (Moyle 1976, Moyle and Yoshiyama 1992). Sacramento splittail are found throughout the Delta (Turner 1966), Suisun Bay, and Suisun and Napa marshes. They migrate upstream from brackish areas to spawn in freshwater. Because they require flooded vegetation for spawning and rearing, Sacramento splittail are frequently found in areas subject to flooding.

The 1985 to 1992 decline in Sacramento splittail abundance (Figure 4b) is concurrent with hydrologic changes to the Estuary. These changes include increases in water diversions during the spawning period from January through July. Diversions, dams and reduced outflow, coupled with severe drought years, introduced aquatic species, and loss of wetlands and shallow-water habitat (DFG 1992) have reduced the species' capacity to reverse its decline.

Environmental Baseline

<u>Delta smelt</u>

Adult delta smelt spawn in central Delta sloughs from February through August in shallow water areas having submersed aquatic plants and other suitable substrates and refugia. These shallow water areas have been identified in the draft Delta Native Fishes Recovery Plan (Service 1994d) as essential to the long-term survival and recovery of delta smelt and other resident fish. A no net loss strategy is proposed in this Recovery Plan.

The delta smelt is adapted to living in the highly productive Estuary where salinity varies spatially and temporally according to tidal cycles and the amount of freshwater inflow. Despite this tremendously variable environment, the historical Estuary probably offered relatively consistent spring transport flows that moved delta smelt juveniles and larvae downstream to the mixing zone (Peter Moyle, UCD, pers. comm.). Since the 1850's, however, the amount and extent of suitable habitat for the delta smelt have declined dramatically. The advent in 1853 of hydraulic mining in the Sacramento and San Joaquin rivers led to increased siltation and alteration of the circulation patterns of the Estuary (Nichols *et al.* 1986, Monroe and Kelly 1992). The reclamation of Merritt Island for agricultural purposes, in the same year, marked the beginning of the present-day cumulative loss of 94 percent of the Estuary's tidal marshes (Nichols *et al.* 1986, Monroe and Kelly 1992).

In addition to the degradation and loss of estuarine habitat, the delta smelt has been increasingly subject to entrainment, upstream or reverse flows of waters in the Delta and San Joaquin River, and constriction of low salinity habitat to deep-water river channels of the interior Delta (Moyle *et al.* 1992). These adverse conditions are primarily a result of drought and the steadily increasing proportion of river flow being diverted from the Delta by the CVP and SWP (Monroe and Kelly 1992). Figure 4a shows the relationship between the portion of the delta smelt population west of the Delta as sampled in the summer townet survey and the natural logarithm of Delta outflow from 1959 to 1988 (DWR and Reclamation 1994). This relationship indicates that the summer townet index increased dramatically when outflow was between 34,000 and 48,000 cfs placing X2 between Chipps and Roe islands. Placement of X2 at Chipps and Roe islands would duplicate these favorable conditions.

Hydrodynamics in channels adjacent to DW's islands depend largely on overall Delta hydrodynamics. Channels bordering Bacon Island and Holland Tract function primarily as transport channels moving water toward the export pumps. Net flow in these channels generally moves upstream toward the CVP and SWP pumps and the Contra Costa Water District intake. Sand Mound Slough along the west side of Holland Tract is blocked by a tide gate at the Rock Slough confluence. This tide gate permits flow only to the north during ebb tides, to prevent water and salt movement into Rock Slough. Existing irrigation diversions and agricultural drainage discharges probably have minor effects on adjacent channel hydrodynamics.

Webb Tract is bordered by the San Joaquin River on the north and east, Fishermans Cut on the west, and False River on the southwest. Franks Tract, a flooded island area, is south of Webb Tract. Net flow near Webb Tract is usually westerly, except during periods of low Delta inflow and high export volumes, when net flow reverses and water is transported into Old River and toward the CVP and SWP pumps.

Bouldin Island is bordered by the Mokelumne River on the north and west, Little Potato Slough on the east, and Potato Slough on the south. Net flow around Bouldin Island is nearly always toward the San Joaquin River. Reverse flows, during periods of low Delta inflow and high export volumes, occur in an easterly direction in Potato Slough along the southern edge of the island.

The results of seven surveys (Figure 5a) currently done by the IEP corroborate the dramatic decline in delta smelt attributable to baseline conditions. Existing baseline conditions provide sufficient Delta outflows from February 1 through June 30 to transport larval and juvenile delta smelt out of the "zone of influence" of the pumps, and provide them low salinity, productive rearing habitat (Figures 3a,3b). This zone of influence has been delineated by DWR's Particle Tracking Model and expands or contracts with CVP and SWP combined pumping increases or decreases (DWR and Reclamation 1993). With the effects of tidal movement contributing additional movement, the influence of the pumps may entrain larvae and juveniles as far west as the Confluence. Placement of X2 downstream of the Confluence, Chipps and Roe islands provides delta smelt with protection from entrainment and low salinity, allowing for productive rearing habitat that increases both smelt abundance and distribution.

The seven abundance indices used to record trends in the status of the delta smelt showed that this species was consistently at low population levels in the last ten years (Stevens *et al.* 1990) (Figure 5a). These same indices also show a pronounced decline from historical levels of abundance (Stevens *et al.* 1990). The summer townet abundance index is thought to be one of the more representative indices because data have been collected over a wide geographic area (from San Pablo Bay upstream through most of the Delta) for the longest period of time (since 1959). Figure 6a shows the distribution of summer townet sampling sites. The summer townet abundance index measures the abundance and distribution of juvenile delta smelt and provides data on the recruitment potential of the species. Except for three years since 1983 (1986, 1993, and 1994), this index has remained at consistently lower levels than experienced previously (Figure 6b). As indicated in Figure 3c, these consistently lower levels correlate with the 1983 to 1992 mean location of X2 upstream of the Confluence, Chipps and Roe islands.

The second longest running survey (since 1967), the FMWT, measures the abundance and distribution of late juveniles and adult delta smelt in a large geographic area from San Pablo Bay upstream to Rio Vista on the Sacramento River and Stockton on the San Joaquin River (Figure 7a)(Stevens *et al.* 1990). The FMWT provides an indication of the abundance of the adult population just prior to upstream spawning migration. The index that is calculated from the FMWT uses numbers of sampled fish multiplied by a factor related to the volume of the area sampled. Figure 7b shows that until recently, except for 1991, this index has declined irregularly over the past 20 years. Since 1983, the delta smelt population has exhibited more low FMWT abundance indices, for more consecutive years, than previously recorded. The 1994 FMWT index of 101.7 is a continuation of this trend (Figure 7b). This occurred despite the high 1994 summer townet index of 13.0. The 1995 summer townet was a low index value of 3.2 but resulted in a high FMWT index of 898.7 reflecting the benefits of large transport and habitat maintenance flows with the March 6 biological opinion in place and a wet year. The 1996 summer townet was 11.1 and resulted in a low FMWT index of 128. Historically, wet years have resulted in low FMWT indices due to dispersal of delta smelt west of Carquinez Strait where suitable rearing habitat is unavailable. In 1995, another wet year, delta smelt were sampled in the Napa River drainage early in the season but disappeared in later surveys. This may have been due to the lack of suitable habitat in the Napa river to allow for juvenile or adult survival.

Delta Smelt Critical Habitat

Delta smelt critical habitat has been affected by activities that destroy spawning and refugial areas. Critical habitat has also been affected by diversions that have shifted the position of X2 upstream. This shift has caused a decreased abundance of delta smelt (Figure 7b). Existing baseline conditions and implementation of the Service's 1994 and 1995 biological opinions provide a substantial part of the necessary positive riverine flows and estuarine outflows to transport delta smelt larvae downstream to suitable rearing habitat in Suisun Bay outside the influence of marinas, agricultural diversions, and Federal and State pumping plants.

Sacramento Splittail

Figure 4b shows the decline of the Sacramento splittail over the past 10 years using FMWT data. Figure 5b shows this decline using eight surveys done by IEP. This decline is due to hydrologic changes in the Estuary and loss of shallow water habitat due to dredging and filling. These changes include increases in water diversions during the spawning period of January through July. Most of the factors that caused delta smelt to decline have also caused the decline of this species. Diversions, dams and reduced outflow, coupled with severe drought years, introduced aquatic species such as the Asiatic clam (Nichols *et al.* 1990), and loss of wetlands and shallow-water habitat (DFG 1992) appear to have perpetuated the species' decline.

Effects of the proposed action

Effects of the proposed action will be similar for delta smelt, delta smelt critical habitat, and Sacramento splittail.

Relationship of DW operations to the CVP and SWP. The March 6, 1995, delta smelt biological opinion on the CVP and SWP established a monthly incidental take limit for the operation of the pumping plants including measurable direct losses at the pumps and immeasurable indirect losses such as hydrological changes and predation. Using a 20-year delta smelt CVP and SWP fish facility salvage data base, a high range was calculated and subsequently used in the biological opinion with the intent that operations not be controlled through take exceedance and biological opinion reinitiation and with the understanding that beneficial actions implemented through the March 6 delta smelt biological opinion would reverse the decline of listed species.

Any export of water above the new CVP and SWP project baseline resulting from new projects would result in: (1) a decrease in the beneficial effects of actions implemented through the March 6 delta smelt biological opinion; (2) an increase in direct and indirect losses of delta smelt and thus a higher probability that the take limit would control operations of the CVP and SWP pumping plants. Decreases in the beneficial effects of the March 6 delta smelt biological opinion would necessitate a re-analysis of all CVP and SWP project effects with a resulting re-analysis of the use of the high range for take number.

One of the actions included in the analysis of the CVP and SWP in the March 6 delta smelt biological opinion was water transfers. Historical transfers modeled and analyzed for effects consisted of short-term, opportunistic, c-user water transfers such as Stockton-East where the CVP and SWP pumps would be used if capacity existed. The Service's intent was to facilitate these types of transfers. Some water transfers could have a beneficial effect to fish if managed effectively by providing fish with transport flows toward rearing habitat in Suisun Bay.

DW relies almost exclusively on CVP and SWP pumping to convey discharged water. Hence, DW is interdependent and interrelated to the operation of the

CVP and SWP. Due to this linkage between projects, effects of the conveyance of Delta Wetlands water by the CVP and SWP must be considered. The Corps has an agreement on the operation of the CVP and SWP that limits pumping to historic levels with the addition of the four new pumps at Banks pumping plant. A method must be derived by which conveyance of DW water is included within the context of the water transfer section of the March 6, 1995, delta smelt biological opinion to allow DW water conveyance by the CVP and SWP.

Relationship of DW operations to the Environmental Baseline Established by the March 6 Delta Smelt Biological Opinion. DW operations would not have a substantial adverse effect on the environmental baseline established by the March 6 delta smelt biological opinion. This is due to the final operations criteria in Appendix 2 that mitigate effects on export/inflow ratios, position of X2, and larval transport flows. In the March 6 delta smelt biological opinion, CVP/SWP export/inflow ratios were calculated based on historic Delta inflows from upstream rivers and tributaries including (1) Sacramento, (2) San Joaquin, (3) Mokelumne, (4) Consumnes, (5) Stanislaus, (6) Merced, (7) Tuolumne, and (8) Feather rivers. They were developed to replace and lead to, at a minimum, equivalency with previously existing criteria, including QWEST.

The biological benefits from these inflows include (1) transport and behavioral cues for eggs, larvae, juveniles, and smolts, (2) water quality maintenance, and (3) dilution of heavy metals and other contaminants. These biological benefits have a seasonal component with various species of fish that have adapted to use higher winter flows to move downstream for rearing or upstream for spawning. Therefore, the seasonal components were used to devise export/inflow ratios that attempted to balance biological benefits with water user demand. The end result did not achieve a perfect balance but the flexibility of the biological opinion allowed for changes in real-time operation of the water projects. The CVPIA 800 TAF is targeted at providing additional fish benefits. This water must not be diverted or subjected to adverse hydrological changes so that fish benefits are realized.

DW discharges were not part of the historical inflows modeled to produce the export/inflow ratios. Additionally, DW discharges do not have benefits similar to inflows produced by the previously mentioned rivers because of their central Delta location. Therefore, DW discharges are not counted as part of the export/inflow ratios for the purpose of this opinion.

Further, criteria developed for the March 6, 1995, delta smelt biological opinion (Service 1995) were based on historical: (1) operation of the CVP and SWP, (2) water transfers, (3) salvage numbers, and (4) fish surveys. Removal of the jeopardy environmental baseline in the Delta occurred through implementation of these March 6 delta smelt biological opinion criteria. New projects proposed subsequently to the March 6 delta smelt biological opinion that incrementally lower the Delta environmental baseline back toward the jeopardy threshold will need additional rigorous criteria to avoid and minimize adverse project effects. Finalized operational criteria contained in Appendix 2 accomplish this for DW.

Delta smelt

The proposed DW operations and associated construction activities and recreational facilities will have immediate effects related to in-water work, including pile-driving, shading of aquatic habitat, soil excavation, rip-rapping and construction of intakes and out takes. These activities will affect delta smelt through direct destruction of spawning and refugial habitat. Aquatic plants may need 2-3 years to recolonize affected areas. Mobilized sediments may contain contaminants and may affect upstream migrating adult spawners. These sediments may also affect delta smelt eggs and larvae. The extent of the effected area is difficult to quantify but may involve up to 50.0 acres. This will be mitigated through securing of an easement on 200-acres of shallow water habitat managed in perpetuity.

DW's project includes operation of reservoir and habitat islands with recreational activities that will have long-term effects related to (1) island filling resulting in entrainment and impingement and changes to Delta hydrology, (2) discharges from islands resulting in changes in Delta hydrology and erosion, and (3) recreational boating resulting in bank erosion and water contamination from spilled fuel and oil. Finalized operational criteria contained in Appendix 2 will remove the effects of these operations.

The following is a summary of the DW project effects remaining with implementation of final operational criteria contained in Appendix 2 (these effects will be mitigated through securing of an easement on shallow water habitat, operational changes, and entrainment compensation):

1. DW project will directly entrain delta smelt larvae;

2. DW project construction will degrade delta smelt spawning and rearing habitat;

3. DW project will increase predation losses due to fish screen structures, siphon and pump stations, and boat docks (this is due to the turbulence caused by structures that disorients fish making them susceptible to predation).

Diversions. Water will be diverted for storage on Bacon Island and Webb Tract with smaller amounts diverted on Bouldin Island and Holland Tract to enable habitat management. Maximum storage will be about 154 TAF and will increase over the life of the project. Water will be diverted to the reservoir islands at a maximum average monthly diversion rate of 4,000 cfs and will take about a month to fill the islands. Maximum initial diversion rate will be 9,000 cfs for several days.

Discharges. Discharges from DW reservoir islands will be exported by the CVP and SWP when unused capacity within the permitted pumping rate exists at the CVP and SWP pumps and if a method is devised for dealing with increased fish loss (*i.e.*, "take") not covered by existing permits. Reclamation and DWR will ultimately be responsible for developing a plan that allows export of DW water. On finalization of a plan to export DW water at the CVP and SWP, new modeling should be done to determine the effects. Modeled changes to operations and resulting effects should include, but are not limited to:

(1) changes to scheduled deliveries, (2) changes to diversions at Rock Slough, (3) changes to diversions at Barker Slough, and (4) changes to operation of all other CVP and SWP facilities effecting position of X2, through Delta transport flows, and Delta hydrology resulting from conveyance of DW water.

Hydrodynamics. Net Delta outflow will be reduced by DW diversions. When reservoir islands are filling, X2 will be shifted upstream in Suisun Bay. This decreases the amount of shallow water habitat available for rearing and the productivity of the entrapment zone. Additionally, flow direction around the reservoir islands will be changed that affect upstream migrating spawning adults and downstream moving larvae and juveniles. This reduction in outflow with resulting upstream shift to X2 and localized changes in flow direction will be mitigated for by measures included in Appendix 2.

<u>Sacramento Splittail</u>

DW project effects for Sacramento splittail are similar to effects for delta smelt. Sacramento splittail spawn in the central Delta and are transported by flows to rearing habitat associated with X2 in Suisun Bay. Sacramento splittail spawn on newly flooded vegetation. Flooding of these shallow areas is dependent on adequate flows that overflow areas of low elevation. Based on available information, reduced outflow attributable to DW project operations will not have a significant effect on Sacramento splittail spawning habitat due to operational constraints in Appendix 2. Entrainment of Sacramento splittail larvae and early juveniles will occur if DW project intakes are located in areas that support spawning and rearing and will affect local production but compensation will be provided. Presence of adults and juveniles near DW project diversions may coincide with the timing of diversions. Although juvenile and adult Sacramento splittail may be effectively screened, larval fish may be entrained or impinged. Construction of DW project facilities could affect localized Sacramento splittail habitat, and DW project diversions could increase entrainment. Sacramento splittail spawning and rearing habitat will be affected near proposed DW project intakes, discharge pumps, and boat docks. Mitigative measures included in Appendix 2 will minimize or, in critical months, avoid these effects.

<u>Delta Smelt Critical Habitat</u>

Construction of DW facilities will not adversely modify or destroy delta smelt critical habitat by affecting the constituent elements listed previously because of the modified operational criteria contained in Appendix 2. Spawning habitat affected by construction of DW project facilities including intake structures, levees, and boat docks will be fully compensated for through an easement on 200-acres of shallow-water habitat managed for perpetuity. Larval and juvenile transport to suitable rearing habitat has been identified as a constituent element of critical habitat. Decreases by DW diversions will be mitigated through operational constraints in Appendix 2. Rearing habitat will not be adversely modified due to diversions that change the location of X2. These effects will be reduced or avoided by implementation of finalized operational criteria contained in Appendix 2.

Cumulative effects

Cumulative effects include the effects of future State, local, or private actions affecting listed species and their critical habitat that are reasonably certain to occur in the area considered in this biological opinion. Future Federal actions not related to this proposed action are not considered in determining the cumulative effects, but are subject to separate consultation requirements pursuant to section 7 of the Act.

Cumulative effects on the delta smelt or its proposed critical habitat also include any continuing or future non-federal diversions of water that may entrain adult or larval fish or that may decrease outflows incrementally, thus shifting upstream the position of the delta smelt's preferred habitat. Water diversions through intakes serving numerous small, private agricultural lands and duck clubs in the Delta, upstream of the Delta, and in Suisun Bay contribute to these cumulative effects. These diversions also include municipal and industrial uses, and provide water for power plants. State or local levee maintenance and channel dredging activities also affect critical habitat by disturbing spawning or rearing habitat. Delta smelt adults seek shallow, tidally-influenced, fresh water (*i.e.*, less than 2 ppt salinity) backwater sloughs and edgewaters for spawning. To assure egg hatching and larval viability, spawning areas also must provide suitable water quality (*i.e.*, low concentrations of contaminants) and substrates for egg attachment (*e.g.*, submerged tree roots, branches, and emergent vegetation). Suitable water quality must be provided by addressing point sources of contaminants so that maturation is not impaired by pollutant concentrations. Levee maintenance disturbs spawning and rearing habitat, and resuspends contaminants into these waters.

Of the entities with water storage greater than 100 TAF, the percent of total storage is the following:

1. Reclamation stores 40.6 percent of Delta water, 42.8 percent of Sacramento River water, and 37.7 percent of San Joaquin River water.

2. DWR stores 17.4 percent of Delta water, 29 percent of Sacramento River water, and has no storage for San Joaquin River water.

3. Therefore, the non-Federal entities (excluding DWR) represent 42.0 percent of Delta water, 28.2 percent of Sacramento River water, and 62.3 percent of San Joaquin River water of those with storage greater than 100 TAF.

DW project effects on hydrodynamic conditions are inextricably tied to past and present hydraulic modifications that have been made in the Delta for various purposes, such as levee construction for land reclamation and flood control; channel dredging for navigation and levee maintenance; channel enlargement and deepening for navigation; operation of diversion pumps, siphons, and drainage pumps; and construction of non-federal export pumping plants and associated facilities for water management. DW project operations will not affect upstream conditions. Upstream conditions for fish, however, will continue to deteriorate. Increased demands may further reduce reservoir storage and will adversely affect riverine conditions. Without criteria to reduce Delta habitat degradation (including entrainment losses), ongoing factors and future projects will reduce the survival and abundance of all fish species. Under future conditions, surplus flows are likely to be less available than under existing conditions. Reduced availability will result from: (1) operations that reduce the frequency of spill from upstream reservoirs; (2) build out by senior water right holders; and (3) changes in the criteria that define surplus flows.

Additional cumulative effects result from the impacts of point and non-point source chemical contaminant discharges. These contaminants include selenium and numerous pesticides and herbicides associated with discharges related to agricultural and urban activities. Implicated as potential sources of mortality for delta smelt and Sacramento splittail, these contaminants may adversely affect delta smelt and Sacramento splittail reproductive success and survival rates. Spawning habitat may also be affected if submersed aquatic plants used as substrates for adhesive egg attachment are lost due to toxic substances.

Conclusion

After reviewing the current status of the delta smelt and the Sacramento splittail, the environmental baseline, the effects of the proposed Delta Wetlands Project, and the cumulative effects, it is the Service's biological opinion that the Delta Wetlands Project, as proposed, including the implementation of final operational criteria contained in Appendix 2 is not likely to jeopardize the continued existence of the delta smelt and the Sacramento splittail and not result in the destruction or adverse modification of critical habitat for delta smelt.

INCIDENTAL TAKE STATEMENT

Section 9 of the Act and Federal regulation pursuant to section 4(d) of the Act prohibit the take of endangered and threatened species, respectively, without special exemption. Take is defined as harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct. Harass is defined by the Service as an intentional or negligent act or omission which creates the likelihood of injury to a listed species by annoying it to such an extent as to significantly disrupt normal behavioral patterns which include, but are not limited to, breeding, feeding, or sheltering. Harm is defined by the Service to include significant habitat modification or degradation that results in death or injury to listed species by impairing behavioral patterns including breeding, feeding, or sheltering. Incidental take is defined as take that is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity. Under the terms of section 7(b)(4) and section 7(o)(2), taking that is incidental to and not intended as part of the agency action is not considered to be prohibited taking under the Act provided that such taking is in compliance with this Incidental Take Statement.

The measures described below are nondiscretionary and must be implemented by the Corps so that they become binding conditions of any grant or permit issued to the applicant, as appropriate, in order for the exemption in section 7(o)(2) to apply. The Corps has a continuing duty to regulate the activity that is covered by this incidental take statement. If the Federal agency (1) fails to require the applicant to adhere to the terms and conditions of the incidental take statement through enforceable terms that are added to the permit or grant document, and/or (2) fails to retain oversight to ensure compliance with these terms and conditions, the protective coverage of section 7(o)(2) may lapse.

Amount or Extent of Incidental Take

The Service anticipates that operation of the Delta Wetlands Project including the avoidance and minimization measures in Appendix 2, will result in the take (by killing and harassment) of delta smelt through (1) construction activities, (2) recreation, maintenance, and monitoring activities, and (3) filling and discharging of reservoir and habitat islands. This take includes that incurred by use of pile-driving, soil excavation, and rip-rapping during construction of recreation facilities, intakes, and outtake structures and wake caused erosion, oil and gas spills, shading from boat docks, and herbicide applications used for plant management. Additionally, take (by killing, harassment, and harm) is expected from normal operation of the reservoir and habitat islands including filling and discharging water resulting in entrainment and impingement, and changes to central Delta hydrology and upstream movement of X2. This take will be difficult to quantify due to the unlikelihood of finding dead or impaired individuals. Adults, juveniles, and larvae may be present in the project area (Figure 1) from December 1 through August. Larval and juvenile delta smelt and Sacramento splittail are flushed to the eastern Suisun Bay by outflows during this interval and removed from the influence of most direct project effects by August 31. With implementation of the reasonable and prudent measures described below, the incidental take of **all** delta smelt killed and harassed as a result of pile-driving, soil excavation, and rip-rapping during construction of recreation facilities, intakes, and outtake structures and wake caused erosion, oil and gas spills, shading from boat docks, herbicide applications used for plant management, monitoring, and normal operation of the reservoir and habitat islands including filling and discharging water as described above or historical operation of the islands for agricultural production, will not be considered a prohibited taking. Fifty acres of habitat will be destroyed and killing, harassing, and harm resulting from this destruction will additionally not be considered a prohibited taking if the following measures are implemented. If listed, Sacramento splittail take due to killing, harassment, and harm will similarly not be considered a prohibited taking if the following measures are implemented.

Effect of the Take

In the accompanying biological opinion, the Service determined that this level of anticipated take is not likely to result in jeopardy of the above-listed and proposed species.

Reasonable and Prudent Measures

The Service believes the following reasonable and prudent measures are necessary and appropriate to minimize the impacts of take of delta smelt. The measures below are non-discretionary, and must be undertaken:

1. The Corps shall minimize the impacts on delta smelt associated with emersed vegetation resulting from soil excavation, placement of rip-rap, and construction of recreation facilities, intake and outtake structures.

2. The Corps shall minimize the impacts on delta smelt associated with submersed vegetation resulting from all in-water work, including, but not limited to, soil excavation, pile-driving, and rip-rapping, associated with the construction of recreation facilities, intake and outtake structures.

3. The Corps shall minimize the impacts on delta smelt associated with normal operation of the reservoir and habitat islands including filling and discharging water as described above or historical operation of the islands for agricultural production.

Terms and Conditions

In order to be exempt from the prohibitions of section 9 of the Act, the Corps must comply with the following terms and conditions, which implement the reasonable and prudent measures described above. These terms and conditions deal with both the near-term, emergency, and the longer-term, routine levee repairs and are non-discretionary:

1. The Corps shall minimize the impacts on delta smelt resulting from the permanent loss of spawning and refugial habitat due to destruction of emersed plants caused by placement of rip-rap, or construction of intake or outtake structures by avoiding areas having emersed plants.

2. The Corps shall minimize the impacts on delta smelt resulting from the permanent loss of spawning and refugial habitat due to destruction of submersed aquatic plants during construction and maintenance by avoiding, to the maximum extent practicable, areas having submersed aquatic plants. All in-water work shall take place between June and November unless real-time monitoring indicates the presence of delta smelt, at which point no in-water work shall occur until delta smelt are no longer present.

3. The Corps shall minimize the impacts on delta smelt associated with normal operation of the reservoir and habitat islands including filling and discharging water as described above or historical operation of the islands for agricultural production by implementing the avoidance, minimization, and compensation measures contained in Appendix 2. Additionally, the "Draft Proposed Delta Wetlands Fish Monitoring Program" (Appendix 4) shall be finalized at least 90 days prior to start of any project related construction.

Reporting Requirements

The Corps shall require DW when performing construction activities to report immediately any information about take or suspected take of delta smelt (and Sacramento splittail should this species be listed). The Corps shall immediately notify the Service within one working day of any such information.

Notification must include the date, time, and precise location of the incident and specimen, and any other pertinent information. The Service contact is the Chief for Endangered Species Division at (916) 979-2725. Any killed specimens that have been taken shall be properly preserved in accordance with the Natural History Museum of Los Angeles County policy of assessioning (10% formalin in a quart jar or freezing). Information concerning how the fish was taken, length of the interval between death and preservation, the water temperature and outflow/tide conditions, and any other relevant information shall be written on 100% rag content paper and included in the container with the specimen. This preserved specimen shall be delivered to the Service's Division of Law Enforcement at 3110 El Camino, Suite 140, Sacramento, California 95821 (telephone 916-979-2987).

Sacramento Splittail

The above requirements for delta smelt will concurrently minimize the impacts of take on Sacramento splittail.

CONSERVATION RECOMMENDATIONS

Sections 2(c) and 7(a)(1) of the Act direct Federal agencies to use their authorities to further the purposes of the Act by carrying out conservation programs for the benefit of endangered and threatened species and the ecosystems upon which they depend. Conservation recommendations are Service suggestions regarding discretionary agency activities to promote the recovery of listed species. Therefore, the Service recommends the following additional actions to promote the recovery of federally listed species and their habitats:

1. The Service recommends that the Corps implement recovery activities in the Delta Native Fishes Recovery Plan.

2. The Service recommends that the Corps develop procedures that minimize the effects of in-water construction activities.

REINITIATION - CLOSING STATEMENT

This concludes formal consultation and conference for the proposed Delta Wetlands Project. You may ask the Service to confirm the conference opinion as a biological opinion issued through formal consultation if the Sacramento splittail is listed. The request must be in writing. If the Service reviews the proposed action and finds that there have been no significant changes in the action as planned or in the information used during conference, the Service may confirm the conference opinion as the biological opinion on the project and no further section 7 consultation may be necessary.

As required by 50 CFR §402.16, reinitiation of formal consultation is required if: (1) the amount or extent of incidental take is exceeded; (2) new information reveals effects of the agency action that may affect listed species or critical habitat in a manner or to an extent not considered in this opinion; (3) the agency action is subsequently modified in a manner that causes an adverse effect to the listed species or critical habitat that was not considered in this biological opinion; or (4) a new species is listed or critical habitat designated that may be affected by the action. In instances where the amount or extent of incidental take is exceeded, any operations causing such take ceases to have the protective coverage of section 7(o)(2) of the Act.

If you have any questions regarding this biological opinion, please contact Mr. Robert Pine at the Sacramento Field Office at (916) 979-2710.

Sincerely,

Dale A. Pierce

/Wayne S. White
Field Supervisor

Enclosures

cc: Mark Littlefield, FWS-SFO, Wetlands, Sacramento, CA
F. Wernette, DFG, Stockton, CA
P. Ruvelas, NMFS, Santa Rosa, CA

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Personal Communications

Cech, J., C. Swanson, P. Young, Department of Wildlife and Fisheries Biology, University of California, Davis, Davis, California 95616

Coulston, P., California Department of Fish and Game, Bay-Delta and Special Water Projects Division, 4001 N. Wilson Way, Stockton, California 95205-2424

Herbold, B., Environmental Protection Agency, 1235 Mission Street, San Francisco, California 94103

Moyle, P.B., University of California, Davis, Davis, California 95616.
delta smelt biological opinion
Sweetnam, D., California Department of Fish and Game, Bay-Delta and Special Water Projects Division, 4001 N. Wilson Way, Stockton, CA 95205-2424.

Tillman, T., Department of Fish and Game, Bay-Delta and Special Water Projects Division, 4001 N. Wilson Way, Stockton, CA 95205-2424.

Appendix 1. March 6, 1995, delta smelt biological opinion changes to the environmental baseline.

The December 14, 1994, signing of the Bay-Delta Accord and its subsequent implementation through the March 6 delta smelt biological opinion provided significant beneficial actions to the Delta. The following are some of the process changes and beneficial actions that changed the Delta environmental baseline:

On December 23, 1994, the CVP and SWP began operations in accordance with the Bay-Delta Accord. The "CALFED Process" is an element of the Bay-Delta Accord and consists of the following process--

(a) Initial deliberations and decisions occur in the "Ops Group". The "Ops Group", or CVP and SWP Operations-Endangered Species Coordination Group, is defined in Exhibit B of the Framework Agreement and consists of representatives of the Service, Reclamation, NMFS, EPA, DWR, and SWRCB. The Ops Group exchanges information and facilitates coordination of water project operations with requirements of the delta smelt and winter-run salmon biological opinions, Federal and State water quality standards, and the CVPIA.

Issues that may be presented within the Ops Group include:

1. review of project operations;

2. review of operating parameters in biological opinions;

3. review of fish distribution and fish population levels;

4. review of status of endangered species take;

5. discussion of strategies for implementation of fishery protections to resolve conflicts between operations, water quality requirements, and fishery needs in the Estuary and its watershed;

6. coordination of the winter-run salmon monitoring and operations and management work groups with the delta smelt management and work groups and with IEP;

7. discussion of strategies for implementation of Estuary standards;

8. review and comment on the annual CVPIA water allocation and on other CVPIA activities related to the Estuary such as the Anadromous Fish Restoration Program; and

9. cooperation with the IEP and others to determine factors affecting Delta habitat and health of fisheries, and to identify appropriate corrective measures for the CVP and SWP.

Ops Group deliberations shall be conducted in consultation with water user, environmental and fishery representatives. Briefings shall periodically be provided to the Governor's Water Policy Council, Club Fed, and other interested groups. The Delta Smelt Working Group, defined in the Reporting Requirements below, will provide technical information to the Ops Group.

(b) If the Ops Group disagrees on a particular issue, or if an Ops Group action requires additional water that it is believed cannot be made up within existing requirements, the issue will be decided by CALFED.

(c) If CALFED cannot reach agreement, and if the issue involves listed species, a final decision will be made by the appropriate listing agency. Other issues not involving the Endangered Species Act will be decided by the appropriate regulatory or resources management agency.

The following water quality standards and operational constraints contain biological benefits:

(a) Delta outflow--

Table 1 shows the minimum monthly average Net Delta Outflow index.

Table 1. Minimum monthly average Net Delta Outflow Index (cfs)

Water Year Type*	Time Period**	Outflow (cfs)
All	January	4,500***
All	February-June	****
Wet, Above Normal	July	8,000
Below Normal	July	6,500
Dry	July	5,000
Critical	July	4,000
Wet, Above and Below Normal	August	4,000
Dry	August	3,500
Critical	August	3,000
All	September	3,000
Wet, Above and Below Normal, Dry	October	4,000
Critical	October	3,000
Wet, Above and Below Normal, Dry	November-December	4,500
Critical	November-December	3,500

*The Sacramento Valley 40-30-30 water year hydrologic classification index at the 50 percent exceedance level applies.

**For the May-January objectives, if the value is less than or equal to 5,000 cfs, the 7-day running average shall not be less than 1,000 cfs below the value; if the value is greater than 5,000 cfs, the 7-day running average shall not be less than 80 percent of the value.

***The objective is increased to 6,000 cfs if the best available estimate of December's Eight River Index (ERI or 8RI) is greater than 800 TAF. The ERI is defined as the sum of the unimpaired runoff as published in the DWR Bulletin 120 for the following locations: Sacramento River flow at Bend Bridge, near Red Bluff; Feather River, total inflow to Oroville Reservoir; Yuba River flow at Smartville; American River, total inflow to Folsom Reservoir; Stanislaus River, total inflow to New Melones Reservoir; Tuolumne River, total inflow to Don Pedro Reservoir; Merced River, total inflow to Exchequer Reservoir; and San Joaquin River, total inflow to Millerton Lake.

****The minimum daily Net Delta Outflow Index shall be 7,100 cfs for this period, calculated as a 3-day running average. This requirement is also met if either the daily average or 14-day running average EC at the Confluence is less than or equal to 2.64 mmhos/cm (Collinsville, station C2). Determination of compliance with an objective expressed as a running average begins on the last day of the averaging period. If the objective is not met on the last day of the averaging period, all days in the averaging period are considered out of compliance. The above standard for March may be relaxed upon the recommendation of the Ops Group (previously defined) established under the Framework Agreement, if the best available estimate of the ERI for February is less than 500 TAF. Disputes will be resolved by the CALFED policy group. The above standard does not apply in May and June if the best available estimate of the May Sacramento River Index for the water year is less than 8,100 TAF at the 90 percent exceedance level. Under this circumstance, a minimum 14-day running average flow of 4,000 cfs is required in May and June.

(b) X2 protection measures--

X2 protection shall be based on Footnote 11 for Table 3 on page 23 of the draft WQCP with errata with the following adjustments: Chipps Island requirement in February will be zero days when the ERI in January is less than 800 TAF and 28 days when it is greater than 1,000 TAF with linear interpolation between 800 and 1,000 TAF. The requirement at the confluence shall be 150 days, except when the best available estimate of the May 1, 90 percent exceedance Sacramento River Index is less than 8,100 TAF, the maximum outflows for May and June shall be 4,000 cfs, with all other flow requirements removed. When the February index falls below 500 TAF, the requirement of March will be reviewed by the Ops Group defined above. Additional refinements, which will involve no further water costs above those which are required for this paragraph may be subsequently made (however some water costs associated with other sections of this Project Description may be above those required for this paragraph).

Table 2 shows the number of days when maximum daily average EC of 2.64 mmhos/cm must be maintained at Chipps Island and Port Chicago.

Number of days when maximum daily average EC of 2.64 mmhos/cm must be maintained at Chipps Island and Port Chicago-- The number of days that an EC of 2.64 mmhos/cm must be maintained at Chipps Island and Port Chicago is determined by the Previous Months ERI (PMI). The number of days from February through June at different PMI is described in Footnote 11 for Table 3 on page 23 of the draft WQCP with errata. The requirement can also be met with maximum 14-day running average EC of 2.64 mmhos/cm, or 3-day running average Delta outflows of 11,400 cfs and 29,000 cfs, for Chipps Island and Port Chicago, respectively. When the PMI is between 800 TAF, the number of the maximum daily average EC of 2.64 mmhos/cm (or maximum 14-day running average EC of 2.64 mmhos/cm, or 3-day running average Delta outflow of 11,400 cfs) must be maintained at Chipps Island in February is determined by linear interpolation between 0 and 28 days. The Port Chicago standard applies only in months when the average EC at Port Chicago during the 14 days immediately prior to the first day of the month are equal to or less than 2.64 mmhos/cm.

(c) San Joaquin River protection measures--

Not later than three years following the adoption of this plan, the SWRCB shall assign responsibility for the following flows, together with other measures in the watershed sufficient to meet all criteria in the San Joaquin River at Vernalis among the water right holders in the watershed. During this three-year period, Reclamation shall provide these flows. Table 3 shows these flows, which are interim flows and will be reevaluated as to timing and magnitude within the next three years.

Table 3. San Joaquin River flows

Year Type*	February-June flows (cfs)**	April-May pulse flows (cfs)***
Critical	710 or 1,140	3,110 or 3,540
Dry	1,420 or 2,280	4,020 or 4,880
Below Normal	1,420 or 2,280	4,620 or 5,480
Above Normal	2,130 or 3,420	5,730 or 7,020
Wet	2,130 or 3,420	7,330 or 8,620

*San Joaquin Valley 60-20-20 water year classification index at the 75 percent exceedance level applies (see Other Operation Changes section below concerning use of 90 percent exceedance).

**higher flows provided when the standard requires the positioning of X2 west of Chipps Island.

***A Vernalis flow for October of 1,000 cfs is provided with up to an additional 28 TAF pulse and attraction flow during all water year types. The pulse flow will be scheduled by the Ops Group defined above. The additional 28 TAF is not required in a critical year following a critical year.

(d) Delta Cross Channel Gate Closure--

During the period November to January, the Delta Cross Channel will be closed a maximum of 45 days. The timing and duration of the closures will be determined by the Ops Group. During the period May 21 through June 15, the

Delta Cross Channel may be rotated closed four consecutive days each week, excluding weekends.

(e) Combined export rate* limits--

In all water year types, during the April and May, 30-day pulse flow interval, maximum combined export rate is 1,500 cfs or 100 percent 3-day running average of San Joaquin River flow at Vernalis, whichever is greater (see below, Other Operational Changes section, for additional San Joaquin River requirements). Variations to this maximum combined export rate are authorized subject to the "CALFED Process" defined above. In all water year types, from February-June, maximum combined export rate is 35 percent of Delta inflow diverted** and from July-January, 65 percent of Delta inflow diverted. This may be changed by the Ops Group, as defined by the flexibility clause.

*Combined export rate for this objective is defined as the Clifton Court Forebay inflow rate (minus actual Byron-Bethany Irrigation District diversions form Clifton Court Forebay) and the export rate of the Tracy pumping plant.

**Percent of delta inflow diverted is defined on page 22 of the draft Water Quality standards. The export rate for this calculation is defined as a 3-day running average. The 14-day averaging period for Delta inflow is reduced to a 3-day period when the CVP or SWP is making storage withdrawals for export. The percent Delta inflow diverted values can be varied either up or down. Variations are authorized if agreed to by the Ops Group previously defined.

February protections-- If the best available estimate of the January ERI is less than or equal to 1.0 MAF, the export limit for February is 45 percent of Delta inflow diverted. If the best available estimate of the January ERI is between 1.0 MAF and 1.5 MAF, the export ratios for February will be adjusted by the Ops Group defined above within the range of 35 percent to 45 percent. Disputes within the Ops Group will be resolved by CALFED as described in the "CALFED Process" above. If the best available estimate of the January ERI is greater than 1.5 MAF, the February export limit is 35 percent of Delta inflow diverted.

March through June protections-- During March through June, exports shall be no greater than 35 percent of Delta inflow, subject to the flexibility provisions described below.

July through January-- During July through January, exports shall be no greater than 65 percent of Delta inflow, subject to the flexibility provisions described below. The criteria will be developed by the Ops Group.

(f) Daily export limits--

Daily export limits shall be based on the average Delta inflow over the preceding three days, when CVP or SWP is making storage withdrawals for exports (as defined in the Coordinated Operations Agreement), or 14 days under all other conditions.

(g) Operational flexibility--

Decisions to exercise operational flexibility under the Ops Group process may increase or decrease water supplies in any month and must be based on best available biological data to ensure biological protection and be consistent with requirements for delta smelt, delta smelt critical habitat, winter-run salmon, and the proposed Sacramento splittail.

(h) All CVP water provided pursuant to these principle's shall be credited toward the CVP obligation under CVPIA Section 3406(b)(2) to provide 800 TAF of project yield for specified purposes.

(i) Brackish tidal marshes of Suisun Bay protections--

Water quality conditions sufficient to support a natural gradient in species composition and wildlife habitat characteristic of a brackish marsh throughout all elevations of the tidal marshes bordering Suisun Bay shall be maintained. Water quality conditions shall be maintained to prevent the loss of diversity.

Other Operational Changes Made to Benefit Delta Smelt, Delta Smelt Critical Habitat, and the Proposed Sacramento Splittail

1. Starting gate-- If the best estimate of the Eight River Index is more than 900 TAF in January, the daily average or 14-day running average electrical conductivity at Collinsville (station C2) shall attain 2.64 mmhos/cm or less between February 1 and February 14 for at least one day. If the Eight River Index is between 650 TAF and 900 TAF in January, the operations coordination group established by the Framework Agreement shall decide if the daily average or 14-day running average electrical conductivity at Collinsville (station C2) shall attain 2.64 mmhos/cm for at least one day between February 1 and February 14. Disputes will be resolved by the CALFED policy group previously described.

   At the discretion of the Ops Group, the starting gate requirement may also be met by a minimum daily Delta 3-day running average outflow of 7,100 cfs, if the January Eight River Index is between 650 and 900 TAF.

2. San Joaquin River pulse flow-- The operating criteria listed above specifies that during the April and May 30-day pulse flow period, combined CVP and SWP exports may be the greater of 1,500 cfs or 100 percent of the Vernalis flow. Reclamation will pursue acquisition of additional flow (acquired flow) to provide San Joaquin flows at Vernalis during the April and May 30-day pulse in excess of those exported by the CVP and SWP. Any such acquired flows will be identified as being in excess of those attributable to CVP releases, unregulated accretions or unstorable flows. Through the CALFED process and other associated discussions, Reclamation and DWR will encourage measures that will minimize the diversion of acquired flows during the 30-day pulse flow period. An Operations Plan shall be submitted to the Service by April 1 of each year describing Reclamation's and DWR's Delta operations and forecasted San Joaquin River flows during the April and May 30-day pulse

flow. The objective of this Operations Plan is to provide a flow at Vernalis that exceeds CVP plus SWP export by an amount equal to 50 percent of the identified pulse flow associated with the most recently available forecasted San Joaquin 60/20/20 Index (at 90 percent of exceedance).* In an effort to accomplish this goal, Reclamation and DWR will also consider re-allocation within the Principles for Agreement or other means to provide Vernalis flows or Delta exports consistent with this objective.

*Two examples of possible Operations Plans that meet the stated objective:

(a) "Above Normal" San Joaquin Index with X2 requirement west of Chipps Island--
Base flow = 5,400 cfs (Reclamation will identify base flow in Operations Plan)
CVP+SWP export = 5,400 cfs (equal to 100 percent of base flow)
Identified pulse flow = 7,020 cfs
Acquired flow objective = 3,510 cfs (equal to 50 percent of identified pulse flow)
Total flow objective at Vernalis = 8,910 cfs (base flow plus acquired flow)

(b) "Critical" San Joaquin Index with X2 requirement at the Confluence--
Base flow = 1,400 cfs
CVP+SWP export = 1,500 cfs (greater of 1,500 cfs or base flow)
Identified pulse flow = 3,110 cfs
Acquired flow objective = 1,555 cfs (equal to 50 percent of identified pulse flow)
Total flow at Vernalis = 3,055 cfs (1,500 cfs export plus acquired flow)

3. San Joaquin River exceedance forecast-- A 90 percent exceedance forecast shall be used to determine required San Joaquin River flows.

4. North Bay Aqueduct Diversion at Barker Slough and Prospect Island:

(a) When monitoring at Barker Slough indicates the presence of delta smelt larvae (under 20 mm), diversions from Barker Slough shall be reduced to a 5-day running average rate of 65 cfs not to exceed a 75 cfs daily average for any day, for a minimum of 5 days, and when monitoring shows no delta smelt are present. Presence is defined as a weighted average of one or more larval delta smelt sampled at Barker Slough stations 720, 720a (between stations 720 and 721), and 721 during a single sampling day. Barker Slough monitoring stations shall be weighted as follows:

station 720-- 20 percent
station 720a (between stations 720 and 721)-- 30 percent
station 721-- 50 percent

If replicate samples are taken, the count used at each monitoring station shall be the average of all replicate samples taken at the monitoring station.

The averaging period for the 65 cfs shall begin 24 hours after the presence of delta smelt is detected. The Service shall be notified within 24 hours when diversions are reduced due to the presence of delta smelt juveniles and larvae and when diversions are subsequently increased due to the absence of delta smelt juveniles and larvae.

(b) A monitoring plan will be developed and submitted to the Service to provide baseline information to allow an estimation of delta smelt numbers and distribution in the Barker/Lindsey/Cache Slough-Prospect Island area. If this monitoring shows increases in delta smelt numbers and distribution when Prospect Island has become operational as a shallow-water habitat, the Working Group will meet and make a recommendation to the Service to amend 4(a) above.

With regard to the new environmental baseline created through implementation of actions within the Bay-Delta Accord, consideration of any future biological opinions based on new or re-initiated consultation will recognize three major initiatives that will shape the dynamics of future estuarine conditions for delta smelt. First, in accordance with a Framework Agreement (1994) between the Governor's Water Policy Council of the State of California (Council) and the Service, National Marine Fisheries Service (NMFS), EPA, and Reclamation (collectively known as "Club Fed"), the SWRCB has drafted water quality standards that will be finalized in 1995. This will occur while water right proceedings are under way to allocate responsibility among water right holders in the Bay-Delta watershed. Second, section 7(a)(1) of the Act imposes an affirmative obligation on Federal agencies to carry out programs for the conservation (recovery) of listed species. With the January 6, 1995, **Federal Register** notice of availability of the draft Delta Native Fishes Recovery Plan (Service 1994e), the Service expects that participating and affected local, State, and Federal agencies will fulfill their responsibilities by assisting in the completion of tasks and objectives in the Recovery Plan. Third, and related to number two above, the scheduled renewal or reopening of water contracts and licenses (such as, reopened or expired Federal Energy Regulatory Commission (FERC) licenses, expired CVP water contracts) will provide an additional opportunity under sections 7(a)(1) and 7(a)(2) of the Act to implement Recovery Plan objectives and meet EPA's or SWRCB's water quality standards. Collectively, these initiatives will result in a phased improvement to habitat requirements for the delta smelt and Sacramento splittail. Accordingly, the Service anticipates that adverse modification or destruction of critical habitat will be avoided by the CVP and SWP through implementation of the above described initiatives.

Additionally, the CVPIA is providing beneficial actions in the Delta. Part of these actions consist of management of 800 TAF of CVP Yield Under the CVPIA. To date, management of the 800 TAF of CVP Yield under the CVPIA has consisted of the following:

1. Springtime pulse flows in the Stanislaus River, and in the lower San Joaquin River.

2. Springtime restrictions on Delta pumping and closure of the Delta Cross Channel gates.

3. Spawning and rearing flow improvements in the mainstem Sacramento, lower American, and Stanislaus rivers in fall and early winter.

4. Carryover storage of a portion of the dedicated yield in New Melones Reservoir as a contingency against future drought-induced reductions.

Appendix 2. Matrix showing DW operations

REF	MEASURE	JSA BA ALTERNATIVE	Final Operations Criteria
1	Export cap	None	250 TAF (see Term I language)
2	Initial diversion Sep-Nov	10 days past Chipps 5 day ramp @ 5500 cfs	X2 at or downstream of Chipps 5 day ramp @ 5500 cfs - no split
3	Initial diversion Dec-Jan	10 days past Chipps 5 day ramp @ 5500 cfs	10 days past Chipps 5 day ramp @ 5500 cfs - no split
4	Initial diversion Feb-Mar	None	10 days past Chipps 5 day ramp @ 5500 cfs - no split
5	X2 position Sep-Nov	West of km 81 (Collinsville)	West of Collinsville salinity gauge
6	X2 position Dec-Jan	West of km 81 (Collinsville)	West of Collinsville salinity gauge
7	X2 position Feb-Mar	None	West of Collinsville salinity gauge
8	X2 shift Oct-Jan	Shift < 2.5 km	Shift < 2.5 km
9	X2 shift Feb-Mar	None	Shift < 2.5 km
10	Fixed prohibitions	No diversions during Apr-May pulse	No diversion Apr-May
11	Outflow limits Oct/Nov/Dec Jan/Feb/Mar Apr/May/Jun Jul/Aug/Sep	Outflow limit (%) 25/25/25 25/na/na na/na/na na/na/na	Outflow limit (%) 25/25/25 15/15/15 na/na/25 25/25/25
12	SJR limits Oct/Nov/Dec Jan/Feb/Mar Apr/May/Jun Jul/Aug/Sep	None	SJR flow limit (%) (applies up to 15 days) na/na/125 125/125/50 na/na/na na/na/na

REF	MEASURE	JSA BA ALTERNATIVE	Final Operations Criteria
13	Available limits Oct/Nov/Dec Jan/Feb/Mar Apr/May/Jun Jul/Aug/Sep	% of available surplus na/na/na na/75/50 25/25/50 75/na/na	% of available surplus 90/90/90 90/75/50 0/0/50 75/90/90
14	Enviro-water Oct/Nov/Dec Jan/Feb/Mar	None	None
15	DS monitoring period	None	In-channel monitoring Dec-Aug if > 50cfs On-island monitoring Jan-Aug if > 50 cfs
16	DS monitoring restrictions	None	Reduce diversions to 50% of previous day's rate during presence of delta smelt
17	DCC gate limits Nov-Jan	None	If DCC is closed for fishery protection, reduce maximum diversion rate to: 3,000 cfs if Delta inflow ≤ 30,000 cfs 4,000 cfs if inflow is 30,000 to 50,000 cfs
18	Summer top-off for evaporation Jun-Oct	None	Max. top-off rate for Jun-Oct in cfs: 215/270/200/100/33 including habitat island diversions
19	FMWT < 239 X2 position	Not applicable	1.4 km west of Collinsville salinity gauge
20	FMWT < 239 Fixed prohibitions	Not applicable	No diversions Feb 15 - Jun 30 except top-off (see # 25)

REF	MEASURE	JSA BA ALTERNATIVE	Final Operations Criteria
21	FMWT < 239 DS monitoring period	Not applicable	In-channel monitoring Dec-Aug if > 50cfs On-island monitoring Jan-Aug if > 50 cfs
22	FMWT < 239 DS monitoring restrictions	Not applicable	Reduce diversions to 50% of previous day's rate during presence of delta smelt
23	FMWT < 239 Outflow limits Jan/Feb/Mar	Not applicable	Outflow limit (%) 15/15/na
24	FMWT < 239 SJR limits Dec/Jan/Feb	Not applicable	SJR flow limit (%) 125/100/50 (applies up to 30 days)
25	FMWT < 239 Summer top-off for evaporation Jun-Oct	Not applicable	Max. top-off rate for Jun-Oct in cfs: 215/270/200/100/33 including habitat island diversions
26	FMWT < 84 Fixed prohibitions	Not applicable	Considered "new information" and reinitiation of BO may occur
27	FMWT < 84 DS monitoring period	Not applicable	Not applicable
28	FMWT < 84 DS monitoring restrictions	Not applicable	Not applicable
29	FMWT < 84 Outflow limits	Not applicable	Not applicable
30	FMWT < 84 SJR limits	Not applicable	Not applicable
31	FMWT < 84 Summer top-off for evaporation	Not applicable	Not applicable

REF	MEASURE	JSA BA ALTERNATIVE	Final Operations Criteria
Ref	Measure	JSA BA Alternative	Final Operations Criteria
32	Delta inflow	DW not included	BO will adopt a neutral position with respect to this action, see DW letter of 10/18/96
33	Fixed prohibitions	None	Webb: no discharges Jan-Jun
34	SJR limits: Bacon	None	50% SJR Apr-Jun
35	Export capacity fraction: Webb	Feb 75% Mar-Jun 50% Jul 75%	Feb-Jun NA Jul 75%
36	Export capacity fraction: Bacon	Capacity available Feb 75% Mar-Jun 50% Jul 75%	Feb 75% Mar-Jun 50% Jul 75%
37	Bacon pulse-flow period exports	Only if Old & Middle flow south	None
38	Enviro-water	None	10% match for export during Dec-Jun subject to Feb-Jun habitat island credit
39	DS monitoring period	None	In-channel monitoring Apr-Aug if > 50cfs
40	DS monitoring restrictions	Not applicable	Reduce diversions to 50% of previous day's rate during presence of delta smelt
41	Habitat island discharge limits	None	No export but may be used for enviro-water match from Feb-Jun (see #38)

REF	MEASURE	JSA BA ALTERNATIVE	Final Operations Criteria
42	FMWT<239 Enviro-water	Not applicable	20% match for export during Dec-Jun subject to Feb-Jun habitat island credit
43	FMWT < 239 DS monitoring period	Not applicable	In-channel monitoring Apr-Aug if > 50cfs
44	FMWT < 239 DS monitoring restrictions	Not applicable	Reduce diversions to 50% of previous day's rate during presence of delta smelt
45	FMWT < 84 Fixed prohibitions	Not applicable	Considered "new information" and reinitiation of BO may occur
46	FMWT < 84 Enviro-water	Not applicable	Not applicable
47	FMWT < 84 DS monitoring period	Not applicable	Not applicable
48	FMWT < 84 DS monitoring restrictions	Not applicable	Not applicable
49	Fish screen design	Not included	0.2 fps approach velocity
50	Rearing habitat	Not included	200 acres
51	Spawning habitat	Not included	Included above
52	SRA habitat	Not included	None
53	Boat wake erosion	Not included	$100/yr/berth for each net additional berth
54	Aquatic habitat	Not included	Replace actual losses at 3:1 ratio

REF	MEASURE	JSA BA ALTERNATIVE	Final Operations Criteria
55	Temperature limits	Per CVRWQB (Basin Plan)	No $\Delta T > 7^{\circ}$ C No channel increase > 1° C for 13° C to 19° C No channel increase > 1° C for 19° to 25 $^{\circ}$C No channel increase > 0.5° C over 25° C
56	DO limits	Per CVRWQB (Basin Plan)	No DO discharge < 6 mg/l Do not cause channel to drop below 5 mg/l
57	Incidental entrainment comp.	None	\$500-\$1000 per TAF for scheduled species, Jan through Aug
58	Service area conditions	None	None
59	HMP conditions	None	Actual costs plus overhead
60	Construction period	Not included	Jun-Nov for in-water work

Appendix 3. - Water Transfer Language from March 6, 1995, Delta Smelt Biological Opinion and Historical Water Transfers (1993 and 1994).

March 6, 1995, Water Transfer Language (Page 5, **Water Transfers**)

Water transfers that are relevant to this opinion are those transfers where a water right holder within the Delta watershed undertakes actions to make water available for transfer generally south of the Delta. Transfers requiring export from the Delta are done at times when pumping capacity at the Federal and State pumping plants is available to move the water. Reclamation and DWR will work to facilitate transfers in accordance with the Principles for Agreement and this biological opinion.

Historical Water Transfers

1993. Fifteen water transfers from the "Exchange Contractors" to the San Luis Unit were approved in April and May of 1993. Two water transfers from the "Exchange Contractors" to the San Luis Unit were approved in July of 1993.

Transfers to Westlands Water District (WD) Total Water include:

1. 37,693 AF Approved by Reclamation in April and May, 1993
2. 36,000 AF Approved through State Board petition, June 22, 1993
3. 60,000 AF Merced Irrigation District (ID) and Merced Wildlife Refuge, approved by State Board petition, no conveyance available
4. 82,000 AF Approved by State Board petition, no conveyance available

Transfers to Pacheco WD include:

1. 2,000 AF Approved by Reclamation in April and May, 1993

Transfers to Panoche WD include:

1. 41,120 AF Approved by Reclamation in April, May, and July, 1993

Transfers to San Luis WD include:

1. 1,205 AF Approved by Reclamation in April, May, and July, 1993

1993 Water Transfer Total:

228,018 AF

1994. Transfers for either the San Joaquin or the Sacramento Valley or the State Water Bank -

San Joaquin Valley

From		Quantity	To
(1)	Columbia Canal Company	310 AF	San Luis WD
(2)	Central California ID	3,580 AF	San Luis WD
(3)	Contra Costa ID	400 AF	Westlands WD
(4)	Firebaugh Canal WD	152 AF	Westlands WD
(5)	Firebaugh Canal WD	552 AF	Westlands WD
(6)	Firebaugh Canal WD	1,070 AF	Westlands WD
(7)	Firebaugh Canal WD	190 AF	Panoche WD
(8)	Firebaugh Canal WD	118 AF	San Luis WD
(9)	San Luis Canal Company	2,250 AF	Panoche WD
(10)	Central California ID	90 AF	Panoche WD
(11)	Merced Refuge	30,000 AF	Westlands WD
(12)	Kern County Water Agency	3,000 AF	Westlands WD
Total		37,213 AF	

Sacramento Valley

(1)	Provident Water District	≤2,300 AF	Kanawha, Glide, and Orland-Artois Wds
(2)	Sutter Mutual Water Company	5,000 AF	Tehama-Colusa Water Users Association
(3)	City of Redding	2,000 AF	Bella Vista WD
Total		9,300 AF	

State Water Bank

(1)	Reclamation Contractor Districts Pelger Mutual Water Company	2,000 AF
(2)	Reclamation District 1004	12,000 AF
(3)	Baber	1,250 AF
(4)	Glenn-Colusa ID	22,363 AF
(5)	Hershey Land	338 AF
(6)	PCG ID	512 AF
(7)	Reclamation District 108	536 AF
Total		39,000 AF

1994 Grand Total **85,513 AF**

Appendix 4. DW Fish Monitoring Program

Delta Wetlands Fish Monitoring Program. The following sets forth a general description of the fish monitoring program that DWC will implement to provide data to minimize, avoid, and compensate for adverse impacts of DW project operations on fish. There are seven components of the program: (1) daily in-channel monitoring for the presence of juvenile and adult delta smelt in the immediate vicinity of DW diversion sites during diversions to storage, (2) daily on-island multiple species monitoring of entrainment of eggs, larvae, and juveniles during diversions to storage, (3) daily in-channel monitoring for the presence of juvenile and adult delta smelt in the general vicinity of DW reservoir islands during discharges for export, (4) reporting requirements, (5) sample handling and quality assurance/quality control (QA/QC) requirements, (6) IEP coordination, and (7) establishing a monitoring technical advisory committee (MTAC). The monitoring program as set forth below is intended to establish general parameters, with final details and specifications determined during final design of the monitoring program. This final design shall be completed after the project is permitted and must be accepted, in writing, by the responsible agencies prior to project operations with concurrence by the resource agencies.

1. *In-Channel Monitoring of Diversions to Storage*

The objective of this component shall be to provide for the detection of juvenile and adult delta smelt that could be vulnerable to entrainment at DW diversions. This DW sampling program would be supplementary to the existing IEP monitoring programs in the Delta. In the event that IEP monitoring is being conducted in a manner and location that satisfies DW sampling requirements, with the concurrence of the resource agencies and notice to the responsible agency, DW would use those data and would not be required to duplicate monitoring effort at those locations (*e.g.*, Real-Time Monitoring Program sampling in Middle River and Old River near DW reservoir islands). To the extent possible, sampling frequency will be stratified to obtain samples representative of any variation in specific conditions with respect to diel and tidal periodicity at each site. In-channel monitoring will utilize sampling technologies consistent with current IEP protocol (sampling gear may vary with season and life stage). Complete siting and sampling specifications will be determined during final design of the DW monitoring program.

DW shall provide daily in-channel monitoring during diversions to storage during allowable periods from December through August, except as provided below. Monitoring stations shall be located in the immediate vicinity of each of the four (4) DW diversion points. Each diversion point shall require two monitoring sites, for a maximum of eight (8) sites. The final location of each monitoring site shall be determined during final design of the DW monitoring program. Monitoring shall begin at a diversion point on the first day of diversions to storage from that site and shall continue throughout the diversion event. In-channel monitoring shall not be required if the total diversion rate at the diversion point is less than 50 cfs and the fish screen approach velocity is less than 0.08 fps (*e.g.*, topping-off).

Should DW be unable to perform in-channel monitoring for any reason except operational safety constraints, the monitoring mitigation measure shall automatically trigger unless waived by the responsible agencies, with concurrence by the resource agencies.

2. On-Island Monitoring of Entrainment during Diversions

The objective of this component shall be to provide for the detection of eggs, larvae, and juveniles entrained by DW diversions to storage. Certain life stages of key fish species may not be effectively screened during diversions to storage. These incidental losses shall therefore be mitigated using a monetary formula which ties measured losses to compensation that can be utilized, to the fullest extent possible, to plan and implement actions that maintain or enhance habitat for target species in the Bay-Delta estuary.

DW shall provide on-island monitoring during diversions to storage during allowable periods from January through August, except as provided below. A typical siphon located at each reservoir diversion point shall be fitted with a sampling apparatus attached to the floating siphon platform at the discharge end of the assembly. The final selection of the specific siphon to be monitored and complete specifications of the sampling apparatus will be determined during final design of the DW monitoring program. These sampling sites shall provide for installation of a variety of fish entrainment sampling gear using DFG-approved methodologies. Therefore, four sampling sites would be constructed (*i.e.*, 1 sampling site within a sixteen-siphon station times 2 siphon stations, times 2 reservoir islands, equals 4 total sampling sites). To the extent possible, sampling at each operating siphon station will be conducted as stratified subsamples with respect to diel and tidal periodicities so that total daily sampling time will be at least two hours each day. Monitoring shall begin at a diversion point on the first day of diversions to storage from that site and shall continue throughout the diversion event. On-island monitoring shall not be required if the total diversion rate at the diversion point is less than 50 cfs and the fish screen approach velocity is less than 0.08 fps (*e.g.*, topping-off).

3. In-Channel Monitoring of Discharge for Export

The objective of this component shall be to provide for the detection of juvenile and adult delta smelt that could be vulnerable to entrainment at the Delta export facilities during the export of DW discharges. This DW sampling program would be supplementary to the existing IEP monitoring programs in the Delta. In the event that IEP monitoring is being conducted in a manner and location that satisfies DW sampling requirements, with concurrence by the resource agencies and notice to the responsible agency, DW would use those data and would not be required to duplicate monitoring effort at those locations (*e.g.*, Real-Time Monitoring Program sampling in Middle and Old Rivers near DW reservoir islands). To the extent possible, sampling frequency will be stratified to obtain samples representative of any variation in specific conditions with respect to diel and tidal periodicity at each site. In-channel monitoring will utilize sampling technologies consistent with current IEP protocol (sampling gear may vary with season and life stage). Complete siting and sampling specifications will be determined during final design of the DW monitoring program.

DW shall provide daily in-channel monitoring during discharges for export from April through August, except as provided below. Monitoring stations shall be located at paired transects at each of the two discharge stations, one in Middle River near Webb Tract and one in Old River near Bacon Island to be selected based on Real-Time Monitoring Program results and technical experience to provide indication of delta smelt density and distribution in this region of the Delta. The final location of each of monitoring site will be determined during final design of the DW monitoring program. Monitoring shall begin on the first day of discharges for export from Webb Tract and shall continue throughout the discharge event. In-channel monitoring shall not be required if the total discharge for export rate is less than 50 cfs.

Reporting

Weekly monitoring reports will be transmitted by FAX and daily reports by INTERNET to the fishery agencies as follows:

Service, Sacramento Field Office
NMFS, Protection Resources and Habitat Conservation Division
DFG, Bay-Delta and Special Water Projects Division

5. *Sample Handling Protocol*

DW will retain samples for a minimum of one year after collection. Agency biologists and law enforcement personnel shall have 24 hour access to fish monitoring personnel, fish samples, and daily fish capture data. A QA/QC protocol, acceptable to the fishery agencies, will be developed by DW and provided to the fishery agencies as part of the final monitoring program plan. The QA/QC protocol will include, but is not limited to, measures to ensure correct identification of larval and juvenile fishes.

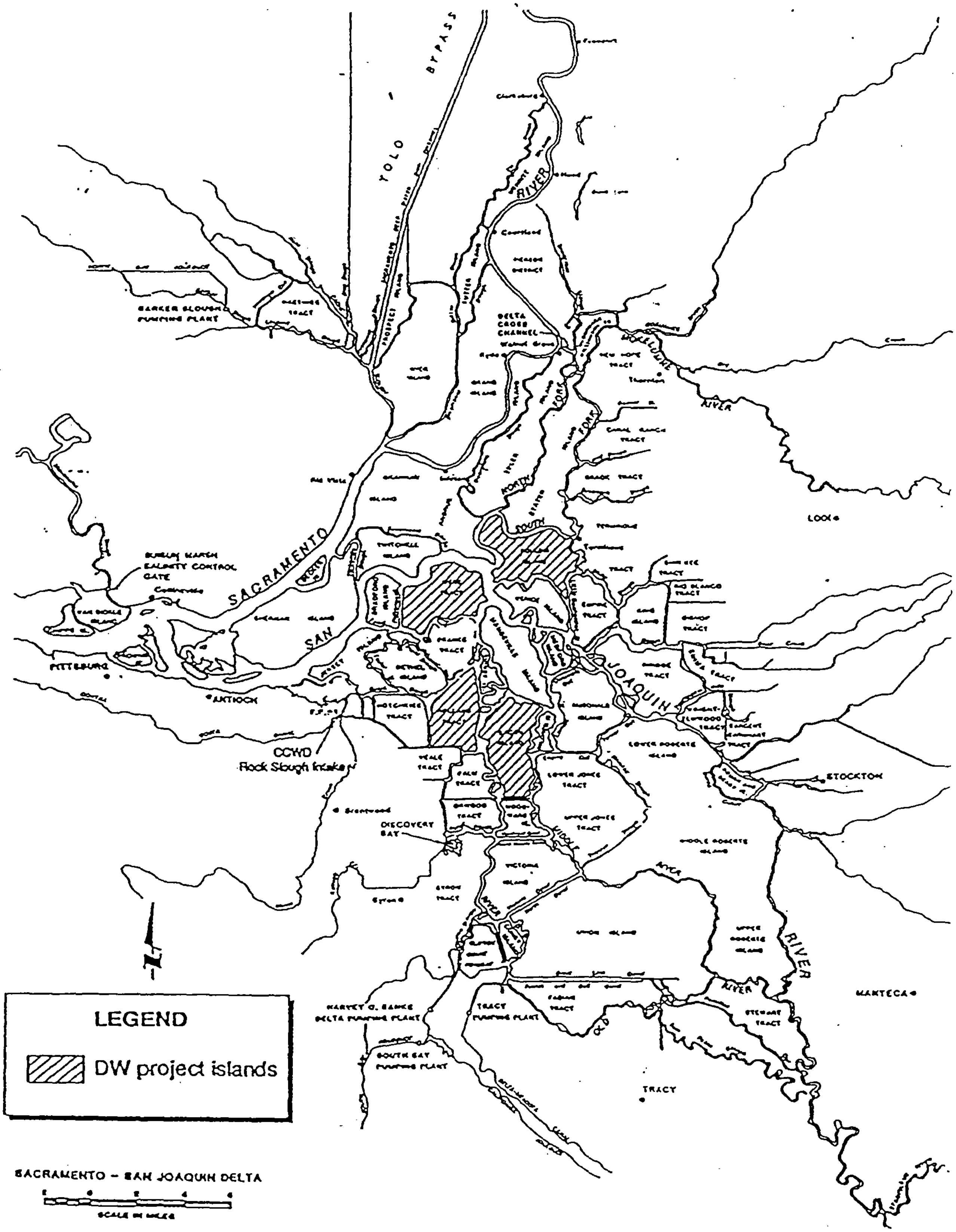
6. *Coordination with IEP Monitoring Programs*

DW will be solely responsible for conducting the required monitoring. In the event that IEP monitoring is being conducted in a manner and location that satisfies the previously described operations requirements, DW may use the data collected and will not be required to conduct duplicate monitoring at those sites. If DW is able to make use of the IEP monitoring data in lieu of project specific monitoring, DW shall compensate IEP for the use of this data by contributing financial support to the IEP monitoring program commensurate to the proportionate share of DW exports to the total Delta exports for the period.

7. *Monitoring Technical Advisory Committee*

The objective of this component is to establish a monitoring technical advisory group (MTAC) to advise and resolve monitoring issues that may develop over the life of the DW project. The MTAC shall be made up of voluntary participants from a variety of agencies, including, but not limited to, invitees from SWRCB, Corps, the Service, NMFS, DFG, DWR, Reclamation, EPA, and DW. DW may convene the MTAC to evaluate and recommend adjustments to the DW monitoring program.

Initially, DW shall work directly with DFG to resolve daily technical monitoring issues but may convene the MTAC to act in a technical capacity to provide review and address any technical inadequacies or disagreements that may occur. The committee may also provide advisory review on issues of waiver occurring during implementation of the monitoring program. Any modifications to the monitoring program must be made with the approval of the responsible agencies and concurrence of the resource agencies who will continue to retain final approval or disapproval of any monitoring changes.

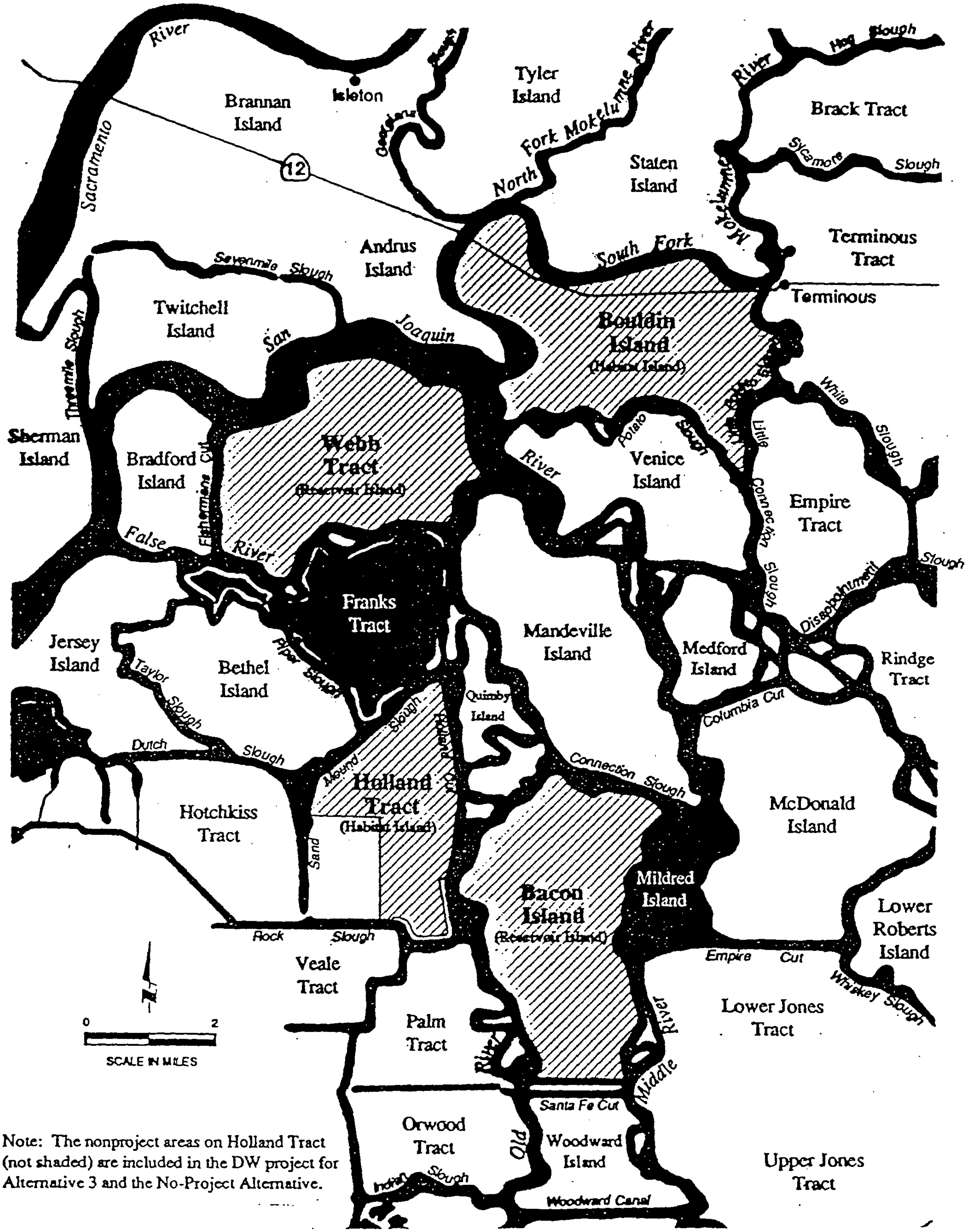


Source: Adapted from California Department of Water Resources 1993a.

Figure 1 .
Sacramento-San Joaquin Delta

DELTA WETL
P R O J E

Prepared by: Jones & Stokes A



Note: The nonproject areas on Holland Tract (not shaded) are included in the DW project for Alternative 3 and the No-Project Alternative.

Source: Adapted from California Department of Water Resources 1993.

Figure 2
DW Project Islands

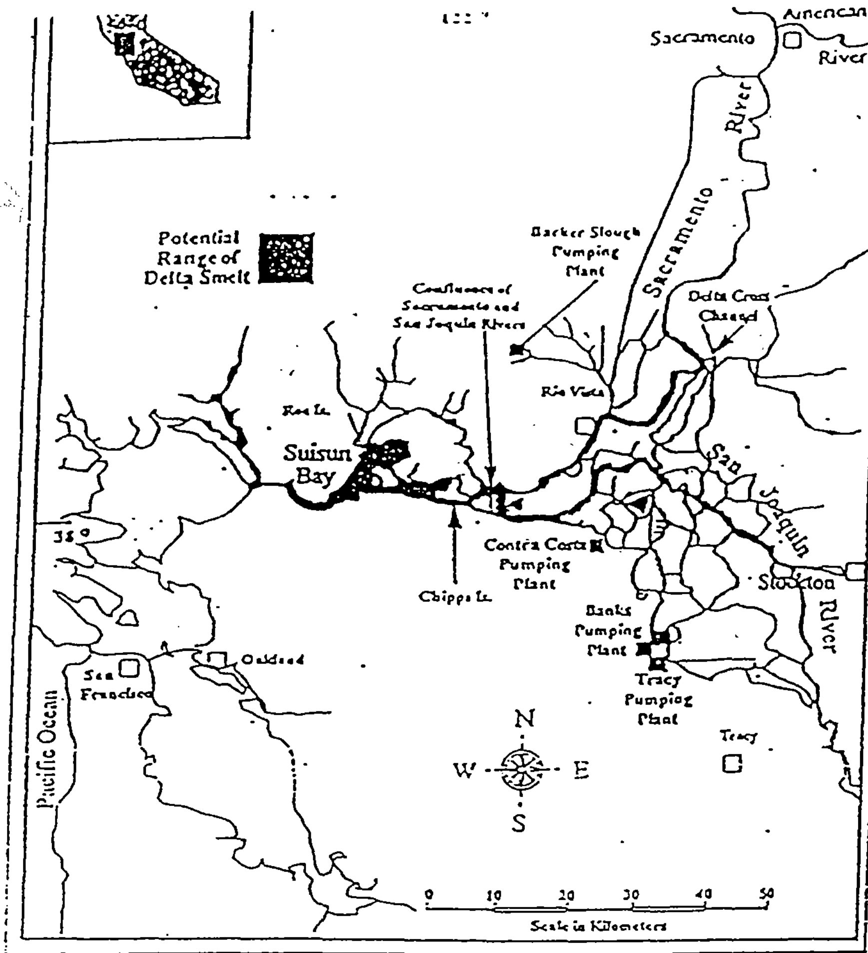


Figure 3a :
SACRAMENTO-SAN JOAQUIN ESTUARY

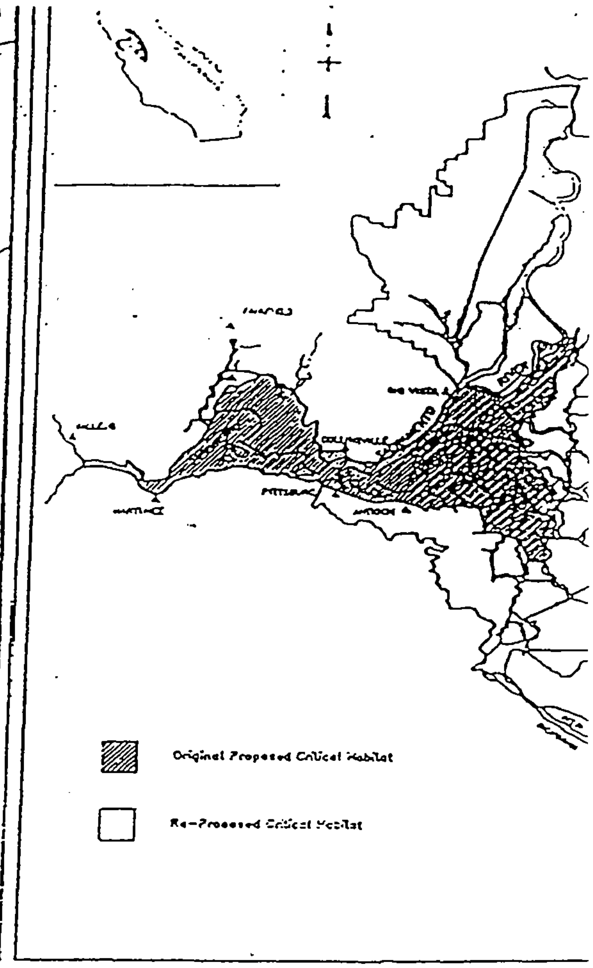


Figure 3b :

Entrapment Zone Position

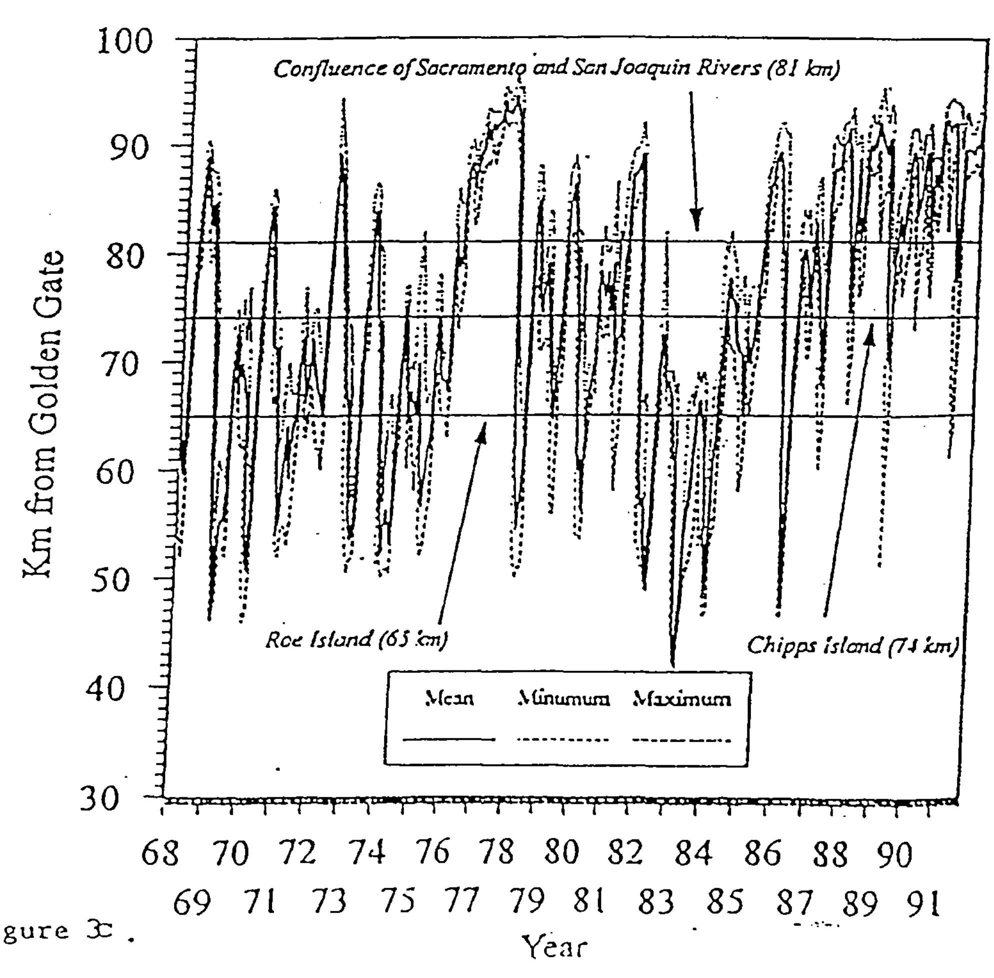


Figure 3c .

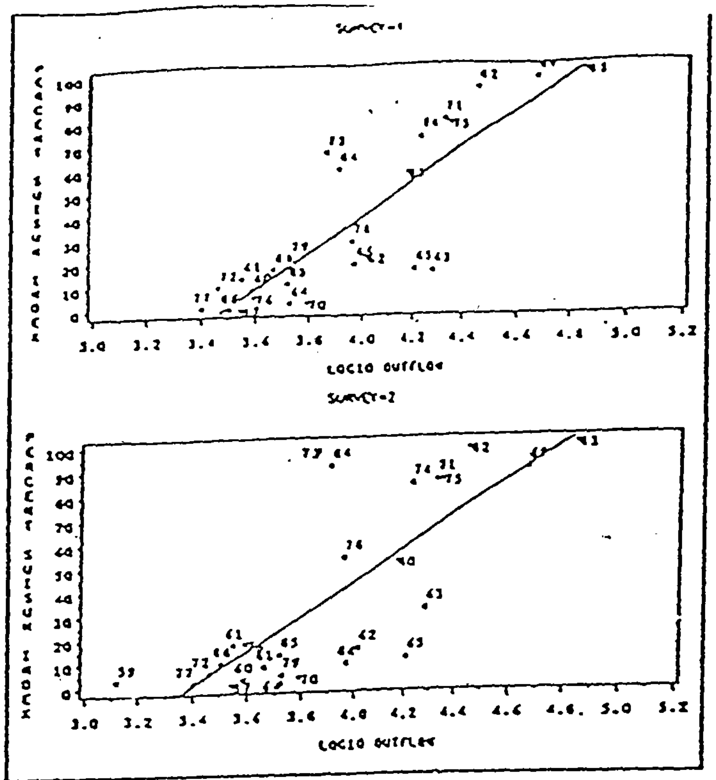


Figure 4a

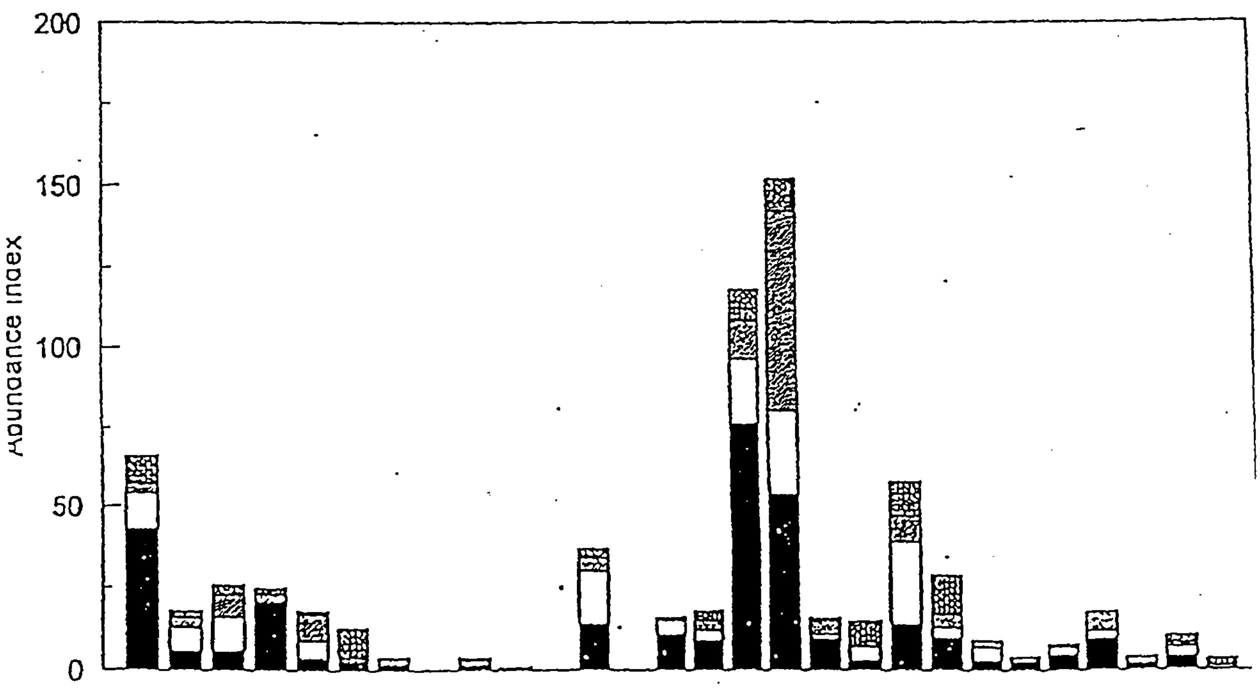
RELATIONSHIP BETWEEN THE PORTION OF DELTA SMELT POPULATION WEST OF THE DELTA AND LOG DELTA OUTFLOW DURING THE SURVEY MONTH FOR SUMMER TOW-NET SURVEY, 1959 TO 1988

For arcsine transformed percentages, $r^2 = 0.74$ for survey 1 and $r^2 = 0.55$ for survey 2.

Source: Sweetnam and Stevens 1993.

Figure 4b.

Splittail Fall Midwater Trawl Abundance Index



Year	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94
Sep ■	43.0	6.0	6.0	21.0	4.0	3.0	2.0		2.0	0.0	0.0	14.0		11.0	8.0	76.0	54.0	10.0	3.0	14.0	10.0	3.0	3.0	5.0	10.0	2.0	4.2	0.0
Oct □	11.0	7.0	10.0	0.0	5.0	0.0	0.0		1.0	0.0	0.0	16.0		4.0	3.0	20.0	26.0	1.0	4.0	25.0	3.0	4.0	1.0	2.0	2.0	0.0	2.8	1.0
Nov	3.0	3.0	7.0	2.0	8.0	1.0	2.0		0.0	1.0	0.0	4.0		1.0	3.0	12.0	62.0	4.0	0.0	8.0	4.0	2.0	0.0	1.0	6.0	2.0	1.2	0.0
Dec	9.0	2.0	3.0	2.0	1.0	9.0	0.0		1.0	0.0	0.0	3.0		0.0	3.0	10.0	10.0	1.0	8.0	11.0	12.0	0.0	0.0	0.0	0.0	0.0	2.4	2.4
ANNUAL	66.0	18.0	26.0	25.0	18.0	13.0	4.0	0.0	4.0	1.0	0.0	37.0	0.0	16.0	18.0	118.0	152.0	16.0	15.0	58.0	29.0	9.0	4.0	8.0	18.0	4.0	[illegible]	[illegible]

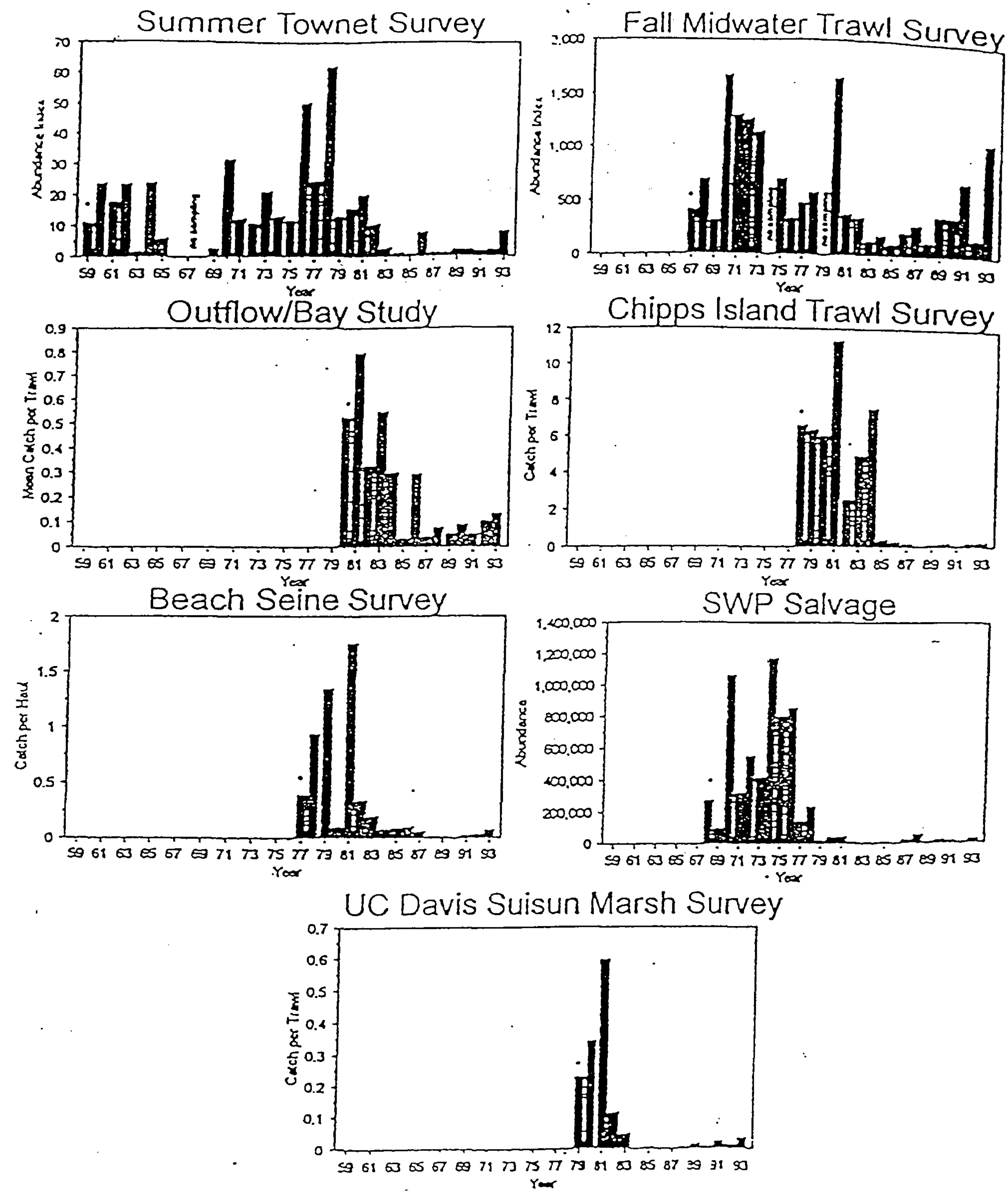


Figure 5a.

TRENDS IN DELTA SMELT POPULATIONS, AS INDEXED BY SEVEN INDEPENDENT SURVEYS

Note that not all surveys were conducted in all years shown.

Source: Department of Fish and Game, updated from Stevens et al 1990.

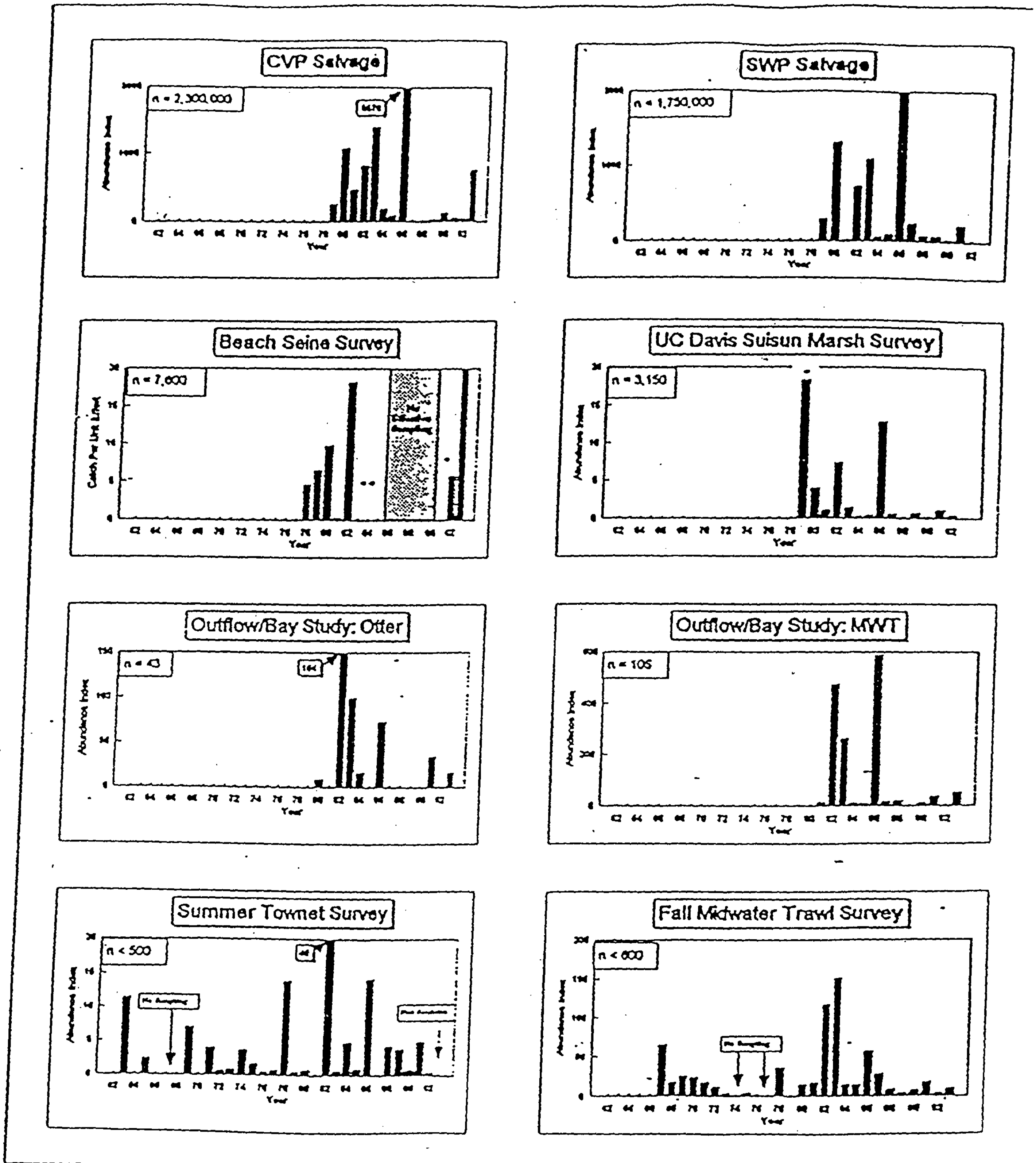


FIGURE 5b· Trends in Young-of-the-Year Splittail Abundance, as Indexed by Eight Independent Surveys

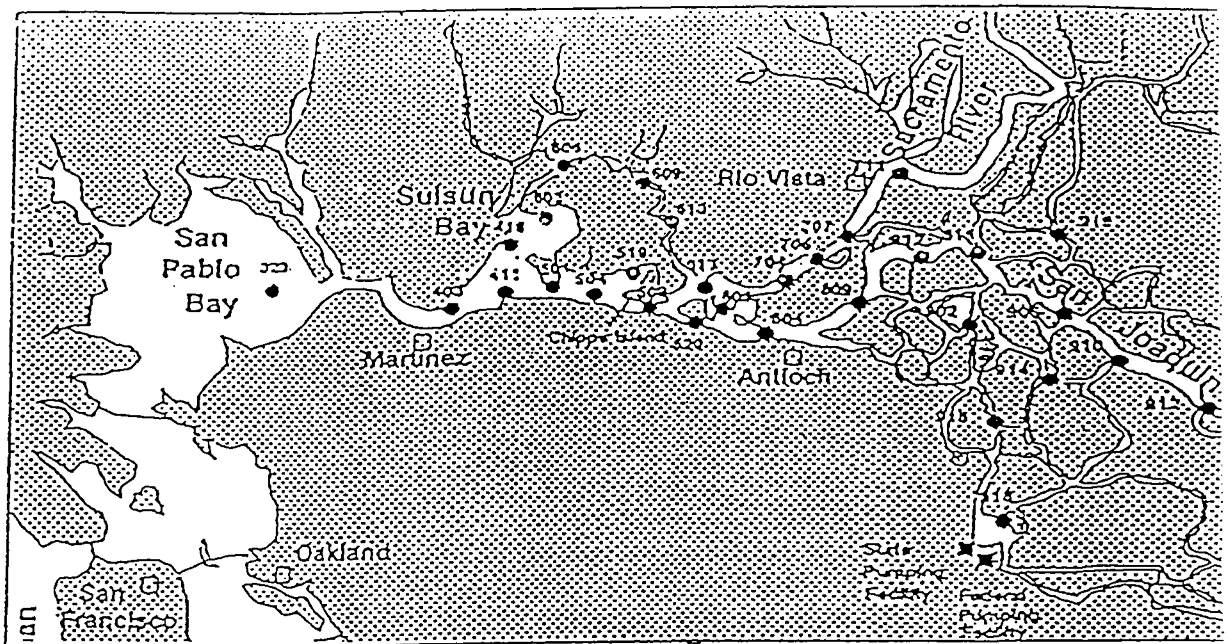


Figure 6a
SUMMER TOW-NET SURVEY SAMPLING SITES IN THE SACRAMENTO-SAN JOAQUIN ESTUARY

Delta Smelt Summer Townet Abundance Index

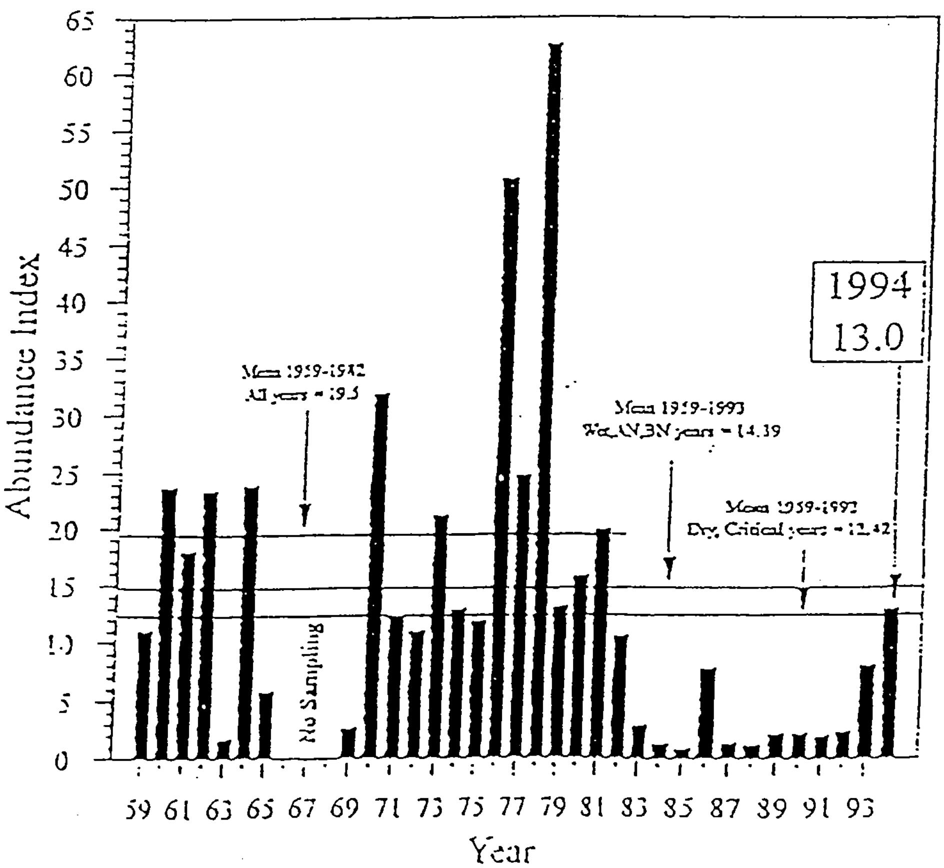


Figure 6b.

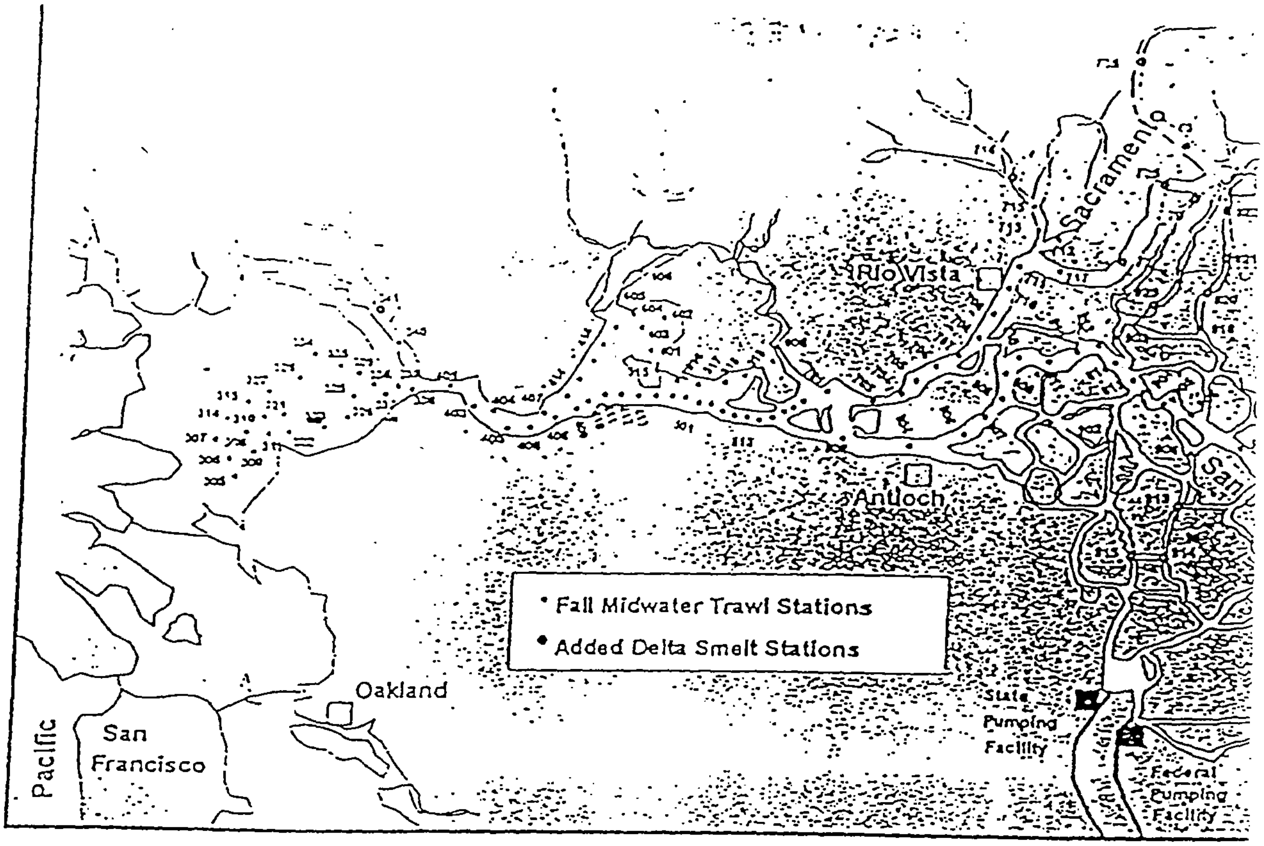


Figure 7a. Fall midwater trawl sampling sites in the Sacramento-San Joaqu

Delta Smelt Fall Midwater Trawl Abundance Inc

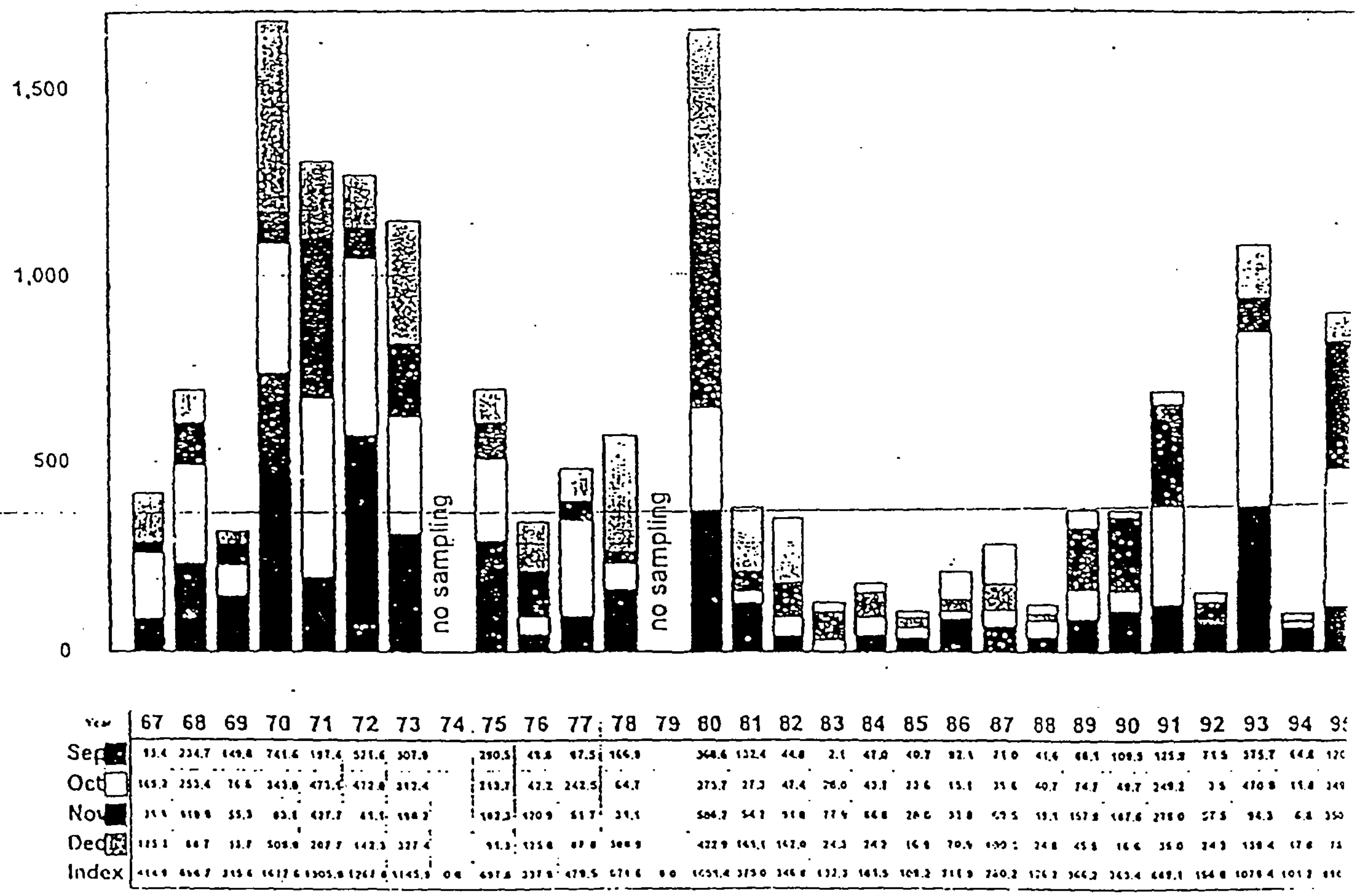


Figure 7b. Fall midwater trawl index showing decline from 1981 to 1992. No
In 1991 and 1993.

Appendix F. Daily Simulations of Delta Wetlands Project Operations

Appendix F. Daily Simulations of Delta Wetlands Project Operations

This appendix presents the results of simulations of daily operations of the Delta Wetlands Project (Alternative 2) for the 1985-1994 simulated period using the Daily Standards and Operations Simulations model (DailySOS). The following text provides a narrative explanation and graphic representation of the results. It describes Delta Wetlands diversions and discharges and the relationship between Delta Wetlands operations and Central Valley Project (CVP) and State Water Project (SWP) operations for each year.

Pursuant to the diversion rules (see Table 3-19), Delta Wetlands cannot divert water to storage unless there is available surplus water (as defined in the Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary [WQCP]) and the X2 location criteria have been met. The timing and magnitude of diversions are also limited by the amount of available surplus water, the amount of Delta outflow, Delta Cross Channel (DCC) gate operations, and the amount of Delta inflow.

According to the discharge rules (see Table 3-19), Delta Wetlands discharges for export are limited to permitted export capacity and a maximum calendar-year total of 250 thousand acre-feet (TAF). Delta Wetlands discharges from Bacon Island are also restricted by the amount of San Joaquin River inflow, and discharges from Webb Tract are prohibited from January through July.

For project simulations, Bacon Island diversions are assumed to be made first. Webb Tract diversions would then be made using any remaining diversion capacity under the final operations criteria (FOC). Several of the criteria are more restrictive if the fall midwater trawl (FMWT) delta smelt index is less than 239; however, because the FMWT index value cannot be calculated, the model assumes a FMWT index greater than 239 for the daily simulations. Likewise, the FOC terms include criteria that limit diversions if delta smelt are located near the Delta Wetlands islands during monitoring; the criteria also give the California Department of Fish and Game (DFG) the discretion to limit diversions for 15 days based on San Joaquin River flows. Because these conditions are not predictable, they also were not modeled in the daily simulation.

The 1985-1994 period was chosen because it includes some characteristically dry years (e.g., 1989 through 1992) and some moderately wet years (e.g., 1985, 1986, 1993). For each year, four figures are shown. The first shows Delta Wetlands daily operations (diversion, discharge to export, and storage) as a function of excess inflow (i.e., available surplus water) and unused permitted export capacity, and the second shows the correlating X2 position. The excess inflow is greater than the minimum outflow and within the allowable amount of exports as a percentage of inflow (i.e., E/I ratio). The "Baseline X2" position in the second figure is the modeled position without the Delta Wetlands Project; the "Adjusted X2" position shows the modeled X2 position with daily Delta Wetlands operations. The third figure for each year shows simulated daily Delta Wetlands operations with simulated daily CVP and SWP operations. This figure demonstrates how the Delta Wetlands Project would operate in relation to SWP and CVP exports, as controlled by outflow limits, the E/I ratio limits, and San Luis Reservoir operations. The fourth figure shows the simulated Delta Wetlands discharges to export in addition to the combined SWP and CVP deliveries from exports and San Luis Reservoir operations modeled by DWRSIM. The Delta Wetlands Project is always modeled as an independent project, and not as an integrated element of assumed SWP and CVP operations (see Chapter 2). To show the maximum possible daily operations of Delta Wetlands as an independent project, Delta Wetlands exports are assumed not to be limited by delivery deficits.

Note that the vertical lines in the graphs divide the years into equal increments representing 31 days. This results in the spring and summer months appearing to begin later than they should (i.e., the lines are shifted to the right of the beginnings of the months). Refer to Table 3-20 in Chapter 3 for more precise information on timing of simulated diversions and discharges.

DELTA WETLANDS 1985 OPERATIONS

Figure F-1a illustrates the simulated daily Delta Wetlands operations for 1985. The available surplus water for diversion is shown by the open triangles ("Excess Inflow"). The unused permitted export capacity is shown by the open diamonds ("Unused Export Capacity"). There is excess inflow (i.e., available surplus water) in November, and Delta Wetlands diversions begin after the X2 position moves downstream of Chipps Island (kilometer [km] 74) in late November (Figure F-1b). Figure F-1a shows that the initial Bacon Island and Webb Tract diversions start in late November and continue into December. The Delta Wetlands diversion is limited to 5,500 cubic feet per second (cfs) for 5 days pursuant to the DCC rule, but because Delta inflows are less than 50,000 cfs and the DCC gates are closed, the maximum diversion is limited to 4,000 cfs. The Delta Wetlands diversion rate is increased above 4,000 cfs for a few days in November when Delta inflows are greater than 50,000 cfs. The diversion rate is assumed to decrease as the storage reservoir fills.

As shown in Figure F-1a, there was a short period for Delta Wetlands discharges to export from Bacon Island in late December and late January, but the island refilled quickly. Both Delta Wetlands islands are simulated to be full from February through May (with some evaporative losses). Bacon Island discharges are simulated in June and are limited to 50% of San Joaquin River inflows (i.e., less than 1,000 cfs). The Bacon Island and Webb Tract discharges simulated in July are limited to 75% of the unused permitted export capacity. The discharge rate is assumed to be reduced as the reservoir islands are emptied. Bacon Island and Webb Tract are simulated to be empty at the end of July. Total Delta Wetlands discharges to export were 17 TAF from October through December and 220 TAF from January through September of 1985. This result is approximately 21% greater than the monthly model's estimate of 195 TAF of Delta Wetlands discharges to export in 1985 (Table 3-20), and the models show different monthly patterns for diversions and discharges. The monthly model allowed exports in March, but San Luis Reservoir was full and this is not a likely period for additional exports. The monthly model overestimated June exports because San Joaquin River flows limited discharges on a daily basis during that time.

Figure F-2 shows the allowable combined SWP and CVP exports for 1985 constrained by the permitted export capacity, the minimum required Delta outflow, and the maximum allowed E/I ratio, which is computed with a 15-day moving average inflow. Delta Wetlands operations are shown as additional diversions above the permitted SWP and CVP exports in November through February, and as additional exports in June and July (with a small increment in December and January) (Figure F-2a). These 1985 daily simulated operations illustrate Delta Wetlands' ability to capture water that is in excess of the permitted export capacity, but within the allowable E/I ratio (during major storm events), and to provide water for export during the summer period of reduced inflows. Figure F-2b shows the additional potential delivery of water from Delta Wetlands discharges to export. The historical 1985 delivery is 5,506 TAF (as shown by the thin line) and the DWRSIM 771 estimated monthly delivery pattern is 6,350 TAF (as shown by the light shaded values). The additional Delta Wetlands exports are shown by the dark shaded area. Total Delta Wetlands discharges to export of 237 TAF were simulated for 1985. Most of the additional Delta Wetlands exports are simulated to occur near the peak demand period (June and July), and available water for delivery south of the Delta would increase by about 4% with the Delta Wetlands exports.

DELTA WETLANDS 1986 OPERATIONS

Figure F-3 illustrates the simulated Delta Wetlands operations under the FOC diversion and discharge measures for water-year 1986. Initial Delta Wetlands diversions occur in February, after the X2 location has been downstream of Chipps Island (km 74) for 10 days (Figure F-3b). The diversions are limited to 5,500 cfs for 5 days pursuant to the DCC rule, and the Delta Wetlands storage reservoirs are both filled in February. Bacon Island discharge begins in June; discharge is limited to 50% of the available unused permitted export capacity. Webb Tract discharge begins in July.

Figure F-4 shows Delta Wetlands operations with the combined SWP and CVP exports and a south-of-Delta delivery pattern. The monthly simulated DWRSIM CVP and SWP delivery is 5,155 TAF for 1986, and the daily historical delivery for 1986 is 4,570 TAF (Figure F-4b). The daily simulated Delta Wetlands discharges to export of 206 TAF would increase south-of-Delta delivery by 4%. The monthly model estimated Delta Wetlands discharges for export during 1986 as 212 TAF. The months of Delta Wetlands exports simulated in the monthly model were also June and July, but more June exports were simulated by the monthly model than the daily model because the percentage of unused export capacity limited June exports.

DELTA WETLANDS 1987 OPERATIONS

Figure F-5 illustrates simulated Delta Wetlands operations under the FOC diversion and discharge measures for water-year 1987. There are two major storm inflows, with available surplus flows in February and March. The initial Delta Wetlands diversions do not occur until late February because the X2 location does not reach Chipps Island (km 74) until the middle of February and the 10-day delay period extends to about the end of the first storm. The Delta Wetlands diversions in March are limited by the allowable E/I ratio of 35% and the FOC measure that limits diversions to 50% of available surplus water. Bacon Island is simulated to fill in March and begins to discharge in June; discharge is limited to 50% of the San Joaquin River inflow. There was not enough Delta Wetlands diversion capacity to fill Webb Tract during March.

Figure F-6 shows Delta Wetlands operations with the combined SWP and CVP exports and a south-of-Delta delivery pattern. Results of the daily model indicate that San Luis Reservoir is full in February, so the full CVP and SWP export capacity cannot be used. CVP and SWP pumping is limited to the monthly deliveries. This allows Delta Wetlands to divert water once the X2 position is downstream of Chipps Island for 10 days. Therefore, Delta Wetlands may divert water in March within the allowable E/I limits. The monthly simulated DWRSIM delivery of 5,775 TAF in 1987 is similar to the daily historical delivery of 5,837 TAF (Figure F-6b). The daily simulated Delta Wetlands discharges to export of 115 TAF, including 16 TAF in October from diversions at the end of September (see Figure F-3a), would have increased total south-of-Delta delivery in 1987 by 2%. The monthly model estimated Delta Wetlands discharges for export during 1987 as only 26 TAF, with June as the month of Delta Wetlands exports. The daily estimated diversions in March were sufficient to fill Bacon Island and provide approximately 70 TAF more exports in June, July, and August than simulated in the monthly model.

DELTA WETLANDS 1988 OPERATIONS

Figure F-7 illustrates simulated Delta Wetlands operations under the FOC diversion and discharge measures for water-year 1988. There is only one major storm inflow, with available surplus flow in January. The X2 location does not reach Chipps Island (km 74) until the middle of the storm event and Delta Wetlands diversions do not begin until after the required 10-day waiting period, which extends to almost the end of the storm. Total Delta Wetlands diversions are 16 TAF in January and are simulated to be discharged in early February.

Figure F-8 shows simulated Delta Wetlands operations with the combined SWP and CVP exports and a south-of-Delta delivery pattern. The monthly simulated DWRSIM delivery of 4,165 TAF in 1988 is less than the historical delivery of 5,780 TAF (Figure F-8b). The monthly model estimated Delta Wetlands discharges for export during 1988 as 184 TAF, with the diversion simulated in January. In the monthly simulation, the months of Delta Wetlands exports were February and March, because the SWP and CVP exports are constrained by the 35% E/I limit. The monthly model overestimated Delta Wetlands diversions because the 10-day waiting period for the X2 criteria cannot be simulated in the monthly model.

DELTA WETLANDS 1989 OPERATIONS

Figure F-9 illustrates simulated Delta Wetlands operations under the FOC diversion and discharge measures for water-year 1989. There is one major storm inflow, with available surplus flow in March, and a smaller storm in early August. Delta Wetlands diversions are not allowed until the middle of March because the X2 location does not reach Chipps Island (km 74) until the middle of the storm event, and the 10-day waiting period extends to almost the end of March. Delta Wetlands diversions simulated in March are 59 TAF. Additional Delta Wetlands diversions of 45 TAF were simulated in August. Bacon Island discharges of 50 TAF were simulated in June, with additional discharges of 37 TAF at the end of August.

Figure F-10 shows Delta Wetlands operations with the combined SWP and CVP exports and a south-of-Delta delivery pattern. The monthly simulated DWRSIM delivery of 4,858 TAF in 1989 is less than the historical delivery of 6,085 TAF (Figure F-10b). The monthly model estimated that the Delta Wetlands discharges for export during 1989 would be 0 TAF. The daily model provides a more accurate estimate of how Delta Wetlands diversions can capture water during the storm inflow periods.

DELTA WETLANDS 1990 OPERATIONS

Figure F-11 illustrates simulated Delta Wetlands operations under the FOC diversion and discharge measures for water-year 1990. There is only one major storm, with available surplus flow in January. Delta Wetlands diversions do not occur because the X2 location never moves downstream of Chipps Island (km 74).

Figure F-12 shows the combined SWP and CVP Delta exports and south-of-Delta delivery pattern. The monthly simulated DWRSIM delivery of 4,216 TAF in 1990 is less than the historical delivery of 5,674 TAF. The monthly model estimated Delta Wetlands discharges for export during 1990 as 0 TAF; the daily model also simulated no Delta Wetlands diversions or discharges in this water year.

DELTA WETLANDS 1991 OPERATIONS

Figure F-13 illustrates simulated Delta Wetlands operations under the FOC diversion and discharge measures for water-year 1991. There is only one major storm, with available surplus flow in March. Delta Wetlands diversions of 12 TAF occur after the X2 location reaches Chipps Island (km 74) a few days before the end of March. Delta Wetlands diversions are prohibited in April and May. Delta Wetlands would discharge 6 TAF for export in June.

Figure F-14 shows the combined SWP and CVP Delta exports and south-of-Delta delivery pattern. The monthly simulated DWRSIM delivery of 2,502 TAF in 1991 is less than the historical delivery of 3,015 TAF. The monthly model estimated Delta Wetlands discharges for export during 1991 as 0 TAF, whereas the daily simulation estimated 6 TAF.

DELTA WETLANDS 1992 OPERATIONS

Figure F-15 illustrates potential Delta Wetlands operations under the FOC diversion and discharge measures for water-year 1992. There is only one major storm, with available surplus flow in February. Delta Wetlands diversions of 5 TAF occur after the X2 location reaches Chipps Island (km 74) a few days before the end of the storm. This water is discharged for export in March.

Figure F-16 shows the combined SWP and CVP Delta exports and south-of-Delta delivery pattern. The monthly simulated DWRSIM delivery of 3,205 TAF in 1992 is similar to the historical delivery of 3,090 TAF. The monthly model estimated Delta Wetlands discharges for export during 1992 as 0 TAF, whereas the daily simulation estimated 5 TAF.

DELTA WETLANDS 1993 OPERATIONS

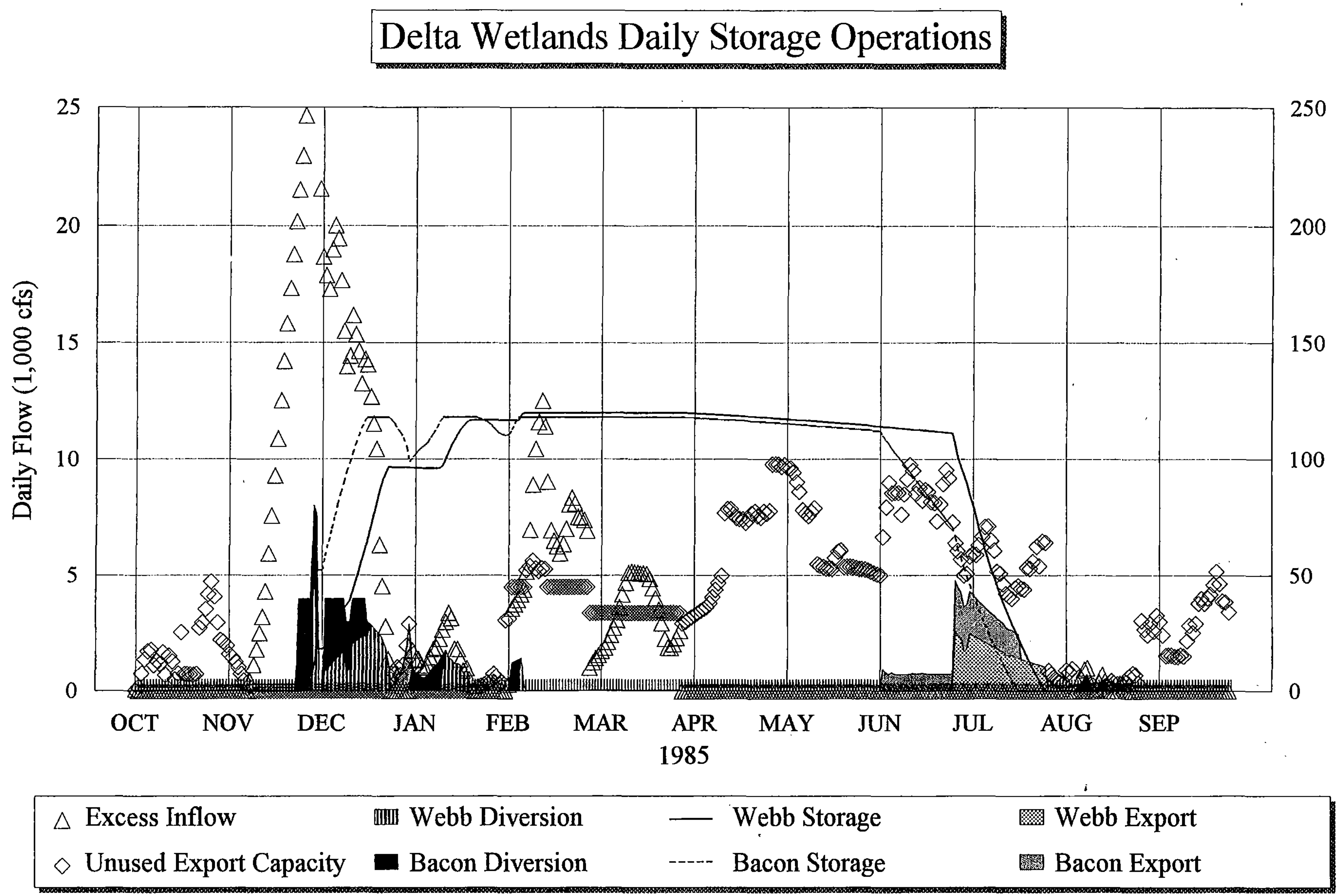
Figure F-17 illustrates potential Delta Wetlands operations under the FOC diversion and discharge measures for water-year 1993. It finally rained again. There was a series of major inflows beginning in January. Simulated Delta Wetlands diversions begin at the end of January, when X2 is downstream of Chipps Island, and continue through February. Both Delta Wetlands reservoir islands are filled by the end of February. Some discharge from Bacon Island is simulated in early March, with refill of 25 TAF at the end of March and another 40 TAF of diversions in early June. Delta Wetlands discharges from Bacon Island and Webb Tract were simulated in late June and July. Delta Wetlands reached its calendar-year total export limit of 250 TAF during July. Bacon Island diverted an additional 26 TAF in August and September, and the Delta Wetlands carryover storage is 65 TAF.

Figure F-18 shows daily simulated Delta Wetlands operations with the combined SWP and CVP Delta exports and a south-of-Delta delivery pattern. The monthly simulated DWRSIM delivery of 5,690 TAF in 1993 is considerably higher than the historical delivery of 3,832 TAF. The 250 TAF of Delta Wetlands exports simulated in March, June, and July would increase south-of-Delta water supply by about 4%. The monthly model estimated Delta Wetlands discharges for export during 1993 as 225 TAF, with all Delta Wetlands diversions in March and all Delta Wetlands discharges for export in July. The daily simulation provides a more accurate picture of the way in which Delta Wetlands could respond to opportunities for diversions and discharges as Delta inflow conditions change during and after major storm events.

DELTA WETLANDS 1994 OPERATIONS

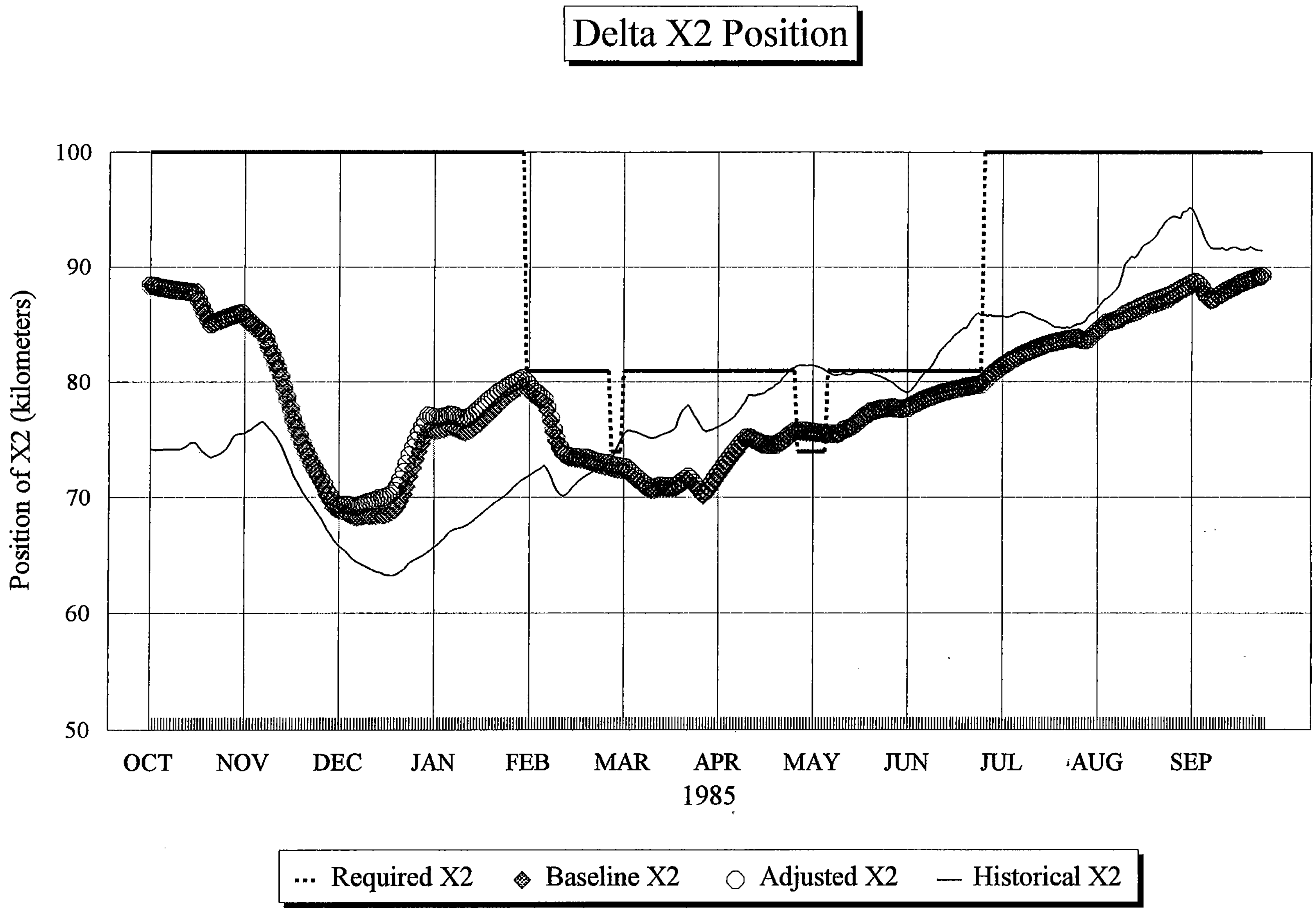
Figure F-19 illustrates potential Delta Wetlands operations under the FOC diversion and discharge measures for water-year 1994. There was only one major inflow event in February and March. Delta Wetlands reservoirs had carryover storage of 65 TAF (Figure F-17). Delta Wetlands exports of 62 TAF were simulated in late October and November. Simulated Delta Wetlands diversions at the end of February and into March were 100 TAF. Discharge from Bacon Island is simulated in June and July, with a minor increment in September, with a total of 90 TAF exported in these months.

Figure F-20 shows daily simulated Delta Wetlands operations with the combined SWP and CVP Delta exports and a south-of-Delta delivery pattern. The monthly simulated DWRSIM delivery of 5,701 TAF in 1994 is higher than the historical delivery of 4,807 TAF. The 153 TAF of Delta Wetlands exports simulated in November and then in May, June, July, and August would increase south-of-Delta water supply by about 3%. The monthly model estimated that Delta Wetlands discharges for export during 1994 would be 76 TAF, with all Delta Wetlands diversions in February and all Delta Wetlands discharges for export in March. The daily simulation modeled available discharge in November from carryover storage and indicated that Delta Wetlands diversions would not occur until March, when San Luis Reservoir was filled. The daily simulation provides a more accurate picture of the way in which Delta Wetlands operations could respond to opportunities for diversions and discharges as Delta inflow and export conditions change during the year.



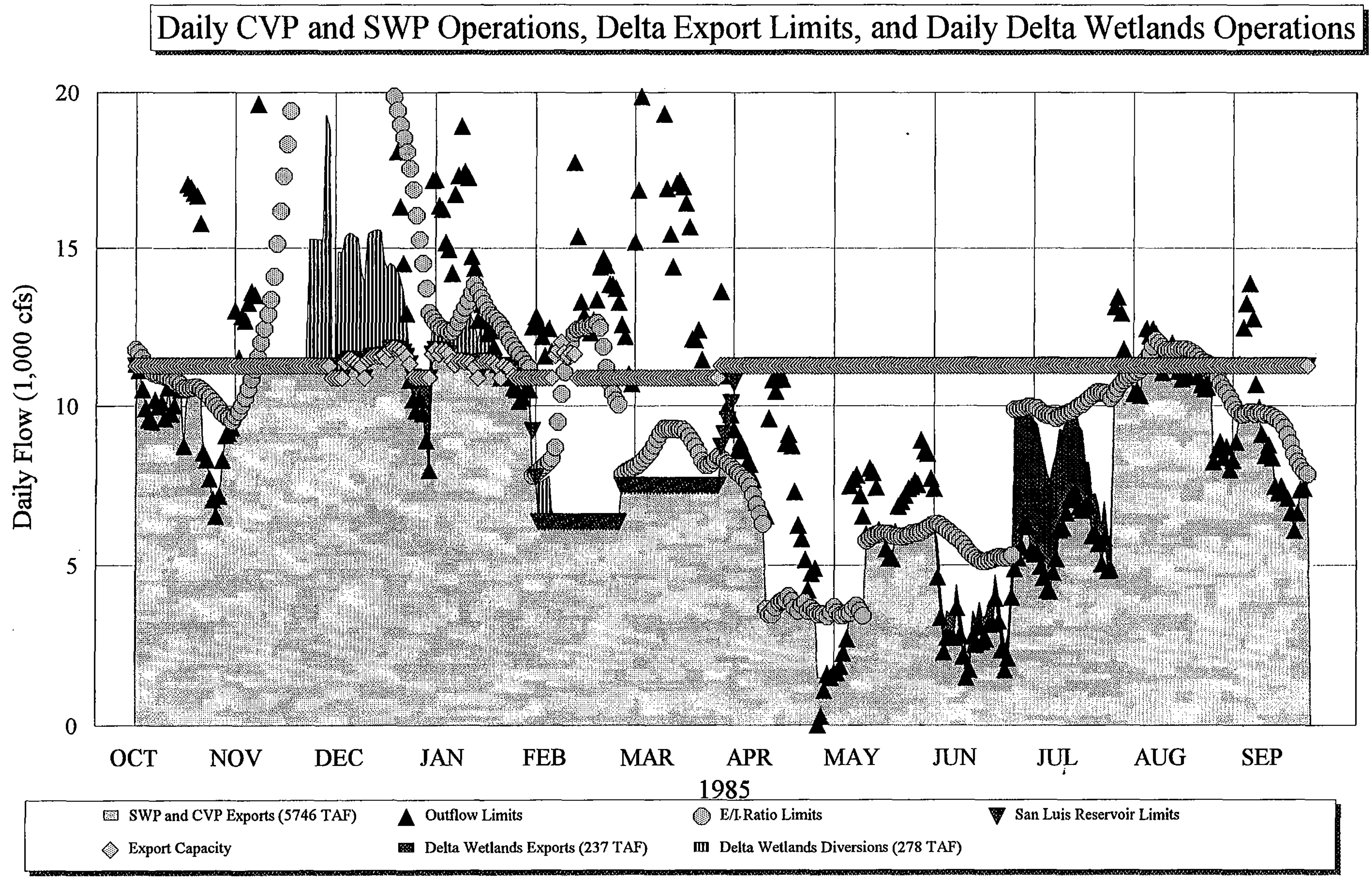
Jones & Stokes

Figure F-1a
Daily Simulated Delta Wetlands Operations and Effect on X2 Position as Allowed under Final Operations Criteria for 1985



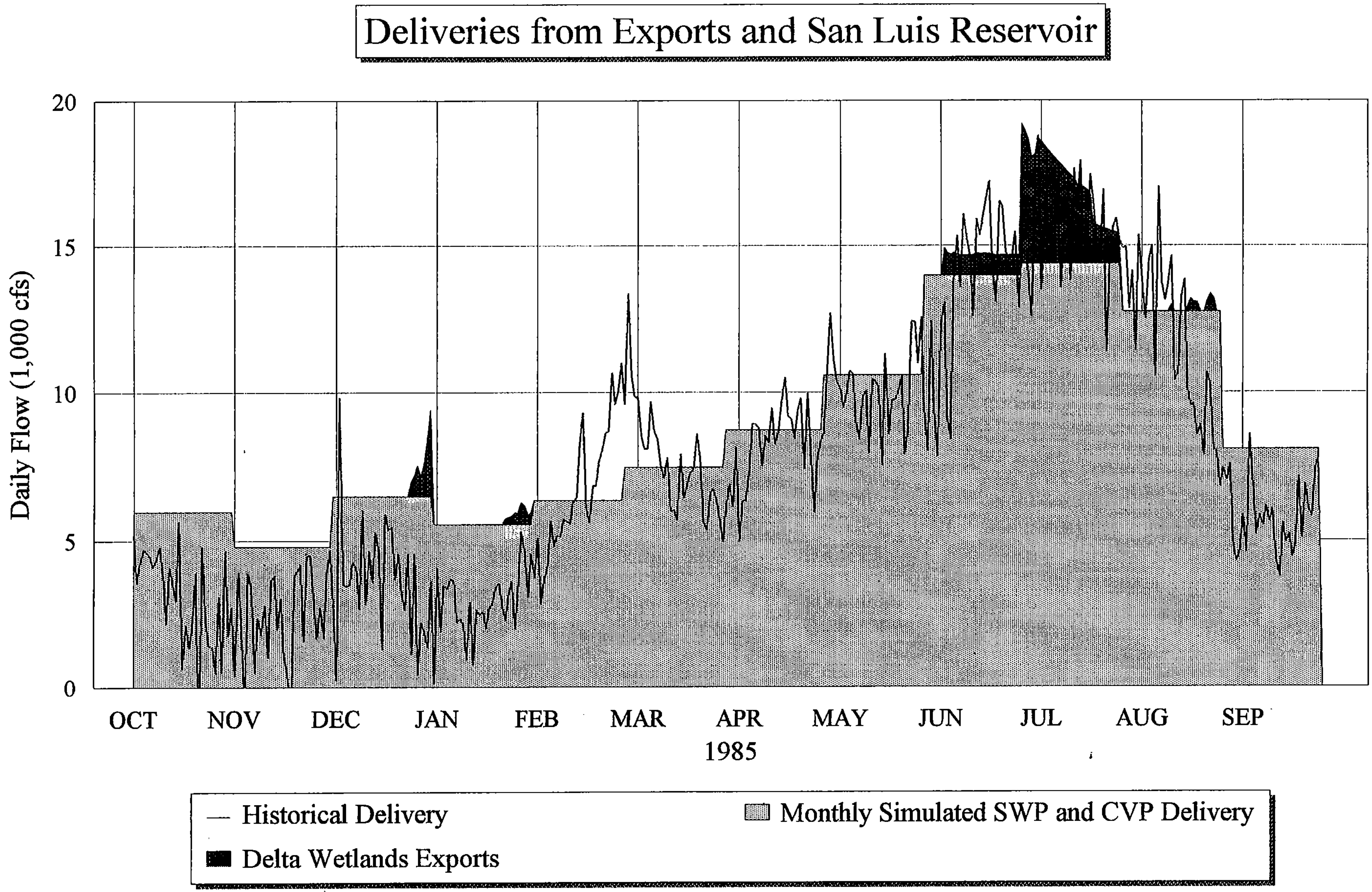
Jones & Stokes

Figure F-1b
Daily Simulated Delta Wetlands Operations and Effect on X2 Position as Allowed under Final Operations Criteria for 1985



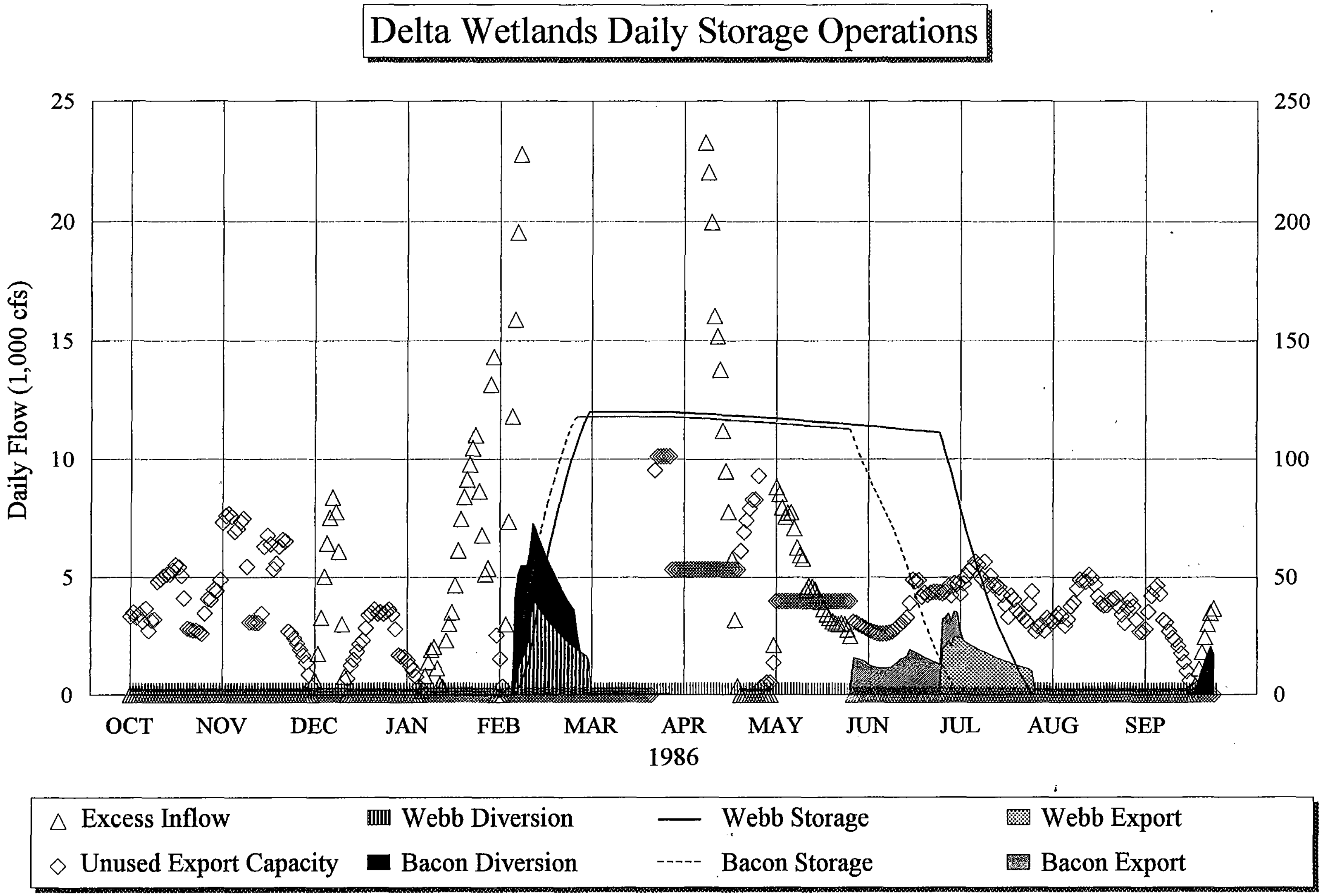
Jones & Stokes

Figure F-2a
Daily Simulated Delta Wetlands Operations with CVP and SWP Project Operations for 1985



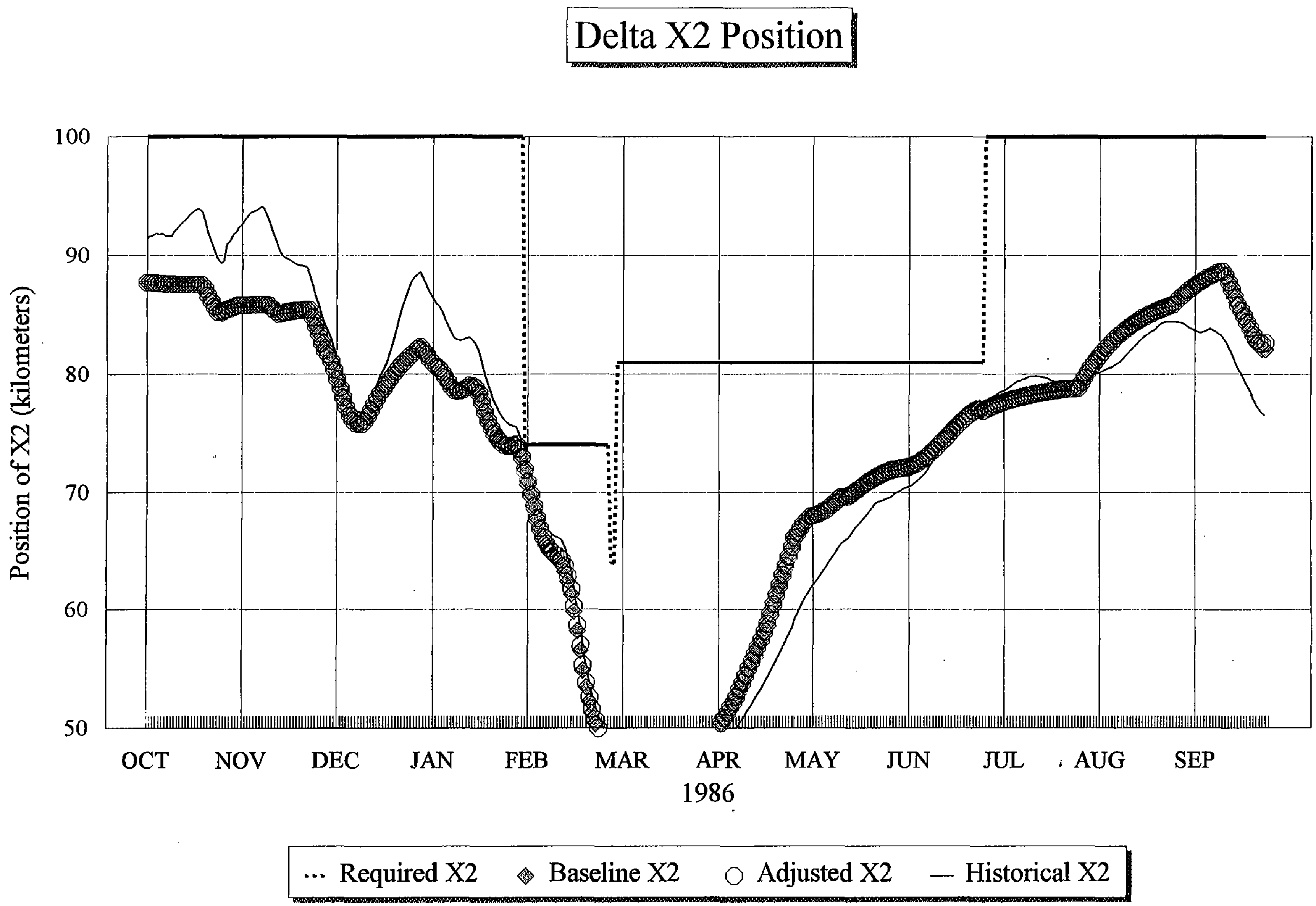
Jones & Stokes

Figure F-2b
Daily Simulated Delta Wetlands Operations with CVP and SWP Project Operations for 1985



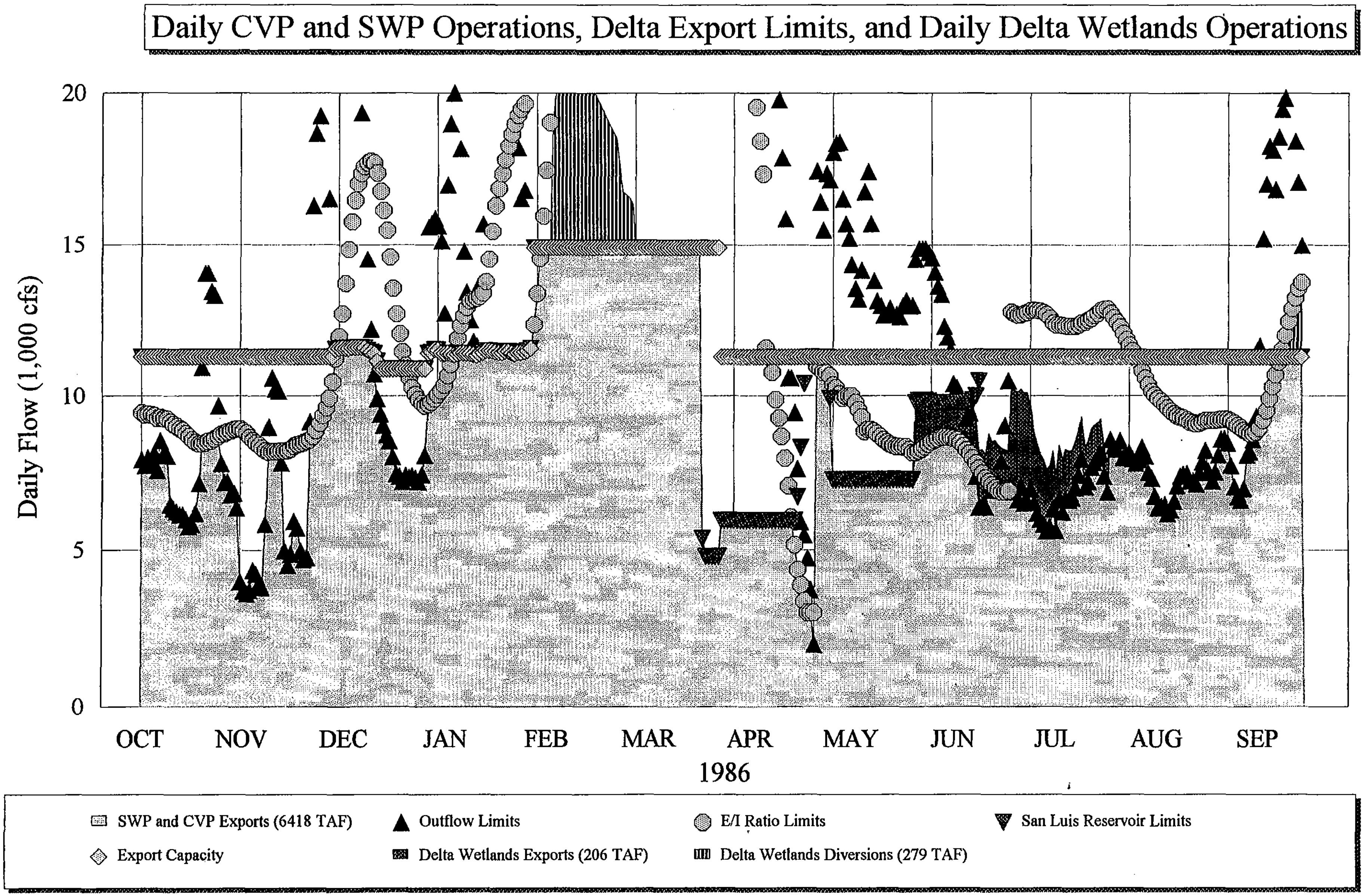
Jones & Stokes

Figure F-3a
Daily Simulated Delta Wetlands Operations and Effect on X2 Position as Allowed under Final Operations Criteria for 1986



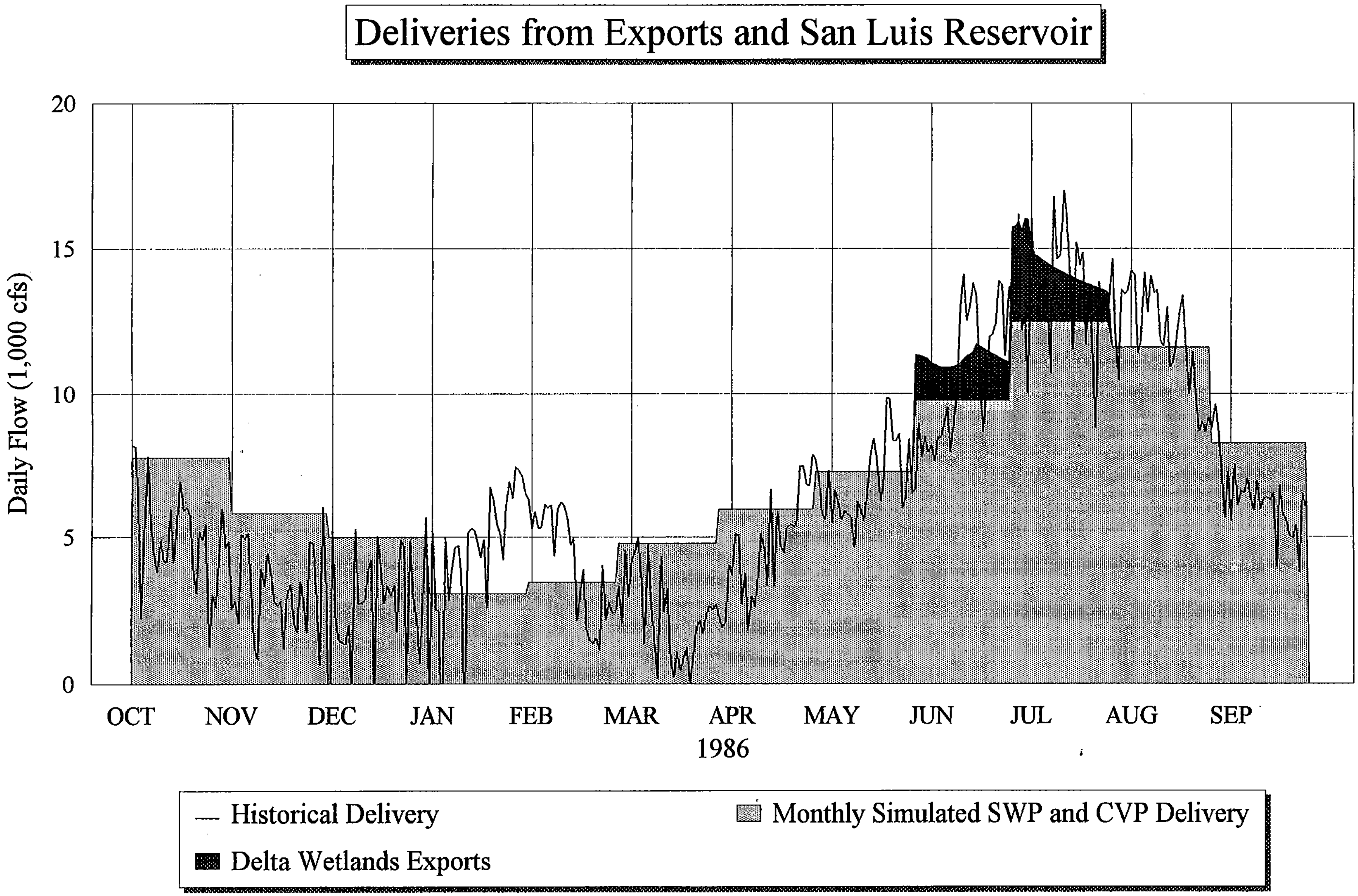
Jones & Stokes

Figure F-3b
Daily Simulated Delta Wetlands Operations and Effect on X2 Position as Allowed under Final Operations Criteria for 1986



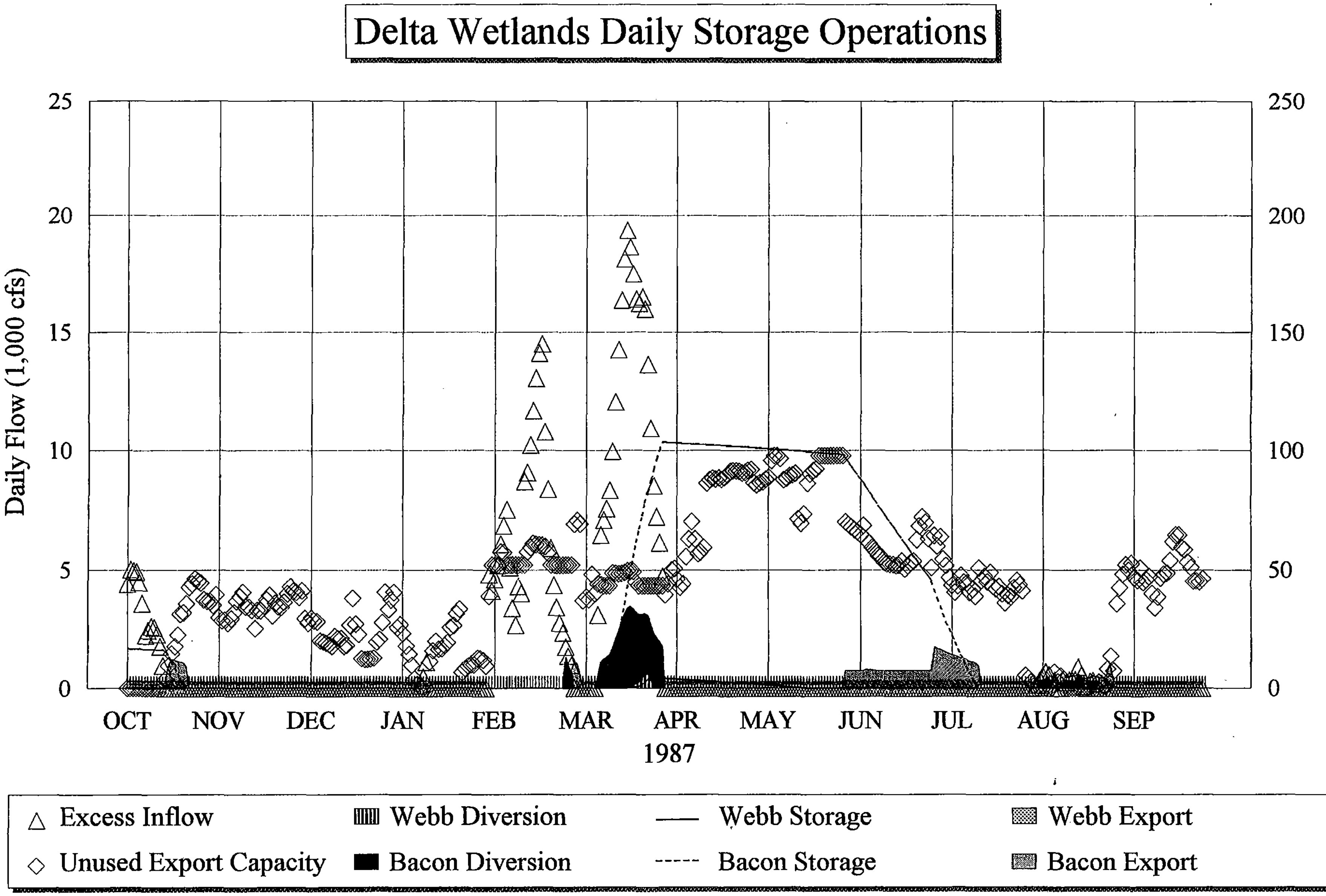
Jones & Stokes

Figure F-4a
Daily Simulated Delta Wetlands Operations with CVP and SWP Project Operations for 1986



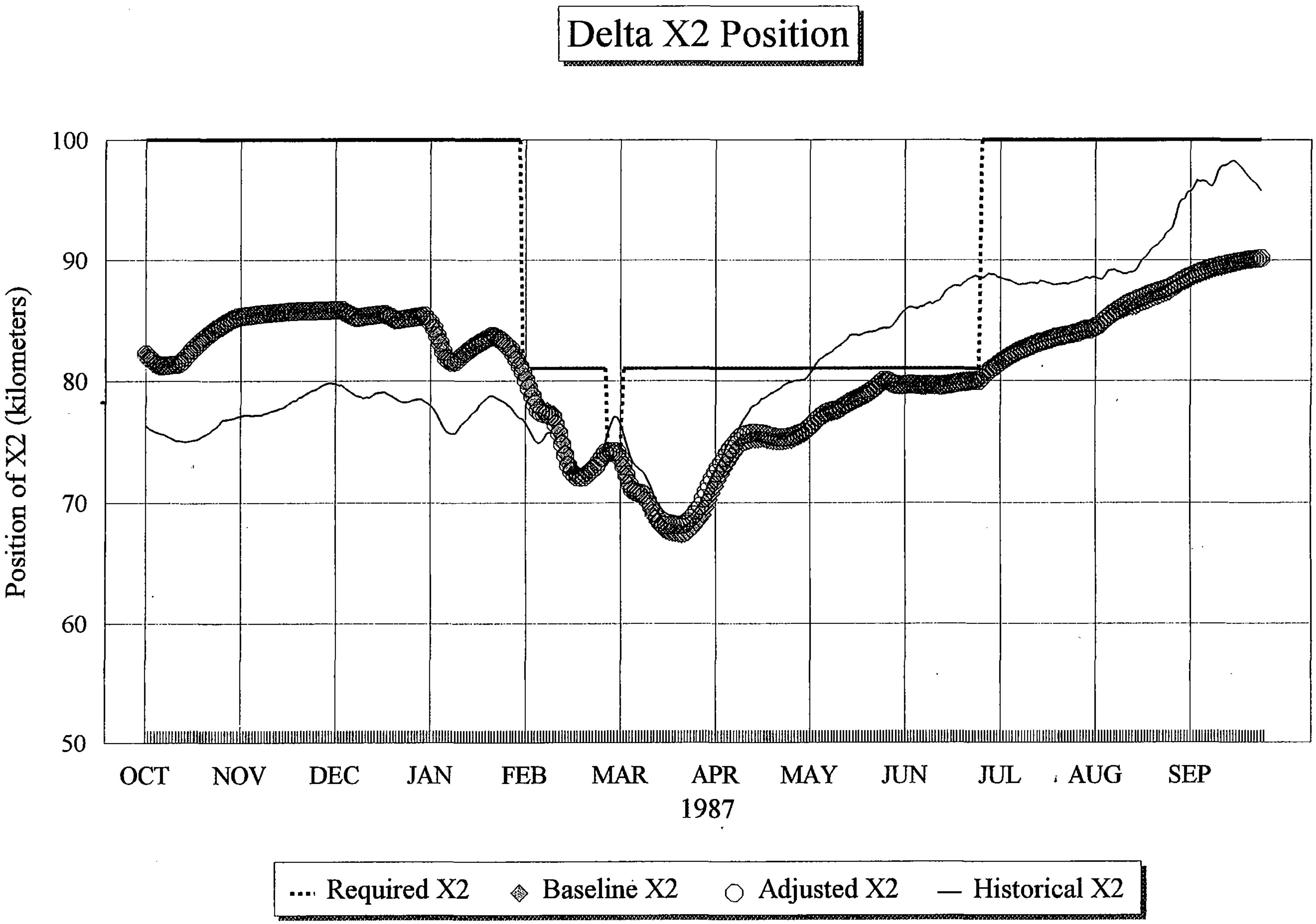
Jones & Stokes

Figure F-4b
Daily Simulated Delta Wetlands Operations with CVP and SWP Project Operations for 1986



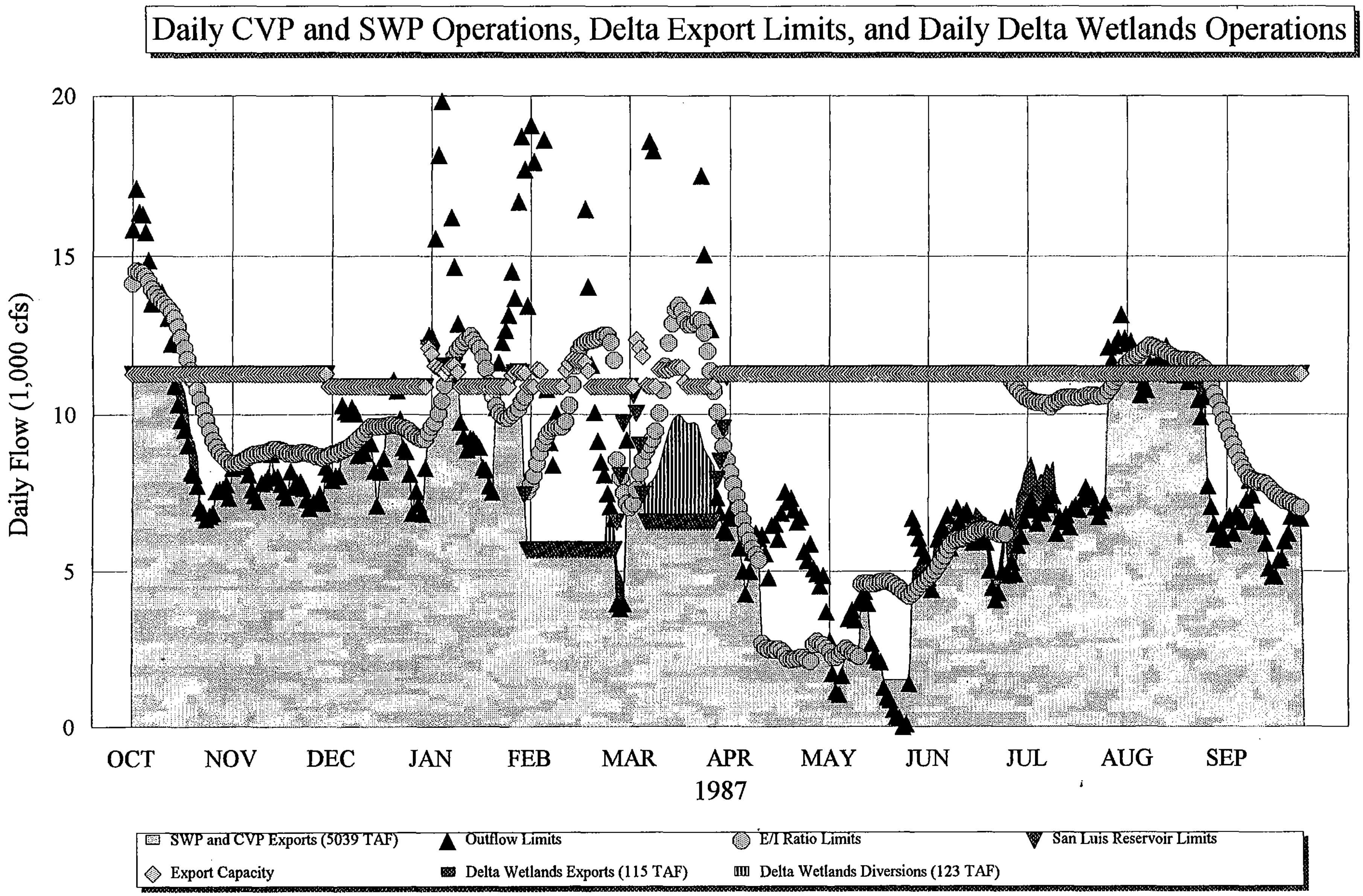
Jones & Stokes

Figure F-5a
Daily Simulated Delta Wetlands Operations and Effect on X2 Position as Allowed under Final Operations Criteria for 1987



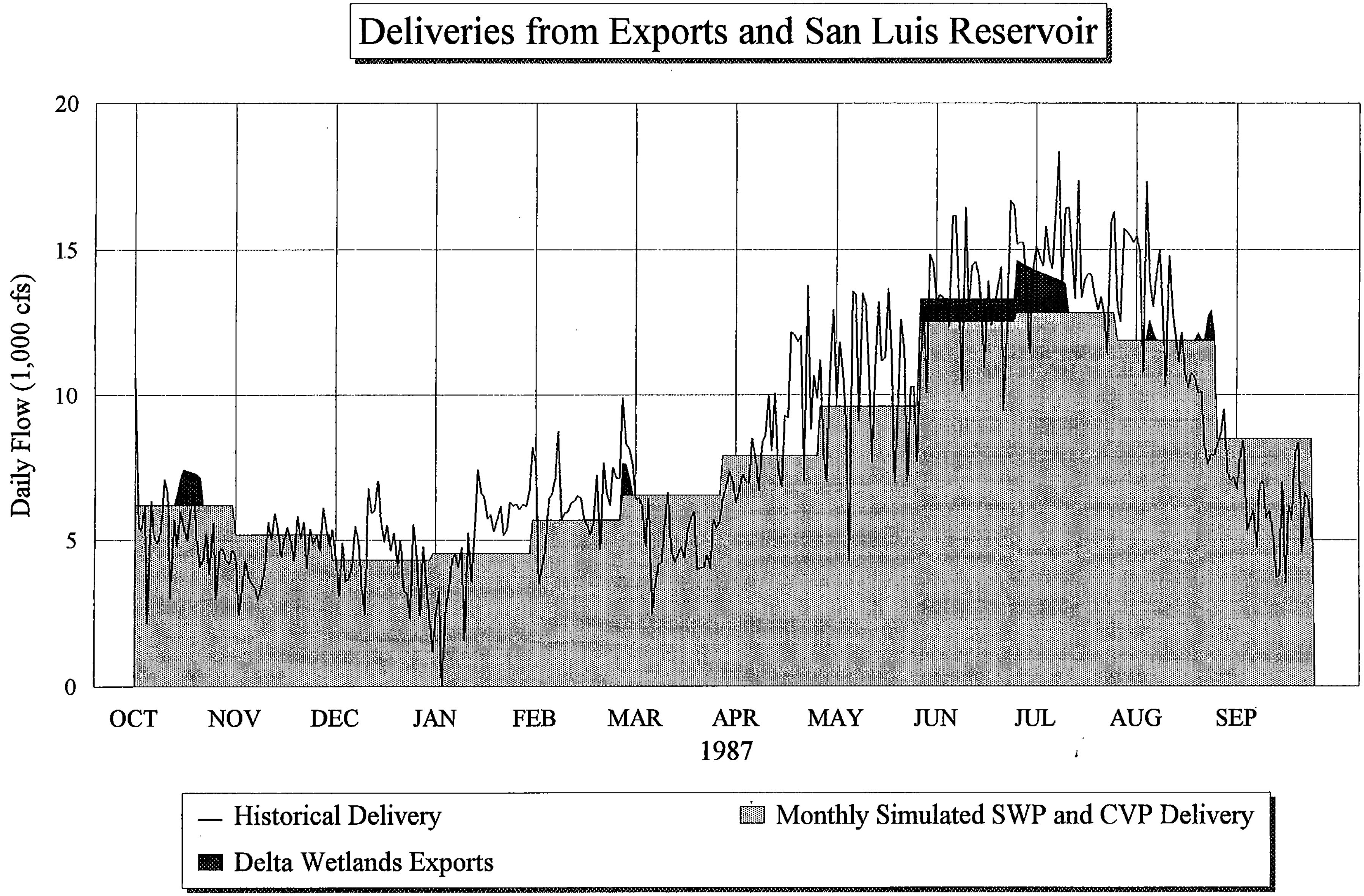
Jones & Stokes

Figure F-5b
Daily Simulated Delta Wetlands Operations and Effect on X2 Position as Allowed under Final Operations Criteria for 1987



Jones & Stokes

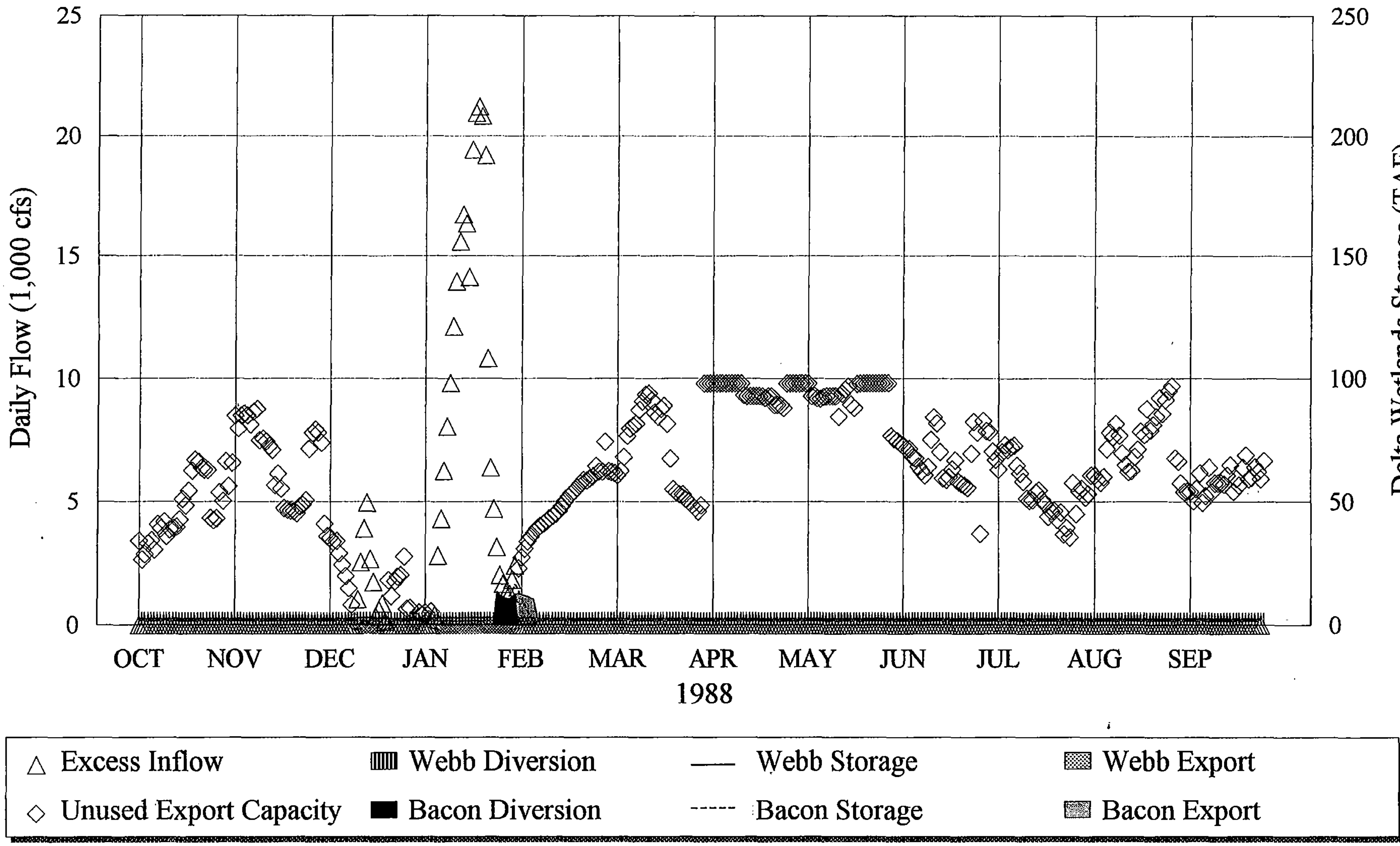
Figure F-6a
Daily Simulated Delta Wetlands Operations with CVP and SWP Project Operations for 1987



Jones & Stokes

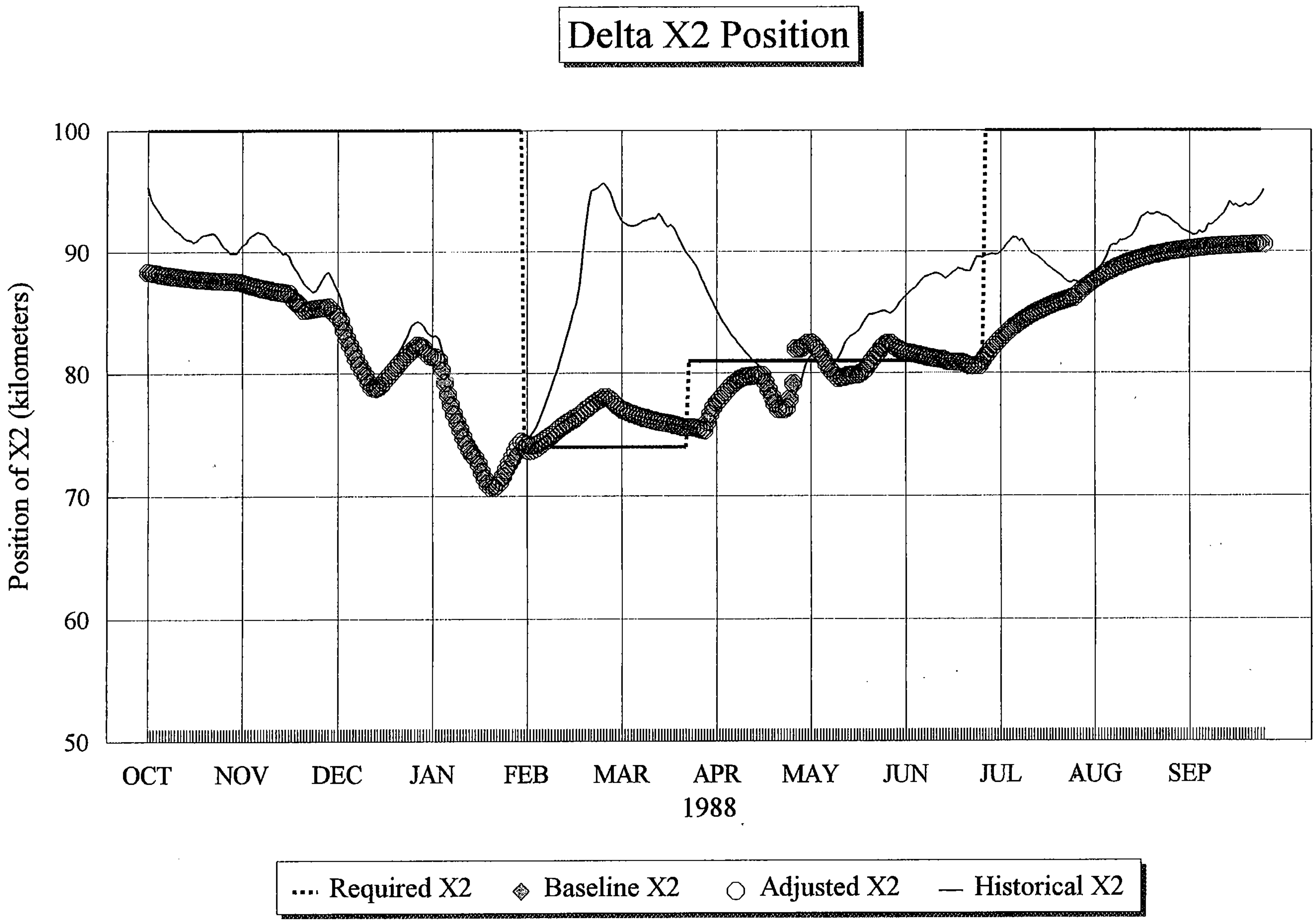
Figure F-6b
Daily Simulated Delta Wetlands Operations with CVP and SWP Project Operations for 1987

Delta Wetlands Daily Storage Operations



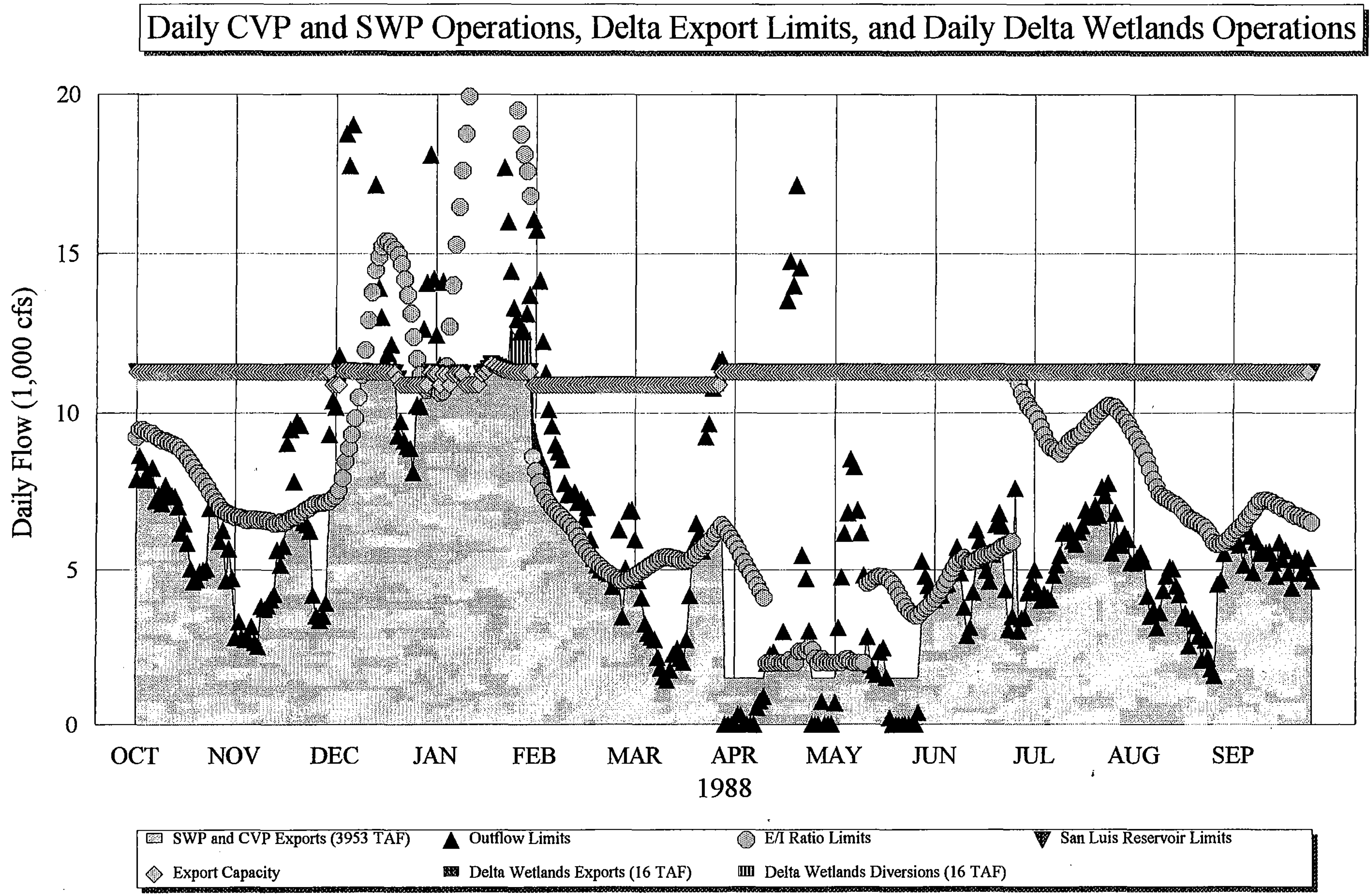
Jones & Stokes

Figure F-7a
Daily Simulated Delta Wetlands Operations and Effect on X2 Position as Allowed under Final Operations Criteria for 1988



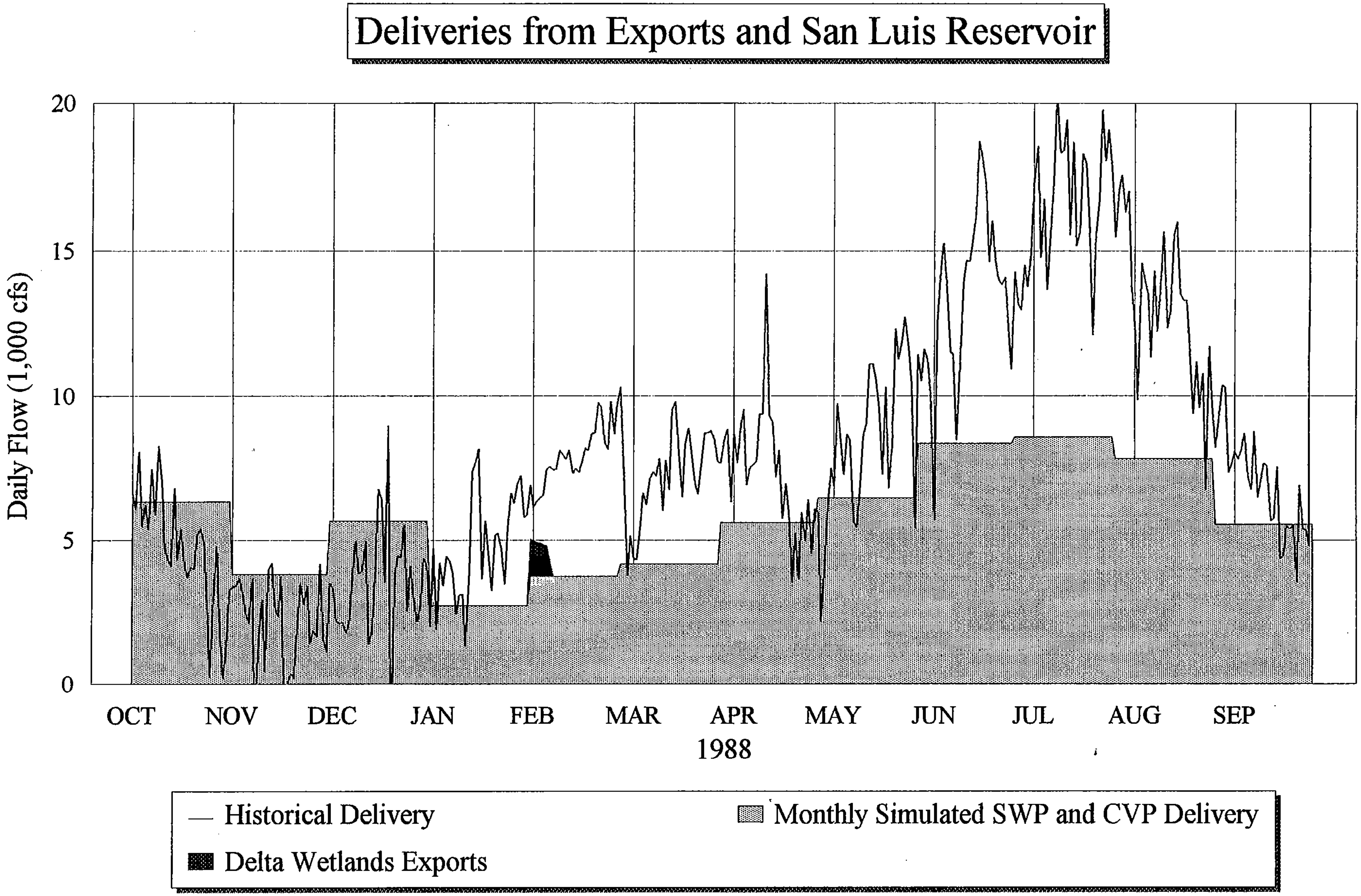
Jones & Stokes

Figure F-7b
Daily Simulated Delta Wetlands Operations and Effect on X2 Position as Allowed under Final Operations Criteria for 1988



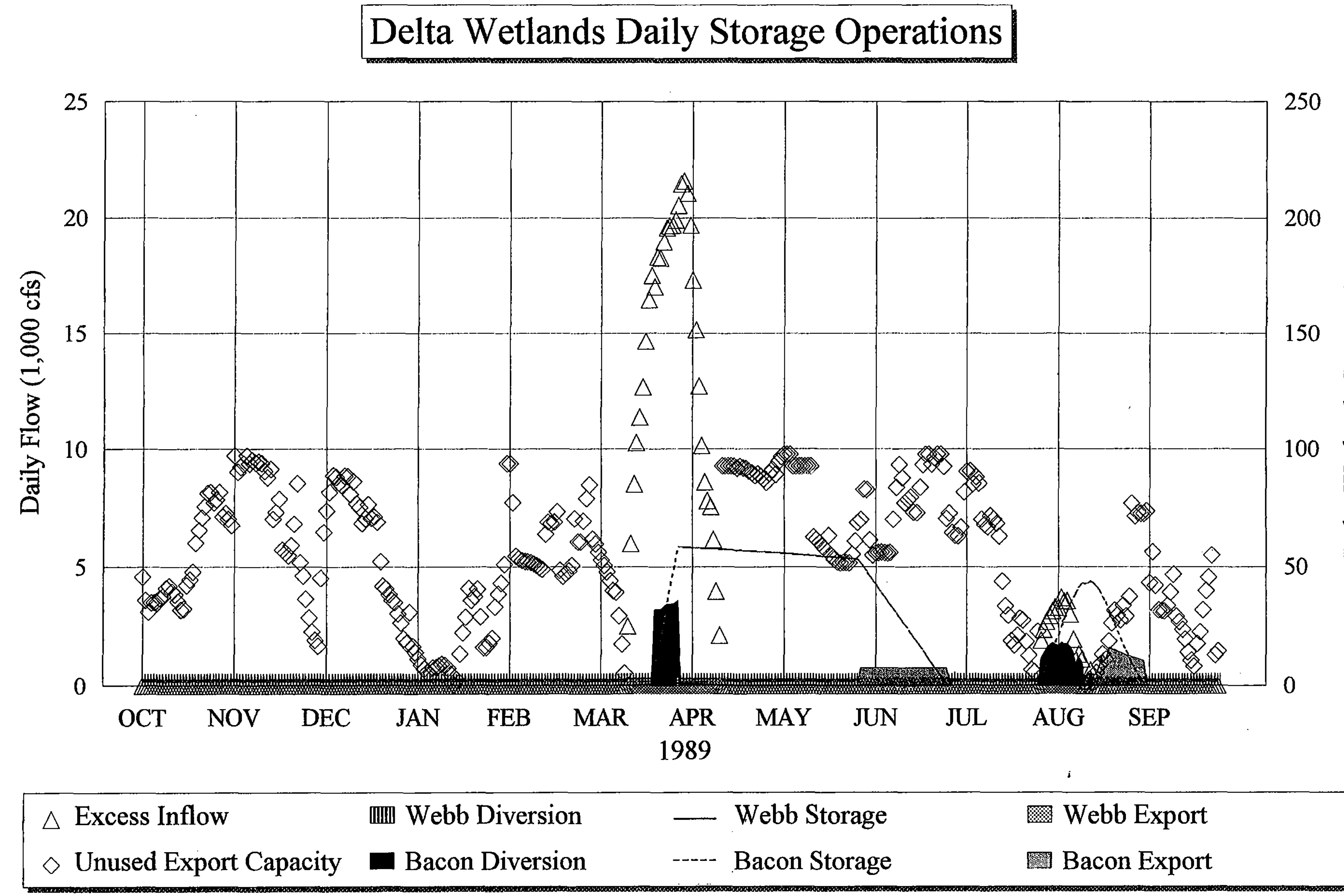
Jones & Stokes

Figure F-8a
Daily Simulated Delta Wetlands Operations with CVP and SWP Project Operations for 1988



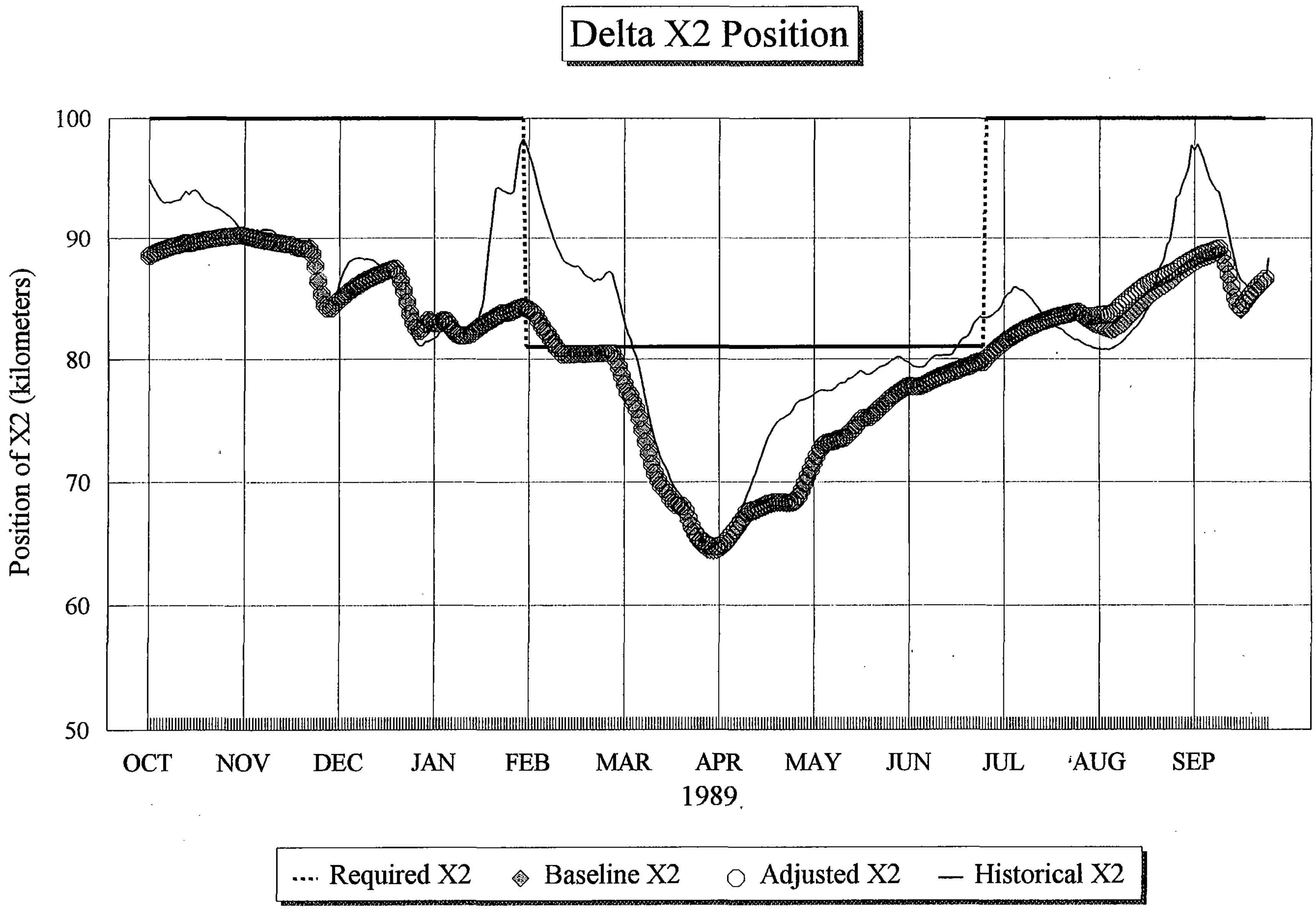
Jones & Stokes

Figure F-8b
Daily Simulated Delta Wetlands Operations with CVP and SWP Project Operations for 1988



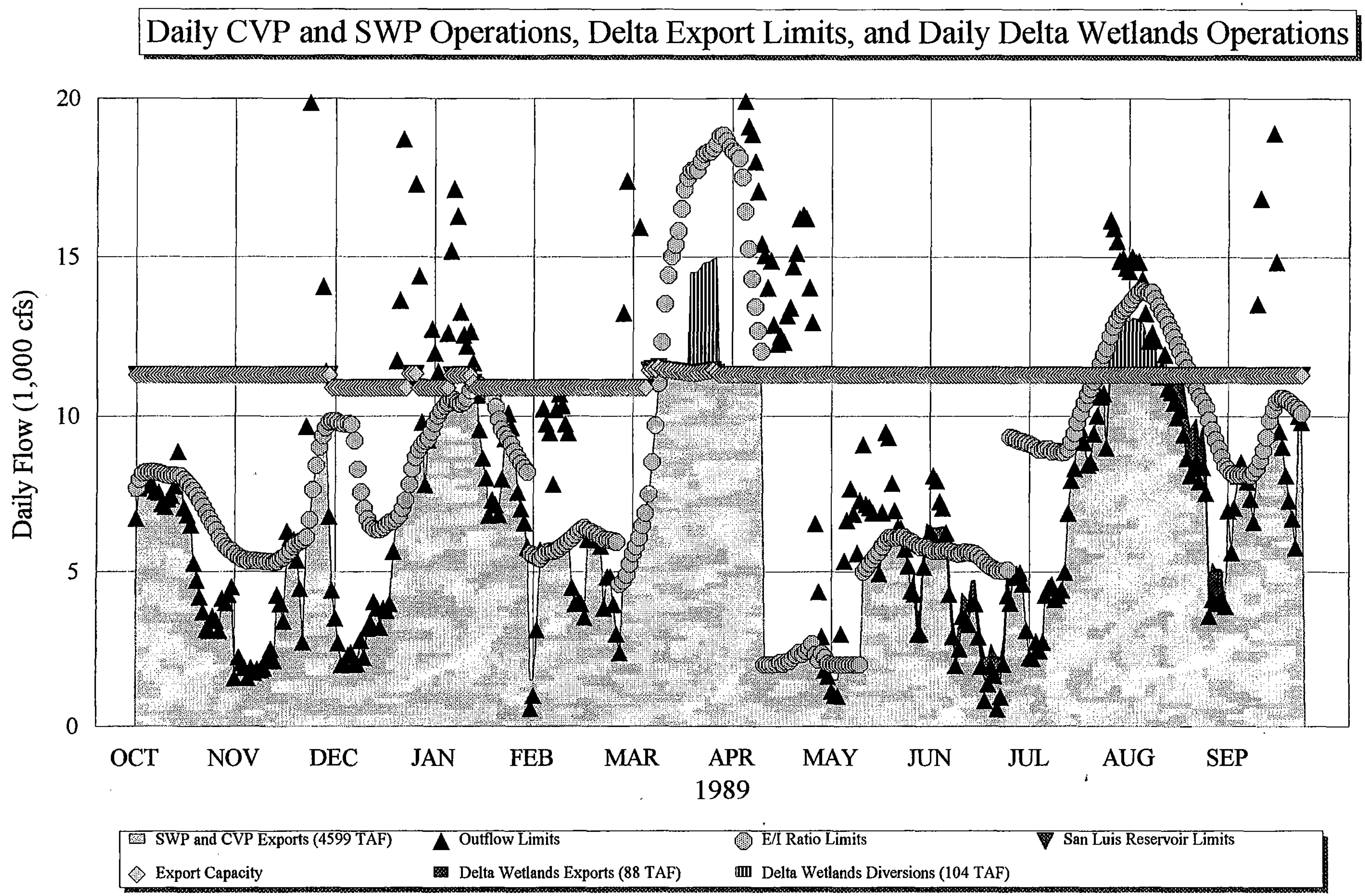
Jones & Stokes

Figure F-9a
Daily Simulated Delta Wetlands Operations and Effect on X2 Position as Allowed under Final Operations Criteria for 1989



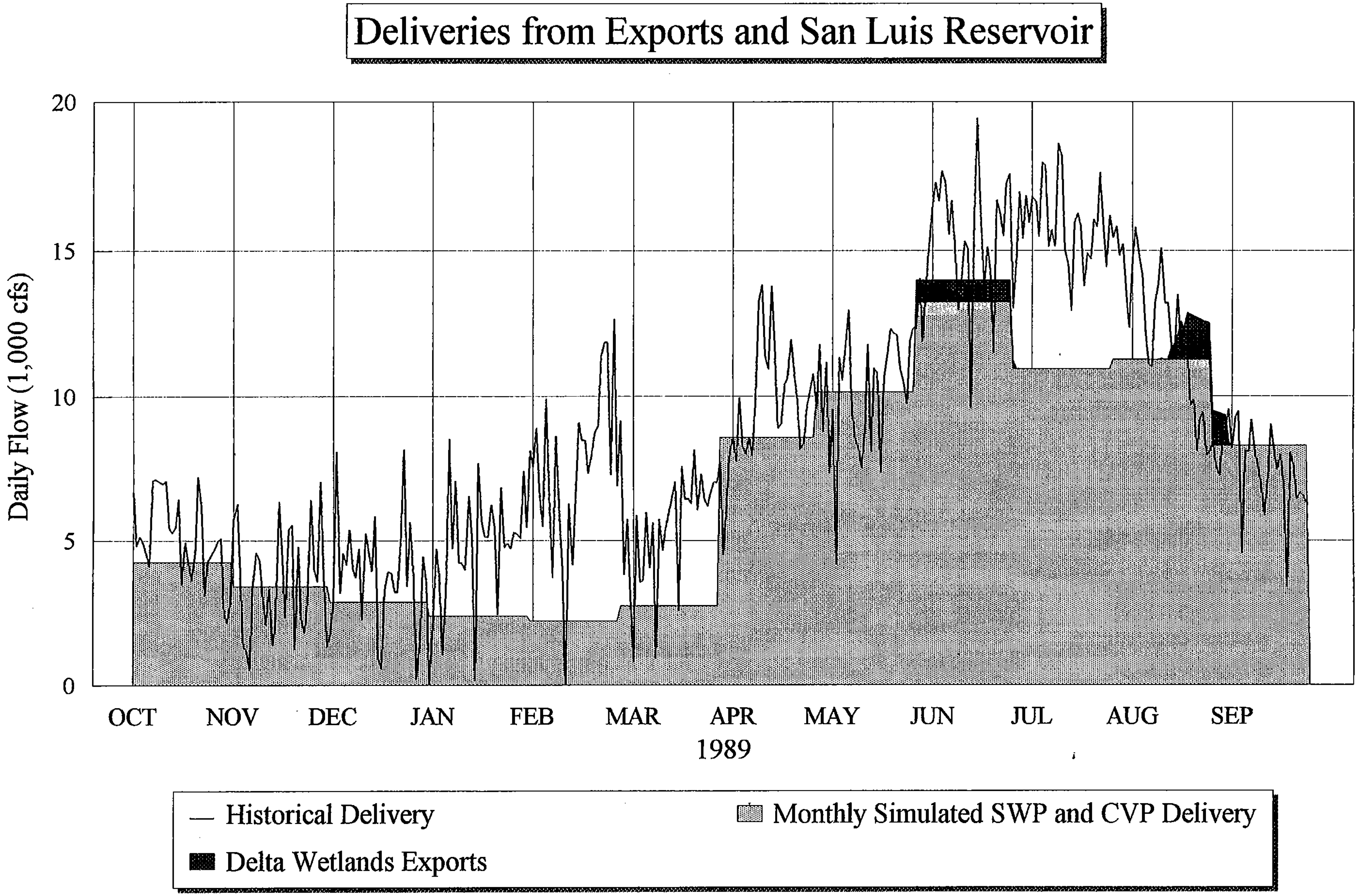
Jones & Stokes

Figure F-9b
Daily Simulated Delta Wetlands Operations and Effect on X2 Position as Allowed under Final Operations Criteria for 1989



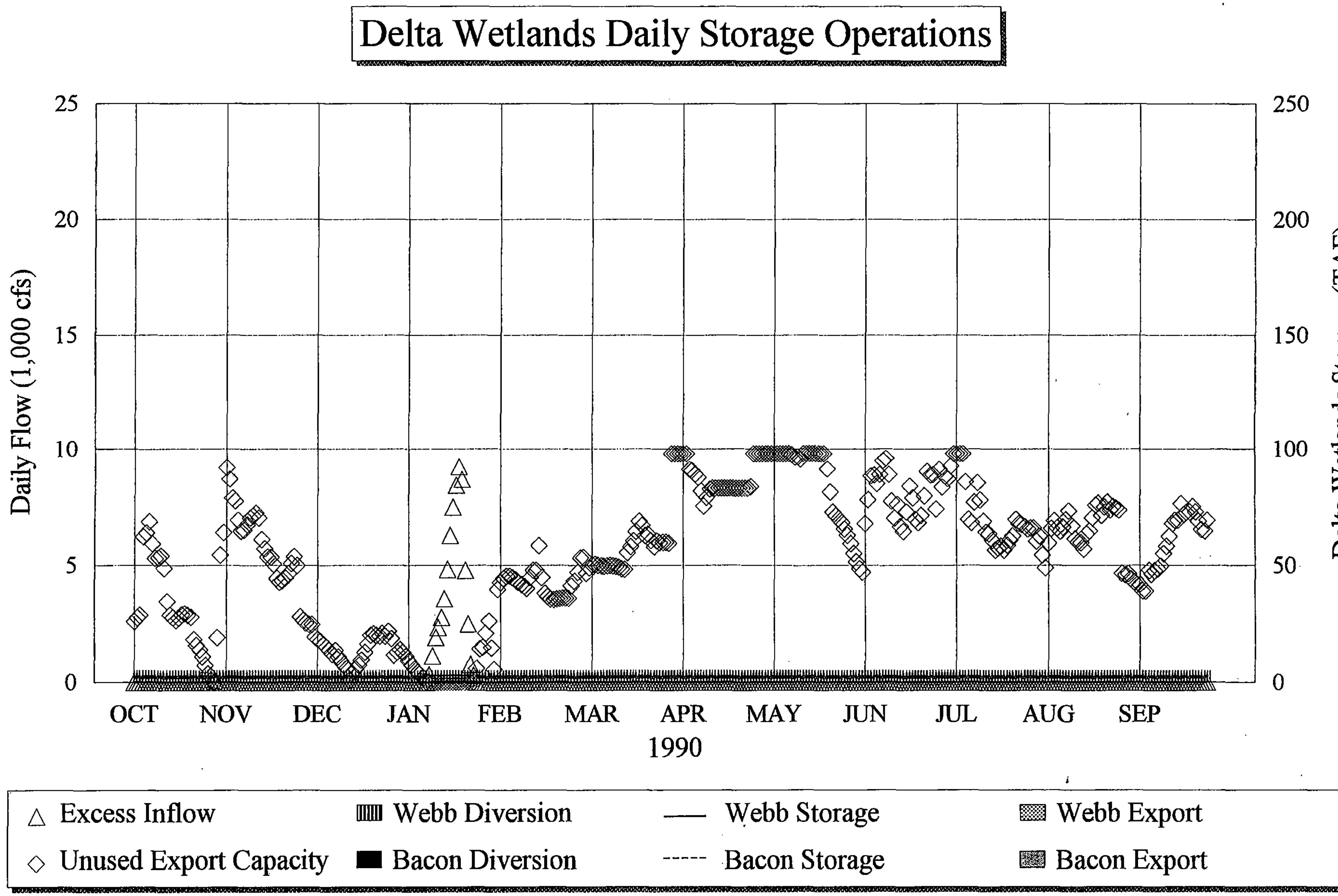
Jones & Stokes

Figure F-10a
Daily Simulated Delta Wetlands Operations with CVP and SWP Project Operations for 1989



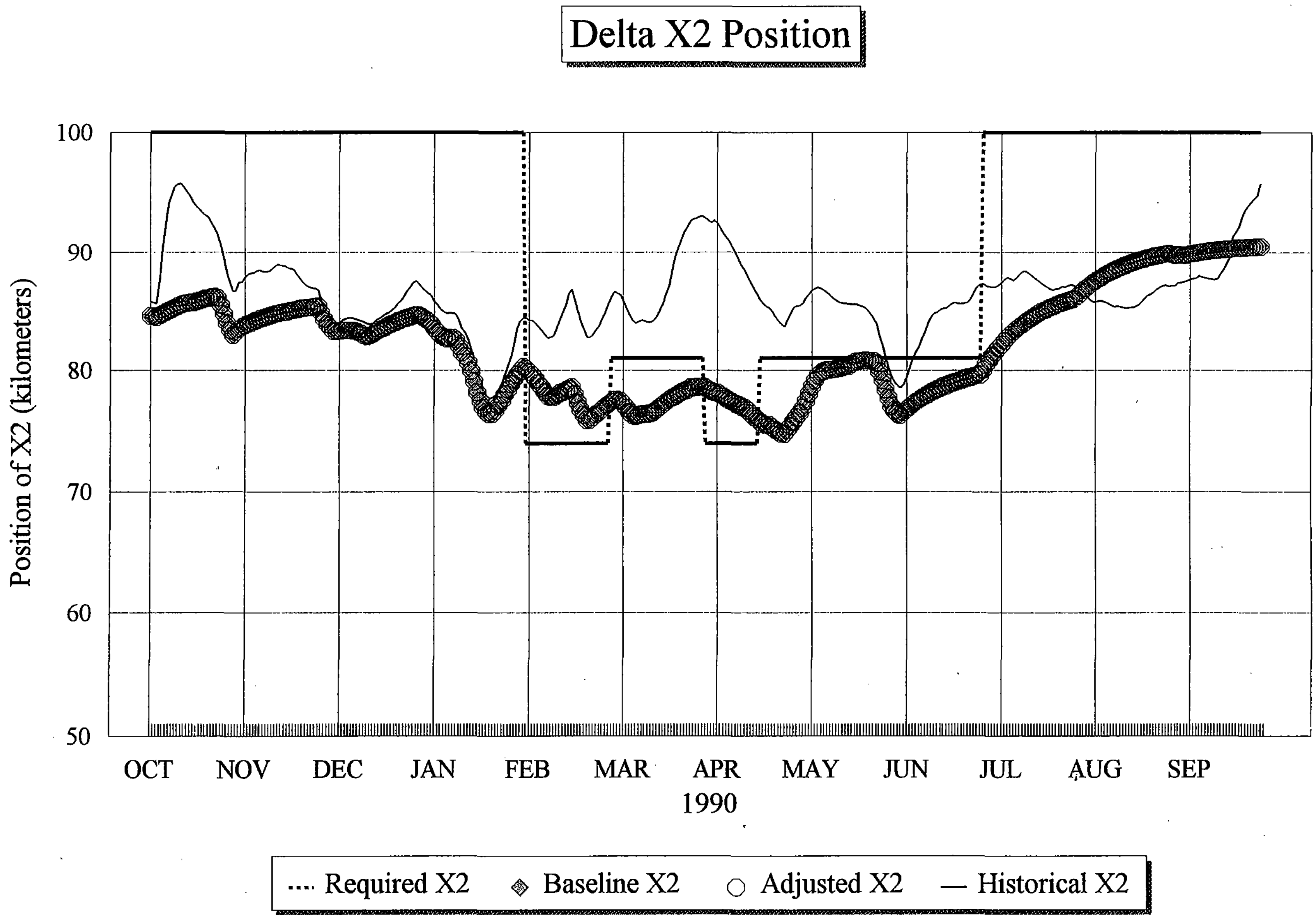
Jones & Stokes

Figure F-10b
Daily Simulated Delta Wetlands Operations with CVP and SWP Project Operations for 1989



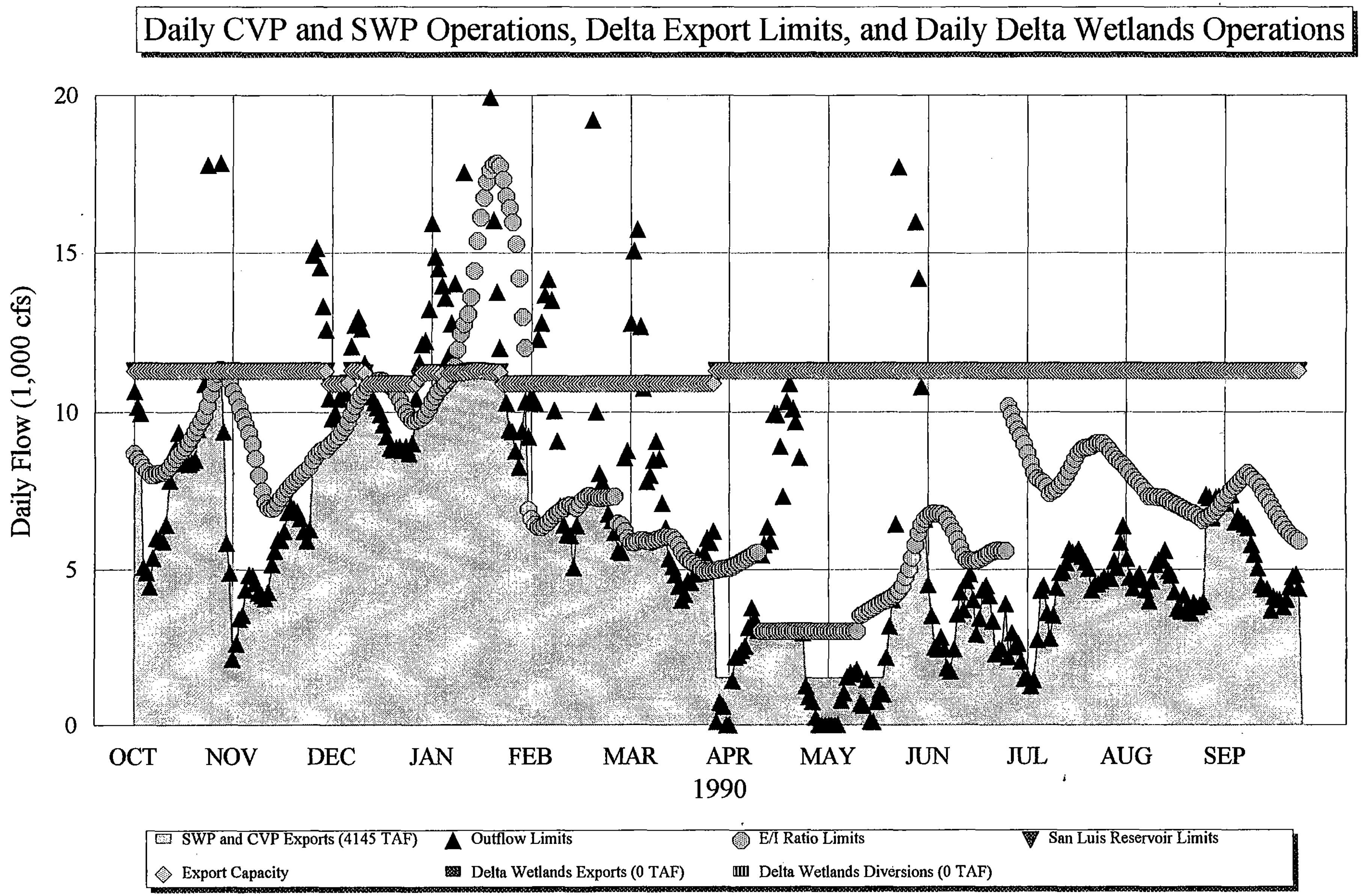
Jones & Stokes

Figure F-11a
Daily Simulated Delta Wetlands Operations and Effect on X2 Position as Allowed under Final Operations Criteria for 1990



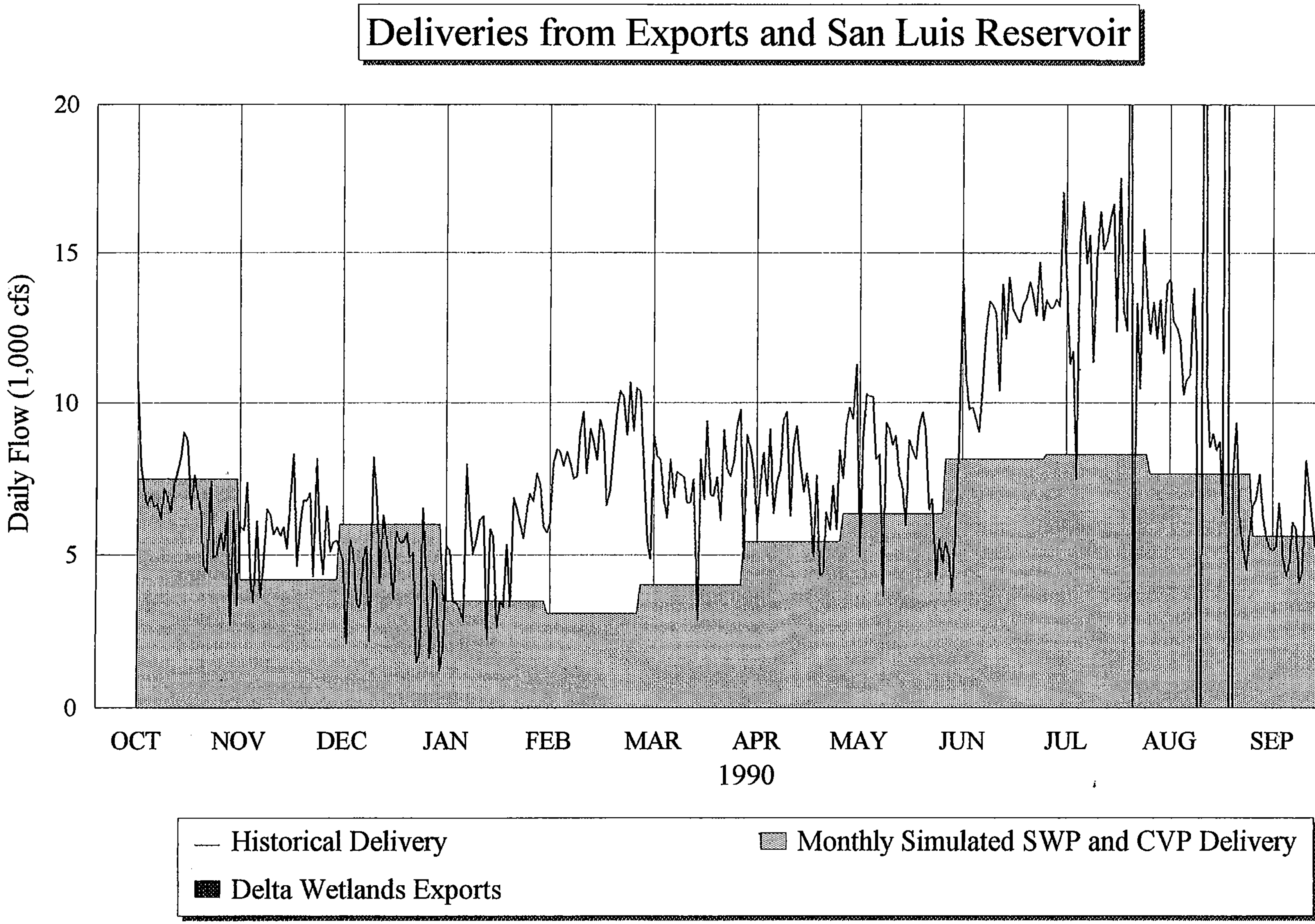
Jones & Stokes

Figure F-11b
Daily Simulated Delta Wetlands Operations and Effect on X2 Position as Allowed under Final Operations Criteria for 1990



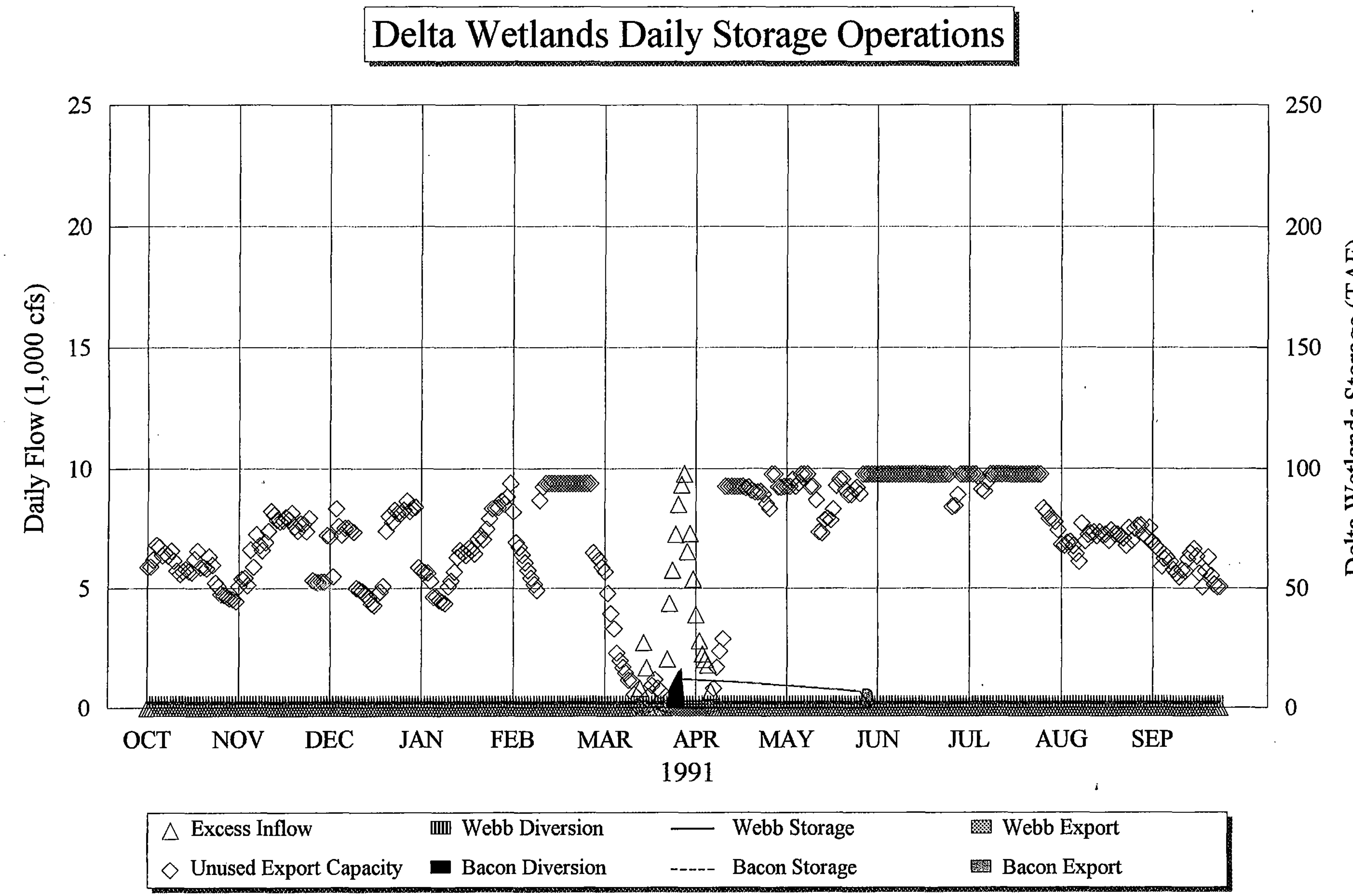
Jones & Stokes

Figure F-12a
Daily Simulated Delta Wetlands Operations with CVP and SWP Project Operations for 1990



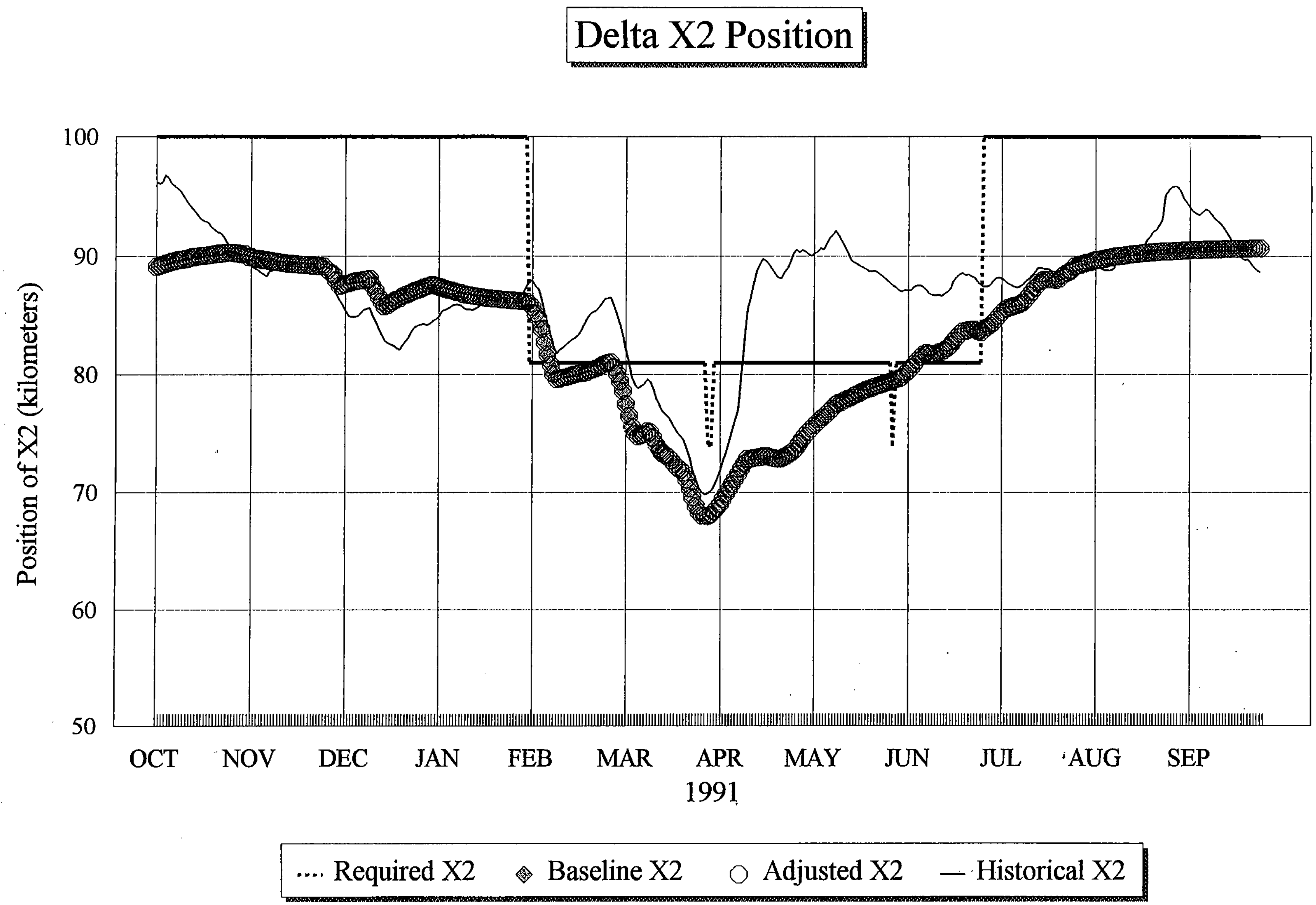
Jones & Stokes

Figure F-12b
Daily Simulated Delta Wetlands Operations with CVP and SWP Project Operations for 1990



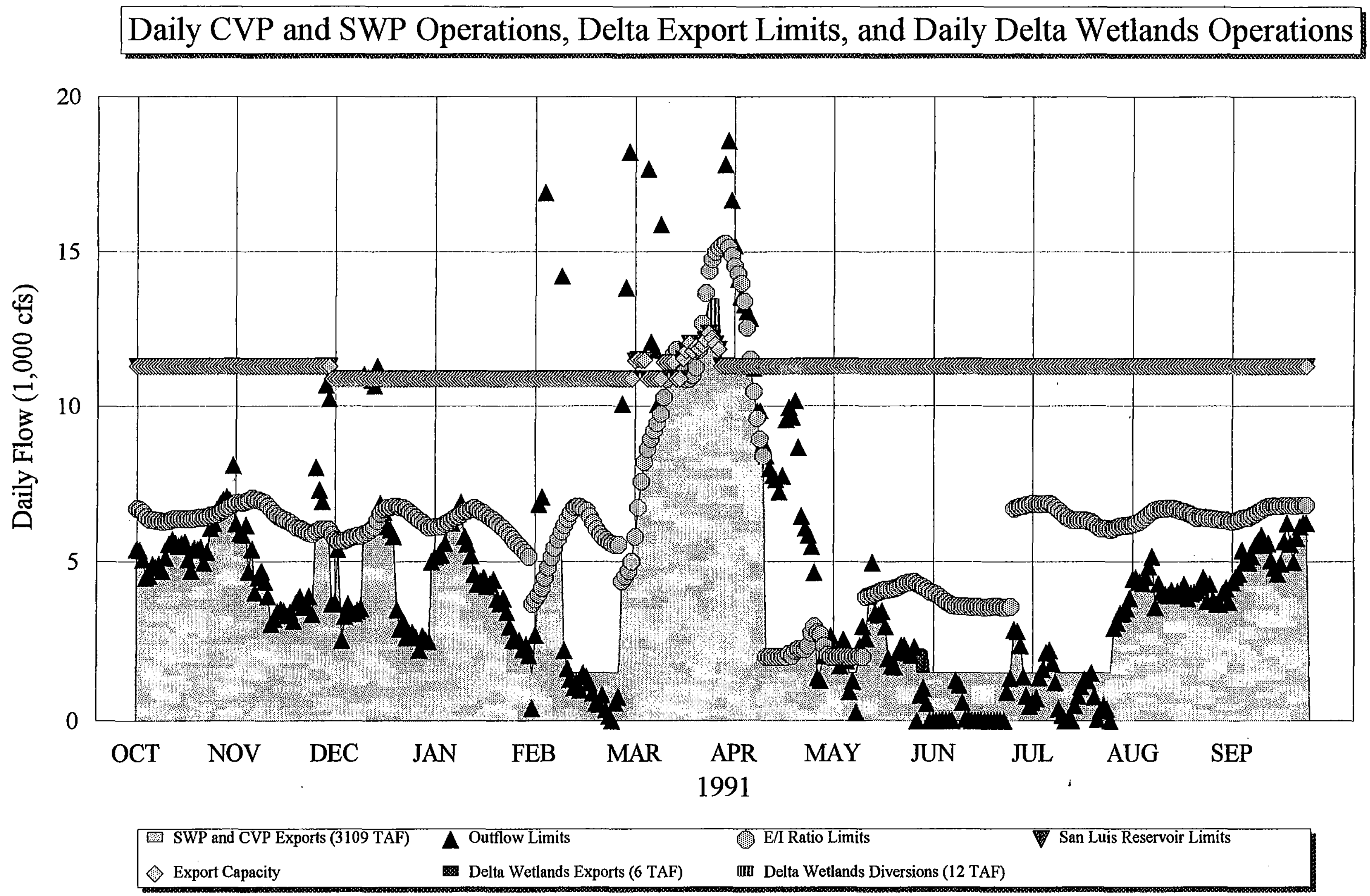
Jones & Stokes

Figure F-13a
Daily Simulated Delta Wetlands Operations and Effect on X2 Position as Allowed under Final Operations Criteria for 1991



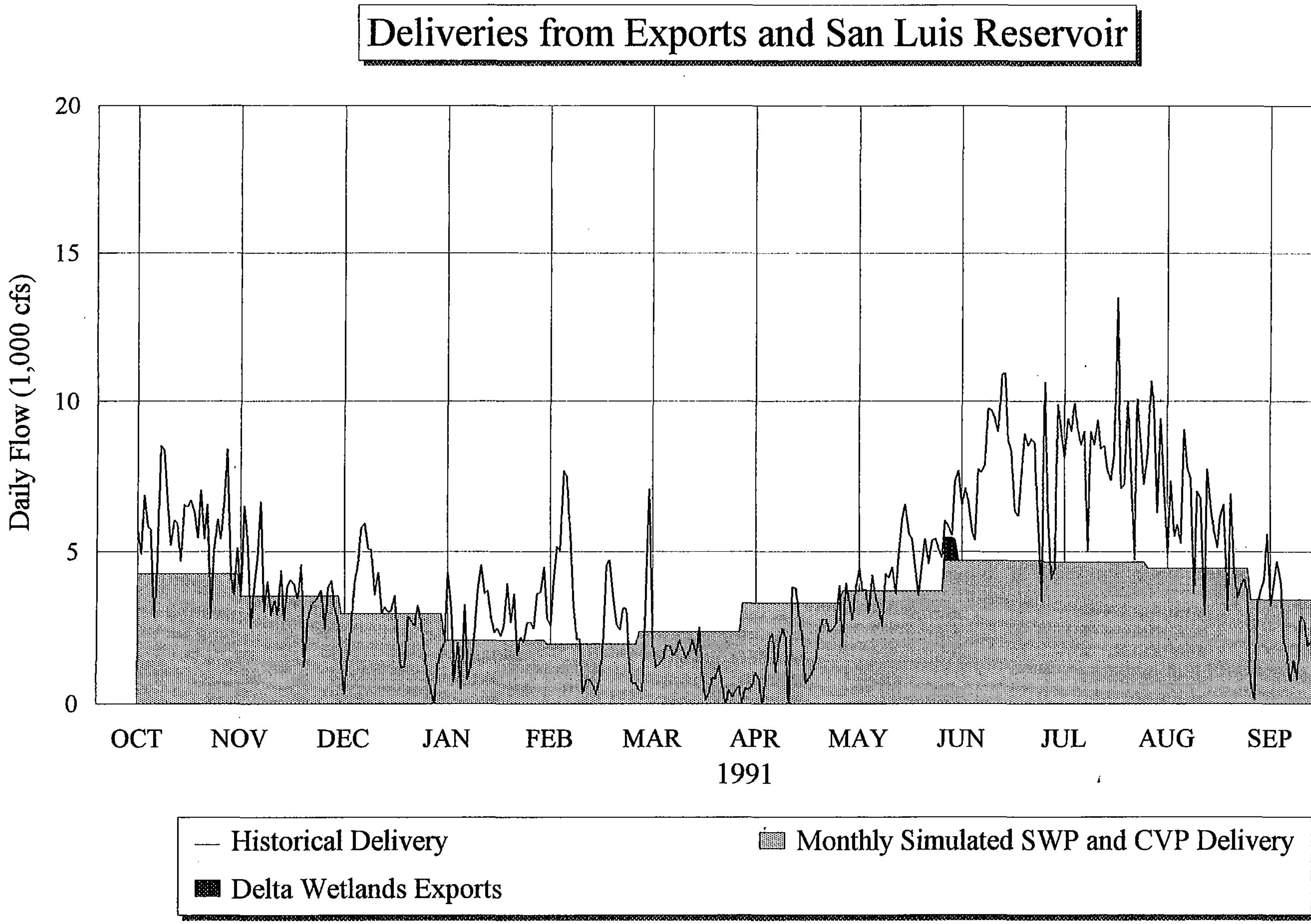
Jones & Stokes

Figure F-13b
Daily Simulated Delta Wetlands Operations and Effect on X2 Position as Allowed under Final Operations Criteria for 1991



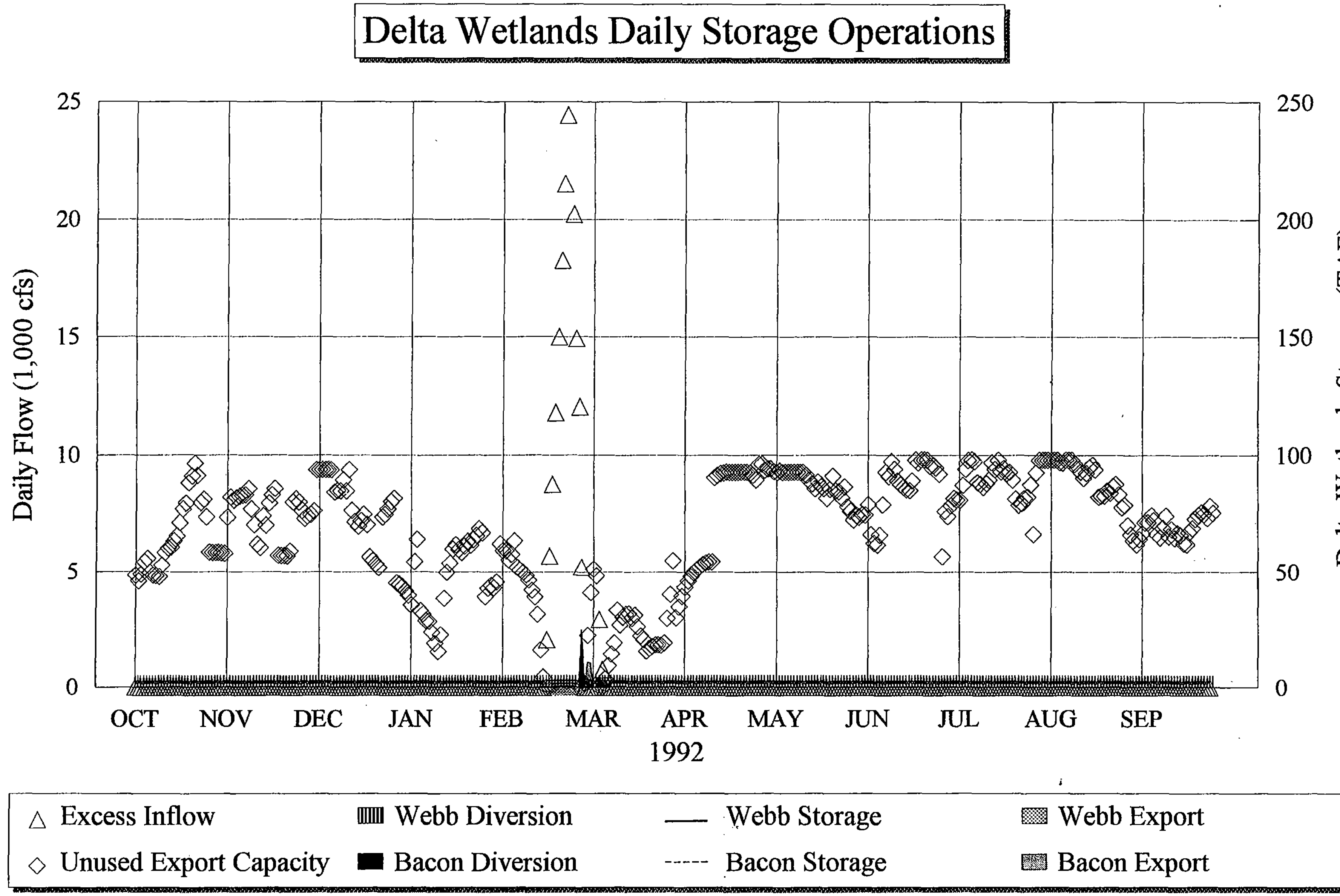
Jones & Stokes

Figure F-14a
Daily Simulated Delta Wetlands Operations with CVP and SWP Project Operations for 1991



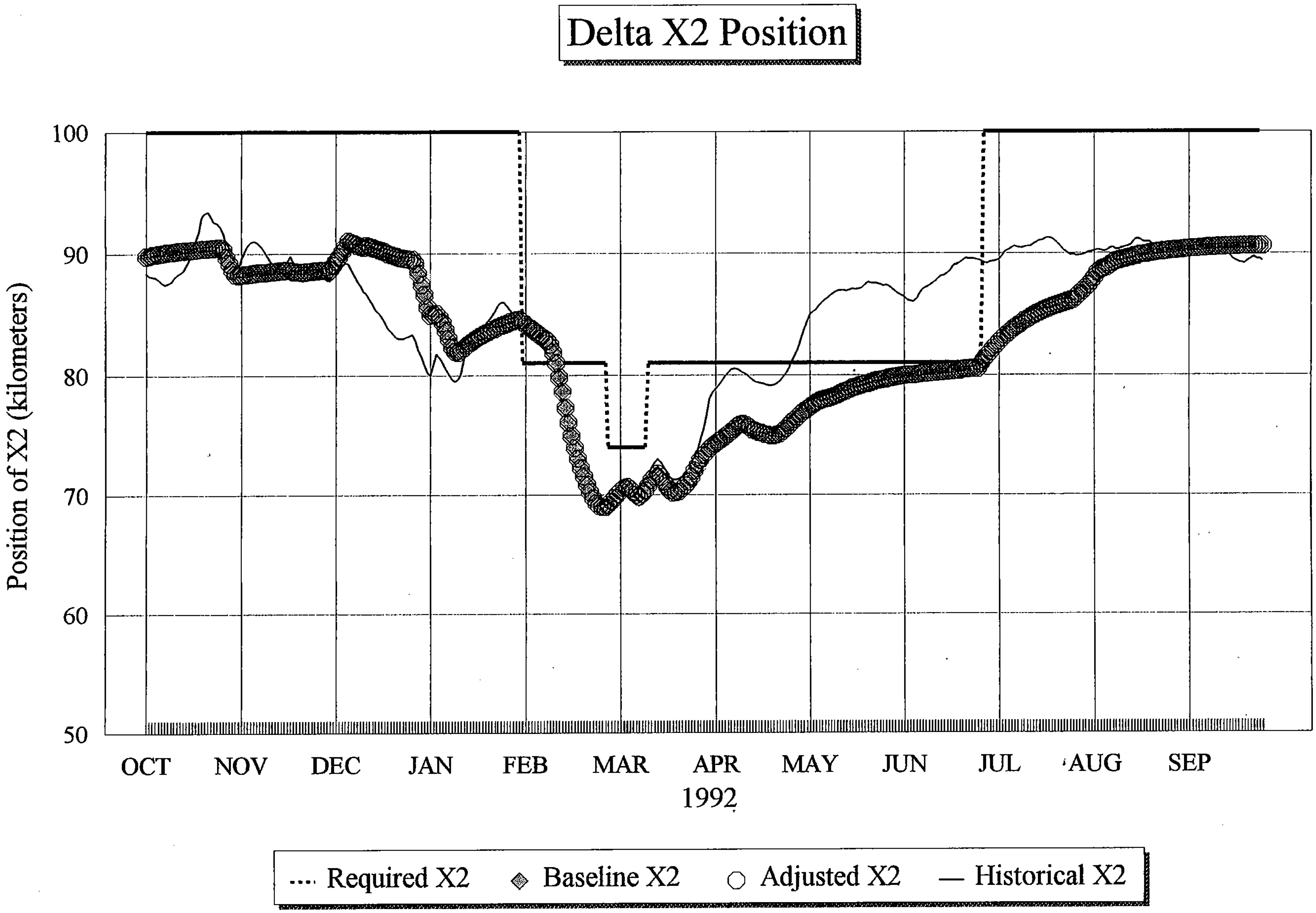
Jones & Stokes

Figure F-14b
Daily Simulated Delta Wetlands Operations with CVP and SWP Project Operations for 1991



Jones & Stokes

Figure F-15a
Daily Simulated Delta Wetlands Operations and Effect on X2 Position as Allowed under Final Operations Criteria for 1992



Jones & Stokes

Figure F-15b
Daily Simulated Delta Wetlands Operations and Effect on X2 Position as Allowed under Final Operations Criteria for 1992

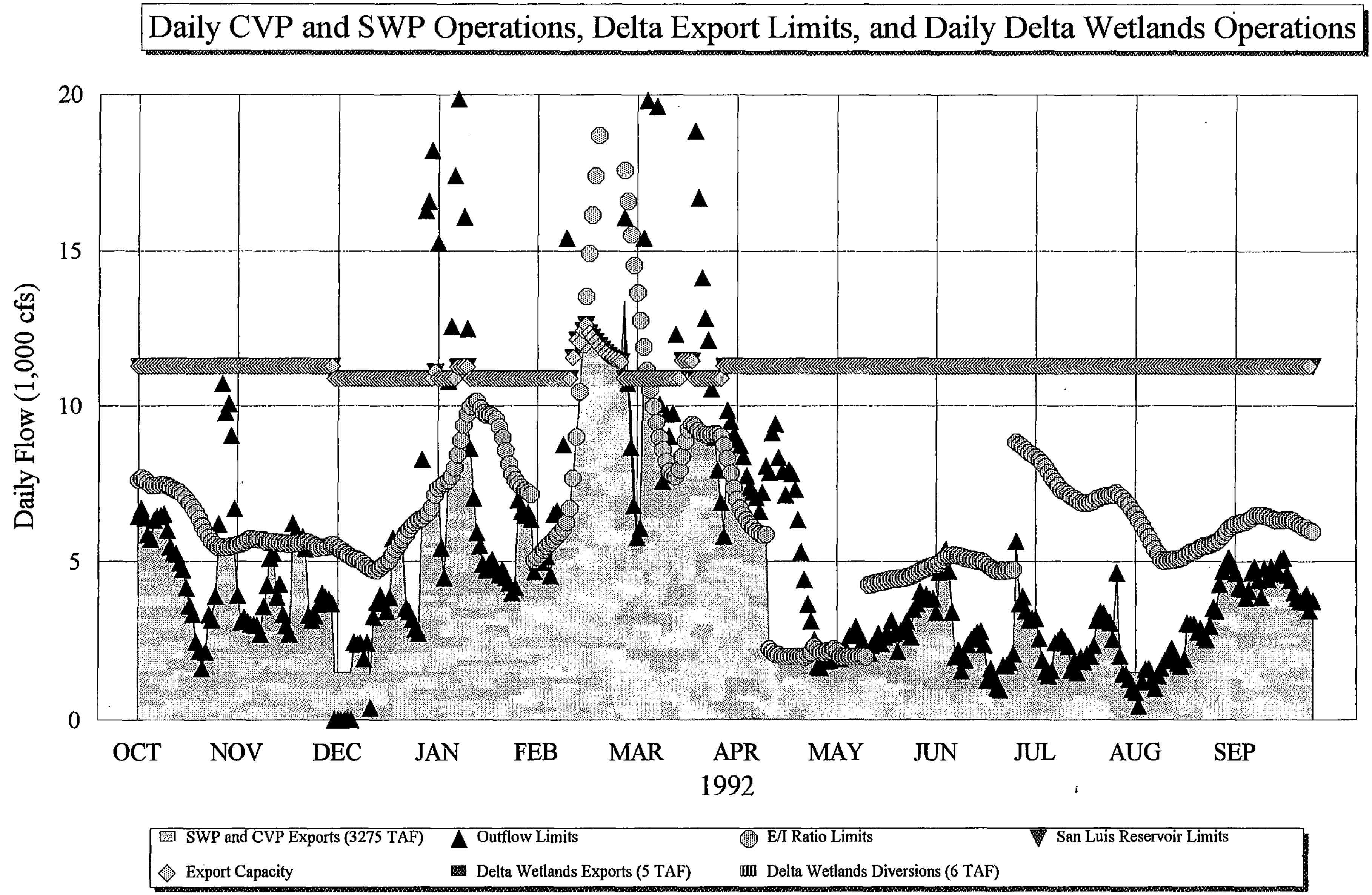
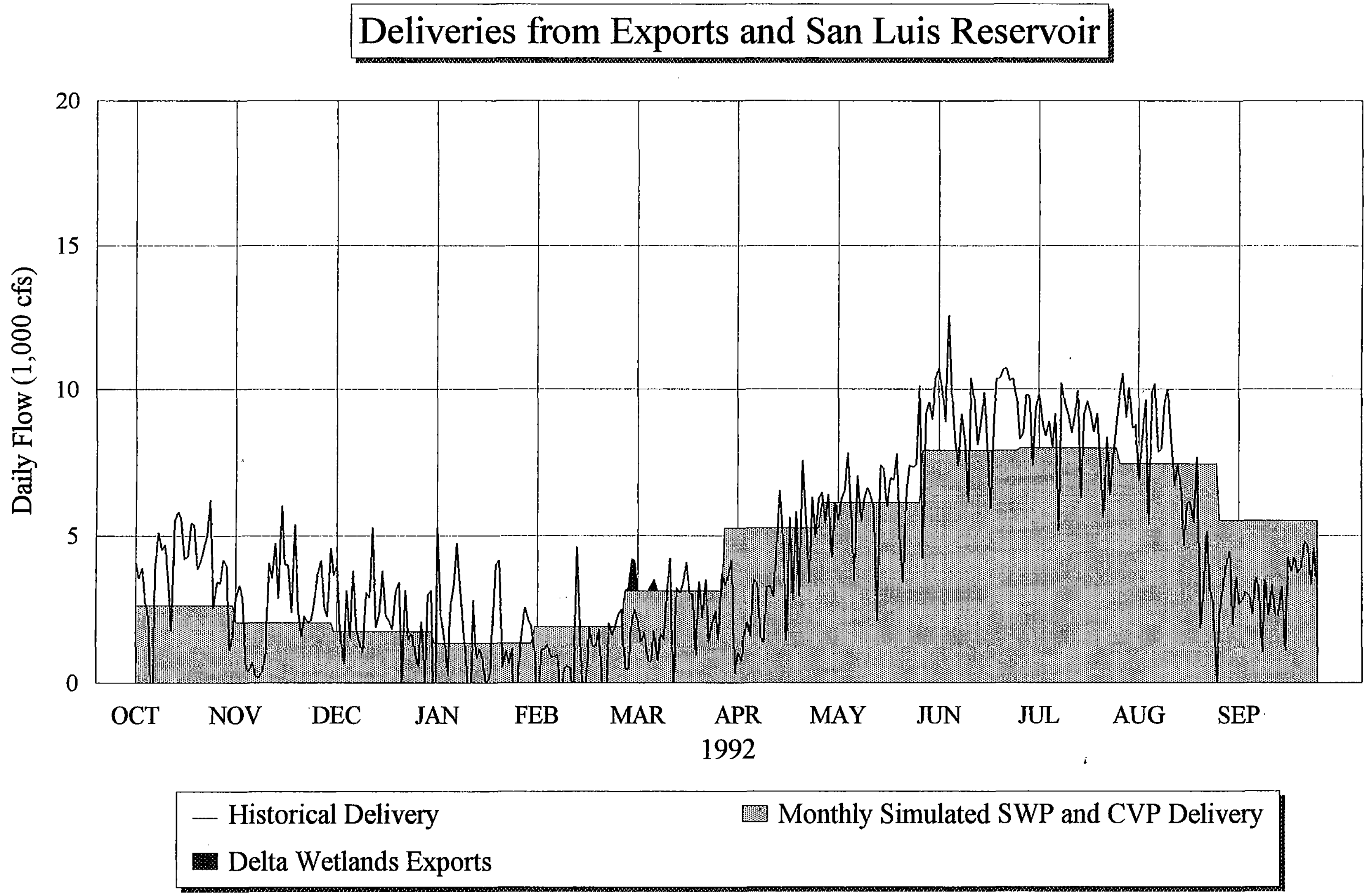
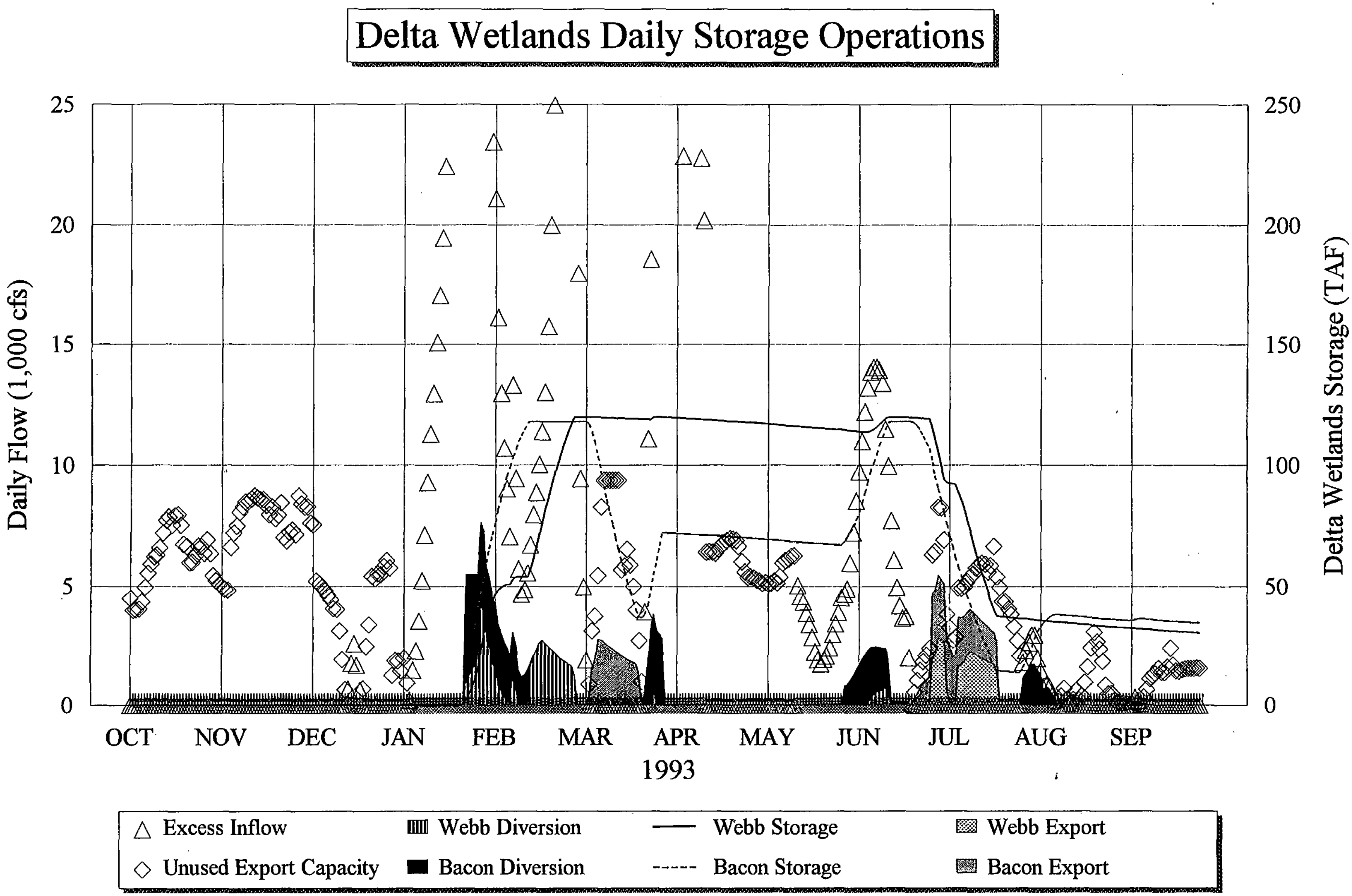


Figure F-16a
Daily Simulated Delta Wetlands Operations with CVP and SWP Project Operations for 1992



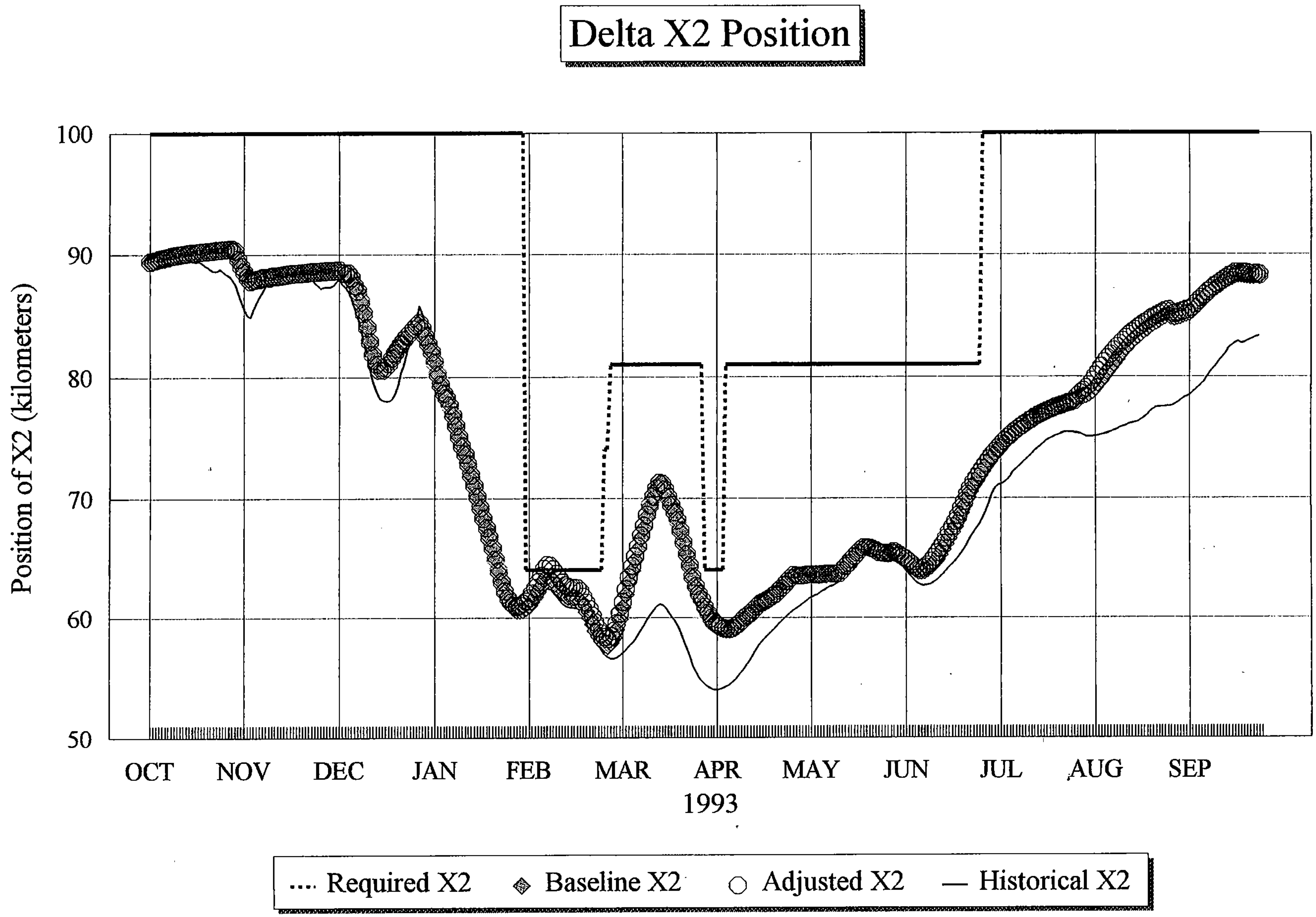
Jones & Stokes

Figure F-16b
Daily Simulated Delta Wetlands Operations with CVP and SWP Project Operations for 1992



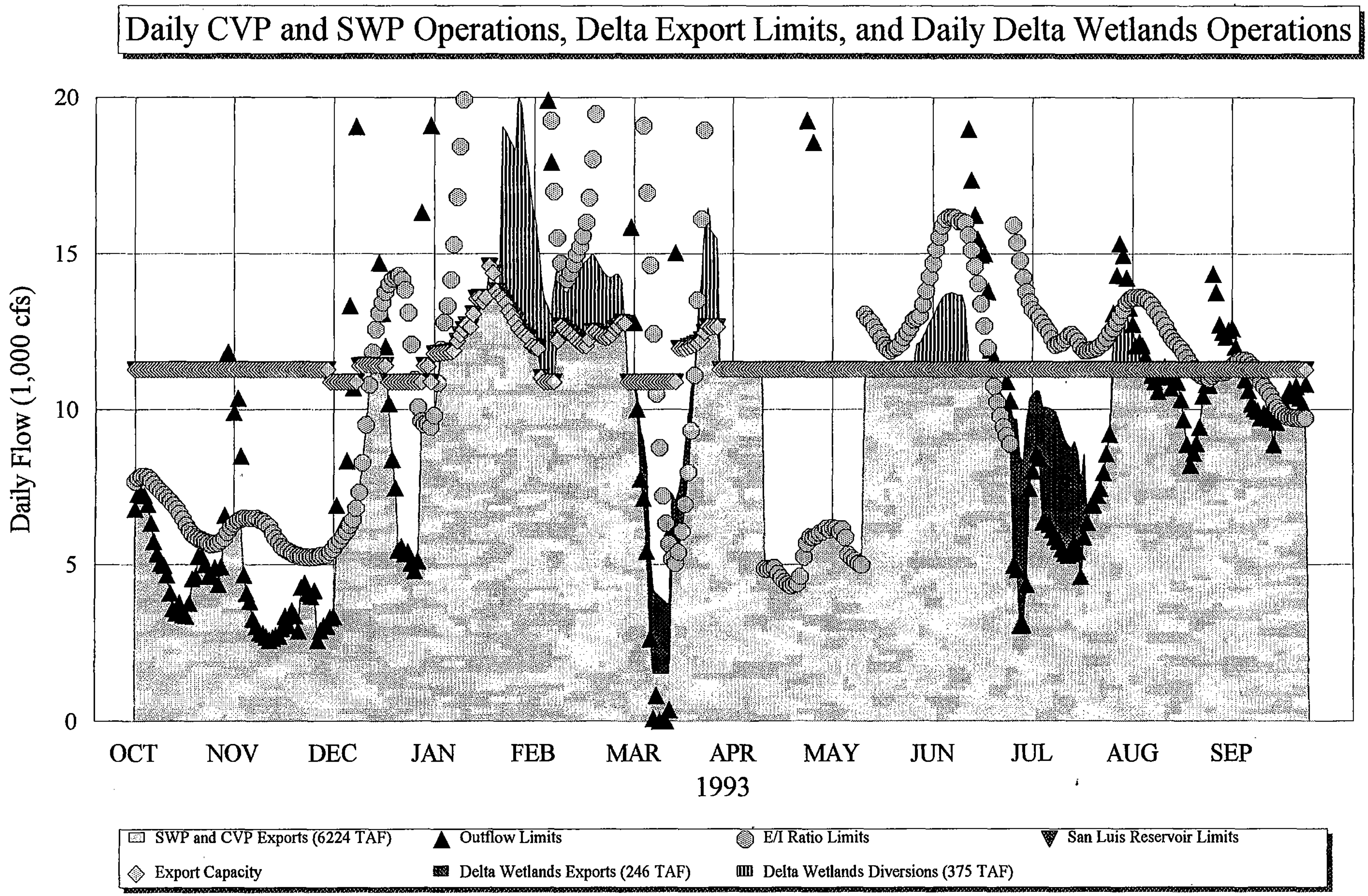
Jones & Stokes

Figure F-17a
Daily Simulated Delta Wetlands Operations and Effect on X2 Position as Allowed under Final Operations Criteria for 1993



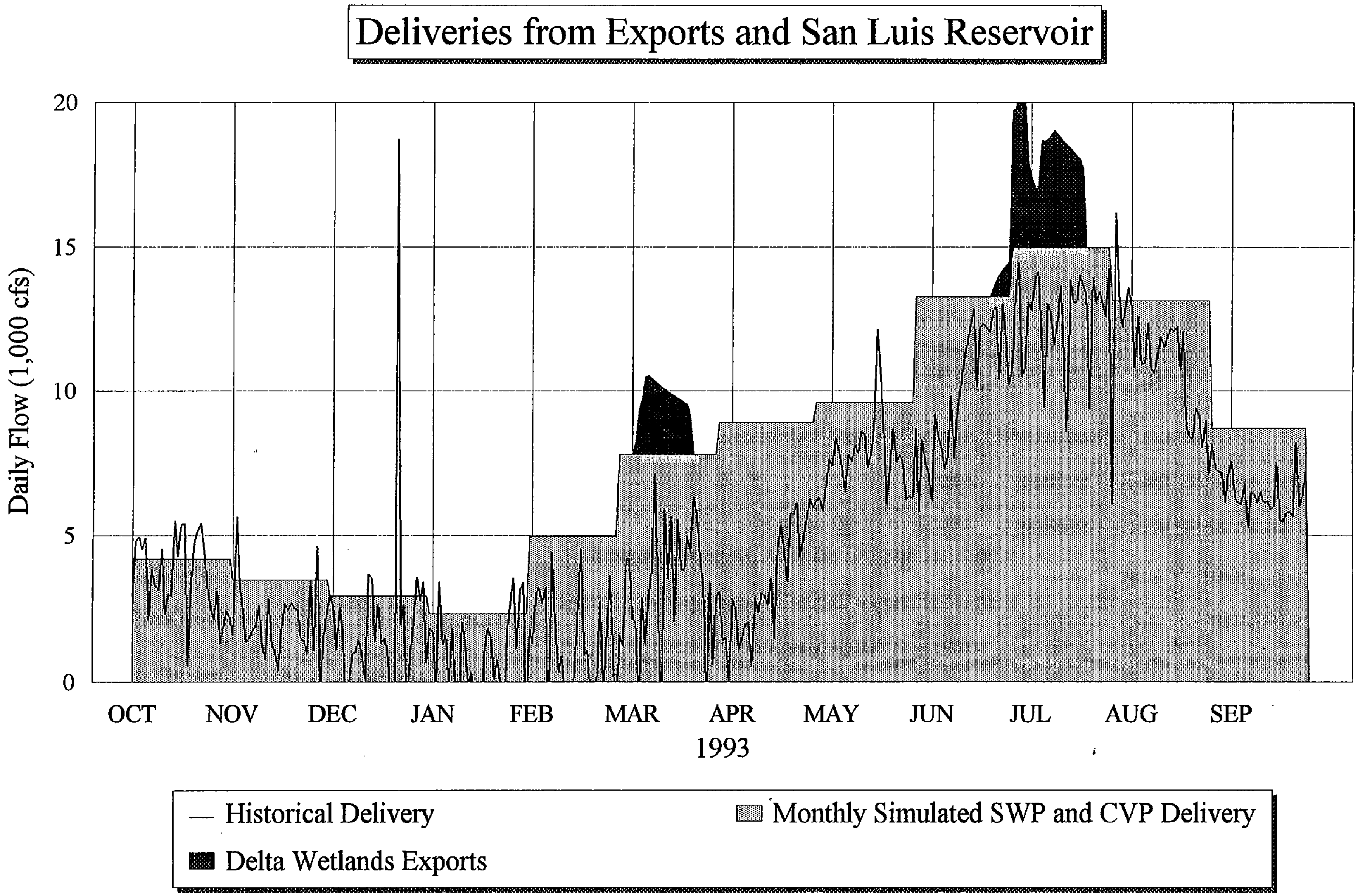
Jones & Stokes

Figure F-17b
Daily Simulated Delta Wetlands Operations and Effect on X2 Position as Allowed under Final Operations Criteria for 1993



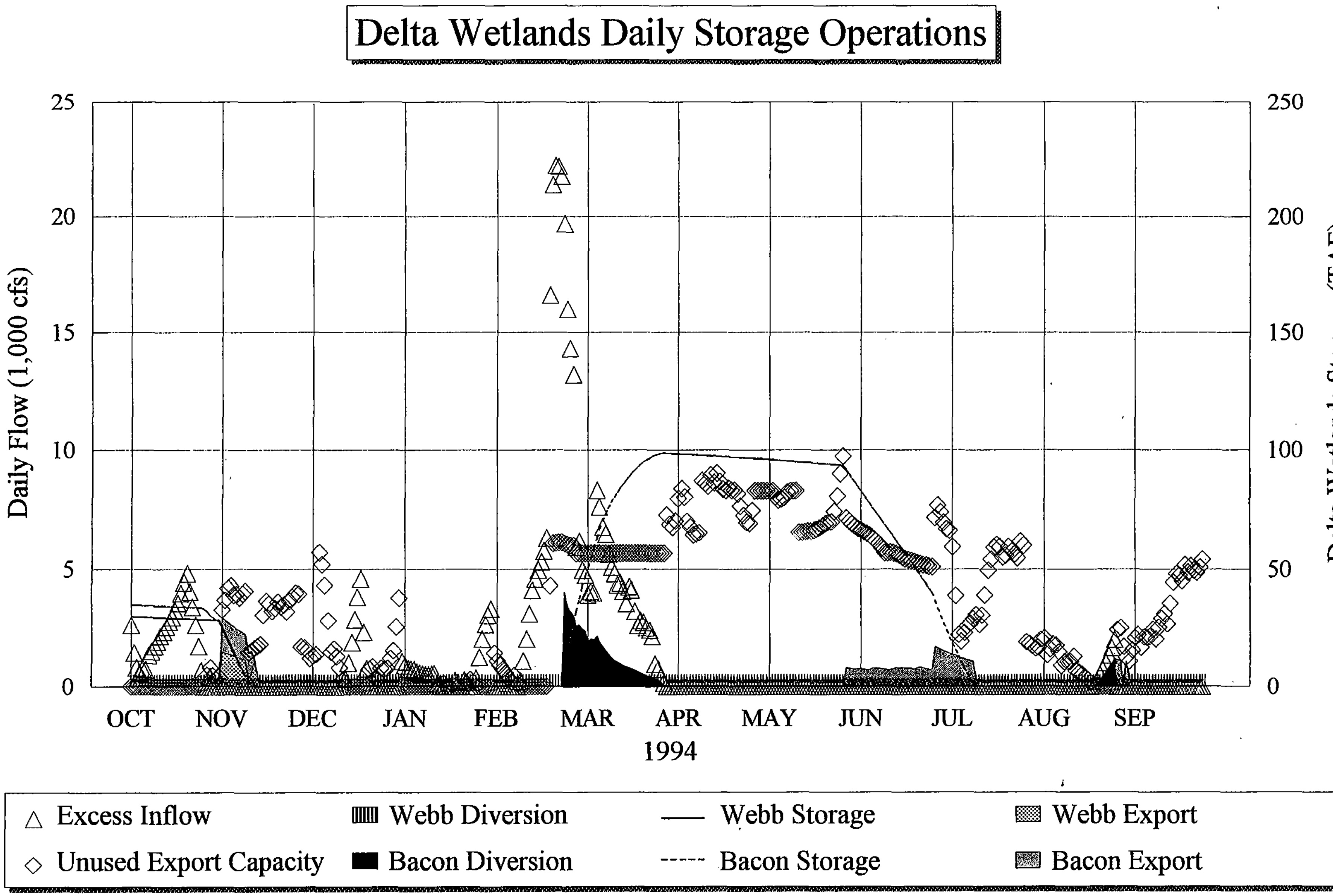
Jones & Stokes

Figure F-18a
Daily Simulated Delta Wetlands Operations with CVP and SWP Project Operations for 1993



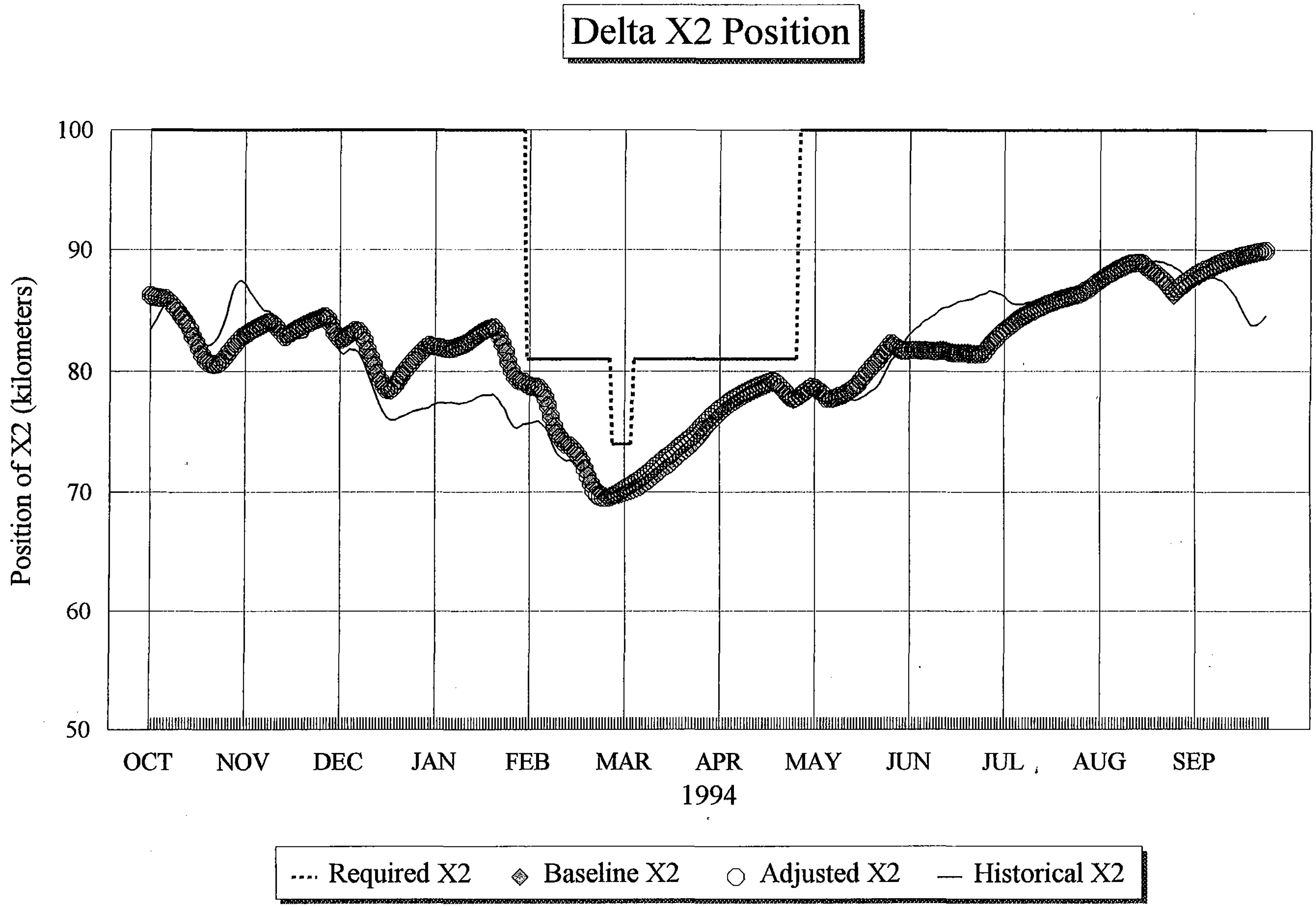
Jones & Stokes

Figure F-18b
Daily Simulated Delta Wetlands Operations with CVP and SWP Project Operations for 1993



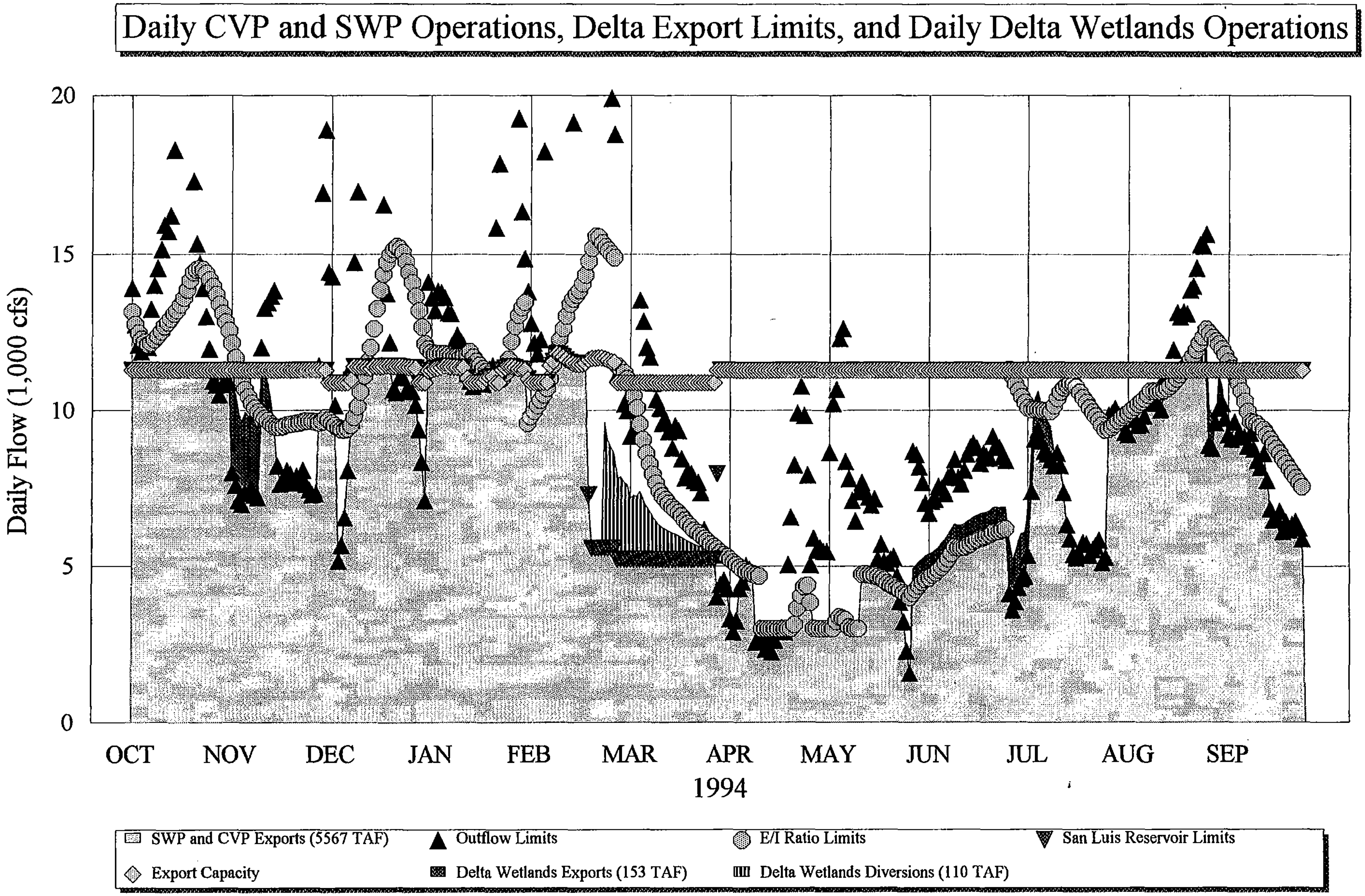
Jones & Stokes

Figure F-19a
Daily Simulated Delta Wetlands Operations and Effect on X2 Position as Allowed under Final Operations Criteria for 1994



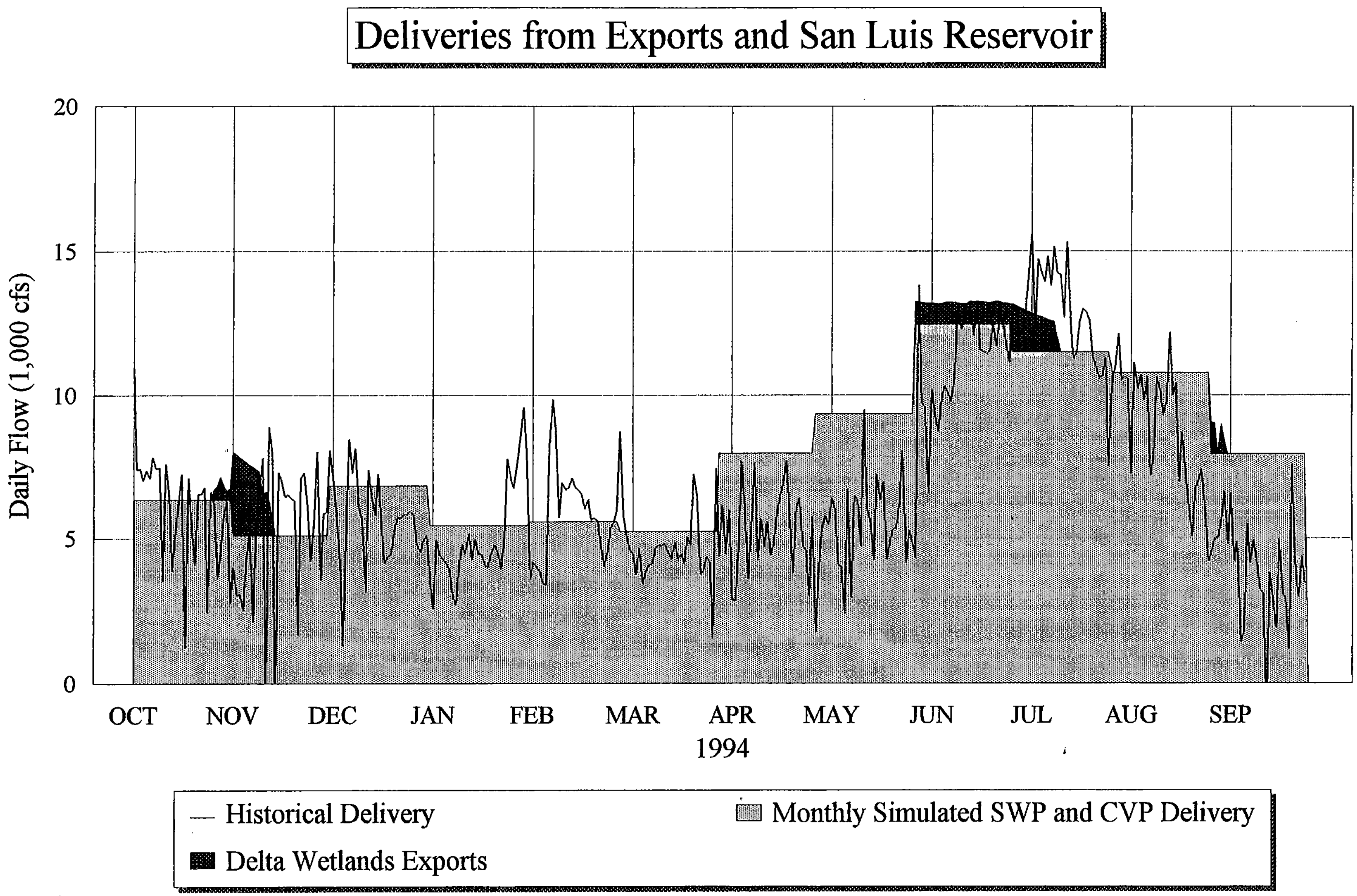
Jones & Stokes

Figure F-19b
Daily Simulated Delta Wetlands Operations and Effect on X2 Position as Allowed under Final Operations Criteria for 1994



Jones & Stokes

Figure F-20a
Daily Simulated Delta Wetlands Operations with CVP and SWP Project Operations for 1994



Jones & Stokes

Figure F-20b
Daily Simulated Delta Wetlands Operations with CVP and SWP Project Operations for 1994

Appendix G. Water Quality Assessment Methods

Appendix G. Water Quality Assessment Methods

INTRODUCTION

This appendix describes the assessment methods used to characterize existing water quality conditions and to analyze the potential effects of Delta Wetlands Project operations on water quality. The appendix is organized into three major sections:

- "Estimating Existing Levels of Dissolved Organic Carbon and Salinity in Agricultural Drainage": Presents an analysis of available data on Delta agricultural drainage, which is used to estimate contributions of dissolved organic carbon (DOC) and salinity from existing agricultural operations to Delta waters.

- "Estimating Project Effects on Salinity and Dissolved Organic Carbon": Describes the Delta Standards, Operations, and Quality model (DeltaSOQ), which is used to analyze the effects of Delta Wetlands Project discharges on monthly Delta export water quality. Presents information on Delta source contributions of salinity and DOC and on the salinity and DOC calculations used in the model. Also describes the range of estimates of DOC loading under reservoir operations that has been incorporated into the analysis.

- "Estimating Project Effects on Trihalomethane and Bromate Concentrations in Treated Water": Presents a review of disinfection byproduct (DBP) prediction equations and identifies the trihalomethane (THM) prediction equation used in the DeltaSOQ model.

ESTIMATING EXISTING LEVELS OF DISSOLVED ORGANIC CARBON AND SALINITY IN DELTA AGRICULTURAL DRAINAGE

The purpose of the agricultural drainage data analysis is to estimate annual loading of DOC and salinity from existing agricultural operations. The following analysis updates information on drainage water quality presented in the 1995 Delta Wetlands Project Draft Environmental Impact Report and Environmental Impact Statement (1995 DEIR/EIS). This section presents the data collected from the Delta Wetlands Project island locations through 1994, with the exception of Bacon Island, where sampling was continued through August 1999, and Twitchell Island, the location of several studies by the California Department of Water Resources (DWR) and U.S. Geological Survey (USGS) that began in 1994.

Bacon Island

Figure G-1 shows drainage measurements for chloride (Cl^-) and DOC as a function of the drainage electrical conductivity (EC) value in Bacon Island samples collected during January 1990–August 1999. Sampling of water quality at Bacon Island pumping plant (PP) 1 has been continued as part of DWR's Municipal Water Quality Investigations (MWQI) agricultural drainage sampling program (Bacon PP 2 sampling was discontinued). The range of drainage EC values varied from 200 to 1,280 microsiemens per centimeter (μS/cm). The mean EC value of these samples was 589 μS/cm, which is similar to the mean value of 650 μS/cm shown in the 1995 DEIR/EIS.

The Cl^-:EC ratio is used as an indicator of the source of irrigation water and of the amount of bromide (Br^-) expected in the agricultural drainage water (see Chapter 4, "Water Quality"). The 1986-1998 data show an average Cl^- concentration of 102 mg/l and a Cl^-:EC ratio of 0.17 in the drainage water, similar to the ratio of 0.18 for the data presented in the 1995 DEIR/EIS. These results suggest that San Joaquin River water and seawater were mixed with Sacramento River water in Bacon Island irrigation water.

DOC concentrations are plotted as a function of EC to investigate the possible relationship between drainage EC and DOC. If DOC behaves as a conservative dissolved substance (i.e., its concentration increases with evaporation, decreases with rainfall, and is not removed by biological or other physical and chemical processes), it is reasonable to suppose that DOC accumulates in soil moisture in the same manner that salt does. For example, if the drainage EC is twice the applied-water EC, the drainage DOC should be twice the applied-water DOC. The same leaching and drainage processes that eventually return salt to Delta channels in agricultural drainage should also return accumulated DOC material. A range of DOC values should be observed, just as a range of EC values is measured. Whereas no significant long-term source or sink for salt exists on Delta islands, a significant source or sink for DOC material may exist. If an island source of DOC exists, DOC concentrations in drainage water would exceed DOC values expected based on typical DOC concentrations in applied irrigation water.

Figure G-1 indicates that DOC concentrations in Bacon Island drainage vary, ranging from less than 5 milligrams per liter (mg/l) to more than 25 mg/l, and increase slightly with drainage-sample EC values. The mean Bacon Island drainage DOC concentration is 11.4 mg/l (compared to 9.4 mg/l shown in the 1995 DEIR/EIS from the 1986-1991 data set). The average of the drainage-sample DOC concentrations may only roughly approximate the actual average DOC concentration from Bacon Island drainage because the volume of drainage associated with each sample is not known.

The mean EC value in drainage water can be used to estimate the expected average increase from applied-water EC values to drainage EC values. For example, if the average EC value in water used for irrigation of Bacon Island (i.e., applied water) was assumed to be 300 μS/cm, which is higher than the Sacramento River EC value but lower than the export EC value (see Table 4-1), and the average drainage EC value is 589 μS/cm, the ratio of drainage EC to applied-water EC would be 1.96 or approximately 2. If the average ratio of drainage EC to applied-water EC is used with the typical measured channel DOC concentrations, the expected average increase from applied-water

DOC to drainage DOC concentrations would also be a factor of 2. If the average applied-water DOC concentration were assumed to be 3 mg/l, which is higher than the mean Sacramento River DOC concentration but lower than the mean export DOC (Figure 4-7), an average of 6 mg/l (3 • 2) of DOC would be expected in drainage water if a source of DOC did not exist on the island.

The difference between the measured DOC (11.4 mg/l) and the expected DOC (6 mg/l) is 5.4 mg/l (grams per cubic meter [g/m^3]) and can be used as an estimate of the contribution of DOC from agricultural practices. Thus, the DOC concentrations being discharged in drainage water can be partitioned into estimates of the contributions of DOC from agricultural sources and from applied channel water. Multiplying the source concentration by the average drainage water depth (69 inches, as shown in Table C2-2 in the 1995 DEIR/EIS) gives a DOC loading estimate for Bacon Island of about 9.3 grams per square meter per year ($g/m^2/yr$) (5.4 g/m^3 • 69 inches • 0.025 meter per inch [m/inch] = 9.3 g/m^2). The estimated DOC contribution from Bacon Island presented in the 1995 DEIR/EIS was about the same at 9 $g/m^2/yr$.

Bouldin Island

Figure G-1 also shows drainage measurements of DOC, Cl^-, and EC for Bouldin Island. Sampling at the Bouldin Island drainage pumps began in March 1987 and was discontinued in July 1994, so fewer samples have been collected and analyzed for the three constituents. The average EC value was 426 $\mu S/cm$. The pattern shown in Figure G-1 is the same as that shown in the 1995 DEIR/EIS.

As shown in the 1995 DEIR/EIS, the average Cl^- concentration was 32 mg/l and the Cl^-:EC value for Bouldin Island drainage samples was less than 0.1, indicating that Sacramento River was the primary source of irrigation water (Mokelumne River flows were below 200 cubic feet per second [cfs]). Therefore, a much lower Br^- concentration is expected in Bouldin Island drainage than in Bacon Island drainage.

Figure G-1 indicates that the drainage DOC concentrations generally increased with drainage EC values; the average of 33.7 mg/l is much greater than the average DOC for Bacon Island. Because Sacramento River DOC concentrations are relatively constant at about 2.5 mg/l (with an EC value of 160 $\mu S/cm$), the expected DOC concentration in drainage water having an average EC value of 426 $\mu S/cm$ would be 6.6 mg/l ([426/160] • 2.5). DOC concentrations in all the Bouldin Island drainage samples are greater than expected, suggesting a major agricultural source of DOC.

The additional 27.1 mg/l (33.7 – 6.6) represents the average DOC concentration contributed by sources on Bouldin Island. Multiplying the source concentration by the average drainage depth (33 inches, as shown in Table C2-2 of the 1995 DEIR/EIS) gives a DOC loading estimate for Bouldin Island of 22.4 $g/m^2/yr$ (27.1 g/m^3 • 33 inches • 0.025 m/inch = 22.4 g/m^2). This estimated value for Bouldin Island is similar to the 23 $g/m^2/yr$ presented in the 1995 DEIR/EIS.

Holland Tract

DWR collected drainage water quality data at Holland Tract between January 1990 and July 1994. The average drainage EC value was 1,177 μS/cm, similar to the average of 1,090 μS/cm shown in the 1995 DEIR/EIS (Figure G-2). Holland Tract is located across the Old River channel from Bacon Island, so the quality of applied irrigation water is assumed to be similar to that assumed for Bacon Island (EC of 300 μS/cm, DOC of 3 mg/l). The higher EC values in Holland Tract drainage are consistent with the lower average measured volume of Holland Tract drainage water (16 inches, as shown in Table C2-2 of the 1995 DEIR/EIS). These data indicate a ratio of 3.9 or approximately 4 for drainage EC to applied-water EC.

The average Cl^- concentration in Holland Tract drainage water for the Holland Tract samples was 211 mg/l, similar to the average of 199 mg/l shown in the 1995 DEIR/EIS. The Cl^-:EC value for Holland Tract drainage samples was 0.18, similar to the value of 0.17 for Bacon Island. This Cl^-:EC value indicates that seawater intrusion or San Joaquin River water was a significant source of salt in Holland Tract irrigation water. Relatively high Br^- concentrations are expected in Holland Tract drainage water.

Figure G-2 indicates that the drainage DOC concentrations averaged 18.2 mg/l. Given an assumed DOC in applied water of 3 mg/l and drainage-to-applied-water EC ratio of 4, the expected average drainage DOC would be 12 mg/l. The estimated source loading of DOC would be only about 2.5 g/m^2/yr (6.2 g/m^3 • 16 inches • 0.025 m/inch). The value is lower than that of the other Delta Wetlands islands and lower than the value (6 g/m^2/yr) presented in the 1995 DEIR/EIS.

Webb Tract

DWR collected drainage water quality data at Webb Tract between January 1990 and April 1993. Most drainage EC values for Webb Tract from 1990 through 1993 ranged between about 500 and 2,000 μS/cm (Figure G-2). The Webb Tract drainage concentrations were similar to those in the Holland Tract samples. The similarity in concentrations is generally consistent with the fact that the source for irrigation water for both islands is similar and that both islands' measured drainage volumes are less than 20 inches (as shown in Table C2-2 of the 1995 DEIR/EIS).

For Webb Tract drainage samples, the average Cl^- concentration was 183 mg/l, similar to the average of 160 mg/l shown in the 1995 DEIR/EIS. The Cl^-:EC value was 0.16, similar to the values for Holland Tract and Bacon Island. Thus, seawater intrusion or San Joaquin River water was also a significant source of salt in Webb Tract irrigation water.

Figure G-2 indicates that Webb Tract drainage DOC concentrations averaged 29.7 mg/l. Given an assumed DOC in applied water of 3 mg/l and drainage-to-applied-water EC ratio of 3, the expected drainage DOC concentration in Webb Tract drainage would be 9 mg/l. The estimated source loading of DOC would be 10.4 $g/m^2/yr$ (20.7 g/m^3 • 20 inches • 0.025 m/inch). The estimated DOC contribution is the same as the estimate of 10 $g/m^2/yr$ presented in the 1995 DEIR/EIS (because few additional drainage samples were collected).

Twitchell Island

DWR began monitoring drainage at Twitchell Island in 1994 and has conducted special agricultural drainage water quality studies on the island in cooperation with USGS and California Urban Water Agencies (CUWA). Figure G-3a shows that during the January 1994 to January 1998 monitoring period, the drainage EC values for Twitchell Island ranged between 337 and 1,980 $\mu S/cm$, with an average of 937 $\mu S/cm$. The drainage DOC values ranged from 1.1 to 58.9 mg/l, with an average of 20.1 mg/l. Some of the siphons supplying irrigation water to Twitchell Island draw from backwater (closed-off) areas of Sevenmile Slough, which received the drainage from Brannon Island. The applied-water EC values and DOC concentrations may therefore be higher than for other Delta islands.

Drainage and siphon measurements for 1995 indicated that seepage must be a major source of drainage water for Twitchell Island. Drainage for 1995 was about 11,000 acre-feet (af), which represents an average drainage depth of 37 inches from the 3,600 acres. This is similar to the drainage measured from Bouldin Island. Rainfall was higher than average, with 25 inches recorded in 1995. The average evapotranspiration (ET) for the Delta lowlands is assumed to be 32 inches. The measured siphon flows during 1995 from 12 of the 21 siphons on Twitchell Island totaled 1,800 af. Because only half the siphons were monitored, the total applied water might have been as much as 3,600 af (i.e., twice the measured amount), which is equivalent to 12 inches. The remaining water needed to balance the water budget would be about 32 inches of seepage, which is derived as follows:

Rain (25 inches) + Applied water (12 inches) + Seepage (32 inches) =
ET (32 inches) + Drainage (37 inches)

This is similar to the estimates from the DWR Delta island consumptive use simulation results (California Department of Water Resources 1995). The DOC concentration for the seepage water is assumed to be the same as channel (i.e., applied-water) DOC concentration.

For Twitchell Island drainage samples, the average Cl^- concentration was 174 mg/l; the Cl^-:EC value was 0.18, similar to the values for Webb Tract, Holland Tract, and Bacon Island. Thus, seawater intrusion or San Joaquin River water was also a significant source of salt in Twitchell Island irrigation water.

Figure G-3a indicates that the Twitchell Island drainage DOC concentrations had an average of 20.1 mg/l. Given an assumed DOC in applied water of 3 mg/l and an assumed ratio of drainage EC to applied-water EC of 3, the expected drainage DOC concentration in Twitchell Island drainage would be 9 mg/l. The estimated source loading of DOC would therefore be 10.4 $g/m^2/yr$ (11.1 g/m^3 • 37.5 inches • 0.025 m/inch).

The Twitchell Island special studies conducted by MWQI and USGS in 1995 provide the most accurate estimate of DOC loading from a Delta agricultural island because direct measurements of drainage flow were taken and DOC concentrations were sampled frequently. Table G-1 shows weekly data from these studies.

USGS (U.S. Geological Survey 1997) reported weekly pumping records that have been combined with daily DOC samples for 1995 to provide weekly flow-weighted DOC drainage loads from Twitchell Island. The results are shown in Table G-1 and Figure G-3b. The flow-weighted annual DOC load was about 28 g/m^2, which includes the assumed DOC load from the applied water of about 9 g/m^2. This DOC drainage load is higher than the load estimated from the average DOC because the highest concentrations were sampled during periods with the highest drainage flow. The highest drainage in the winter of 1995 corresponded with the highest EC values and the highest DOC concentrations. The DOC loading based on these weekly flow and concentration patterns was about 19 g/m^2, which is about twice the DOC load of 10.4 g/m^2 estimated from the average drainage concentration. This suggests that the DOC loads estimated from average-drainage concentrations and total annual drainage depth may be substantially less than the actual flow-weighted DOC loads that would be obtained from more frequent drainage flow and concentration estimates.

Summary of Dissolved Organic Carbon Loading Estimates for Agricultural Operations

The available drainage data from Bacon Island, Bouldin Island, Holland Tract, Webb Tract, and Twitchell Island suggest that agricultural land use increases DOC in applied water by 3 to 23 $g/m^2/yr$, giving an average DOC loading rate of 12 $g/m^2/yr$. This is consistent with the average agricultural-use DOC loading presented in the 1995 DEIR/EIS.

ESTIMATING PROJECT EFFECTS ON SALINITY AND DISSOLVED ORGANIC CARBON

Water quality at Delta export locations is a function of the quality of water coming into the Delta, the way in which that quality may change as a result of in-Delta activities, the volume of Delta inflows and exports, and the proportion of the export water coming from each source. Export water is a mixture of water from the central Delta (which is assumed to be a mixture of water from the Sacramento, Mokelumne, and Cosumnes Rivers; seawater intrusion from the western Delta; and some portion of the San Joaquin River that does not flow directly to the export locations), San Joaquin River water, and Delta agricultural drainage. Under Delta Wetlands Project operations, Delta Wetlands discharges would be another source of export water and would therefore affect Delta export water quality. Quantitative modeling is used to estimate the contribution of the Delta Wetlands islands to levels of water quality constituents at Delta channel locations and in Delta diversions and exports.

This section describes DeltaSOQ, which is used to analyze the effects of Delta Wetlands Project discharges on monthly Delta export water quality. Information on Delta source contributions of salinity and DOC is first presented, then salinity and DOC calculations used in DeltaSOQ are described. To confirm the accuracy of the DeltaSOQ calculations, simulated results are compared to historical measured results for salinity and DOC and presented in a series of figures for the 1972-1994 time period. Data on all variables for all years are not available. However, the graphs show all available data plotted against the 1972-1994 time period to provide for easy comparison of water quality conditions for each year.

Delta Source Contributions of Salinity and Dissolved Organic Carbon

Data on inflow and export water quality constituents, as reported by the DWR MWQI program and described earlier in this appendix, are used to describe existing conditions and to determine how the concentrations of constituents change as water flows through the Delta. The difference between Delta inflow and Delta export concentrations for a selected water quality constituent (e.g., DOC) is used to estimate the net contribution from Delta sources, including agricultural drains.

The net contribution of a water quality constituent from Delta sources can be estimated from:

- the observed increase in concentration in the exports (above the assumed baseline concentration),
- the Delta export pumping volume, and
- the assumed fraction of the Delta-source contribution transported to the Delta export locations.

For example, if the water quality constituent amount increased by 1 mg/l above the Sacramento River concentration in a monthly average export flow of 5,000 cfs, the net contribution from Delta sources would be calculated as follows:

$$\text{Delta source contribution rate (kilograms [kg]/month)} = 73.5 \bullet 5{,}000 \text{ cfs} \bullet 1 \text{ mg/l} = 367{,}500 \text{ kg/month}$$

where 73.5 is the conversion from cfs and mg/l to kg/month.

If some known area of the Delta uniformly contributed this amount of the water quality constituent, the average uniform contribution per unit area (grams per square meter per month [g/m^2/month]), or "areal contribution rate", could be estimated. For the example given above, with an assumed source area equal to the Delta lowlands (396,000 acres), the average areal contribution rate would be calculated as follows:

$$\text{Areal contribution rate} = \frac{0.25 \bullet 367{,}500 \text{ kg/month}}{396{,}000 \text{ acres}} = 0.23 \text{g/m}^2\text{/month}$$

where 0.25 is the conversion from kg/acre to g/m^2 (4,047 m^2 per acre).

Therefore, a monthly load of about 1 g/m^2/month from an area of about 400,000 acres (about 4 times the loading in the example) would cause an increase of about 4 mg/l in exports of about 5,000 cfs. (Refer to Appendix C1 of the 1995 DEIR/EIS for a complete description of these calculations.) This is larger than the average increase in DOC concentration observed at the export locations compared with the Sacramento River concentration.

A systematic framework for estimating these net contributions from Delta sources was developed for the 1995 DEIR/EIS (refer to Appendix C4) based on observed concentration changes, Delta inflows, and export pumping rates. A version of these calculations that considers Delta lowlands only has been included in Delta Wetlands Project simulations conducted with the DeltaSOQ model for this revised draft environmental impact report/environmental impact statement (REIR/EIS). These calculations are described in the following sections.

Salinity Calculations in the Delta Standards, Operations, and Quality Model

As mentioned previously, export water is a mixture of water from the central Delta, the San Joaquin River, and agricultural drainage. Under Delta Wetlands Project operations, export water would include Delta Wetlands discharges in addition to water from these sources. The salinity (EC and Cl^-) of water from the central Delta, the San Joaquin River, agricultural drainage, and the Delta Wetlands Project islands and the proportions in which they are present in the exports determine export salinity. The export EC is estimated in DeltaSOQ based on the fraction of water from the four assumed sources as follows:

$$\text{Export EC} = (\text{central Delta fraction} \bullet \text{central Delta EC}) + (\text{San Joaquin River fraction} \bullet \text{San Joaquin River EC}) + (\text{drainage fraction} \bullet \text{drainage EC}) + (\text{Delta Wetlands fraction} \bullet \text{Delta Wetlands EC})$$

Delta Export Source Fractions

The export fractions are estimated with simple equations that depend on the volume of Delta flows and exports. The fraction of exports not contributed by the other sources is assumed to come from the central Delta.

A constant fraction (75%) of the San Joaquin River water is assumed to be exported:

$$\text{San Joaquin River fraction} = \frac{0.75 \bullet \text{San Joaquin River flow}}{\text{Total exports}}$$

If the total San Joaquin River flow is greater than the exports, then the San Joaquin River fraction can be 1 and the export EC and Cl^- is equal to the San Joaquin River EC and Cl^-.

The central Delta diversions and drainage flow are assumed to represent 40% of the Delta acreage and 40% of all Delta diversions and drainage flow. The remainder of Delta drainage is assumed to flow out of the Delta at Chipps Island. Because net drainage exists only if the rainfall is greater than the assumed ET value, drainage is highest in the winter months. Substantial seepage occurs from the channels to the drainage canals in the Delta lowlands, so a minimum drainage flow of 1 inch per month is assumed. In addition, 1 inch of drainage from salt leaching is assumed to occur in December, January, and February. The assumed drainage is therefore 15 inches in addition to the net drainage from rainfall. The 1 inch of drainage per month is equivalent to about 410 cfs from the assumed central Delta drainage acreage of 295,000 acres (i.e., 0.4 • 738,000 acres).

Table G-2 shows the calculated monthly central Delta drainage flows that are assumed to influence the export salinity and DOC concentrations in the DeltaSOQ model. For exports shown in Table 3-4 in Chapter 3, "Water Supply and Operations", drainage fractions are generally less than 5% of export pumping during the summer but increase to as much as 20% in some months with high rainfall.

Drainage water can be diverted by Delta diversions, Delta Wetlands diversions, or export pumping or can leave the central Delta as QWEST flow past Jersey Point. (QWEST is a calculated flow parameter that represents net flow between the central and western Delta.) The drainage fraction is calculated as:

$$\frac{\text{central Delta drainage flow}}{\text{Delta Wetlands diversion} + \text{central Delta diversions} + \max(\text{QWEST},0) + \text{exports} - 0.75\ \text{San Joaquin River flow}}$$

To establish the maximum potential effects from Delta Wetlands Project operations, 100% of the project discharges are assumed to reach the exports. The Delta Wetlands Project fraction is therefore:

$$\text{Delta Wetlands fraction} = \frac{\text{Delta Wetlands discharge}}{\text{Total exports}}$$

Salinity Intrusion

Salinity intrusion from Suisun Bay is an important factor in calculations of Delta salinity. Effects are simulated in DeltaSOQ using the Contra Costa Water District (CCWD) methodology, which is based on effective outflow and negative exponential relationships between effective outflow and salinity at Delta channel locations (see Appendix B2 in the 1995 DEIR/EIS). The effective outflow is similar to a weighted running average of outflow, with a weighting function that depends on outflow. For a monthly time step, the effective outflow is calculated as:

$$\text{New effective outflow (cfs)} = \frac{\text{Outflow (cfs)}}{1 + \left(\frac{\text{outflow}}{\text{old effective outflow}} - 1\right) \bullet \exp\left(\frac{-\text{outflow}}{6{,}600}\right)}$$

The EC values for the end of each month depend on the effective outflow for the month. For Chipps Island, Emmaton, and Jersey Point, the EC was calculated as follows, with a constant of 150 μS/cm representing the assumed EC value for the Sacramento River:

Chipps Island EC (μS/cm) = 150 + 30,000 • exp(-0.00025 • effective outflow)
Emmaton EC (μS/cm) = 150 + 12,500 • exp(-0.00040 • effective outflow)
Jersey Point EC (μS/cm) = 150 + 10,000 • exp(-0.00040 • effective outflow)

To confirm the accuracy of this component of the DeltaSOQ calculations, simulated EC (for historical Delta outflows) was compared with the monthly average measured EC at Chipps Island, Emmaton, and Jersey Point. This comparison is shown in Figure G-4. The model generally reproduces the seasonal effects of reduced outflow on increased EC. The Emmaton and Jersey Point EC values are similar, with Emmaton EC values higher than Jersey Point values when outflow is very low. The model represents the basic relationship between Delta outflow and measured EC values, although the historical monthly data are not always simulated exactly.

Central-Delta Salinity

The EC and Cl^- concentrations from the central Delta are calculated in DeltaSOQ as a function of the effective outflow, as shown in the following equation. One-third of the central Delta EC value is assumed to be derived from Jersey Point EC and two-thirds from Sacramento River EC. The constant of 7.5 mg/l is the assumed Cl^- concentration for the Sacramento River:

Central Delta EC (μS/cm) = 150 + 3,333 • exp(-0.00040 • effective outflow)
Central Delta Cl^- (mg/l) = 7.5 + 1,000 • exp(-0.00040 • effective outflow)

San Joaquin River Salinity

The San Joaquin River EC is assumed to be related to Vernalis flow as follows. The San Joaquin River Cl^-:EC ratio is assumed to be 0.15.

San Joaquin River EC (μS/cm) = 25,000 • flow (cfs) $^{-0.5}$
San Joaquin River Cl^- (mg/l) = 3,750 • flow (cfs) $^{-0.5}$

Agricultural Drainage and Delta Wetlands Salinity

Agricultural drainage salinity is calculated from a mass balance that tracks soil (i.e., pore-water) salinity. It is assumed, therefore, that there are no long-term changes in soil salinity. Agricultural drainage discharge from Delta islands originates from a complex drainage network. DeltaSOQ uses a very basic conceptual model of the soil pore-water budget. During the irrigation season, water is applied to the fields and generally evaporates, but some small fraction enters the drainage network. The drainage salinity is only slightly higher than that of the applied water because most of the applied salt remains in the soil. During winter, when rainfall and applied salt-leaching water are drained from the fields, some fraction of the accumulated soil salt is transported to the drainage network. The DeltaSOQ model can only approximate this seasonal accumulation of salt.

In DeltaSOQ, the soil pore-water depth is assumed to be 12 inches (peat-soil porosity is about 50%, and the soil depth is about 2 feet) based on DWR's Delta depletion analysis. Applied-water EC is assumed to be equal to the previous month's export EC. Drainage-water salinity is assumed to be equal to soil pore-water salinity. Pore-water salt increases as water evaporates and channel water is applied. Only drainage water removes salt from the soil pore-water volume. The soil pore-water salinity increases during the spring and summer months and decreases during the winter months when there is rain and applied leaching water.

Figure G-5 compares the simulated drainage EC values with MWQI drainage EC measurements from ten of the Delta lowland islands. Winter drainage EC values were typically higher than summer values. These EC measurements have a wide range and can only generally confirm the simulated drainage EC patterns. The drainage EC values are quite variable; the simulated range of drainage EC is between approximately 300 and 1,800 μS/cm. The measured range of EC values is also broad and is generally between 200 and 2,000 μS/cm. Therefore, although the simulated range of EC values does not always capture the extreme ends of the measured range, it represents most measured values. Simulated drainage EC is generally 2 or 3 times the applied EC.

Comparison of Simulated and Measured Export Concentrations

Figure G-6 compares the simulated export Cl^- concentrations with historical monthly Cl^- measurements from the CCWD pumping plant at Rock Slough. The seasonal variation of Cl^- concentrations generally matches the simulation results. The simulated results include the effects of the San Joaquin River, seawater intrusion, and central Delta agricultural drainage under historical flow and export conditions on export Cl^-. Some of the measured Cl^- concentrations are higher than the simulated values, suggesting that local drainage may affect Rock Slough more than it affects average south-Delta exports.

Figure G-7 compares simulated export EC concentrations with historical EC measurements from the Central Valley Project (CVP) and State Water Project (SWP) export locations. CVP measurements are made at the Delta-Mendota Canal (DMC). The seasonal patterns of measured EC generally match the simulation results.

Dissolved Organic Carbon Calculations in the Delta Standards, Operations, and Quality Model

DeltaSOQ establishes baseline DOC levels at Delta exports, determines DOC loading under agricultural conditions (i.e., the No-Project Alternative), and estimates DOC loading under flooded reservoir conditions (i.e., the proposed project). Project effects on DOC concentrations in Delta exports are a function of the following:

- the DOC concentrations in water diverted onto the Delta Wetlands islands;
- evaporative losses;
- DOC loading from peat soils and plant growth;
- residence time (i.e., the length of time water is stored on the islands before being discharged);
- DOC concentrations in Delta receiving waters at the time of Delta Wetlands discharges; and
- the relative amount of Delta Wetlands water in exports.

DeltaSOQ incorporates these factors into the calculation of DOC effects in a manner similar to that described above for EC and Cl^- calculations.

Dissolved Organic Carbon in Delta Inflows

Estimated DOC concentrations in Delta inflows and from agricultural drainage are used in DeltaSOQ to determine the DOC of Delta exports under no-project conditions and at times of Delta Wetlands Project diversions and discharges. The Sacramento River is assumed to have a constant DOC concentration of 2 mg/l. The San Joaquin River DOC concentration is assumed to be a constant of 4 mg/l. Central-Delta DOC is also assumed to be 2 mg/l, with no increase in DOC concentration from seawater intrusion.

Dissolved Organic Carbon in Agricultural Drainage

The DeltaSOQ model provides a logical mass-balance framework for estimating agricultural drainage DOC loads that parallels the salt balance estimates for EC and Cl^- drainage loads. The agricultural drainage DOC is estimated from a mass balance that tracks the soil pore-water DOC concentration.

As described under "Estimating Existing Levels of Dissolved Organic Carbon in Delta Agricultural Drainage" above, the DOC loading rates calculated from MWQI measurements of DOC concentrations in Delta island drainage range from 2.5 to 22.4 $g/m^2/yr$. Based on these results, DeltaSOQ simulated two estimates of DOC loading under agricultural operations to determine which more closely represents the measured drainage and export DOC concentrations and, therefore, should be used in the impact analysis. An estimate of approximately 12 $g/m^2/yr$, or 1 $g/m^2/month$, for DOC loading was simulated to represent most of the MWQI estimates; a second estimate of 24 $g/m^2/yr$, or 2 $g/m^2/month$, was simulated to encompass the higher rate measured in Bouldin Island drainage. The simulated Delta drainage and export DOC concentrations under each assumption were compared with measured data presented in Figures G-8 and G-9, respectively, and are discussed below. The results indicate that an assumed average agricultural DOC loading of 1 $g/m^2/month$ (i.e., 12 $g/m^2/yr$)

more closely matches measured data for the central Delta region than an assumption of 24 $g/m^2/yr$. Therefore, this value is used in the impact analysis.

Figure G-8 shows the simulated agricultural drainage DOC and the MWQI drainage DOC measurements from ten of the Delta lowland islands. For the assumed seepage and leaching volumes and the rainfall drainage that occurs in the winter months, the simulated soil pore-water DOC concentrations fluctuate seasonally between about 20 and 40 mg/l when an assumed loading factor of 1 $g/m^2/month$ is used. The measured drainage DOC concentrations are generally within this range, although the flow-weighted average DOC in the drainage water cannot be determined because there are no drainage flow records. Only the basic seasonal DOC patterns and DOC increases during dry years can be confirmed with these data. As shown in Figure G-8, simulated results using an assumed loading factor of 2 $g/m^2/month$ are considerably higher than the MWQI drainage DOC measurements. The 23-year period is shown to illustrate the simulated variations between wet and dry years.

Figure G-9 shows the simulated export DOC and the MWQI measurements of export DOC concentrations from the CVP and SWP facilities. In the simulation, 40% of total Delta agricultural drainage is assumed to originate from the Delta lowlands and be transported toward the export pumps. The seasonal fluctuations in the measured DOC concentrations generally match the DeltaSOQ results with an assumed load of 1 $g/m^2/month$. As shown in Figure G-9, the larger assumed monthly load of 2 $g/m^2/month$ from agricultural islands results in simulated export DOC concentrations that are almost always higher than measured values. With the higher assumed load, the simulated export DOC concentrations of between 5 and 15 mg/l are much greater than the measured DOC values. This indicates that an assumed average agricultural DOC loading of about 1 $g/m^2/month$ (i.e., 12 $g/m^2/yr$) is a reasonable estimate for the central Delta. The model mixes this drainage with the water from the river sources to calculate the export DOC.

Dissolved Organic Carbon Loading under Reservoir Operations

An additional load of DOC could result from inundation of the peat soils during reservoir operations under the proposed project. Reservoir operations would likely cause more DOC to be mixed from the pore water into the water column than when the peat soils are drained under agricultural practices. DOC loading is a function of many variables, including peat-soil depth, pore-water concentration, pore-water and water column mixing, plant material growth and degradation, resuspension of peat because of wind, and the length of time water is held. The storage DOC concentrations will also increase with evaporation and seepage control (i.e., interceptor well) pumping and discharge. Measured data on DOC loading under flooded peat-soil conditions similar to conditions proposed by Delta Wetlands are not available; therefore, estimates of DOC loading from reservoir operations are based on experimental results.

In the long term, repeated filling and emptying of the Delta Wetlands reservoir islands might leach out most of the soluble organic material; therefore, DOC loading from peat soils might decline over time. At least the first few fillings, however, would likely result in high DOC loading. Therefore, the analysis presents three simulations of potential project effects on DOC in Delta exports: an assumption for long-term DOC loading, an assumption for initial-filling DOC loading, and an assumption for high initial-filling DOC loading.

The DeltaSOQ model was used to determine how an increased DOC load resulting from Delta Wetlands Project operations would affect export DOC concentrations. The largest DOC increases would occur in months with Delta Wetlands discharges. As discussed in Chapter 4 under "Environmental Consequences", the simulated increases in DOC concentrations with Delta Wetlands operations are a function of the fraction of the exports coming from the Delta Wetlands discharge, which is almost always less than 20% (see Tables 3-4 and 3-15), and the estimated Delta Wetlands discharge DOC concentrations.

Additionally, this REIR/EIS method accounts differently for cessation of agricultural activities on the Delta Wetlands islands than does the method used in the 1995 DEIR/EIS. Because project impacts change water quality conditions relative to conditions under the No-Project Alternative, the 1995 DEIR/EIS reported that the cessation of agricultural activities on the Delta Wetlands islands and the subsequent reduction in agricultural drainage DOC loading would benefit water quality. Commenters on the 1995 DEIR/EIS argued that this assumption may not be valid and that DOC loading under reservoir operations should be considered in addition to the agricultural loading estimates. Therefore, the agricultural drainage DOC loading estimate of 1 g/m^2/month (or 12 g/m^2/yr) is assumed under both the no-project and proposed project conditions. In other words, the contribution of Delta Wetlands islands to agricultural drainage DOC is not considered to change in this REIR/EIS analysis under simulated no-project and proposed project conditions.

Initial-Filling DOC Loading Estimate. For purposes of this analysis, DOC loading for the initial reservoir filling is assumed to be 5 times greater than DOC loading under agricultural conditions. This assumption results in a DOC loading estimate of 4 g/m^2/month during storage periods (in addition to the constant agricultural contribution of 1 g/m^2/month described above). This estimate is based on Special Multipurpose Applied Research Technology Station (SMARTS) 1 results for static tanks, for which a DOC load of 24 to 54 g/m^2/yr was estimated; it is also compatible with the SMARTS 2 results for static tanks filled with peat soil that produced pore-water DOC concentrations of 46.8 and 57.8 mg/l (i.e., tanks 5 and 7, respectively), for which a DOC load of 23 to 42 g/m^2/yr was estimated (see Tables 4-3, 4-4, and 4-5 in Chapter 4). This assumed initial-fill DOC load is also consistent with results from the flooded wetland demonstration project on Holland Tract and the Tyler Island flooding study (Table 4-5).

As discussed in Chapter 4, experts disagree regarding potential DOC loading under reservoir operations. The ranges of data from experiments (e.g., SMARTS) and theoretical estimates of DOC loading vary widely. The DOC loading estimate of 5 g/m^2/month of storage (4 g/m^2/month for reservoir operations plus 1 g/m^2/month for agricultural contributions) is 5 times greater than the estimate used in the 1995 DEIR/EIS, and is presented along with the long-term loading estimate described below to provide a range of DOC loading estimates for impact analysis. As described above, the 4 g/m^2/month value is based on the results of measured data from the SMARTS reports, the Holland Tract flooded wetland demonstration, and the Tyler Island flooding experiment. For all these estimates, the measured loading was assumed to represent total annual loading because, in most cases, results indicated that peat-soil pore-water samples would approach loading limits in less than 6 months. However, in recognition of the debate regarding worst-case initial-fill DOC loading, results for a high initial-fill loading estimate of 9 g/m^2/month are also presented. Combined with loading of 1 g/m^2/month for agricultural contributions, this represents a DOC loading rate that is 10 times higher than the estimated agricultural drainage loading under no-project conditions.

Long-Term DOC Loading Estimates. For long-term (versus initial-filling) DOC loading estimates, additional loading is specified in the DeltaSOQ model as an additional 1 g/m^2/month during the storage period (i.e., 1 g/m^2/month in addition to the assumed constant agricultural load of 1 g/m^2/month in the Delta). This estimate doubles the agricultural loading estimate assumed under no-project conditions.

Dissolved Organic Carbon Loads from Interceptor Wells. Commenters on the 1995 DEIR/EIS and parties testifying at the State Water Resources Control Board (SWRCB) water right hearing also contended that DOC-loading effects of interceptor wells used to control seepage from the Delta Wetlands reservoir islands (see Chapter 6, "Levee Stability and Seepage") would be a potentially significant source of DOC from the reservoir islands. When the reservoir islands are full, water seeping from the reservoirs would be captured by interceptor wells located in the perimeter levees and returned to the reservoirs.

Based on results of the levee stability and seepage technical report (see Section 2.3, "Seepage Analysis", in Appendix H of this REIR/EIS), it was assumed that the pumping rates in the interceptor well system under full storage conditions would be 0.033 to 0.238 gallon per minute (gpm) per foot of levee. Under the proposed seepage control system (see Chapter 6), interceptor wells would be installed along the entire perimeter of Bacon Island (approximately 14.5 miles) and less than half the perimeter of Webb Tract (estimated as approximately 6.5 miles). Using these estimates, the amount of water pumped when both islands are at full storage is calculated to be approximately 3,700 to 26,400 gpm, which corresponds to approximately 500 to 3,500 af/month (1,000 gpm = 4.4 af/day). This is equivalent to pumping 0.6 to 4.2 inches of water onto the reservoir islands (surface area of Bacon Island and Webb Tract is approximately 10,000 acres). Assuming a 6-month full-storage period for both islands and a DOC concentration in the seepage water that is 10 mg/l higher than reservoir DOC concentration, the additional DOC load is calculated to be 1 to 6 g/m^2/yr:

$$\text{DOC loading } (g/m^2/yr) = \text{change in DOC concentration (mg/l per year)} \bullet \text{depth (m)}$$

If it is assumed that the water will be stored for a longer period or that the DOC concentrations will change more as a result of interceptor well pumping, the resulting change in annual DOC load from the reservoir islands would be greater. For example, using the equations outlined above, a 9-month storage period with an assumed DOC concentration of 20 mg/l in pumped water results in an increased DOC loading estimate of 3 to 19 g/m^2/yr. This DOC loading rate is relatively high compared to estimates of DOC loading under existing agricultural practices, which include a considerable amount of drainage pumping to balance seepage from adjacent channels and maintain acceptable water levels for crop production.

Although seepage prevention operations could increase DOC loading on the reservoir islands, an increase of this magnitude is more likely to occur during initial storage operations. The peat soils underlying the reservoir islands may be flushed over time, and the difference in DOC concentrations between reservoir island water and pumped water is not likely to remain as high as in the estimates presented above. The assumed initial-filling DOC loads for reservoir islands (i.e., 4 and 9 g/m^2 per month of storage) include the estimated load from the interceptor well pumping.

ESTIMATING PROJECT EFFECTS ON TRIHALOMETHANE AND BROMATE CONCENTRATIONS IN TREATED WATER

SWRCB staff determined that the potential effects of Delta Wetlands Project operations on treated-drinking-water DBPs (THM and bromate) would be evaluated as an additional level of water quality impact assessment. Because DBP concentrations are determined by both the raw water quality parameters (DOC and Br^-) and the treatment process parameters (chlorination dose, pH, temperature, holding time), only representative estimates of the incremental effects of increased DOC and Br^- concentrations on these DBP concentrations can be calculated. Potential effects of Delta Wetlands operations on THM concentrations are calculated and reported; the effects on bromate concentrations are not calculated because no reliable relationship with DOC or Br^- could be identified. The effects of Delta Wetlands Project operations on THM concentrations are calculated using an approximate relationship between export water DOC and Br^- concentrations and treated water THM concentrations. This relationship is described in the following section.

Calculations Using the Malcolm Pirnie Equation

In the 1995 DEIR/EIS, the U.S. Environmental Protection Agency's (EPA's) Water Treatment Plant (WTP) model was used to estimate THM concentrations at a typical water treatment plant that may use Delta exports containing water released from the Delta Wetlands Project islands. The model consists of a series of subroutines that simulate THM formation and removal of organic THM precursor compounds. A more detailed description of the operation of the WTP model is provided in Appendix C5 of the 1995 DEIR/EIS. Estimates of THM in treated Delta exports were evaluated in the 1995 DEIR/EIS with simulated Delta conditions for 1968-1991. Export concentrations of water quality variables were estimated from the Delta Drainage Water Quality model (DeltaDWQ) results for Cl^- and DOC.

The WTP model predicts total THM concentration, then determines the concentrations of different types of THM molecules by estimating relative concentrations from separate regression equations for each of the four types of THM molecules (chloroform [$CHCl_3$], dichlorobromomethane [$CHCl_2Br$], dibromochloromethane [$CHClBr_2$], and bromoform [$CHBr_3$]). All of the multiple-logarithmic regressions are similar, but the coefficient values for the independent variables differ. The original equation for total THM concentration is:

$$\text{THM}\ (\mu g/l) = 0.3254 \bullet \text{DOC}^{0.44} \bullet \text{UVA}^{0.351} \bullet \text{Cl}_2^{0.409} \bullet \text{Hours}^{0.265} \bullet \text{Temp}^{1.06} \bullet (\text{pH} - 2.6)^{0.715} \bullet (\text{Br}^- + 1)^{0.516}$$

DOC units are mg/l. Ultraviolet absorbance (UVA) is estimated as 0.0375 • DOC in the model. Chlorine (Cl_2) dose is assumed to be a fraction (i.e., 1.0) of the DOC concentration (California Urban Water Agencies 1996). Temperature is measured in Celsius. Br^- units are mg/l. The ratio of Br^- to Cl^- is assumed to be 0.0035, and the maximum allowable Cl^- concentration in Delta exports is 250 mg/l, so the maximum allowable Br^- concentration is about 0.875 mg/l, and the (Br^- + 1) term varies from about 1.05 to 1.875.

The THM equation was modified by Malcolm Pirnie (Malcolm Pirnie 1993), using experimental data measured by the Metropolitan Water District of Southern California (MWD), to specifically address differences in THM formation with high Br^- concentration in Delta source waters. The revised equation developed with MWD data is:

$$\text{THM}\ (\mu g/l) = 7.21 \bullet DOC^{0.004} \bullet UVA^{0.534} \bullet (Cl_2 - 7.6 \bullet NH_3 - N)^{0.224} \bullet Hours^{0.255} \bullet Temp^{0.48} \bullet (pH - 2.6)^{0.719} \bullet (Br^- + 1)^{2.01}$$

The magnitude of the coefficient for each independent variable indicates the degree to which THM concentrations will respond to a change in that variable when other conditions remain the same. Because UVA is a linear function of DOC, and Cl_2 dose generally increases as a linear function of DOC (Cl_2 dose is approximately 1.0 • DOC), an increase in DOC will generally cause all three variables to increase. The effective DOC exponent of the original equation is 1.2 (0.44 + 0.351 + 0.409), whereas for the revised equation it is only 0.762 (0.004 + 0.534 + 0.224). If source-water DOC increased by 20%, THM formation would increase by about 25% with the original equation and only by about 15% with the revised equation. However, both equations suggest that THM increases almost linearly with DOC. A linear relationship between THM and DOC was also assumed in the DeltaSOQ model, which is used to evaluate Delta Wetlands Project impacts on THM concentrations.

The modification in the equation for Br^-, however, may not accurately represent the effect of Br^- concentrations on THM formation. Basic THM chemistry dictates that the number of THM molecules formed from a given concentration of DOC depends on the chlorination dose; the only effect of the Br^- concentration will be to influence which species of THM molecules will form (see Appendix C5 of the 1995 DEIR/EIS). If all the THM formed during treatment were $CHBr_3$, the THM concentration would be about twice (2.12 x) as high as if no Br^- were present and $CHCl_3$ were formed instead (because a mole of $CHBr_3$ weighs 252 g and a mole of $CHCl_3$ weighs 119 g). Therefore, the maximum effect of Br^- should be to double the concentration (weight) of THM. However, with the original equation, THM increases by only 42% (a factor of less than 0.5) as Br^- increases from 0.05 mg/l to 1 mg/l. With the revised equation, as Br^- increases from 0.05 mg/l to 1 mg/l, the predicted THM concentration would increase by a factor of 4. Both of these results are inconsistent with the basic THM chemistry described above. Therefore, the exponent in the original equation of 0.516 is considered too low, and the exponent of 2.01 in the revised equation is considered too high.

For the approximate relationship used in the DeltaSOQ model, the exponent of the (1 + Br^-) term has been set to 1 to calculate a doubling of THM concentration as Br^- increases from 0.05 mg/l to 1 mg/l. A constant Br^-:Cl^- ratio of 0.0035 is used to estimate export Br^- concentrations. The coefficient of the equation used in DeltaSOQ (10.0) was set to simulate the ability of the water treatment plants to adjust their operating conditions to provide treated water with THM concentrations that are generally less than the current MCL concentration of 80 μg/l. The actual slope of this relationship between DOC and THM depends on specific water treatment plant operations. The simplified equation used in DeltaSOQ is:

$$THM (\mu g/l) = 10.0 \bullet DOC \bullet [1 + 0.0035 \bullet Export\ Cl^- (mg/l)]^{1.0}$$

Figures G-10a and G-10b show the treated-water THM concentrations actually measured at Penitencia WTP compared with the raw DOC and Br^- concentrations. A linear regression between DOC and THM concentrations from the Penitencia WTP data indicates a very small effect of DOC on THM (i.e., THM = 65 + 2.0 • DOC, r^2 = 0.01). The predicted THM concentrations for the original and revised Malcolm Pirnie equations as well as the simplified equation used for impact assessment purposes are also shown in the figures.

Although SWRCB staff asked CUWA to provide additional treatment plant DOC, Br^-, and THM data to help confirm the revised THM equation, CUWA was unable to provide any other data and instead resubmitted data from the MWD testing used by Malcolm Pirnie to revise the THM equation. The treatment conditions (i.e., temperature, pH, coagulant dose, and Cl_2 dose) vary too widely for relationships between THM and DOC or Br^- to be evident. Because CUWA provided no additional data to identify this relationship between DOC and THM, the DeltaSOQ model used the approximate value of 10.0 to evaluate the likely effects on THM concentrations of Delta Wetlands' discharge of water with higher DOC concentrations.

The simplified equation preserves the predicted effect of DOC on THM concentration identified in the Malcolm Pirnie equations (exponent of about 1.0) and simulates that an increase of Br^- from 0 to 1 mg/l will double the THM concentration. Using the simplified equation, an increase of 0.8 mg/l DOC will result in an expected increase in THM concentration of 8 μg/l if Br^- is 0.0 mg/l and of 16 μg/l if Br^- is 1.0 mg/l.

Estimating Bromate Concentrations in the Delta Standards, Operations, and Quality Model

Federal regulations for bromate (BrO_3) were first proposed in 1994, revised in 1997, and finally promulgated in December 1998 (63 FR 63 69389; December 16, 1998). The MCL for bromate was established at 10 μg/l. This chemical is formed during disinfection of raw water with ozone (O_3). Disinfection with O_3 is preferable to chlorination in certain situations in which DOC is elevated, because it generally produces fewer THMs than chlorination and provides greater disinfection against viruses and other microorganisms.

The predictive equation for bromate formation in treated drinking water developed by Ozekin (Ozekin 1994) was assessed for use in this REIR/EIS analysis. As described below, however, this equation does not match the measured relationship between bromate and Br^- and DOC concentration in source water. Absence of a reliable predictor of a relationship between bromate and Br^- or DOC limits the ability to evaluate Delta Wetlands Project effects on bromate.

The equation developed by Ozekin has the following form:

$$BrO_3\ (\mu g/l) =$$
$$(1.63 \bullet 10^{-6}) \bullet DOC^{0.004} \bullet pH^{5.82} \bullet (O_3\ dose)^{1.57} \bullet Br^{-\ 0.73} \bullet Time^{0.28}$$

The O_3 dose is assumed to be some fraction (e.g., 0.5) of the DOC concentration, the Br^- units are μg/l, and the time units are minutes. The exponents in this equation indicate that bromate is not sensitive to DOC concentration; a 20% increase in DOC will increase bromate by less than 0.1%. A 20% increase in Br^- concentration will increase the predicted bromate concentration by 14%.

CUWA funded a study (California Urban Water Agencies 1996) to investigate the water treatment strategies and improvements that would be needed to comply with the revised Stage 1 rules for total THMs and other DBPs, including bromate and haloacetic acids. The study included DBP formation potential experiments using waters with high Br^- concentrations; it assessed the effectiveness of disinfection by chlorination and ozonation and the ability of enhanced coagulation processes to reduce DBPs. Measured data were also collected from CUWA member agency treatment plants for evaluation of potential compliance performance. The CUWA-funded ozonation experiments used variable ratios of O_3 to DOC, variable pH levels, and a constant O_3 contact time of 12 minutes (Malcolm Pirnie 1993).

Figures G-11a and G-11b compare data from member agency treatment plants to results predicted with the Ozekin model. Most of the data are from MWD laboratory pilot scale tests. The results of the bromate equation exceed the MCL for bromate (10 μg/l) when total organic carbon (TOC) is greater than 2 mg/l and when Br^- concentrations are higher than about 250 μg/l, with the other parameters specified as suggested by the CUWA study. This means that existing Delta water quality conditions will produce bromate concentrations that are higher than allowable if ozonation is used with the pH and O_3 doses suggested by the MWD study. However, this finding is not consistent with full-scale treatment plant measurements: the bromate prediction equation produces values that are generally higher than measured values. There appears to be no direct correlation between treatment plant measurements of bromate and measurements of either Br^- or DOC in the source water.

Based on the lack of any observed relationship between bromate formation and Br^- or DOC concentrations in the source water, it was determined that the impact analysis should address the effects of Delta Wetlands Project operations effects on Br^- and DOC, but not try to predict changes in bromate concentrations expected in drinking water treated by O_3. The impact analysis for the Delta Wetlands Project identifies the changes in DOC and Br^- that are likely to be observed at Delta diversion and export locations. Therefore, the basic proposed mitigation for water quality impacts (see "Recommended Mitigation and Delta Wetlands Project Operations" in Chapter 4) can be used to limit the allowable increase in DOC and Br^-, thus limiting the expected effect on bromate. If a predictable relationship between Br^- and bromate is identified in the future, it can be used to regulate Delta Wetlands operations to maintain acceptable changes in DOC and Br^- at the export and diversion locations, relative to the MCL value of bromate.

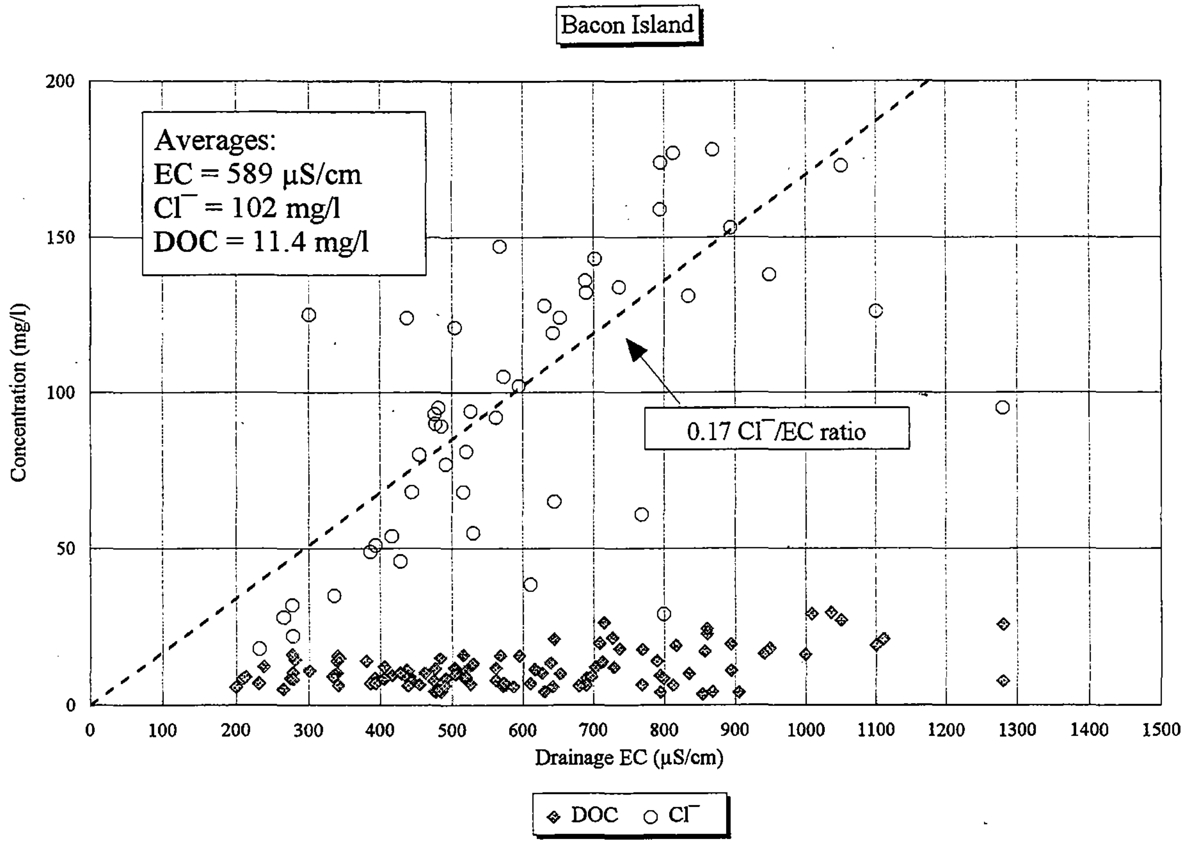
Table G-1. Weekly Drainage and Average DOC Concentrations for Agricultural Drainage from Twitchell Island in 1995

Date	Drainage (AF)	EC (µS/cm)	DOC mg/l	DOC Load (g/m²)	Drainage (inches)
01/04	373.4	1300	29.1	0.9	1.3
01/11	500.4	1330	31.5	1.4	1.7
01/18	564.3	1560	37.1	1.8	1.9
01/25	559.5	1860	43.2	2.1	1.9
02/01	552.9	1780	46.6	2.2	1.9
02/08	372.6	1780	41.9	1.4	1.3
02/15	295.5	1600	37.4	1.0	1.0
02/22	288.2	1570	37.0	0.9	1.0
03/01	214.2	1600	34.5	0.6	0.7
03/08	340.8	1740	51.4	1.5	1.2
03/15	534.8	1630	49.8	2.3	1.8
03/22	425.2	1780	44.8	1.7	1.5
03/29	557.1	1670	45.5	2.2	1.9
04/05	207.3	1460	30.1	0.5	0.7
04/12	178.0	1320	28.4	0.4	0.6
04/19	168.8	1120	23.8	0.3	0.6
04/26	164.0	1060	22.6	0.3	0.6
05/01	112.5	1020	21.9	0.2	0.4
05/08	164.0	1000	20.9	0.3	0.6
05/15	154.3	860	17.3	0.2	0.5
05/22	146.0	970	20.2	0.3	0.5
05/29	157.3	840	15.8	0.2	0.5
06/05	118.5	830	17.3	0.2	0.4
06/12	121.4	770	13.9	0.1	0.4
06/19	127.5	760	11.2	0.1	0.4
06/26	138.8	780	14.2	0.2	0.5
07/03	144.2	680	11.3	0.1	0.5
07/10	114.2	630	8.4	0.1	0.4
07/17	145.0	510	7.7	0.1	0.5
07/24	157.3	590	9.1	0.1	0.5
07/31	225.9	450	12.7	0.2	0.8
08/07	206.6	540	15.3	0.3	0.7
08/14	210.0	440	10.7	0.2	0.7
08/21	205.9	440	10.5	0.2	0.7
08/28	173.6	530	13.6	0.2	0.6
09/05	135.7	590	15.3	0.2	0.5
09/11	69.0	640	8.4	0.1	0.2
09/18	72.0	640	11.5	0.1	0.2
09/25	68.6	680	7.1	0.0	0.2
10/02	72.6	640	7.4	0.0	0.2
10/10	72.6	700	6.6	0.0	0.2
10/16	65.9	700	6.8	0.0	0.2
10/23	60.2	720	6.0	0.0	0.2
10/30				0.0	0.0
11/06	148.9	550	7.5	0.1	0.5
11/14				0.0	0.0
11/20	153.0	740	7.4	0.1	0.5
11/27	74.7	710	7.2	0.0	0.3
12/04	80.6	600	8.6	0.1	0.3
12/11				0.0	0.0
12/18	311.3	1070	16.9	0.5	1.1
12/31	481.7	1030	29.1	1.2	1.6
Annual Average		1000	21.1		
Annual Total	10986			27.5	37.5

Sources: U.S. Geological Survey 1997 and California Department of Water Resources 1999a.

Table G-2. Calculated Central Delta Drainage Flows (cfs)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1922	410	410	410	1477	2044	820	410	410	410	410	410	410
1923	410	410	1379	1516	820	820	410	410	410	410	410	410
1924	410	410	410	872	820	820	410	410	410	410	410	410
1925	410	410	482	1087	1886	820	410	410	410	410	410	410
1926	410	410	410	1015	1605	820	410	410	410	410	410	410
1927	410	410	410	1210	2080	820	410	410	410	410	410	410
1928	410	410	410	1074	820	1035	410	410	410	410	410	410
1929	410	410	410	989	820	820	410	410	410	410	410	410
1930	410	410	410	1275	1101	833	410	410	410	410	410	410
1931	410	410	410	1067	842	820	410	410	410	410	410	410
1932	410	410	1178	1243	1522	820	410	410	410	410	410	410
1933	410	410	410	1262	820	820	410	410	410	410	410	410
1934	410	410	410	931	1360	820	410	410	410	410	410	410
1935	410	410	410	1672	820	1145	524	410	410	410	410	410
1936	410	410	410	1340	2447	820	410	410	410	410	410	410
1937	410	410	410	1243	1951	1932	410	410	410	410	410	410
1938	410	410	410	1288	3038	1601	410	410	410	410	410	410
1939	410	410	410	879	820	820	410	410	410	410	410	410
1940	410	410	410	1874	2579	1139	410	410	410	410	410	410
1941	410	410	898	2245	2023	853	410	410	410	410	410	410
1942	410	410	417	2030	1108	820	497	410	410	410	410	410
1943	410	410	410	1815	921	1009	410	410	410	410	410	410
1944	410	410	410	911	1446	820	410	410	410	410	410	410
1945	410	410	410	944	1317	1028	410	410	410	410	410	410
1946	410	410	683	911	820	820	410	410	410	410	410	410
1947	410	410	410	859	878	820	410	410	410	410	410	410
1948	410	410	410	820	820	820	410	410	410	410	410	410
1949	410	410	410	937	863	1080	410	410	410	410	410	410
1950	410	410	410	1269	935	820	410	410	410	410	410	410
1951	410	410	1126	1594	1029	820	410	410	410	410	410	410
1952	410	410	833	2726	855	1171	410	410	410	410	410	410
1953	410	410	696	1327	820	820	410	410	410	410	410	410
1954	410	410	410	885	820	820	410	410	410	410	410	410
1955	410	410	410	1588	820	820	410	410	410	410	410	410
1956	410	410	1555	2596	820	820	410	410	410	410	410	410
1957	410	410	410	866	935	820	410	410	410	410	410	410
1958	410	410	410	1776	2815	1607	652	410	410	410	410	410
1959	410	410	410	970	1295	820	410	410	410	410	410	410
1960	410	410	410	1028	1154	820	410	410	410	410	410	410
1961	410	410	410	1366	820	820	410	410	410	410	410	410
1962	410	410	410	885	2513	820	410	410	410	410	410	410
1963	410	410	410	1562	1252	1022	773	410	410	410	410	410
1964	410	410	410	1282	820	820	410	410	410	410	410	410
1965	410	410	768	1588	820	820	410	410	410	410	410	410
1966	410	410	469	1217	906	820	410	410	410	410	410	410
1967	410	410	631	2941	820	1100	686	410	410	410	410	410
1968	410	410	410	1165	917	820	410	410	410	410	410	410
1969	410	410	410	2752	2347	820	410	410	410	410	410	410
1970	410	410	410	2524	827	820	410	410	410	410	410	410
1971	410	410	1139	1035	820	820	410	410	410	410	410	410
1972	410	410	410	898	820	820	410	410	410	410	410	410
1973	410	679	514	2993	2016	898	410	410	410	410	410	410
1974	410	410	781	1412	820	918	410	410	410	410	410	410
1975	410	410	410	833	1346	1236	410	410	410	410	410	410
1976	410	410	410	820	820	820	410	410	410	410	410	410
1977	410	410	410	853	820	820	410	410	410	410	410	410
1978	410	410	410	2798	1562	1425	410	410	410	410	410	410
1979	410	410	410	1633	1814	820	410	410	410	410	410	410
1980	410	410	410	1848	2190	820	410	410	410	410	410	410
1981	410	410	410	1061	820	898	410	410	410	410	410	410
1982	410	410	566	2550	1036	1958	410	410	410	410	410	410
1983	410	780	703	2687	2217	2648	410	410	410	410	410	410
1984	410	410	1178	846	862	820	410	410	410	410	410	410
1985	410	518	410	989	820	944	410	410	410	410	410	410
1986	410	410	410	1386	3161	1295	410	410	410	410	410	410
1987	410	410	410	866	928	833	410	410	410	410	410	410
1988	410	410	410	1373	820	820	410	410	410	410	410	410
1989	410	410	410	853	820	820	410	410	410	410	410	410
1990	410	410	410	976	899	820	410	410	410	410	410	410
1991	410	410	410	820	820	983	410	410	410	410	410	410
1992	410	410	410	879	1578	846	410	410	410	410	410	410
1993	410	410	527	3364	2232	859	410	410	410	410	410	410
1994	410	410	410	989	1231	820	410	410	410	410	410	410
Average	410	420	524	1417	1288	959	425	410	410	410	410	410



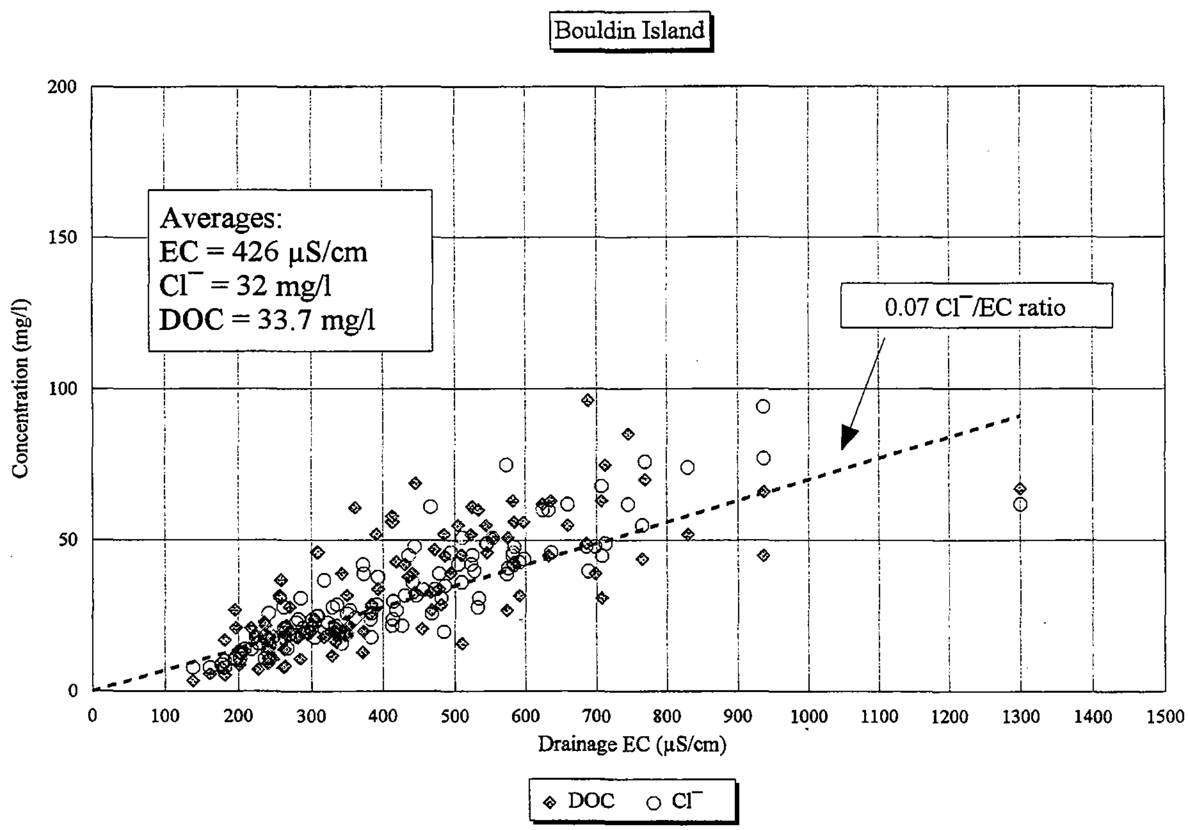


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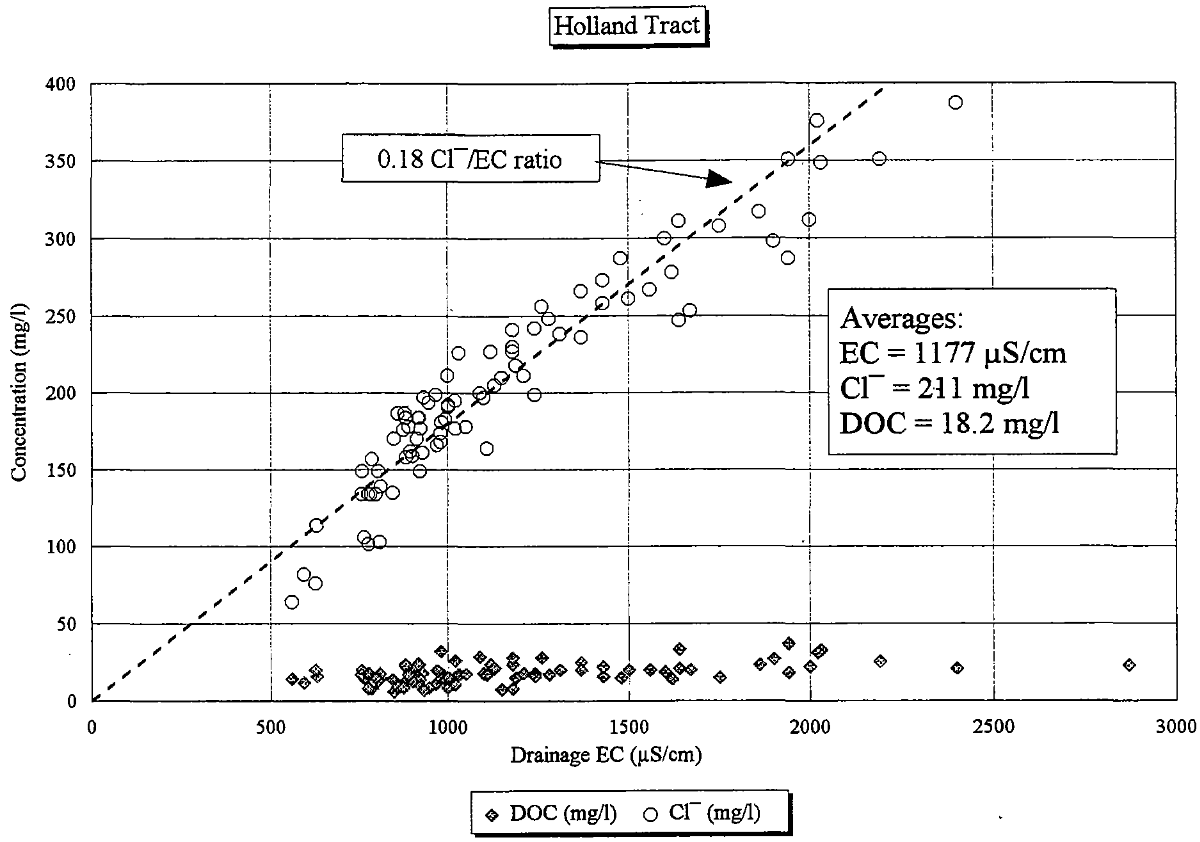
Figure G-1
DOC and Cl^- Compared to EC Values in Monthly Bacon and Bouldin Island Drainage Samples



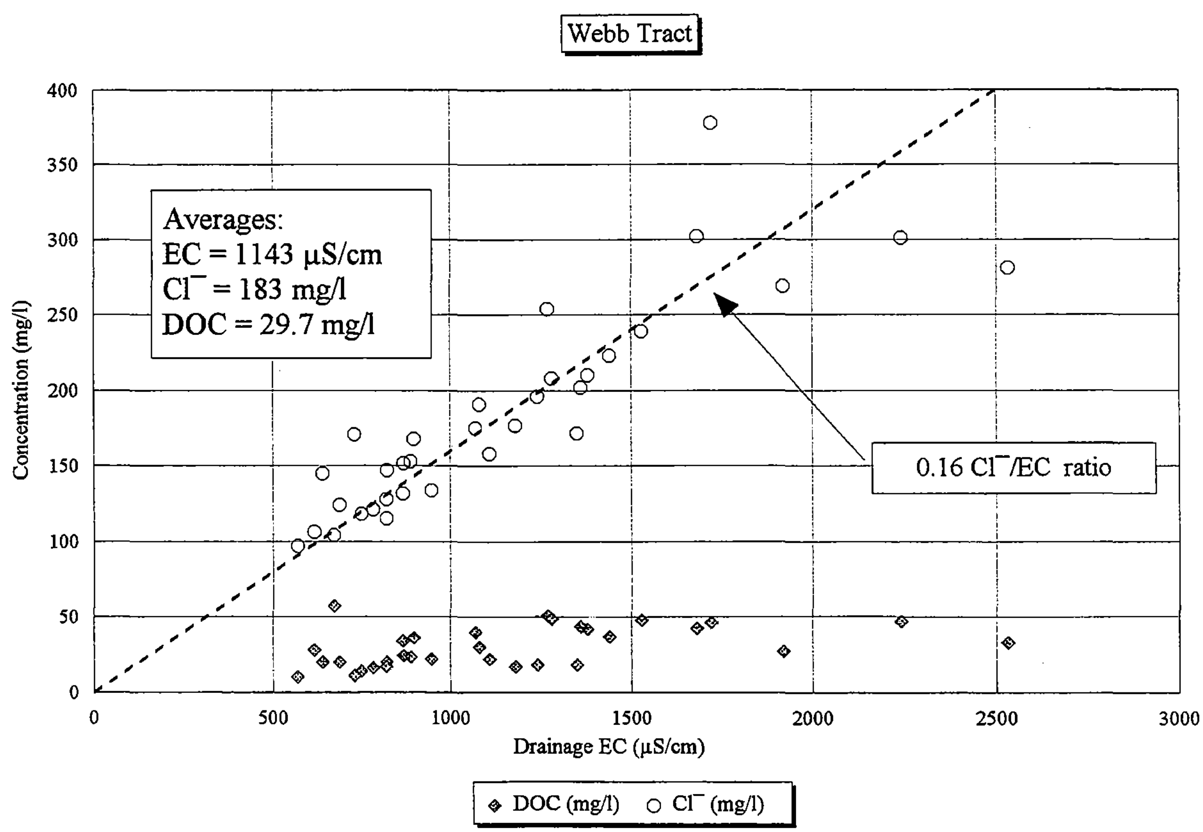


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Figure G-2
DOC and Cl^- Compared to EC Values in Monthly Holland Tract and Webb Tract Drainage Samples

Figure G-3a
DOC and Cl⁻ Compared to EC Values in
1994-1998 Twitchell Island Drainage Samples

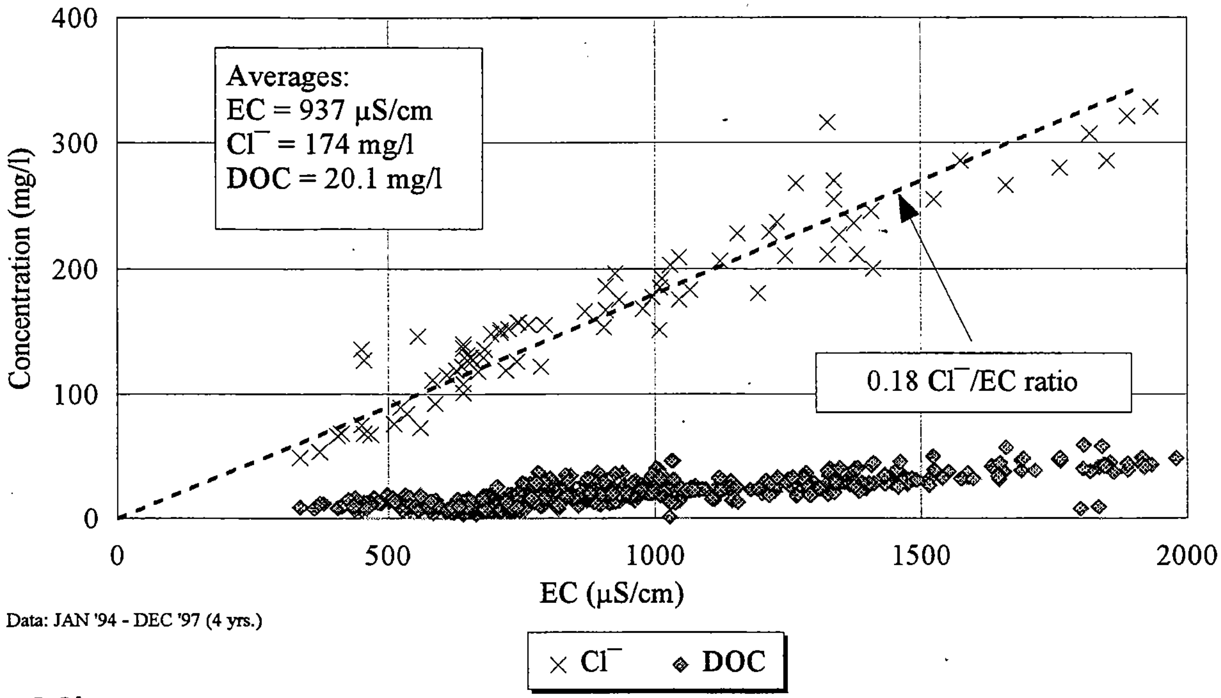
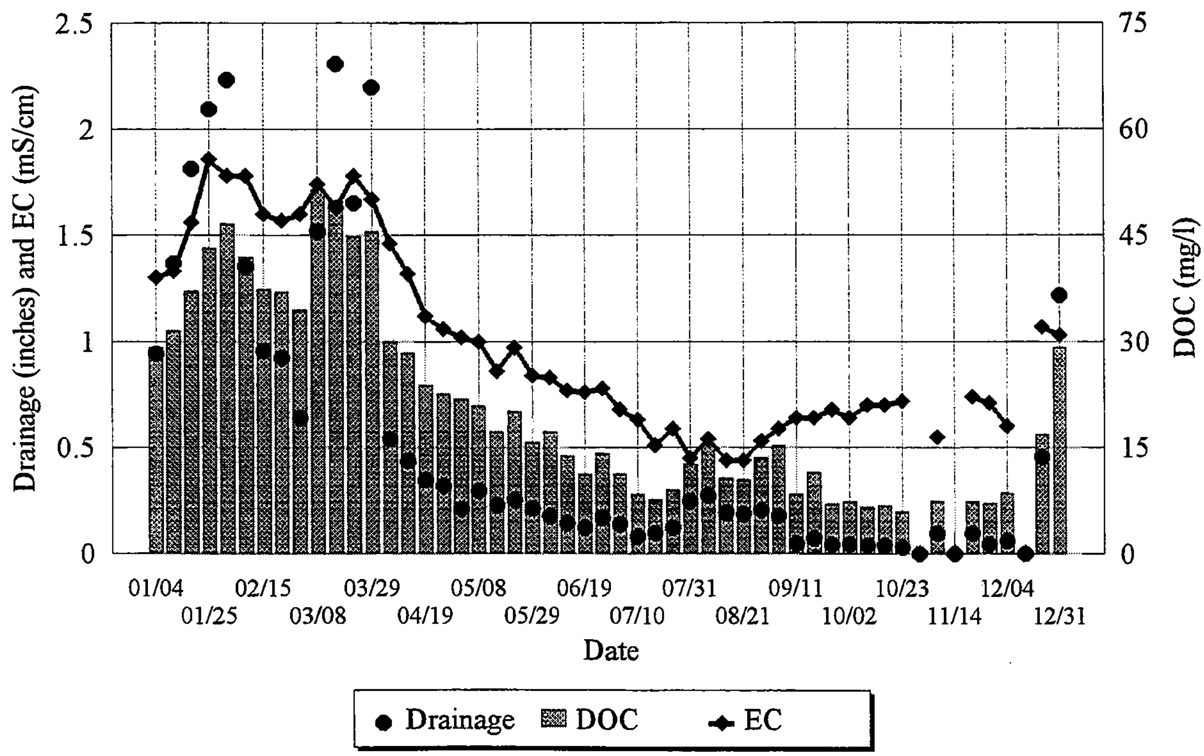


Figure G-3b
Measured Twitchell Island Drainage
and DOC Loading in 1995



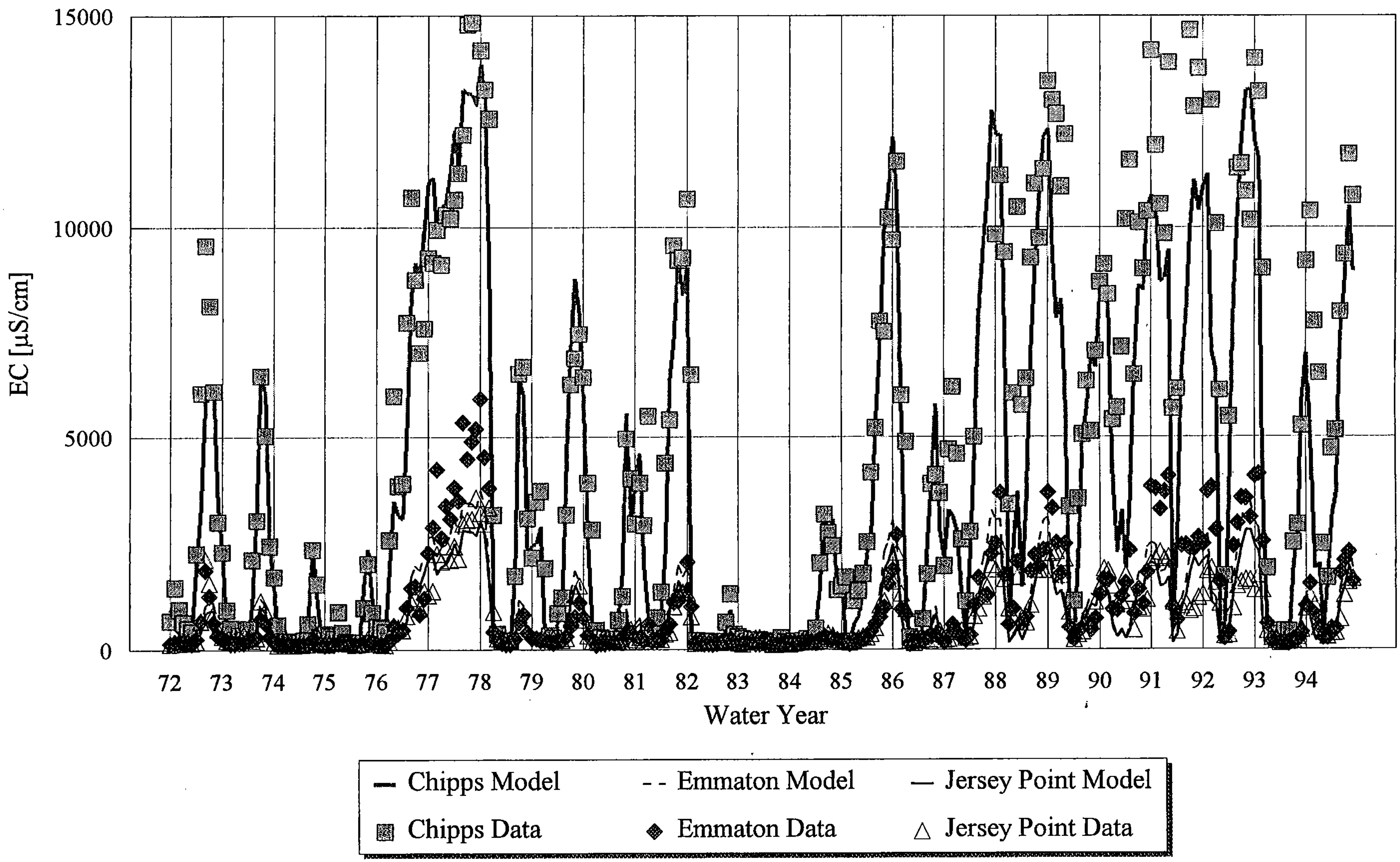


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Figure G-4
Comparison of Simulated EC and Historical EC Measurements at Chipps Island, Emmaton, and Jersey Point

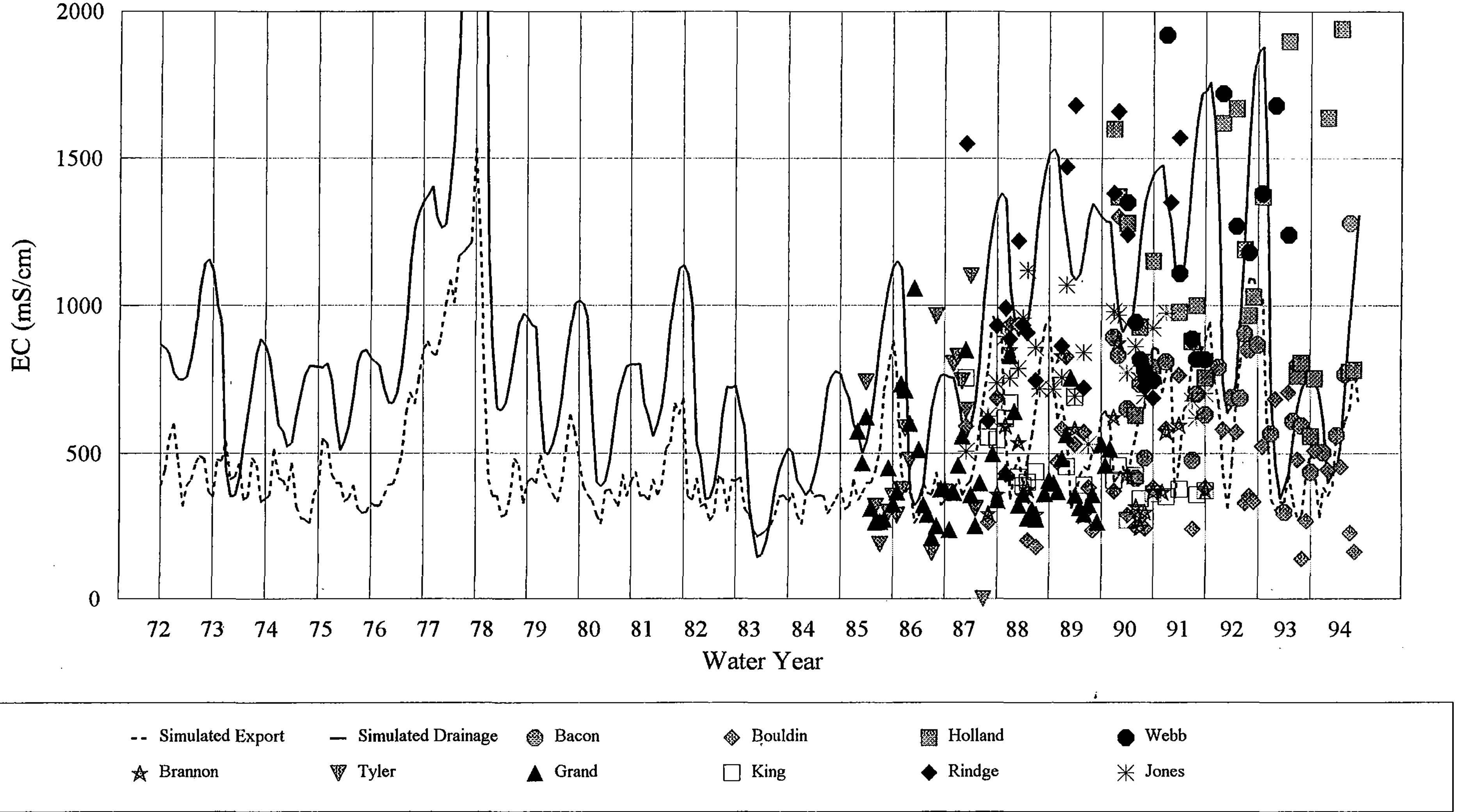

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Figure G-5
Comparison of Simulated Delta Drainage EC Values with MWQI Drainage EC Measurements

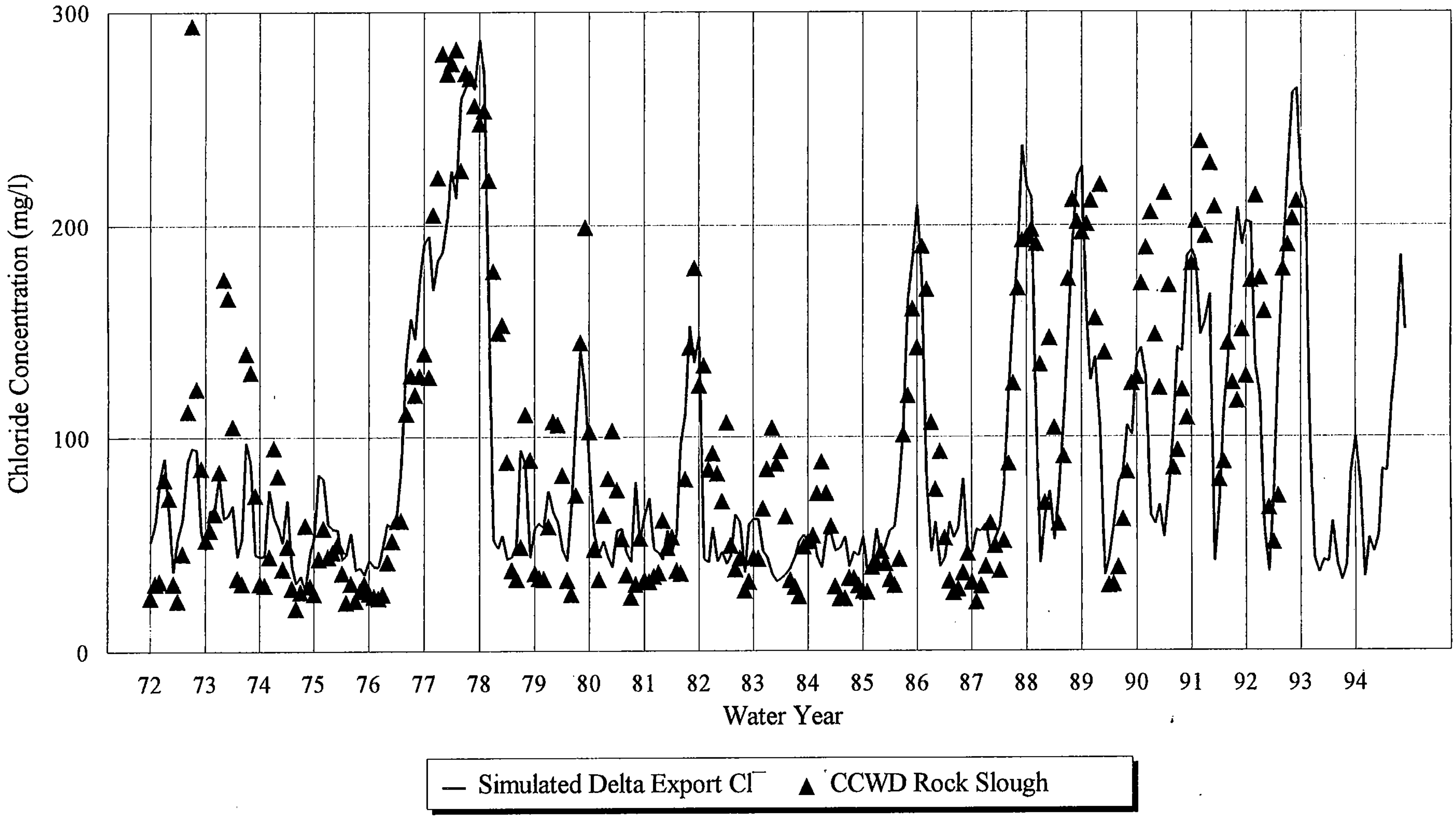

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Figure G-6
Comparison of Simulated Export Cl^- Concentration with Historical CCWD Rock Slough Cl^- Values

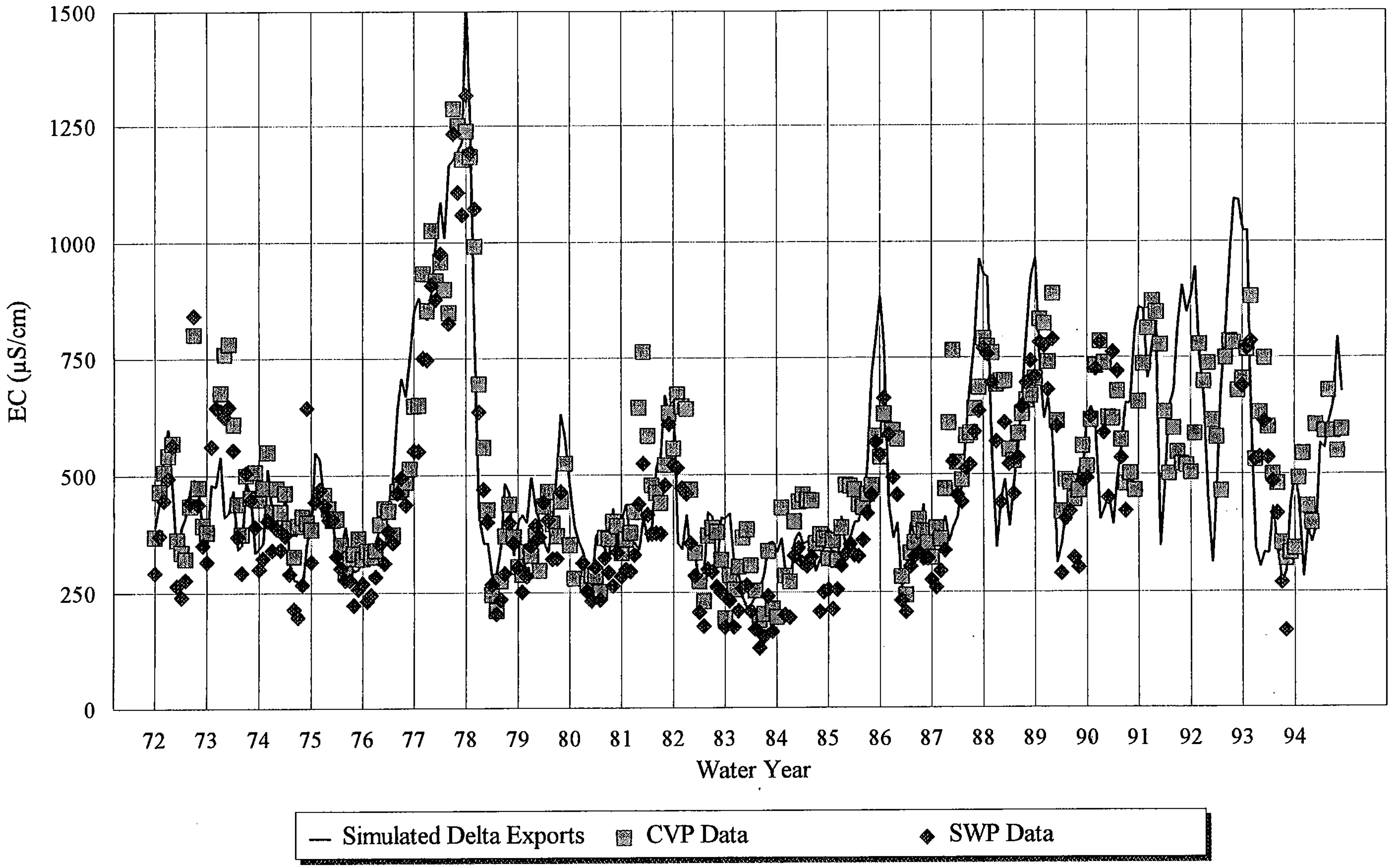


Figure G-7
Comparison of Simulated Export EC Values with Historical MWQI Export EC Values

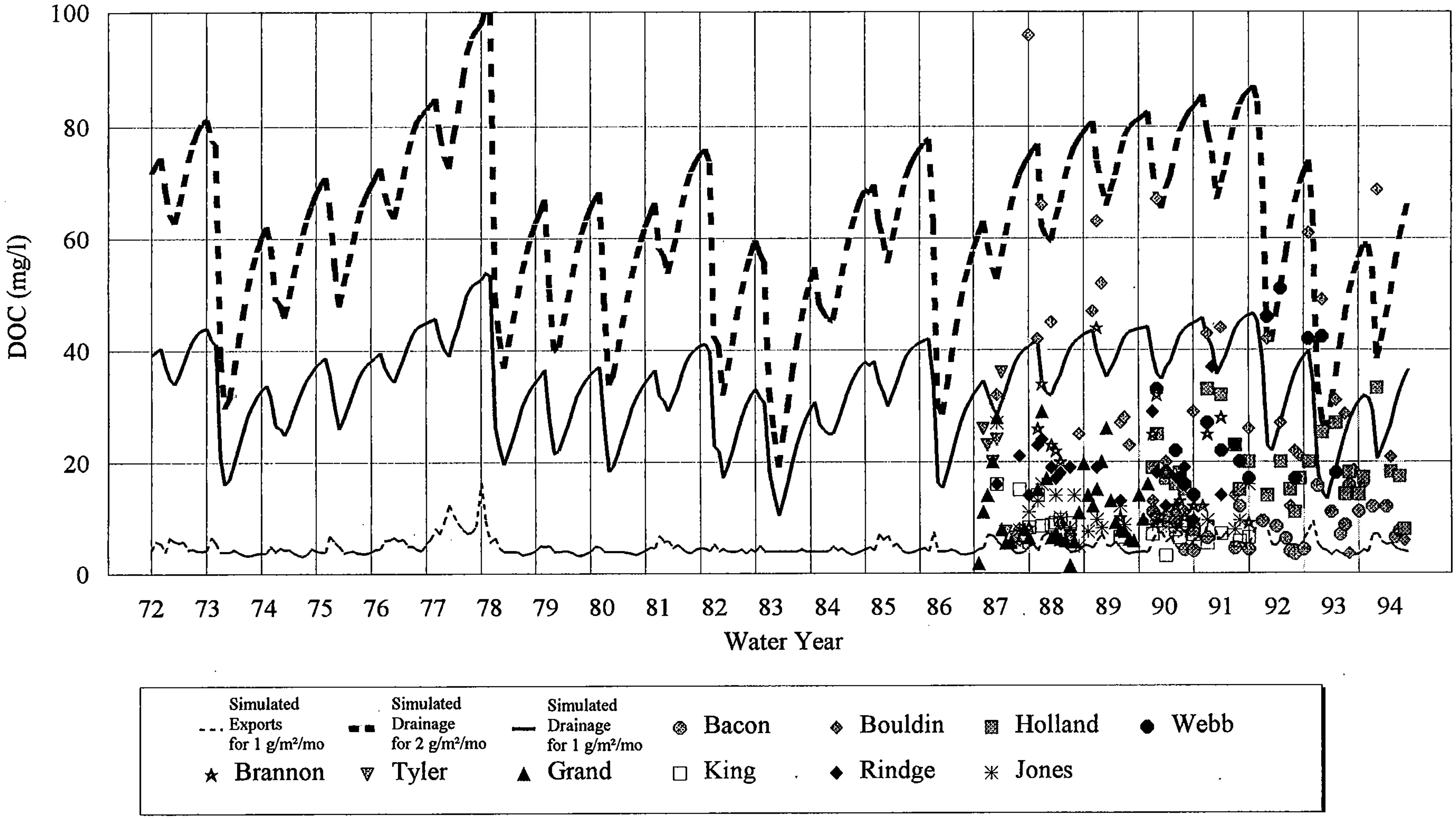


Figure G-8
Comparison of Simulated Delta Drainage DOC Concentration with MWQI Drainage DOC Measurements

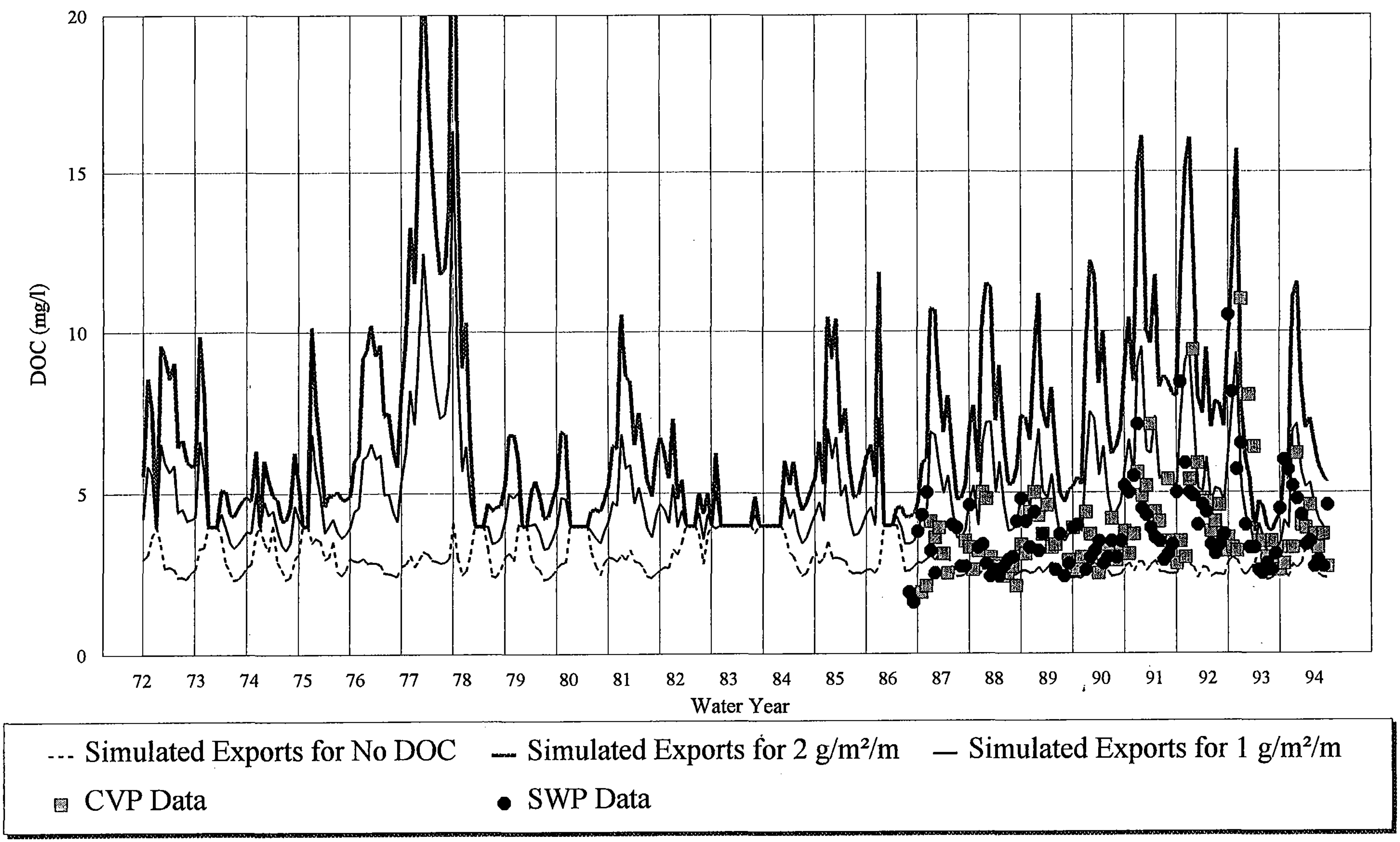


Figure G-9
Comparison of Simulated Export DOC Concentration with Historical MWQI Export DOC Values

Figure G-10a
Measured Source Water DOC and Treated Water THM Concentration, Penitencia Water Treatment Plant (SCVWD)

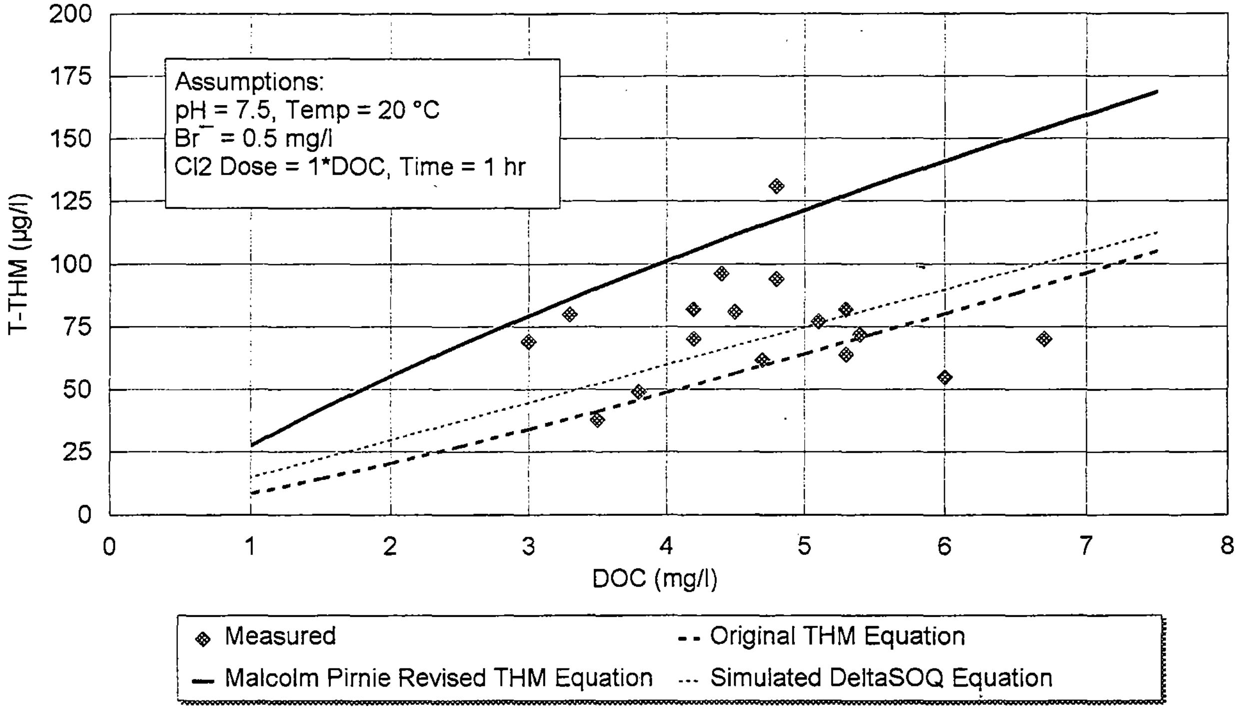


Figure G-10b
Measured Source Water Br- and Treated Water THM Concentration, Penitencia Water Treatment Plant (SCVWD)

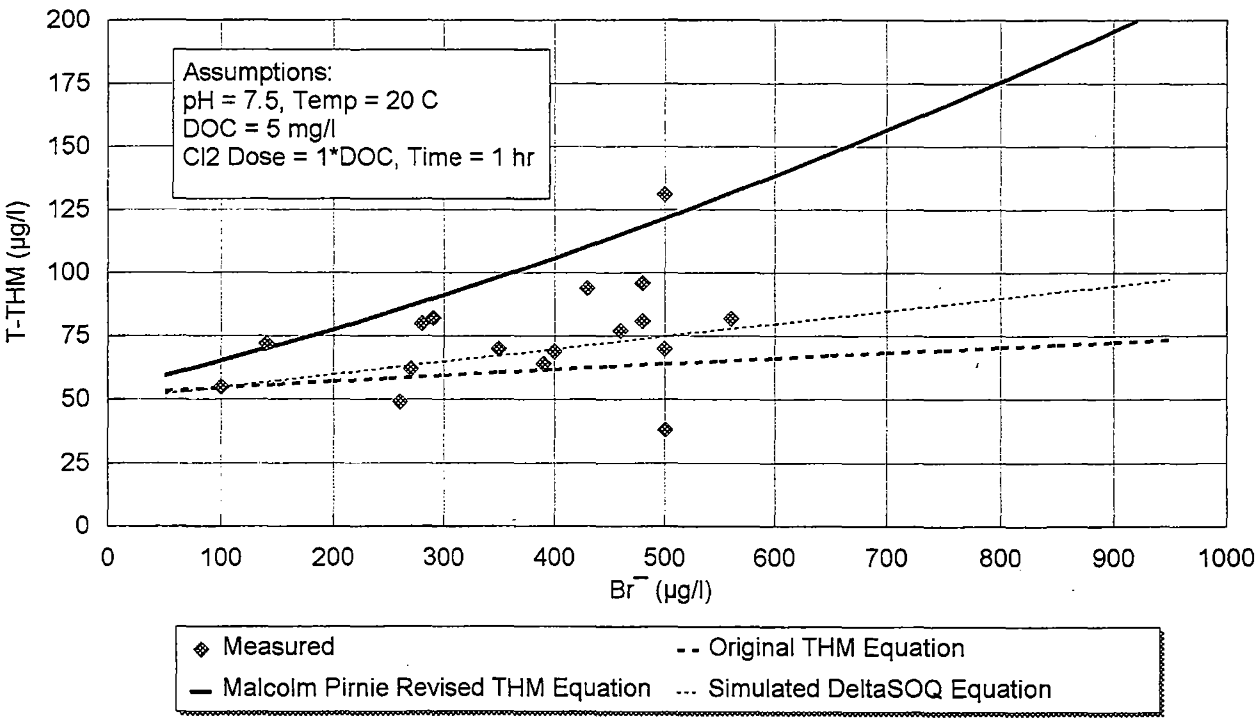


Figure G-11a
Measured Source Water TOC and Treated Water Bromate Concentration

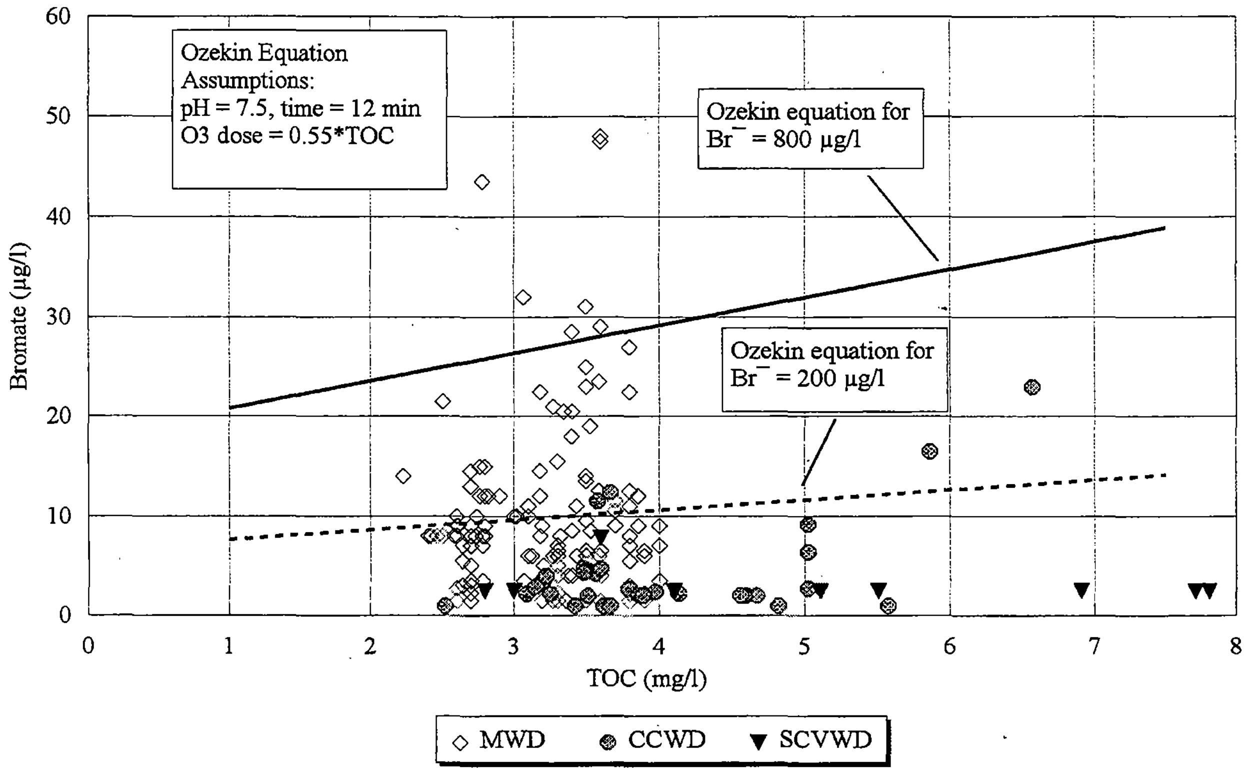
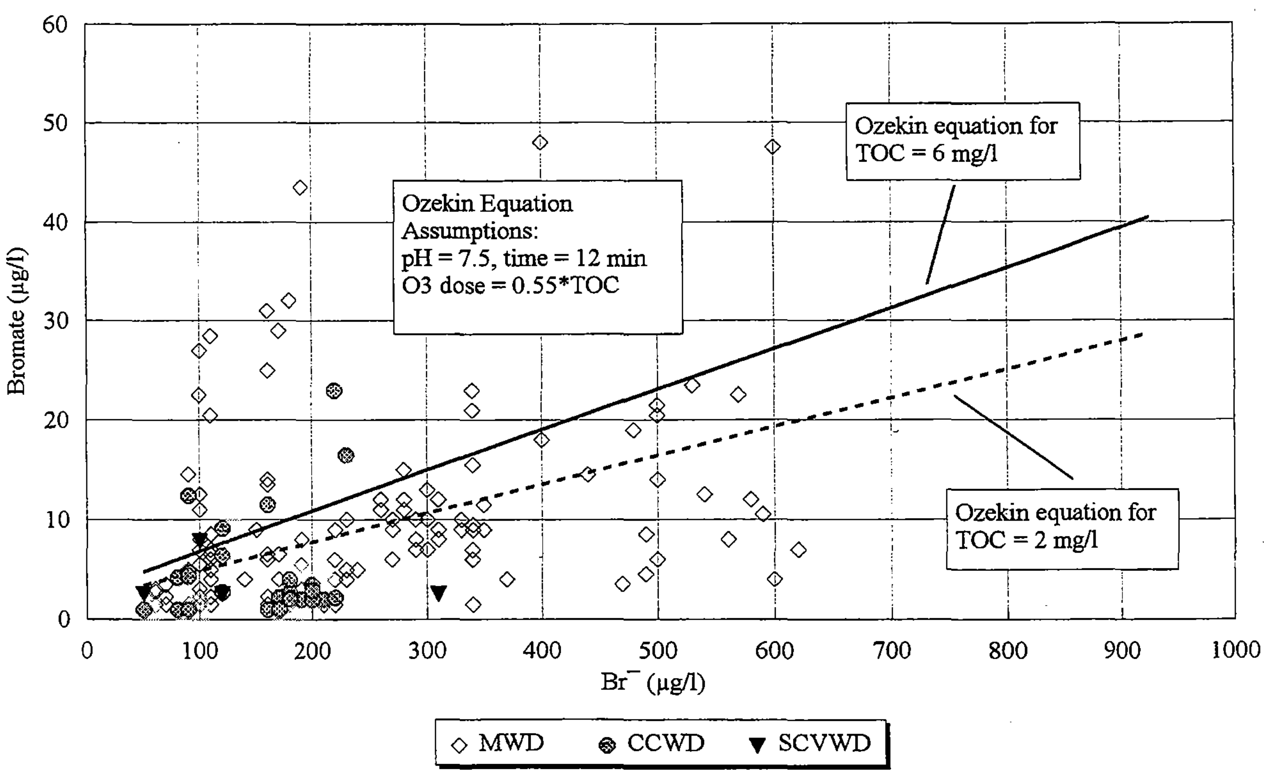


Figure G-11b
Measured Source Water Br⁻ and Treated Water Bromate Concentration



Appendix H. Levee Stability and Seepage Technical Report

SUPPLEMENTAL GEOTECHNICAL REPORT

LEVEE STABILITY AND SEEPAGE ANALYSIS REPORT FOR THE DELTA WETLANDS PROJECT REVISED EIR/EIS

Prepared for
Jones & Stokes Associates, Inc.
2600 V Street
Sacramento, California 95818

May 22, 2000

URS Greiner Woodward Clyde
500 12th Street, Suite 200
Oakland, California 94607

4107099030

URS

May 22, 2000

Ms. Aimee Dour-Smith
Jones & Stokes Associates, Inc.
2600 V Street,
Sacramento, CA 95818
Ph. (916) 737-3000

Subject: Supplemental Geotechnical Report
Levee Stability and Seepage Analysis Report
for the Delta Wetlands Project Revised EIR/EIS

Dear Ms. Dour-Smith:

We have completed our report for the geotechnical evaluation of the proposed storage islands (Bacon Island and Webb Tract) for the Delta Wetlands Project as described in your draft EIR/EIS dated September 1995. The work included in this report has been conducted in accordance with our revised scope of work dated September 13, 1999. This report also incorporates responses to comments by the State Water Resources Control Board received on our draft report dated December 15, 1999, and the second draft dated March 17, 2000.

The report includes our evaluation of the geotechnical issues and concerns raised in the State Water Resources Control Board's letter dated November 25, 1998 in regards to the draft EIR/EIS report. The findings and conclusions from our evaluation for the seepage issues are presented in Section 2 of this report, and those from stability and settlement evaluations are included in Section 3. In addition, a summary of the key findings for all aspect of our evaluation is included in Section 4.

The work included in this report was conducted in accordance with URS quality assurance plan. Dr. Ulrich Luscher was the senior technical review officer.

We will be pleased and available to provide any clarification, explanation or further details on the contents of this report.

Sincerely,

URS Greiner Woodward-Clyde

Said Salah-Mars, Ph.D., P.E.
Senior Project Manager

Ulrich Luscher, Ph.D., P.E., G.E.
Senior Consultant

URS Corporation
500 12th Street, Suite 200
Oakland, CA 94607-4014
Tel: 510.893.3600
Fax: 510.874.3268

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PURPOSE OF SUPPLEMENTAL GEOTECHNICAL STUDY

The primary purpose of this supplemental geotechnical evaluation of the Delta Wetlands Project is to address concerns expressed by the State Water Resources Control Board in a letter dated November 25, 1998. The letter raised a number of questions related to geotechnical issues included in the Draft EIR/EIS (Jones & Stokes, 1995). Specific issues raised in Section III of Attachment A to the SWRCB letter included several aspects of seepage, seepage control by interceptor wells, and seepage monitoring; and levee stability aspects. A decision was then made that a supplemental EIR/EIS (referred to as a Revised EIR/EIS or REIR/EIS) for the project should address these issues and provide more detailed evaluation of the geotechnical issues of the project. Jones & Stokes Associates engaged URS Greiner Woodward Clyde (URSGWC) to provide the supplemental geotechnical evaluations and prepare a supplemental geotechnical report. The present report is the result of this work.

PROJECT UNDERSTANDING AND BACKGROUND

The objective of the Delta Wetlands (DW) Project is to provide water storage in the Sacramento/San Joaquin River Delta. The project plans to store excess runoff water during heavy winter and spring runoff on two Delta islands and release the water later in the year for beneficial use and water supply. The planned reservoir islands are Bacon Island and Webb Tract. In addition, two islands are planned to be converted to wetlands for environmental mitigation; these islands are Bouldin Island and Holland Tract. The project is fully described in the Draft EIR/EIS prepared by Jones & Stokes Associates (1995).

Conceptual plans for the conversion of the reservoir islands from agricultural use to water storage use have been developed by DW and are also described in the Draft EIR/EIS. A brief summary of the proposed concept is provided below.

The levees around the reservoir islands will be raised and strengthened, such that the islands could store water up to a maximum elevation of +6 feet (all elevations are related to NGVD). Erosion protection on the levees will be raised on the channel side and will also be provided on the reservoir side. Siphons with supplemental pumps will be installed to fill the reservoir islands during periods of surplus flows through the Delta. Pumps will move the stored water back into the Delta waterways when it is needed by the users. The reservoir islands could be completely emptied by pumping.

A system of a large number of extraction wells installed on the levees of the reservoir islands has been proposed by DW to protect the islands adjacent to the reservoir islands from the anticipated effects of seepage from the reservoir islands. Such seepage effects are expected because of a deep sand aquifer that underlies the reservoir and the adjacent islands as well as the channel or slough separating them. To control the amount and duration of pumping from these wells that the effect on the adjacent islands is small or insignificant, DW has proposed a network of monitoring wells. This network would include both seepage monitoring wells immediately across the channel from the reservoir islands and background wells to establish water level changes that would occur without water storage on the reservoir islands. DW has also proposed significance criteria that will provide the method by which monitoring well data are used to control pumping of the extraction wells.

ASSUMPTIONS AND LEVEL OF EFFORT

The scope of the work presented in this report was to review the geotechnical aspects of the Draft EIR/EIS related to seepage and stability, and perform an independent evaluation of the completeness and adequacy of the findings and conclusions. In general the work performed for the Draft EIR/EIS was presented at a conceptual level typically commensurate with environmental impact statements. Similarly our independent evaluation has been developed at a comparable conceptual level, and hence no detailed engineering and design are intended to be part of this study. The level of detail involved in our analyses is based on existing information developed by others in previous studies.

No additional investigations or testing programs were conducted for this work. Site-specific investigations and testing programs were not part of the scope of this evaluation. The levees' properties, subsurface soil conditions, seismic setting and hydraulic and hydrologic conditions were therefore characterized based on available data, publications, and engineering judgement and experience. Because of the size of the project (over 30 miles of levees) and the number of extraction and monitoring wells, the characterization of the site-specific subsurface conditions at each and every well or at every mile post of levee is beyond the scope of this work. The existing data, although limited in scope for design purposes, are nonetheless useable for a feasibility-level evaluation.

Where previous work has been done from a reliable source, such as the seismic vulnerability work performed by the CALFED committee, our seismic stability analysis was built on the findings from that work. The use of available levee and subsurface data was optimized by locating cross sections and/or profiles for analysis where the most information was available. The analyses are hence performed for values within the boundaries of the data ranges available at the site. Assumptions of extreme lower or higher values outside the range of available data were not considered in the analyses.

The principal approach used in the evaluation of the project impacts was to identify the relative incremental changes of the proposed project to the "without-project" condition (baseline case). The analytical models developed for the existing conditions (baseline or "without-project" condition) concentrated on calibrating the aquifer properties such that the groundwater levels inside the islands are matched given the levee geometry and water level in the sloughs. The project impacts were assessed by allowing the project criteria, such as the reservoir water level and the levee configuration, to change while maintaining constant the inherent parameters of the baseline condition. For example, for the seepage control measures, a parametric variation was applied to the extraction wells' pumping rate until no significant change in the neighboring islands was observed.

Our evaluations were made on two cross sections on each proposed reservoir island. These cross sections, which were different for seepage and stability evaluations, were selected based on available data to be reasonably representative but on the conservative side for seepage and stability issues, respectively. The most severe conditions that may be encountered may not have been considered. Nevertheless, the results for the sections that were analyzed suggested in all cases that more severe conditions could be accommodated with suitable changes in the design. Such accommodation will need to be considered in the final design.

EVALUATION AND FINDINGS

The work presented in this report can be defined along three main aspects. One aspect addresses the seepage issues and extraction wells operation, the second aspect addresses the significance criteria, and the third aspect addresses the levee stability condition.

Seepage Evaluation

To evaluate the project-induced seepage impacts on the neighboring islands and the proposed seepage mitigation, we have developed a two-step approach. First we built a seepage model that represents the baseline conditions (without-project) and calibrated the model against the observed conditions. Specifically, the levee and subsurface conditions and geologic profiles were developed using exiting boring log data. The monitoring well data were used to define the ground water condition within the project islands. The surface water levels in the drainage ditch were used to establish the data along the surface drainage system. The water levels recorded in the nearby gauging stations, within the Delta, were used to set the water levels in the surrounding sloughs. Empirical correlation relationships between grain size distribution and soil permeability were developed from available grain size distribution curves for the various soil strata and available permeability tests. Except for the potential variation of the permeability values, the rest of the data was relatively anchored into soil test results or water level readings. We have consequently calibrated the model by allowing the permeability values to vary until conditions similar to the baseline case are matched.

In a second phase, we built the "with-project" seepage model to assess the impact on the neighboring islands as a result of filling the reservoir islands. The outcome of the analysis focused on evaluating the impacts of the reservoir filling and the new levee configuration on the changes in the hydraulic head, the exit gradients (hydraulic gradient just below the ground surface), the flow rates, and the groundwater level in the neighboring islands. Based on the observed changes, the pumping rate and well spacing were varied consecutively until the baseline conditions "without-project" were restored. This exercise was repeated for a range of permeability values of the aquifer as supported by the soil test data.

For the borrow site, we used the same seepage model and added a borrow pit at various distances from the levee to estimate the minimum distance to the levee beyond which no impact to the above parameters was observed.

The findings from the seepage analysis were based on two representative cross sections for each island. The cross sections at each island were selected for the "narrowest" and "widest" slough width across a reservoir island and its neighboring islands. These cross sections represent somewhat a bounding of the seepage conditions. Below is a summary of our evaluation and findings.

- The proposed reservoir islands will have undesirable seepage flooding effects on adjacent islands if seepage mitigation measures are not used.
- Seepage control by extraction wells placed on the levees of the reservoir islands, as proposed by DW, appears effective to control undesirable seepage effects. Required well spacing and pumping rates appear to be manageable.

- A system of checking the performance of individual wells and of well maintenance needs to be developed and implemented. Well maintenance should be documented and tracked, to identify wells requiring excessive maintenance and potential adverse de-silting of the aquifer.
- The seepage analysis also indicates that the seepage flow from the nearby sloughs is not significantly different from the flows that occur currently into the islands without the project. Further, the percentage of the pumped flow originating from the slough side is at most 8% of the total pumped flow when the reservoir is full.
- Operation of the reservoir islands will lead to only small additional settlements, smaller than the settlements that the islands would experience with continued use as farmland.
- Wind-induced waves during reservoir operation are expected to be significant enough to require scour and erosion protection of the inner levee slopes.
- A minimum of 800 to 1,000 feet offset from the levee toe should be maintained for the location of borrow sites. With this offset, there is no discernible effect of the borrow areas on seepage.
- The sensitivity analysis considered the channel silt permeability, aquifer permeability, and the thickness of the peat layer within the reservoir island. The results indicated that the permeability of the channel silt and the aquifer have a significant impact on the seepage conditions and pumping volume, while the peat thickness has little effect.

Significance Criteria

DW proposed a seepage monitoring system to identify potential adverse impacts on the neighboring islands due to the implementation of the project. Significance standards were proposed by DW to evaluate when the seepage monitoring data would require initiation of seepage control measures. The work performed in this study consisted of reviewing the proposed seepage monitoring system, the historic water level data, the significance standards, and the seepage control measures. Further, an evaluation of the adequacy of the proposed seepage monitoring system and the significance standards was conducted.

The data collected from existing monitoring wells over the past 10 years are proposed as the "historic" conditions around which the significance criteria were developed. DW proposes to install a network of monitoring wells (piezometers) in the neighboring islands to provide seepage data during project implementation. In addition, background wells (far from the reservoir islands) are proposed to be used as future baseline data. During filling and storage, data from monitoring wells on neighboring islands will be compared to the historical and background data. The purpose of the comparison with historic data is to evaluate whether a correlation exists between the piezometric levels and the reservoir filling and storage. The comparison with the background data is to check whether deviations from historic data are occurring throughout the Delta or only near the reservoir islands. Below is a summary of our evaluation and findings.

- The need for monitoring and maintaining compliance with significance criteria is essential and must be carefully adopted and implemented.

- Use of seepage monitoring wells, as proposed by DW, appears suitable and reasonable. The number of background wells should be such that enough redundancy is available at each row of monitoring wells (piezometers) within the neighboring islands.
- Background wells should include both those conceptually proposed by DW and additional rows of shallow background wells across each adjacent island.
- Well readings by means of automatic data acquisition is appropriate and necessary for rapid response.
- Significance criteria have been developed by DW in consultation with others to apply the monitoring results to trigger seepage mitigation, consisting in the first place in pumping from the interceptor wells. The concept and format of the significance criteria appear appropriate, but some changes in the criteria appear desirable.
- The significance criteria should be reevaluated and updated periodically.

Stability Analysis

The stability of the project's levees has been evaluated by extensive stability analyses of sections selected to be representative of the more severe stability situations expected at the reservoir islands. The calculated factors of safety have been compared to various published stability criteria, and judgments were made of the adequacy of the proposed project in regard to levee stability.

For the seismic performance of the levees, two horizontal earthquake acceleration time histories recorded during past earthquakes were selected as the base motions for the analysis. These records were from the 1992 Landers and the 1987 Whittier Narrows earthquakes. The selected acceleration time histories were then modified to match the "design" earthquake response spectrum. Results from the recent CALFED study on the seismic hazard and levee failure probability of the Delta project were used to construct the "design" response spectrum . A hazard exposure level corresponding to a 10% probability of exceedance in 50 years was selected as "design" basis ground motions. This hazard exposure level results in a return period of about 475 years and is consistent with the requirement adopted by the 1997 Uniform Building Code (UBC).

For the assessment of geologic hazards, two earthquake design criteria were used: earthquakes with magnitude (M_w) 6 and peak ground acceleration of 0.25g, and magnitude (M_w) 7.7 and peak ground acceleration of 0.13g. These ground motions represent the local and distant controlling seismic events and are consistent with the results of the CALFED study (CALFED, 1999).

The resulting conclusions and recommendations are:

- The levee strengthening measures conceptually proposed by DW are generally appropriate and adequate to provide stability of the reservoir islands' levees, except as noted below.
- Similarly, the seepage monitoring and control measures are generally adequate to avoid reducing the stability of adjacent islands' levees, provided the recommended measures are implemented.

- Construction of the levee strengthening fills must be implemented in a manner to prevent stability failures due to the new fill loads. This will require carefully planned, staged construction, and monitoring to observe the behavior as the fill is placed. The staged construction will require a construction period estimated to extend over 4 to 6 years, depending on final design.

- Long-term stability toward the slough side will be reduced by the construction and reservoir filling to an excessive degree. Measures should be provided to improve this stability. Some conceptual slope stabilization measures may include: 1) flattening the slough side levee slope, 2) widening of the levee crest to provide redundant levee width, 3) rock buttressing the levee toe on the slough side. The environmental impacts of slope failure are not part of the scope of this work.

- Stability with respect to sudden drawdown of the water in the reservoir may be inadequate at some locations. This potential failure mode can be remediated by controlling the reservoir lowering, flattening the levee slopes, and armoring the slope faces.

- The seismic stability evaluation of the reservoir islands levees indicates that as much as 2 feet of downslope deformation on the reservoir side and 4 feet of deformation on the slough side could be experienced during a probable earthquake in the region.

- As indicated by DW, it is planned, as a part of final design, to implement extensive and detailed subsurface exploration programs along the reservoir island levees, followed by stability evaluations and site-specific detailed design and construction to provide adequate levee stability. These steps will be essential to achieve safety and effectiveness of the proposed levee system.

Overall Findings

Taking a broader view, we consider the overall findings of this reevaluation of geotechnical issues of the proposed Delta Wetlands Project to be as follows:

- The seepage mitigation design proposed by DW appears appropriate and has the potential to be effective, provided that
  - the interceptor well system is appropriately designed, constructed and operated,
  - the monitoring system consisting of seepage monitoring wells and background wells is appropriately designed, constructed and operated, and
  - the significance criteria are rigorously applied and continually updated based on experience.

- The levee strengthening conceptually proposed by DW appears appropriate, except that measures need to be developed to improve the stability of the raised levees toward the slough.

- Because conditions around the islands' perimeter vary, it will be essential that a "mile-by-mile" geotechnical exploration and, based on it, a detailed final design, be implemented. The exploration should consist of borings and soundings spaced closely enough that adverse conditions extending over some distance would be identified. Appropriate detailed geotechnical laboratory tests, in particular grain size, permeability and strength tests, should be made on recovered samples. Final design of seepage control and monitoring, and levee strengthening, should consider the specific conditions identified on a site-specific basis.

- Construction of the improvements will require detailed geotechnical construction oversight, construction quality control and quality assurance, and documentation of as-built features, to maximize the chances that unexpected conditions are identified and accommodated, that construction will be implemented to satisfy the intent of the design, and that construction is documented.
- In particular, the design, construction, and operation of extraction wells will be critical to maximize the reliability of the seepage control system. It will also minimize the possibility of flushing fine particles out of the levee foundation, which could over time lead to weakened levee foundations and potential settlement and stability problems.
- It is recognized that pumping from the crest of the reservoir levee to mitigate seepage effects across the slough in the adjacent island is not the most effective way to achieve the seepage mitigation. It has been selected because of ownership and access issues. Other measures to achieve the seepage mitigation could be developed. In particular, pumping from the adjacent islands' levee across the slough from the reservoir islands would be hydraulically more efficient, and would likely require fewer wells and lower pumping volume. Passive or active relief wells or trenches on the adjacent islands would also be effective. A continuous cutoff around the reservoir islands would also be effective, but would likely be cost prohibitive.

1.1 DESCRIPTION OF DELTA WETLANDS PROJECT

The Delta Wetlands (DW) Project's purpose is to provide water storage in the Sacramento/San Joaquin River Delta. The project plans to store excess runoff water during heavy winter and spring runoff on two Delta islands and release the water later in the year for beneficial use. The planned reservoir islands are Bacon Island and Webb Tract, shown in Figure 1.1.1. In addition, two islands are planned to be converted to wetlands for environmental mitigation; these islands are Bouldin Island and most of Holland Tract, also shown in Figure 1.1.1. The project is fully described in the Draft EIR/EIS prepared by Jones & Stokes Associates (1995).

Conceptual plans for the conversion of the reservoir islands from agricultural use to water storage use have been developed by DW and are also described in the Draft EIR/EIS. A brief summary of the proposed concept is provided below.

The levees around the reservoir islands will be raised and strengthened, such that the islands could store water up to a maximum elevation of +6 feet (all elevations are related to NGVD). Erosion protection on the levees will be raised on the channel side and will also be provided on the reservoir side. Siphons with supplemental pumps will be installed to fill the reservoir islands during periods of surplus flows through the Delta. Pumps will move the stored water back into the Delta waterways when it is needed by the users. The reservoir islands could be completely emptied by pumping.

Sandy fill for levee raising and strengthening will be obtained from the interior of the reservoir islands far from the levees. Surficial peat will need to be excavated to reach the suitable sandy fill soil. Disposition of the excavated peat overburden is at the discretion of DW. It could be backfilled into the excavation after sand removal, but this is not necessary for seepage control if the excavations are at least 800 feet from the levee (as shown later in this report).

A system of a large number of extraction wells installed on the levees of the reservoir islands has been proposed by DW to protect the islands adjacent to the reservoir islands from the anticipated effects of seepage from the reservoir islands. Such seepage effects are expected because of a deep sand aquifer that underlies the reservoir and the adjacent islands as well as the channel or slough separating them. This layer facilitates movement of water from the reservoir islands (with a higher water table) to adjacent islands. To control the amount and duration of pumping from these wells to such an extent that the effect on the adjacent islands is small or imperceptible, DW has proposed a complex monitoring system. The system would include both seepage monitoring wells immediately across the channel from the reservoir islands and background wells to establish water-level changes that could occur unrelated to water storage on the reservoir islands. DW has also proposed significance criteria that will provide the method by which monitoring well data are used to control pumping of the extraction wells and to provide threshold levels that would trigger emergency response.

1.2 REASONS FOR SUPPLEMENTAL EVALUATION

The primary reason for this supplemental geotechnical evaluation of the Delta Wetlands Project is to address concerns expressed by the State Water Resources Control Board (SWRCB) in a letter dated November 25, 1998. The SWRCB's letter is included herewith in Appendix C. The letter raised a number of questions related to geotechnical issues included in the Draft EIR/EIS

(Jones & Stokes, 1995). Specific issues raised in Section III of Attachment A to the SWRCB letter included several aspects of seepage, seepage control by interceptor wells, and seepage monitoring; and levee stability aspects. A decision was then made that a supplemental EIR/EIS (referred to as Revised EIR/EIS or REIR/EIS) for the project should address these issues and provide more detailed evaluation of the geotechnical issues of the project. A decision was then made by Jones & Stokes Associates to engage URS Greiner Woodward Clyde (URSGWC) to provide the supplemental geotechnical evaluations and prepare a supplemental geotechnical report. The present report is the result of this work.

1.3 DEVELOPMENT OF SCOPE OF EVALUATIONS

In response to a request by Jones & Stokes Associates, URSGWC prepared a scope of work dated June 25, 1999 to address the specific geotechnical issues raised in SWRCB's letter and attachment. The scope included a relatively brief review of prior work, since additional more detailed reviews would be conducted under the specific work tasks. In response to comments by Delta Wetlands stating that they had already implemented a portion of the proposed evaluation, URSGWC developed a revised scope dated July 6, 1999 that included a two-phase study. Phase 1 involved a more detailed review of prior work by Delta Wetlands, including review and responses to a detailed letter by Delta Wetlands dated August 3, 1999, where they pointed out issues they felt they had adequately covered in previous studies. Phase Two involved the basic geotechnical evaluation scope, incorporating any changes to the remainder of the proposed work. Subsequently Phase 1 was authorized, and our report on this phase, dated September 13, 1999, contained a revised scope of work for the geotechnical evaluations and responses to Delta Wetlands' August 3 letter. This revised scope was subsequently authorized, and has been implemented. Copies of the original scope, comments from DW, and a revised scope are included in Appendix D.

1.4 OUTLINE OF REPORT

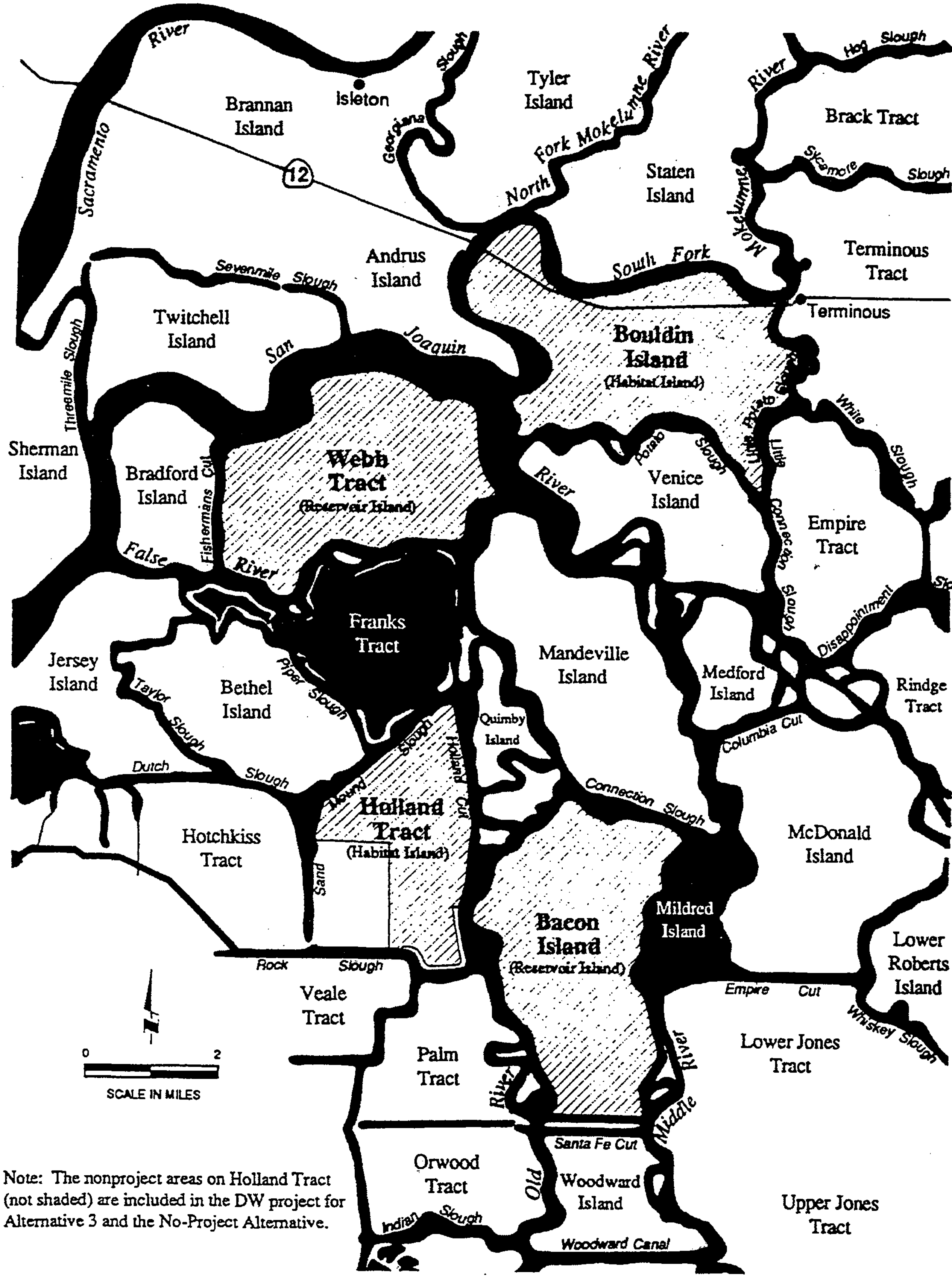
This report is organized essentially according to the proposed revised scope of work. Section 2 addresses all seepage issues, and includes in turn the objectives, review of prior work, seepage analyses for conditions without and with interceptor wells and their results, and review of the proposed monitoring system including proposed "significance standards." Additional items addressed in Section 2 include maintenance and reliability of interceptor wells, potential water diversions, and potential settlements due to operation of the reservoir islands.

Section 3 addresses levee stability issues. Included in turn are objectives, review of prior work, static stability analyses, seismic stability/deformation analyses, and seismic and geologic hazards. Further included are estimates of levee settlements and their effects on stability, slope erosion/scour, review of borrow requirements, and assessment of potential effects of interceptor wells on stability.

Section 4 summarizes the key findings from our evaluation of seepage and stability issues

Section 5 notes limitations of our evaluations.

Section 6 contains references.



Note: The nonproject areas on Holland Tract (not shaded) are included in the DW project for Alternative 3 and the No-Project Alternative.

Source: Adapted from California Department of Water Resources 1993.

Source: from Jones and Stokes, 1995

Project No. 41-07099030.00	Delta Wetlands	DELTA WETLANDS PROJECT ISLANDS	Figure 1.1.1
URS Greiner Woodward Clyde			

2.1 SEEPAGE ANALYSIS OBJECTIVES

Active interceptor well systems have been proposed by Delta Wetlands (DW) to mitigate potentially detrimental seepage impacts on neighboring islands as a result of filling the proposed reservoirs at Webb Tract and Bacon Island. In response to the SWRCB concerns about the feasibility, adequacy and effectiveness of the proposed interceptor well system, we have performed independent seepage analyses to evaluate the proposed system. Seepage analyses have been conducted for the conditions anticipated at four different locations along the reservoir islands. Included in the evaluation of the interceptor well system were:

- Review of previous seepage studies, including review of the subsurface conditions and material properties.
- Generation of two-dimensional finite element models for four locations to simulate various seepage conditions.
- Evaluation of the effects of proposed reservoirs on existing seepage conditions and the required performance of the interceptor well system.
- Evaluation of the effects of proposed borrow area locations on seepage conditions and the performance of the interceptor well system.
- Completion of sensitivity analysis, in which critical parameters used in the seepage models are varied.

In addition, an evaluation of the effectiveness of the proposed monitoring system and procedures has been completed. The monitoring system for groundwater seepage, developed by HLA, is to provide a standard of performance against which project related seepage can be determined. Using the results of the seepage modeling and reviews of the proposed monitoring system, the adequacy and effectiveness of the proposed procedures was assessed, including the criteria (termed "significance standards") developed to determine whether observed seepage conditions merit mitigating action.

An evaluation of potential water diversions was made using the seepage models created for the two islands. This evaluation was required to address SWRCB's concern that, during certain water level conditions in the storage islands and constraints on permissible DW operations, pumping from the interceptor well system may constitute water diversions from adjacent channels into the storage islands. The seepage models have been used to estimate such diversions.

Finally, settlements that may be caused by reservoir filling and pumping were estimated. Rapid reservoir filling, drawdown, and groundwater pumping may induce additional soil stresses that may lead to additional settlements of levees and island interiors.

We note here that all elevations in this report refers to the National Geodetic Vertical Datum (NGVD).

2.2 REVIEW OF PREVIOUS SEEPAGE EVALUATIONS

Harding Lawson Associates (HLA) and then Hultgren Geotechnical Engineers (HGE) have performed geotechnical studies on the proposed project since 1988 on behalf of the project owner DW. The studies included collecting data from site explorations and performing analyses to address geotechnical engineering concerns including settlement, erosion, seepage, stability and seismic hazards. A number of reports were prepared during the previous studies, and the Reference section lists these reports. In this section a review of the previous studies related to the seepage issues of Webb Tract and Bacon Island is presented.

As a part of a preliminary geotechnical investigation in 1989 (HLA 1989), the following subsurface exploration was performed:

Webb Tract	Twenty-six Cone Penetration Tests (CPTs) for subsurface characterization, and seven borings and four monitoring wells around the island perimeter for subsurface sampling and characterization of soils and groundwater levels.
Bacon Island	Twenty-one CPTs, eight borings and four monitoring wells around the island perimeter.

Figure 2.2.1 shows locations of some of the CPTs and borings in Webb Tract, (those in the vicinity of our analysis sections) and Figure 2.2.2 shows similar information for Bacon Island. Soil borings and CPTs were located on the levees and in the interior of the islands to characterize the site stratigraphy. Soil samples from the borings were selected by HLA (based on stratigraphy and need for information) for laboratory testing, including moisture content, dry density, shear strength, compressibility, grain size, specific gravity and permeability.

2.2.1 Typical Stratigraphy of Interior Island

From the investigations, it was found that the general stratigraphy of the interior of Webb Tract and Bacon Island was similar. In general, the interior stratigraphy consisted of a surfacial soft, organic fibrous peat layer underlain by a silty sand aquifer, below which lies stiff silty clay. These units are laterally continuous and relatively constant in thickness. In some areas, deeper sand aquifers are present below these units. Soil borings for the groundwater monitoring wells indicate that a similar stratigraphy exists on adjacent islands. The thicknesses of the peat and sand layers vary from one part of the islands to another. The sand layer is exposed in some portions of Webb Tract.

2.2.2 Typical Levee Condition

Typical levee conditions of the islands consist of a layer of fill about 10 feet thick consisting mostly of sand with some peat and clay. The fill is typically underlain by peat and soft clay that in turn is underlain by a sand aquifer and deeper silty clay layer.

Because the levee was originally constructed at about sea level and levee settlement and raising have occurred periodically since initial construction, it is likely that the upper portion of the peat and soft clay is also fill. It was not possible during the explorations to differentiate this soil from the undisturbed native peat or clay.

2.2.3 Soil Permeability Used in Prior Studies

Table 2.2.1 presents vertical and horizontal permeabilities of the existing soil layers. The vertical permeability was measured by the laboratory tests, and the horizontal permeability was estimated by typical anisotropy ratios for similar deposits. The values presented in Table 2.2.1 were used in the HLA (1989) report to develop a preliminary computer-based seepage model. Additional data collection (pump tests and laboratory permeability tests) was recommended as part of final design of the project to verify that the permeability values used in the analysis are reasonable.

Pump Test Results: After the 1989 preliminary geotechnical investigations, DW and HLA performed two constant rate pump tests, one on Holland Tract and the other on McDonald Island (HLA 1991b).

The pump test on Holland Tract was conducted from April 24 through 26, 1989. A pumping well and four observation piezometers (two deep, fully penetrating the sand aquifer, and two shallow piezometers in peat layers extending to 8.5 feet) were installed. During the testing, a constant discharge rate of 30 gallon per minute (gpm) was maintained. Based on the analysis of the data, permeability values were estimated at 15.3 feet/day (5.4 x 10^{-3} cm/sec) at one deep observation well (20 feet from the pumping well) and 18.2 feet/day (6.4 x 10^{-3} cm/sec) at the other deep observation well (30 feet from the pumping well).

The pump test on McDonald Island was performed from August 15 through 16, 1989 as a part of the Phase I drawdown demonstration. Brief details of the Phase I as well as Phase II (or final phase) drawdown demonstration are presented in the next section. A constant pump rate of 215 gpm was maintained during the test. The estimated permeability value for this test was 390 feet/day (1.4 x 10^{-1} cm/sec) . Because the tidal fluctuations had an influence on the drawdown data, HLA used a distance vs. drawdown method (instead of time vs. drawdown) for the estimation of this value.

The average permeability value of 16.8 feet/day (5.9 x 10^{-3} cm/sec) for the Holland Tract test site corresponded to a very fine to fine grained, poorly graded sand with silty sand. The permeability value for the McDonald Island represented medium grained silty sands with gravel. HLA indicated that this was the coarsest material encountered as part of the investigations.

2.2.4 Field Drawdown Demonstration Studies

A drawdown demonstration was performed by DW and HLA on a quarter-mile long levee on McDonald Island. The purpose of the demonstration was to evaluate whether the hydraulic head within the sand aquifer could be lowered by pumping from interceptor wells and by using gravity flow relief wells. (Pumped interceptor wells use submersible pumps to draw water from the wells, whereas relief wells simply use passive flows from the wells into low lying ditches to relieve some of the water pressure in the sand aquifer.) If effective, systems using pumped interceptor wells or gravity flow wells could be used to control the seepage resulting from the operation of the DW reservoir islands. During Phase I of the demonstration, the pumped interceptor well system was studied, and in Phase II the gravity flow relief well system was studied.

During the Phase I demonstration (HLA 1990a), an interceptor well system consisting of 15 wells was tested. The wells were located on the levee with an approximate spacing of 125 feet. The 6-inch diameter wells were screened within the entire sand aquifer thickness. All wells were connected by a 12-inch diameter header pipe, which was connected to a suction pump with a capacity of approximately 1,500 to 1,800 gpm. Average flow rates for individual wells ranged from 75 to 90 gpm and the total system flow was between 1,100 to 1,300 gpm. During the operation of the interceptor well system, the water elevation in the sand aquifer became flat with an average elevation of about -16 feet (the elevation before pumping was -13.3 feet). It was concluded by HLA that the pumped interceptor well system was effective in controlling the seepage.

Phase II (HLA 1990c) used the same wells, modified to a passive flow relief well system by connecting the tops of the wells to drainage ditches dug three to four feet below the ground surface. In the passive well system, groundwater flows from wells into seepage ditches due to the artesian pressure in the sand aquifer. The total average discharge from the 14 wells was approximately 600 gpm, and the average discharge per well was approximately 44 gpm. Water levels in the sand aquifer were lowered to -15 feet elevation beneath the island interior. It was concluded by HLA that the gravity well system also was effective in controlling the seepage, but achieved somewhat less water level drawdown.

HLA reported that settlement rates increased slightly during the drawdown test, and explained that these increased rates were due to the fill material that had been recently placed and due to the lowering of the water table around the wells. They noted, however, seepage control measures installed by Delta Wetlands would maintain water levels within historic ranges, and that no increased ground loading and corresponding settlement should result.

Following the McDonald Island drawdown tests, there was some question regarding the long term effectiveness of the interceptor well system. Specifically, during the rebuttal testimony of Mr. Edwin Hultgren (July 31, 1997), a question was raised as to why the fields of Mr. Alfred Zuckerman on McDonald Island again became saturated and unfarmable after the drawdown test was completed and only the relief wells remained operating. The response was that the relief wells had become less efficient in drawing down the water table with time because they had become clogged with silt. Mr. Hultgren explained that the wells were not designed and built for long-term operation, and they were not maintained once the test program was completed.

2.2.5 Background Groundwater Monitoring

A groundwater monitoring program was established to provide regional groundwater elevations in the islands before the construction of the Delta Wetlands project (HLA 1990b, 1991a, 1992f, 19995c, 1995d). Data collected before project construction would provide baseline information on the existing condition. The baseline information was intended to be used for the evaluation of seepage due to the project. The groundwater monitoring program consisted of 32 monitoring wells located in 17 Delta Wetlands and adjoining islands. Figure 2.2.3 shows the location of the monitoring wells. Data collection began in February 1989, and continues today. Water levels are measured manually at a weekly frequency. The monitoring data were presented in a number of reports (HLA 1990b, 1991a, 1992f). From the data, it was concluded that the groundwater levels varied with the tidal fluctuations in nearby sloughs and rivers. It was also found by HLA that the groundwater variations over a year could be fitted either with a straight line or with a simple harmonic (sine function) curve (HLA 1995c, 1995d).

2.2.6 Interceptor Well Modeling Results from HLA

HLA performed groundwater computer modeling to simulate the control of seepage into neighboring islands using various interceptor well systems located on the DW island levees (HLA 1991b). The purpose of the simulation was to establish parametric relationships to develop the basis of a conceptual design of an interceptor well system. Simulation was performed using a two-dimensional, steady state flow, finite difference program called FLOWPATH. The modeling considered the following range of parameters:

- Two types of aquifer systems (one confined aquifer, and one unconfined aquifer starting 100 feet from the perimeter levee),
- Three transmissivities (200, 3,500 and 20,000 ft^2/day),
- Three interceptor well spacings (80, 160, and 320 feet), and
- Two borrow pit excavations (borrow pits were simulated in confined aquifers; borrow pits were assumed to be excavated into the aquifer at 2,000 and 400 feet from the levee; each borrow pit was 500 feet wide).

Several FLOWPATH runs were performed for various combination of the above parameters. The results provided a range of pump rates corresponding to well spacings and aquifer parameters.

Based on the modeling it was concluded by HLA that an interceptor well system installed on the perimeter of the reservoir islands was a viable solution to control seepage. Furthermore, a possible interceptor well system location was presented. The interceptor wells were estimated to cost $120,000 (1991 dollar value) per mile of levee. This estimate was based on a well spacing of 160 feet, and 50-foot deep wells equipped to pump at 70 gpm.

2.2.7 Main Findings and Conclusions from Previous Studies

The following text summarizes the conclusions drawn by HLA and DW based on their studies:

- There is a possibility of increased seepage into the neighboring islands due to the storage of water in the reservoir islands, if no mitigation is implemented.
- The islands' interior stratigraphy generally consisted of peat underlain by a silty sand aquifer, below which lies stiff clay. These units are laterally continuous, but the thicknesses of the peat and sand layers were observed to vary somewhat from one part of the islands to another.
- Vertical soil permeability values were measured in the laboratory, and drawdown pump tests were performed to determine soil permeability values. However, the majority of the horizontal permeability values were estimated based on the gradation of the soil.
- The groundwater level beneath the levees is generally near sea level. Beneath the island interiors, the water head in the sand aquifer is generally five feet below the ground surface.

In some locations, where artesian conditions exist in the confined aquifer, the head is as much as five feet above the ground.

- A program of background regional groundwater level measurements was started in February 1989, and this monitoring program still continues today. Thirty-two monitoring wells are used in this program. Based on the data collected, it was found that the groundwater levels varied with tidal fluctuations in nearby sloughs and rivers and also with the seasons. It was also found that the groundwater variations over a year could be fitted either with a straight line or with a simple harmonic (sine function) curve.
- It was concluded by HLA that the drawdown test on McDonald Island showed that the interceptor well system would be effective in controlling seepage. Regarding the loss of effectiveness of the relief wells with time, HLA explained that the wells were not designed and built for long-term operation, and they were not maintained once the test program was completed. Although minor settlement occurred during the drawdown test, HLA does not anticipate any ground settlement associated with the proposed interceptor well system proposed for the Delta Wetland project.
- Interceptor well modeling showed that an interceptor well system installed on the perimeter of the reservoir islands could be a viable system to control the seepage into the neighboring islands.

URSGWC generally agrees with these findings, but offer the following additional comments:

In our opinion, the McDonald Island drawdown test provides valuable information on the effort required to draw down the groundwater table to acceptable levels on neighboring islands. However, the actual pumping conditions that the proposed interceptor well system will experience will be more severe than those seen at McDonald Island could. On the reservoir island levees, the interceptor wells will be working against a higher head (being so close to the reservoir) and will have to pump at a higher rate to intercept the reservoir-induced seepage and lower the groundwater table on the neighboring island. Also, even though the sand aquifer underlying McDonald Island is similar to that underlying Webb Tract and Bacon Island, the sand aquifer at the test location on McDonald Island was overlain by a confining layer of silt. This overlying layer, which effectively reduces the groundwater seepage rates toward the ground surface, is not present everywhere on Webb Tract and Bacon Island. Subsurface investigations indicate that on most of Webb Tract and Bacon Island, only a thin layer of peat overlies the sand aquifer. Without the silt layer, the interceptor well system would have to pump at a higher rate to effectively lower the groundwater table. In addition, the proposed interceptor well system will be located on the reservoir island levee, not inside the levees of the neighboring island.

- The drawdown test at McDonald also provides valuable information on the response of the sand aquifer to pumping. The sand aquifer beneath McDonald Island appears to be hydraulically similar to that under Webb Tract and Bacon Island, based on gradation tests performed on samples taken in the aquifers. The hydraulic conductivity of the sand aquifer is controlled by the proportion of fine materials present, as shown by the relationship given by Cedergren (1989)

$$k = C \times D_{10}^2$$

Where:

k = hydraulic conductivity (cm/sec)

C = constant (approximately 100)

D_{10} = diameter (cm) of soil particle below which 10% of the sample particles are smaller

This approximate relationship shows that the D_{10} values control the hydraulic conductivity of the material. From the sand samples taken at McDonald Island, the average D_{10} value is approximately 0.007 cm, and the corresponding calculated hydraulic conductivity is about $5x10^{-3}$ cm/sec. From the range of typical gradations given for aquifer samples taken at Webb Tract and Bacon Island (HLA 1989, Plate B-1), the average D_{10} values are approximately 0.005 to 0.006 cm, and the corresponding calculated hydraulic conductivities are about $2.5x10^{-3}$ to $3.5x10^{-3}$ cm/sec. This indicates that the sand under McDonald is slightly more pervious than that under Webb Tract and Bacon Island.

- In our opinion, the drawdown tests at McDonald Island show that potential migration of fine materials from the sand aquifer to the pumping system is of concern at the interceptor wells proposed for Webb Tract and Bacon Island, and the wells will have to be carefully designed and constructed to maintain their effectiveness and minimize migration of fines from the aquifer into the well. Regular maintenance and redevelopment of the wells will be required to restore pumping efficiency when required. Monitoring of ground surface elevations near the interceptor wells should be performed to observe any minor ground subsidence that may occur due to potential loss of fine materials from the underlying sand aquifer. A record of required well maintenance should also be kept to identify any wells that might have silt losses.

2.3 SEEPAGE ANALYSES

2.3.1 Seepage Analysis Approach

Previous Models. Previous seepage models used by DW to analyze the interceptor well system used plan view modeling techniques to estimate seepage conditions within the sand aquifer only. Those plan view models considered seepage conditions within the sand aquifer (considering the aquifer as being either confined or unconfined) over a large area, extending 3000 feet on either side of the interceptor well system. The boundary conditions for the plan view models were established a large distance (over 2000 feet) from the interceptor wells, where a constant head boundary was used to simulate the reservoir and adjacent island background conditions.

The limitations of this modeling approach include the fact that the plan view model only considers the seepage conditions within the sand aquifer. While a significant portion of the seepage will occur within the aquifer, the effects of the other elements of the subsurface stratigraphy are not seen. In addition, the plan view model does not consider the influence of surface water infiltration from the proposed reservoirs or the existing sloughs. Neglecting the effects of surface water infiltration will limit the plan view model's ability to simulate localized seepage conditions near the interceptor well system.

Current Seepage Analysis Approach. To evaluate the effectiveness of the active interceptor well system proposed for Webb Tract and Bacon Island, two-dimensional cross-sectional finite element models were used to simulate seepage conditions and estimate the required pumping effort at the interceptor well system. The cross-sectional modeling approach was chosen as it considers all major elements of the subsurface stratigraphy at each section. The models were built to simulate seepage conditions along sections taken perpendicular to the levees and sloughs, and were developed to model average conditions in close proximity to the interceptor well system. The potentially significant effects of surface water infiltration from both the slough and proposed reservoir can be modeled using this method.

The drawdown condition along the line of interceptor wells that is induced by pumping is expected to vary significantly along the levee. Figure 2.3.1 shows an example of a plan view model for a 50-foot thick confined sand aquifer with boundary conditions similar to those anticipated near the interceptor well systems on Webb Tract and Bacon Island. As shown on Figure 2.3.1, the total head conditions along the line of wells spaced at 160 feet varies considerably, with the maximum amount of drawdown occurring at the pumping wells.

In order to represent this drawdown effect in the cross-sectional models, an average total head along the interceptor well line (as shown on Figure 2.3.1) was used to model average drawdown conditions along the levee. All of the cross-sectional models developed for this seepage analysis therefore generate average seepage conditions across the section of levee considered. Average pump rates along the levee estimated by the cross-sectional models (presented in gallons per minute (gpm) per foot of levee) can be converted to actual pump rates at a single well by multiplying the average pump rate by the well spacing used.

The cross sectional models developed for the seepage analysis were used to estimate parameters that were considered critical for the evaluation of the influence of the proposed reservoirs and the interceptor well system. Specific parameters include:

- The average total head (in feet) in the sand aquifer near the levee centerline (reservoir island).
- The total seepage flow through a vertical section, termed the seepage flux (in gpm per foot of levee), near the levee centerline.
- The average total head (in feet) in the sand aquifer at the far (adjacent island) levee centerline.
- The flux quantity (in gpm per foot of levee) at the far levee centerline.
- The water table level at the far toe of the far levee (near the ditch).

The water table level at the far toe was considered to be an important indicator of impacts detrimental to adjacent islands, as a significant rise in the ground water table may impact agricultural production rates.

A description of the transverse sections modeled for Webb Tract and Bacon Island is presented in Section 2.3.2. Included in the description is the subsurface stratigraphy at each location, the hydraulic properties of each material within the model, the model's boundary conditions and the seepage conditions considered.

Computer Model. The computer program SEEP/W (Geo-Slope International Ltd., 1994) was used to estimate seepage conditions through transverse sections of the existing levees at Webb

Tract and Bacon Island. SEEP/W uses a two-dimensional finite element method to model seepage conditions and assumes that flow through both saturated and unsaturated media follows Darcy's Law. (Finite-element modeling is generally considered to be similar to or more effective than the finite-difference modeling used by DW.) The seepage analyses were conducted considering steady-state conditions.

Using the SEEP/W mesh generation program, finite element meshes were generated to model the multiple seepage conditions considered for the levees on Webb Tract and Bacon Island. The element material types are represented in the models as different colors, as shown on Figure 2.3.2. Fixed boundary conditions were used to model constant reservoir and slough heads, heads within pumping wells and far-field groundwater levels. Other portions of the levee and ground surfaces on the islands were modeled using an unrestricted, free-flowing boundary condition; that is, a boundary condition that is determined at each node by SEEP/W during the analysis of flow conditions. The bottoms of the cross sections were modeled as no-flow boundaries.

The SEEP/W analysis program was used to evaluate the steady-state phreatic surface location, the head distribution throughout the model and flow quantities at particular locations. The SEEP/W contouring program was used to generate head distribution diagrams. Phreatic surfaces, total head contours (in feet of water) and flux quantities (in gallons per minute per foot width of levee) are presented on each of the figures presenting the analysis results for each section. The flux quantities represent the flow quantity across the length of a particular flux section, which is symbolized as a blue arrow on the figure.

2.3.2 Analysis Sections and Boundary Conditions

Analysis Sections. Four sections were considered for the seepage analysis, two at Webb Tract and two at Bacon Island. The locations of the Webb Tract sections, at Stations 260+00 and 630+00, are shown on Figure 2.2.1. The locations of the Bacon Island sections, at Stations 220+00 and 665+00, are shown on Figure 2.2.2.

For each island, one section was chosen to model more critical seepage conditions (Webb Tract Station 630+00 and Bacon Island Station 220+00), considering both the subsurface conditions and the geographic conditions relative to adjacent islands. More critical seepage conditions are expected to occur at locations where the slough is narrower, where the sand aquifer is thicker, or where less pervious materials that overlie the sand aquifer (such as peat or channel silt) may be thinner. The other two sections were chosen at typical but less critical locations where subsurface conditions were available to consider the effects of varying conditions and to provide a range of analysis results, including flow rates, phreatic surface locations and required pump rates. It should be noted that these are not the least critical locations on the islands (which occur at locations like those adjacent to the San Joaquin River at Webb Tract where there is no nearby adjacent island), but instead are less critical locations chosen, after review of the range of levee and subsurface conditions, to model varying surface and subsurface effects on the interceptor well system.

The subsurface conditions at Webb Tract Stations 260+00 and 630+00 and the approximate thickness of each layer are presented on Table 2.3.1. This stratigraphy is based on field investigations performed previously by others (see Section 2.2). Typical subsurface conditions at the levees along Webb Tract include levee fill material (clay with peat and sand) underlain by native peat. An approximately 50-foot thick layer of sand underlies the peat layer. The sand aquifer is underlain by a clay layer of relatively low hydraulic conductivity. Also included in the model is a channel silt deposit, with an estimated thickness of three feet (see next paragraph), and the proposed new fill material for the land-side portion of the levee. The simplified subsurface stratigraphy at Stations 260+00 and 630+00 is shown on Figures 2.3.4 and 2.3.2, respectively.

We could not locate any direct data on thickness, permeability and continuity of the channel silt. The best "proof" of the reasonableness of the assumptions made is the analysis of the present conditions (without project), which looks reasonable with the channel silt as assumed. The sensitivity analysis using higher permeability in the channel silt indicated that the neighboring islands would experience serious seepage problems, which is not the case. It was also decided at a project meeting that dredging of the channel silt would not be considered in the evaluation of the Delta Wetlands Project, because the effects of such dredging would have to be addressed and accommodated by whoever planned to dredge the channels.

The subsurface conditions at Bacon Island Stations 220+00 and 665+00 and the approximate thickness of each layer are also presented on Table 2.3.1. Typical subsurface conditions at Bacon Island Station 220+00 include levee fill material (clay with peat and sand) underlain by native peat. An approximately 20-foot thick layer of sand underlies the peat layer. The sand aquifer is underlain by a clay layer of relatively low hydraulic conductivity. Typical subsurface conditions at Bacon Island Station 665+00 include levee fill material (clay with peat and sand) underlain by native peat and an upper layer of relatively low hydraulic conductivity clay. An approximately 20-foot thick layer of sand underlies the upper clay layer. The sand aquifer is underlain by a lower clay of low hydraulic conductivity. Also included in both models is a channel silt deposit, with an estimated thickness of about three feet, and the proposed new fill material for the land side portion of the levee. The simplified subsurface stratigraphy at Stations 220+00 and 665+00 is shown on Figures 2.3.6 and 2.3.8, respectively.

Analysis Conditions. For each section considered at Webb Tract and Bacon Island, three seepage conditions were evaluated: (1) existing conditions, (2) with-project, full reservoir with no pumping at the interceptor wells, and (3) with-project, full reservoir with required pumping at the interceptor wells. Existing conditions were first analyzed to calibrate the model against field observations and to verify that the boundary conditions and material properties were appropriate. Full reservoir conditions with no pumping were analyzed as an intermediate condition to estimate the effects of a loss of pumping capacity on the neighboring islands. Full reservoir conditions with pumping at the interceptor well system were analyzed to evaluate the effects of the proposed interceptor well system. The minimum pump rate (in gallons per minute per foot of levee) required to retain pre-reservoir seepage conditions at the far levee was estimated.

In addition to the three cases described above, additional analyses were performed to evaluate the sensitivity of the results to variations in material properties and to the location of proposed borrow pits. Sensitivity analyses were conducted by varying the hydraulic conductivities of the channel silt and the aquifer sand, and by varying the thickness of the peat layer on the land side of the levees. The proposed borrow pits, which were assumed to be 500 feet wide and extend to the sand aquifer, were modeled at locations of 400 and 1000 feet away from the levee, and were assumed to allow direct inflow of water into the aquifer. These sensitivity analyses were conducted only for Webb Tract at Station 630+00.

Boundary Conditions. The primary boundary conditions affecting the seepage models include the constant head boundaries imposed by presence of the slough, the full reservoir, and the groundwater conditions within the adjacent island. The slough was modeled as having a constant elevation head of +1 feet (using the NGVD elevation datum). The slough level at the islands will vary up to about three feet between daily high and low tides; however, the average daily value of +1 feet was considered representative for the model. The average daily value was considered appropriate because tidal fluctuations at the surface are not expected to significantly influence conditions within the confined sand aquifer at any point in time. For the full reservoir condition, a constant elevation head of +6 feet was used, based on our understanding of expected reservoir operation levels.

The far-field boundary condition at the neighboring island under existing conditions was estimated through a calibration procedure. The model meshes were constructed so that the far-field boundary conditions occurred at a significant distance from the levees (i.e., about 600 feet from the levee at Webb Tract Station 630+00) so that the boundary reflected background groundwater conditions. The far-field head was iteratively varied until the phreatic surface estimated by the model matched the observed groundwater levels about 2 to 3 feet below the surface observed in piezometers and ditches on the islands. Once the far-field boundary condition was established on the adjacent island, it was held constant for the other two full reservoir conditions.

For the full reservoir condition with pumping at the interceptor wells, a constant head boundary was also placed through the sand aquifer at the location of the well line. This boundary condition was used to represent the average total head along the well line during pumping, and was varied to determine the required pump rate. The actual pump rate (gpm per foot of levee) was determined by estimating the flow rates at the well under the pumping head conditions.

2.3.3 Hydraulic Conductivities

As mentioned in Section 2.2, several analyses have been previously performed by others to estimate the subsurface materials' hydraulic conductivities at Webb Tract and Bacon Island. These analyses have included laboratory tests, field pump tests and estimates made using material gradation characteristics. Considering the results of these previous studies, we have used the hydraulic conductivities shown on Table 2.3.1. As shown, the fill material, peat, and sand were all modeled with an anisotropy (the ratio of horizontal to vertical hydraulic conductivity) of 10. Previous studies have shown an anisotropy of up to 100 for peat; however, a more conservative factor of 10 (using a higher vertical conductivity of 1×10^{-4} cm/s) was used for these analyses.

Variations in the hydraulic conductivities of the channel bottom silt and aquifer sand were made for the sensitivity analyses, as these two materials were expected to have a large influence on the overall seepage conditions at the levees. The channel silt controls the infiltration rate of water seeping from the slough, and the aquifer sand permeability may have the greatest influence on overall subsurface flow rates beneath the levees. For the sensitivity analysis, the hydraulic conductivities of the channel silt and aquifer sand were each separately increased by a factor of 5. These values were chosen to reflect the variations of field conductivities considered reasonable for the channel silt, and to consider the estimate of the sand's hydraulic conductivity derived from the McDonald Island pump test (where 5.4×10^{-3} to 6.2×10^{-3} cm/sec was estimated, see also Section 2.2.7). In addition, a sensitivity analysis was conducted by halving the peat layer thickness over the island from six feet to three feet. The island peat thickness and permeability control the infiltration rate of water seeping from the reservoirs, provided (as shown later) that the borrow pits are located at least 800 feet away from the levee.

2.3.4 Analyses Results

Figures 2.3.2 through 2.3.9 present the seepage analyses results for Webb Tract Stations 260+00 and 630+00, and Bacon Island Stations 220+00 and 665+00. Each set of two figures presents, for one cross section, (1) the cross-section stratigraphy, model mesh and hydraulic conductivities, (2) the existing seepage conditions, (3) the seepage condition corresponding to a full reservoir with no pumping at the interceptor wells, and (4) the seepage condition corresponding to a full reservoir with required pumping at the interceptor wells. On all figures, total head contours (in feet) are drawn across the entire section. (Note that the program SEEP/W automatically draws total head contour lines above the phreatic surface as well as below, however it is only those contours below the phreatic surface that are considered). The figures also show the flux quantities across lines at both the near and far levees for each seepage condition.

The analysis results are also summarized for each case on Table 2.3.2. The table presents the following:

- The average total head (in feet) in the sand aquifer at the near levee centerline.
- The seepage flux (in gpm per foot of levee) at the near levee centerline. Where two flux quantities are given for the pumping condition, each flux rate represents the flow from one side of the line of pumps. The total pumping rate is the sum of the two values.
- The average total head (in feet) in the sand aquifer at the far levee centerline.
- The flux quantity (in gpm per foot of levee) at the near far centerline.
- The water table level at the far toe of the far levee (near the ditch).
- The corresponding pump rate for individual interceptor wells spaced at 160 feet (for pumping conditions only).

For the flux quantities, flows away from the slough within the sand aquifer (like those found in existing conditions) are considered positive and those flows toward the slough are considered negative. This sign convention was adopted to easily identify reversals in flow directions on Table 2.3.2.

Webb Tract Station 630+00. This cross-section was considered to be a critical seepage condition for Webb Tract, as the adjacent island levee is only about 400 feet away (levee center to levee center across Fisherman's Cut). The total head within the sand aquifer at each levee under existing seepage conditions is about –15 ½ feet, as shown on Figure 2.3.2. The existing conditions diagram shows a significant drop in total head within the channel silt, indicating the importance of the channel silt's influence on the seepage rates under the levees (see also the discussion in Section 2.3.2 under "Analysis Sections" regarding evidence of the existence of channel silt). The calculated water table at the far toe of the far levee is at about elevation –17 feet, which is just below the drainage ditch.

Under full reservoir conditions with no pumping at the interceptor wells, there is a seven-foot increase in the total head beneath the far levee and upward flow into the neighboring island, as shown on Figure 2.3.3. In addition, a review of the exit gradients near the drainage ditch on the land side of the far levee indicates that gradients over 0.6 exist at the ground surface. Under these gradients, there would likely be sand boils and piping of levee material on the neighboring island.

Under full reservoir conditions with pumping at the interceptor wells, the minimum head at the pump needed to retain pre-reservoir conditions at the adjacent island is about –15 feet. This corresponds to an average pumping rate along the well line of 0.076 gpm per foot of levee, or about 12 gpm for wells spaced at 160 feet.

Webb Tract Station 260+00. This second cross section for Webb Tract was considered to be a less critical seepage condition than that at Station 630+00, as the adjacent island levee on Mandeville Island is about 1200 feet away (center to center). The total head within the sand aquifer at each levee under existing seepage conditions is about –9 to –10 feet, as shown on Figure 2.3.4. The water table at the far toe of the far levee is at about elevation –9 feet, which is about the level of the drainage ditch.

Under full reservoir conditions with no pumping at the interceptor wells, there is only a ½ -foot increase in the total head beneath the far levee, which is hardly enough to cause a change in flow into the neighboring island, as shown on Figure 2.3.5. Nevertheless, in order to maintain a no-change condition, the minimum head at the pump needed to retain pre-reservoir conditions at the adjacent island is about –10 feet. This corresponds to an average pump rate along the well line of 0.066 gpm per foot of levee, or about 10-½ gpm for wells spaced at 160 feet. The required pump rate is slightly smaller that that found at Webb Tract Station 630+00, which is a more critical case with a narrower slough. The smaller pump rate to maintain the required head in the adjacent island is due to the greater length of the sand aquifer beneath the slough at Station 260+00 through which the groundwater must flow to reach the adjacent island.

Bacon Island Station 220+00. This cross section was considered to be a critical seepage condition for the Bacon Island, as the adjacent island levee on Mandeville Island is only about 450 feet away (center to center). The total head within the sand aquifer at each levee under existing seepage conditions is about –14 feet, as shown on Figure 2.3.6. The existing conditions diagram shows a significant head drop within the channel silt (as it did at Webb Tract), indicating the importance of the channel silt's influence on the seepage rates under the levees. The water table at the far toe of the far levee is at about elevation –17 feet, which is about the bottom of the drainage ditch.

Under full reservoir conditions with no pumping at the interceptor wells, there is a four-foot increase in the total head beneath the far levee, as shown on Figure 2.3.7. However, the phreatic surface still lies beneath the ground surface on the adjacent island (no surface flow). Under full reservoir conditions with pumping at the interceptor wells, the minimum head at the pump needed to retain pre-reservoir conditions at the adjacent island is about –14 feet. This corresponds to an average pump rate along the well line of 0.053 gpm per foot of levee, or about 8-½ gpm for wells spaced at 160 feet.

Bacon Island Station 665+00. This second cross section for Bacon Island at Station 665+00 was considered to be a less critical seepage condition than that at Station 220+00 because of the presence of a 16-foot thick layer of clay above the sand aquifer and the greater distance between levees. Under existing seepage conditions the total head within the sand aquifer at each levee was about -14 feet, as shown on Figure 2.3.8. The water table at the far toe of the far levee on Woodward Island was at about elevation –9 feet, which is about the level of the drainage ditch.

Under full reservoir conditions with no pumping at the interceptor wells, there is a five-foot increase in the total head beneath the far levee, as shown on Figure 2.3.9. The phreatic surface rises to just below the ground surface on the adjacent island. Under full reservoir conditions with pumping at the interceptor wells, the minimum head at the pump needed to retain pre-reservoir conditions at the adjacent island is about –14 feet. This corresponds to an average pump rate along the well line of 0.033 gpm per foot of levee, or about 5 gpm for wells spaced at 160 feet.

Sensitivity Analyses. Three sensitivity analyses were conducted to evaluate the change in seepage conditions when changes occur in the hydraulic conductivities of the channel silt and aquifer sand, and in the thickness of the peat on each island. Webb Tract Station 630+00 was used for all sensitivity analyses, and the specific variation were as follows:

- Increasing the channel silt hydraulic conductivity from $1x10^{-6}$ cm/s to $5x10^{-6}$ cm/s.
- Increasing the aquifer sand hydraulic conductivity from $1x10^{-3}$ cm/s to $5x10^{-3}$ cm/s.
- Decreasing the peat thickness over the islands from six feet to three feet.

When increasing the channel silt hydraulic conductivity from $1x10^{-6}$ cm/s to $5x10^{-6}$ cm/s, a smaller head loss occurs within the silt layer and water levels increase throughout the aquifer, as shown on Figure 2.3.10. When compared to the baseline case (Figure 2.3.2), the head in the aquifer sand at the levees increased from –15 ½ feet to –10 ½ feet. Flows beneath the levees also increase from 0.0066 gpm per foot of levee for the baseline case, to 0.0159 gpm per foot of levee for the case using a higher silt hydraulic conductivity. So for an increase in the channel silt's hydraulic conductivity by a factor of five, the flow rates increased by a factor of 2 ½.

This model using a higher hydraulic conductivity for the channel silt also shows that the phreatic surface is above the ground surface (indicating flooding) on both islands under existing conditions, which is not seen in the field. For this reason it is felt that this modeled condition is not representative of actual conditions. As shown on Figure 2.3.11, this model shows a similar increase in the total head distribution for the condition of a full reservoir both with and without pumping, when compared to the baseline cases. The pump rate required to retain pre-reservoir conditions for this case is comparable to that found for the baseline case (11gpm vs. 12 gpm for wells at 160 feet). Therefore, when considering the performance of the well interceptor system, the project is not sensitive to a change by factor of five in the channel silt hydraulic conductivity.

When increasing the aquifer sand hydraulic conductivity from $1x10^{-3}$ cm/s to $5x10^{-3}$ cm/s (which is approximately the value determined from the McDonald Island drawdown test), the total head under each levee decreases from –15 ½ feet (baseline case) to –18 ½ feet, as shown on Figure 2.3.12. For the condition of a full reservoir with no pumping (Figure 2.3.13), the total head within the aquifer at each levee is about one foot lower than that found in the base case, and the flow rate beneath each levee increases by a factor of about four. The pump rate at the interceptor wells necessary to achieve conditions at the far levee similar to those found during pre-reservoir conditions is about three times the pump rate for the base case (38 gpm vs. 12 gpm for wells at

160 foot spacing). This analysis illustrates the dependency of the required pump rates on the hydraulic conductivity.

When decreasing the estimated peat thickness over the reservoir and neighboring islands from six feet to three feet, there was little affect on the total head contours within the sand aquifer, as shown on Figure 2.3.14. However the model also shows the phreatic surface is above the ground surface on both islands (indicating flooding) under existing conditions, which is not seen in the field. For this reason it is felt that this model is not representative of actual conditions. The thinning of the peat also has only a minimal affect on the total head values and pump rates for the condition of a full reservoir with and without pumping at the interceptor wells, as shown on Figure 2.3.15. The thinning of the peat layer resulted in an increase in the required pump rate from 12 to 13 gpm for wells at 160-foot spacing. Overall, the influence of the peat layer thickness on seepage conditions within the section is considered minimal.

Borrow Areas. In order to determine the effect of the proposed borrow areas on the seepage conditions within the sand aquifer, a model was constructed in which the 500-foot wide and 40-foot deep borrow area was added to the model of Webb Tract at Station 630+00. The borrow area was located about 400 feet from the toe of the levee as shown on Figure 2.3.16. The seepage condition of full reservoir with pumping at the interceptor wells was considered for the comparison, the results of which are detailed on Table 2.2. The construction of the borrow area 400 feet from the levee has little to no effect on the total head conditions within the aquifer near the levees, or on the required pump rate at the interceptor well when compared to baseline estimates. To follow US Army Corps of Engineers requirements (USACE, 1978), the borrow areas should be constructed at least 800 feet from the levee toe. This seepage analysis shows that a borrow area constructed 800 feet from the levee will not have a detrimental impact on the seepage conditions or on operation of the well interceptor system. Therefore, there is no need to "seal" the borrow excavation by placing the excavated silt overburden back into the excavation.

2.3.5 Summary of Findings

The seepage analyses conducted for four cross sections taken along the Webb Tract and Bacon Island levees show considerable variations in the existing flow conditions and those anticipated following filling of the proposed reservoirs and installation of the interceptor well system. These variations in subsurface stratigraphy and levee configuration between adjacent islands result in varying total head conditions and flow rates within the sand aquifer as well as the required pump rate. However, for all of the cases considered, a properly functioning interceptor well system can be used to minimize the effects of the proposed reservoirs on adjacent islands, including the potential for rises in the ground water table or flooding.

Seepage analyses show that the proposed reservoir at Webb Tract may increase the water table beneath the levee at adjacent islands from ½ to 7 feet at the sections analyzed, and that flooding may occur in the neighboring islands in the absence of pumping at the interceptor well system. In order for the well system to intercept the reservoir-induced seepage and maintain existing seepage conditions beneath the levees at adjacent islands, pump rates of 10 to 12 gpm (for wells at 160-foot spacing) would be required. However, previous studies have shown variations in the hydraulic conductivity of the sand aquifer to levels five to six times those used in these analyses. As shown in the sensitivity analyses, such a variation in the sand's hydraulic conductivity would result in an increase in the required pump rate to 50 to 60 gpm for wells spaced at 160 feet.

Seepage analyses show that the proposed reservoir at Bacon Island may increase the water table beneath the levee at adjacent islands from about 5 feet at the sections analyzed. In order for the well system to intercept the reservoir-induced seepage and maintain existing seepage conditions beneath the levees at adjacent islands, pump rates of 5 to 8-½ gpm (for wells at 160-foot spacing) would be required. As mentioned above, possible variations in the sand aquifer's hydraulic conductivity may result in an increase in the required pump rate to up to five times these values.

The proposed borrow area locations of 400 feet or farther from the existing levees on the reservoir islands should have little or no influence on the seepage conditions beneath the island levees. To follow US Army Corps of Engineers requirements, the borrow areas should be constructed at least 800 feet from the levee toe. The seepage analysis shows that a borrow area constructed 800 feet from the levee will not have a detrimental impact on the seepage conditions or on operation of the well interceptor system.

For both Webb Tract and Bacon Island, the interceptor well system should extend to the bottom of the sand aquifer. The pumping well should be screened over the entire length of the aquifer to achieve the required drawdown at the well, and the pumps should efficiently handle the required pump rate. The proposed spacing of 160 feet between pumping wells seems to be adequate; however, more optimum spacings and pump rates may be found for each levee section during the final design of the project. Following detailed investigations of subsurface conditions, adjustments in the well interceptor system design will be required to accommodate varying conditions, ranging from areas where little or no pumping may be needed (e.g., next to the San Joaquin River) to areas where pumping rates may be much higher than is typical (e.g., along localized gravelly portions of the aquifer).

The interceptor well concept generally appears to be able to mitigate seepage problems induced by the proposed reservoirs; however, proper design and construction will be key to the success of the interceptor well system. The water table level on the adjacent islands is considered to be an important indicator of impacts detrimental to those islands, as a significant rise in the ground water table may affect agricultural operations and production rates. The wells will have to be maintained at regular intervals to ensure their effectiveness. Further, the proposed observation wells that will be installed on the adjacent island levees must be monitored consistently to help ensure that the interceptor wells are operated at the pump rate that minimizes potential impacts on neighboring islands. (Estimated effects of pump outages are discussed in Section 2.5.2.)

2.4 EVALUATION OF MONITORING SYSTEM AND PROCEDURES

DW proposed a seepage monitoring system for the detection of seepage in the neighboring islands due to the implementation of the project (HLA 1991c, 1991d, 1992c; Hultgren 1997a, 1997b). Significance standards were proposed by DW to evaluate the seepage monitoring data for the determination of implementing seepage control measures.

This section presents a review of the proposed seepage monitoring system, the significance standards and the seepage control measures (Section 2.4.1); and an evaluation of the adequacy of the proposed seepage monitoring system and the significance standards (Section 2.4.2).

2.4.1 Proposed Seepage Monitoring System and Significance Standards

Seepage Monitoring System

At least one year prior to first filling of the DW reservoir islands (Webb Tract and Bacon Island), approximately 104 groundwater monitoring wells are recommended by DW for installation on neighboring islands. About 77 of the wells are seepage monitoring wells that will be sited directly opposite the DW reservoir islands. The other about 27 wells are background monitoring wells to provide groundwater variations at locations that are not expected to be impacted by the project related seepage. Conceptual locations of the proposed monitoring wells are shown in Figure 2.4.1. The purpose of the monitoring wells is to provide an early detection of seepage caused by the project.

Since the majority of the seepage into the neighboring islands is likely to occur through the most permeable sand layer (referred to as "deep seepage" in the DW reports), the piezometers will be screened in the sand layer. The following guidelines were used for the seepage monitoring piezometer spacing:

- A spacing of 1,500 to 2,000 feet on neighboring islands to closely monitor a continuous sand aquifer that underlies both the DW project and neighboring islands,
- A minimum spacing of 1,000 feet at critical sections, and
- A maximum spacing of 4,000 feet at other sections.

The background piezometers will be located in neighboring island locations which will not be impacted by the project related seepage.

The piezometers will be instrumented with pressure transducers, which will be connected with programmable data loggers. The data loggers will be programmed to collect water levels hourly, and the hourly water level readings will be averaged to compute a daily mean for each piezometer. Water levels will be concurrently recorded in the rivers and sloughs near the project islands.

Significance Standards

DW proposed seepage performance standards or significance standards to identify net seepage increases in the neighboring islands attributable to the reservoir islands. The data collected from the monitoring network will be used for application of the significance standards. If the data show exceedance of the significance standards, DW proposes to trigger seepage control measures to control the increased seepage.

Data collection from the piezometers will commence at least one year prior to filling of reservoirs. The data collected during this period will form the "historic" conditions at these locations. During filling and storage, water levels in monitoring wells on neighboring islands will be compared to the historical data and to the background data collected from the background wells. The purpose of the comparison with historic data is to evaluate whether a correlation exists between the piezometric levels and the reservoir filling and storage. The comparison with the background data is to check whether the variations observed are occurring throughout the Delta or only near the reservoir islands.

The proposed significance standards are presented below:

Significance Standards Proposed by Delta Wetlands

Standard	Condition 1		Condition 2		Condition 3
One Monitoring Well	Groundwater level in monitoring well > historic mean groundwater level + two standard deviation +1 foot	*and*	Increased groundwater level in monitoring well correlates with reservoir filling	*and*	Level corrected for current variations in background groundwater level
3 or More Contiguous Monitoring Wells	Groundwater level in monitoring wells > historic mean groundwater level + two standard deviation + 0.25 foot	*and*	Increased groundwater level in monitoring wells correlates with reservoir filling	*and*	Level corrected for current variations in background groundwater level

Note: All three conditions must be met simultaneously to trigger seepage control measures.

Hypothetical patterns related to seepage performance standards for a group of three wells are shown in Figure 2.4.2. This figure shows three scenarios: no reservoir related seepage case (Case I), seepage increase not attributable to the project (Case II), and seepage increase caused by the project (Case III). In Case II, mean water levels in three wells exceed the significance standards, but mean background water levels in background piezometers show a corresponding increase, indicating a regional water level rise not caused by the project. In Case III, seepage increase is attributable to the project because the background piezometers do not show a corresponding increase.

Seepage Control Measures

If seepage increase is detected as identified in Case III, DW will undertake measures to control the seepage. The primary means to control seepage is pumping from seepage interceptor wells placed on the reservoir islands levee. If the interceptors wells alone, even with increased pumping, may not be enough to control seepage, DW proposes to install additional interceptor wells, install relief wells (wells that passively relieve elevated water pressures in an aquifer), and take other methods acceptable to the landowners and reclamation districts. If DW is unable to control project related seepage and it cannot work out a satisfactory solution with the landowners and the reclamation district, DW proposes to lower the reservoir levels to avoid the impacts. In the most extreme case, DW proposes to completely eliminate the reservoir operations (Hultgren 1997a). The report indicates that the significance standards have been approved by the Seepage Review Committee. However, hearing testimony and oral statements at meetings contradict this.

2.4.2 Comments on Adequacy of Seepage Monitoring System and Significance Standards

Seepage Monitoring System

DW proposes to monitor the achievement of the no-net-seepage condition to neighboring islands by two sets of monitoring wells, seepage monitoring wells and background wells. Seepage monitoring wells are proposed to be placed on the crest of the levees of islands located across sloughs or channels from the DW reservoir islands. Background well are proposed to be located typically on the opposite sides of the neighboring islands. The proposed system of monitoring wells and background wells is shown in Figure 2.4.1.

To review the effectiveness of the proposed background wells, we evaluated the relationship between water levels measured in monitoring wells spaced some distance apart from each other. Existing monitoring wells located in various islands neighboring the reservoir islands were received and compared for similarity in trend and groundwater elevation in time. The objective of the comparison is to determine if all the wells located in an individual island show similar groundwater level increase and decrease trends before project implementation. Groundwater monitoring data collected as part of the ongoing background groundwater monitoring (see Section 2.2 for details) were used in the comparison. The groundwater monitoring data are presented in HLA 1995c and 1995d; data for one monitoring well (BA-6) are reproduced in Figure 2.4.3 as a sample of the data reviewed.

The observations from the review of 22 monitoring wells within the project islands or the neighboring islands indicate:

- The recorded water elevations in wells within the same island are different. The differences in water elevation within each island vary from 2 feet (Bethel Island, wells BE-11 and BE-12) to as much as 12 feet (Venice Island, wells VN-32 and VN-34).
- Most of the wells show a cyclical trend in groundwater elevation, which is higher in the winter seasons. However, there are some exceptions where no particular trends were noted, such as at Bouldin Island (well BO-28), Holland Tract (well HO-2), Palm Tract (well PA-30), Venice Island (wells VN-32 and VN-33). At Woodward Tract there exists a trend but it is out of phase from the other wells (peaks in water table do not occur at the same time).
- Because of the lack of correlation in groundwater elevations and seasonal trends, it is recommended that a revised background well system be considered in each neighboring island. This will allow accounting for the local variation of groundwater level within each adjacent island. Multiple background monitoring wells will also offer the opportunity to account for groundwater changes due to local pumping operations for various farming needs within each neighboring island.
- This system of background wells can be composed of the proposed background wells by Delta Wetland, supplemented by shallow background wells (10 to 20 feet deep) installed across each neighboring island to monitor the trend of groundwater away from the reservoir islands. These additional background wells can be placed a half-mile to one mile apart. The specific location and spacing should be finalized in the design phase of the project based on groundwater conditions in each neighboring island.

Significance Standards

The significance standards established by DW to trigger initiation of seepage control measures (i.e., pumping of the seepage monitoring wells in the first place) are summarized in Section 2.2. They use three simultaneous conditions to identify triggering conditions: exceedance of water level in one or several monitoring wells of significance levels, correction for background water levels, and correlation with reservoir filling. All three conditions must be satisfied to actuate the trigger. The three conditions appear appropriate to identify project-related seepage. Provided that background wells are installed as noted previously, the significance standards are the only condition of concern.

Use of one year to establish a reference base of water levels in the seepage monitoring well and background wells does not appear to be long enough. We recommend a base of three years, to optimize the probability that realistic variations in the water levels with the seasons and with relatively dry and wet years are established. Considering that construction of the improvements to the reservoir island levees will likely take more than three years, this condition should be easy to satisfy. The three-year base should be used for the background wells and at least a portion, say half, of the seepage monitoring wells.

Use of the mean plus two standard deviations (to include about 95 percent of the data points) appears reasonable in the calculation of the significance standard. (There would be too many "false alarms" if a smaller value were used.) We also recommend the use of the straight line running mean rather than the simple harmonic (sine function).

Use of one foot of "leeway" in a single monitoring well is judged to be too high. This judgment is based primarily on the results of the seepage analyses, which show that the difference in water heads in the aquifer below the toe of the near levee of the adjacent island is only four feet, when comparing full reservoir conditions with and without pumping. Further, as discussed earlier, there is a time lag involved between the onset of pumping and the time there is an effect on the water head at the toe of the adjacent island's levee. This lag time is expected to be on the order of one day, as discussed in Section 2.5.2. It is our judgment that undesirable seepage effects in the adjacent island could start with a one-foot rise in the water table. Considering that the one-foot margin includes the two standard deviations in the monitoring well reading, the "leeway" and the time lag effect, it is our judgment that the "leeway" should be limited to 0.5 foot for a single well. The leeway of 0.25 foot for the average of three wells appears acceptable.

2.4.3 Conclusions and Recommendations

- The proposed system of seepage monitoring wells appears appropriate.
- Background wells shall include both those conceptually proposed by DW and additional rows of shallow monitoring wells across adjacent islands.
- Use more than one well for background data collection for each row of seepage monitoring wells.
- Use at least three years of data to establish reference water levels in the background wells and at least one half of the seepage monitoring wells.
- Use running straight-line mean from monitoring well data in the application of the significance criteria.

- Reduce the "leeway" for a single monitoring well to 0.5 foot; 0.25-foot leeway for the average of three wells is acceptable.
- Other data (e.g., undesirable seepage effects such as reported impacts on agriculture in adjacent islands, or results of well effectiveness tests as discussed in Section 2.5) may be used in conjunction with significance standards to justify deviations from the standards.
- The significance standards should be reviewed periodically after startup of reservoir operations to validate their utility; suggested times of reevaluation are after 2, 5 and 10 years of operation.

2.5 LONG-TERM MONITORING OF SYSTEM PERFORMANCE

2.5.1 Long-Term Reliability of Proposed Well System

The main components of the proposed interceptor well system will be the wells, the collector piping, and the power supply and controls. Long-term reliability of the system will depend on the functioning of all these constituents.

It is important that the individual wells making up the interceptor well system are carefully designed and constructed as long-term production wells. Specifically, this will involve design of the well screen and surrounding gravel pack to be done to accommodate the grain sizes of the aquifer, in accordance with applicable criteria. Subsequently, the wells must be constructed and developed appropriately. Further, the perforated section of the well casing should stay permanently submerged (i.e., should not extend above the elevation of the deepest expected drawdown of the water table), to minimize the possibility of fouling of the screen by organic growths. Over time, regular well and pump maintenance must be performed to ensure continued optimal functioning of the wells. It will be useful in this connection if the individual wells were equipped with flow meters, such that any dropoff in output could be identified.

The collector piping is unlikely to be the source of any system reliability problems.

The electrical power supply may be interrupted at times. It is expected that a power outage not exceeding a few hours will have no significant effect. It may be worthwhile, in final design, to evaluate the likely power outages and their consequences on seepage control, and consider if provision of standby generators is advisable.

The control system will include the piezometers, their monitoring, transmission and evaluation of data, and the tie-in between the monitoring and pumping, i.e., the application of the "significance criteria." It is expected that the piezometer reading and transmission and evaluation of data will be implemented in such a way, and with sufficient manual checks, that these items will not significantly impact reliability.

In summary, therefore, long-term operability of the individual wells and reliability of power supply are expected to be the main potential sources of inadequate system performance. We believe that rigorous well O&M and consideration of standby power will provide high likelihood of long-term system reliability.

The possibility that the extraction wells could cause long-term loss of fines in the vicinity of the well, which can have potential stability and settlement implications, is discussed in Section 3.11.

2.5.2 Estimated Effects of Pump Outages

The seepage analyses presented in this report were made for steady-state conditions; i.e., for a condition expected to last sufficiently long that transient effects are not present. Rough hand calculations suggest that the "travel time" from the pumps to the land side toe of the adjacent island is at least one day. Therefore, a pump outage would be felt in the adjacent island at least a day later. Correspondingly a restart of pumping is expected to have a similar time lag in its effect starting to be felt.

This time estimate confirms the judgment that a pump outage, for instance due to a power failure, of a few hours would have no significant effect. An outage extending to day or more would be expected to cause a rise in the groundwater table in the adjacent islands. Another possibility is that one or several adjacent pumps may not be performing as expected. This would not be known (absent individual flow meters on the wells and their periodic reading) until a piezometer showed an unusual rise in the water table at a location. With piezometers spaced a minimum of 1000 feet apart, such a lack of performance might not be noticed for quite some time if the affected wells are located between piezometers. It is possible that the effects of such an event would be identified on the ground before they were detected by the piezometers. Installation of individual flow meters on wells and their periodic monitoring would minimize the potential of this occurrence.

2.5.3 Monitoring Procedures to Detect and Respond to Outages

The needed monitoring procedures follow from the above discussion. The principal monitoring method to detect the effects of poorly performing well(s) is the periodic reading of the piezometers, ideally by remote-operating and transmitting means. To guard against the effects of partial or complete outages of individual or groups of wells, the output of individual wells (by permanently or temporarily installed flow meters) should be monitored periodically. In areas considered critical, closer spacing of piezometers to minimize the possibility of occurrence of high water tables between piezometers may also be considered.

In the event of partial or system-wide power outages (with stored water in the reservoir), the responsible reservoir operators should be notified immediately by automatic alert. If the outage should last more than a few hours, appropriate notice should be given to adjacent island operators. Should the outage last more than a few hours, adjacent islands should be patrolled for potentially undesirable seepage effects, and appropriate remedial measures (including reservoir lowering in the extreme) should be taken if such effects are apparent.

2.6 WATER DIVERSIONS FROM ADJACENT CHANNELS THROUGH THE INTERCEPTOR WELLS

During certain conditions in the reservoir islands and adjacent channels, the pumping from the interceptor well system may divert water from the channels onto the reservoir islands. Based on the results of the seepage analyses performed for Webb Tract and Bacon Island, which are described in detail in Section 2.3, this report contains an assessment of the amount of water that could be inadvertently diverted onto the reservoir islands through operation of the interceptor well system and direct seepage.

The pump rates estimated for the interceptor well system that would be required to avoid the effect of reservoir induced seepage and described in Section 2.3. This pump rate would create seepage conditions beneath the adjacent levee that are approximately equal to those seen under pre-reservoir (without-project) conditions. The estimated required pump rates to achieve pre-reservoir conditions at the adjacent island levee at each of the four sections considered are summarized below:

Case	Flux Away from Slough, Toward Reservoir Island (gpm per foot of levee)		
	Existing Conditions	**Full Reservoir with No Pumping**	**Full Reservoir with Required Pumping**
1. Webb Tract, Station 630+00	0.0066	-0.0167	0.0061
2. Webb Tract, Station 265+00	0.0163	-0.0076	0.0174
3. Bacon Island, Station 220+00	0.0080	-0.0069	0.0089
4. Bacon Island, Station 665+00	0.0010	-0.0057	0.0061

For Cases 1, 2 and 3, when the required pumping rate is used, the flux from the slough toward the reservoir island is about the same as the flux seen during existing conditions. For these cases, the pumps are drawing no more water from the slough than is flowing under existing conditions. The exception is in Case 4, in which some additional flux from the slough flows towards the well system as it draws down the water level to achieve the required conditions at the neighboring island. The reason for this additional pumping effort appears to be the presence of the upper clay layer near Station 665+00 at Bacon Island.

To further illustrate an example of how the interceptor wells would capture water from the adjacent channel, the seepage model developed for Webb Tract at Station 630+00 was used. As shown in Figure 2.6.1, a required pump rate of 0.0759 gpm per foot of levee (or 12 gpm per well spaced at 160 feet) was found to correspond to a drawdown of –15 feet at the pumping well. At this rate the average total head (-17 feet) and flow rate (0.007 gpm per foot) beneath the adjacent island's levee are approximately equal to the values seen under existing conditions (without the project). Should the pump rate at the interceptor well be increased 25% to 0.0955 gpm per foot (or 15 gpm for wells spaced at 160 feet), the drawdown at the well increases to –20 feet (see Figure 2.6.1). As shown on the figure, the flux rate from the slough side of the pump would increase from 0.0061 to 0.0128 gpm per foot. In addition, the average total head in the sand aquifer beneath the adjacent levee would drop from -15 ½ to -17 ½ feet, and the flux rate there (from the slough toward the island) would decrease from 0.0071 to 0.0033 gpm per foot.

A method for monitoring water seeping onto the reservoir islands from the adjacent slough could include both monitoring of pump rate at the interceptor well system as well as monitoring piezometer levels on the adjacent island's levee to watch for significant changes from baseline values. To account for the influence of seasonal changes in the existing seepage conditions beneath the adjacent island levees, the monitoring program on the adjacent levees should be established well in advance of reservoir filling to develop the record of the baseline conditions against which new readings can be compared. Discussions of the adequacy of the monitoring system and the proposed significance criteria are presented in the preceding sections.

2.7 POTENTIAL SETTLEMENTS CAUSED BY FILLING AND EMPTYING RESERVOIR ISLANDS

There will be some additional island surface settlement associated with initial and subsequent filling and emptying of the reservoir islands. Conceptual consideration of the mechanisms that would lead to additional settlements leads us to the conclusion that additional settlements are expected to be nominal, of the order of one additional foot of settlement. This amount is less than would be expected from continued use of the islands for agriculture, which would over time lead to essentially complete oxidation of the peat. This process would correspond to as much as 15 feet of additional settlement on Webb Tract and 10 feet of additional settlement on Bacon Island. In fact, flooding of islands has been proposed as one method to minimize further oxidation of peat and associated subsidence in the Delta islands.

Table 2.2.1
Permeability of Soils Used in Prior Seepage Analysis

Material	Vertical Permeability Ky (cm/s)	Horizontal Permeability Kx (cm/s)	Ky/Kx	Ref.
Existing Sandy Fill (with clay and peat)	1×10^{-5}	1×10^{-4}	0.1	1
Existing Clayey Fill (Bay Mud)	1×10^{-7}	1×10^{-6}	0.1	1
Peat	1×10^{-6}	1×10^{-4}	0.01	1, 2
Silty Sand	1×10^{-4} to 5×10^{-4}	1×10^{-3}	0.1 to 0.5	1
		5.4×10^{-3} to 6.4×10^{-3}		3
Sand with gravel		1.4×10^{-1}	1	3
Clay/Silt (at bottom of channel)	1×10^{-6}	1×10^{-6}	1	1
Planned Fill (sand)	1×10^{-4}	1×10^{-3}	0.1	1
		1.1×10^{-3}		2

1 - HLA 1989. Preliminary Geotechnical Investigation for the Delta Wetlands Project. Feb 15, 89. pp -13.
2 - HLA 1992. Geotechnical Investigation & Design of the Wilkerson Dam on Bouldin Island. May 27, 92. pp -16.
3 - HLA 1991. Interceptor Well Modelling for the Delta Wetlands project. pp A-7 to A-8.

Notes: In ref. 1, vertical permeabilities were measured, and horizontal permeabilities were estimated.
It is not clear if the permeabilities from ref. 2 were measured or not (this ref gives only horizontal permeability).
Permeabilities from ref. 3 were measured using McDonald Island pump tests data (this ref. gives only horizontal permeability).

Table 2.3.1
Soil Properties Used in Seepage Analysis of Four Cross Sectional Models

Cross Section	Soil Layer	Approximate Soil Layer Thickness (feet)	Horizontal Hydraulic Conductivity K_x (cm/s)	Vertical Hydraulic Conductivity K_y (cm/s)
Webb Tract Sta. 260+00	Fill Material (Clay with Peat and Sand)	12	1×10^{-4}	1×10^{-5}
	Peat	25	1×10^{-4}	1×10^{-5}
	Sand	46	1×10^{-3}	1×10^{-4}
	Lower Clay	--	1×10^{-6}	1×10^{-6}
	Channel Silt	3	1×10^{-6}	1×10^{-6}
	New Fill (Sand)	Varies	1×10^{-3}	1×10^{-3}
Webb Tract Sta. 630+00	Fill Material (Sand)	10	1×10^{-4}	1×10^{-5}
	Fill Material (Clay)	5	1×10^{-6}	1×10^{-6}
	Peat	15	1×10^{-4}	1×10^{-5}
	Sand	50	1×10^{-3}	1×10^{-4}
	Lower Clay	--	1×10^{-6}	1×10^{-6}
	Channel Silt	3	1×10^{-6}	1×10^{-6}
	New Fill (Sand)	Varies	1×10^{-3}	1×10^{-3}

Table 2.3.1

Soil Properties Used in Seepage Analysis of Four Cross Sectional Models (continued)

Cross Section	Soil Layer	Approximate Soil Layer Thickness (feet)	Horizontal Hydraulic Conductivity K_x (cm/s)	Vertical Hydraulic Conductivity K_y (cm/s)
Bacon Island Sta. 220+00	Fill (Sand and Clay)	7	1×10^{-4}	1×10^{-5}
	Peat	30	1×10^{-4}	1×10^{-5}
	Sand	20	1×10^{-3}	1×10^{-4}
	Lower Clay	--	1×10^{-6}	1×10^{-6}
	Channel Silt	3	1×10^{-6}	1×10^{-6}
	New Fill (Sand)	Varies	1×10^{-3}	1×10^{-3}
Bacon Island Sta. 665+00	Fill Material (Peat)	20	1×10^{-4}	1×10^{-5}
	Upper Clay	16	1×10^{-6}	1×10^{-6}
	Sand	19	1×10^{-3}	1×10^{-4}
	Lower Clay	--	1×10^{-6}	1×10^{-6}
	Channel Silt	3	1×10^{-6}	1×10^{-6}
	New Fill (Sand)	Varies	1×10^{-3}	1×10^{-3}

Table 2.3.2
Seepage Analysis Results

Case	Description	Figure Number	Head in Sand at Near Levee CL (feet)	Flow at Near Levee CL (gpm/ft)	Head in Sand at Far Levee CL (feet)	Flow at Far Levee CL (gpm/ft)	Water Table At Far Toe of Far Levee (feet)	Pumping Rate Required for Wells at 160' (gpm)
1	Webb Tract - Station 630+00 Existing Conditions	2.3.2	-15 ½	0.0066	-15 ½	0.0067	-17	NA
2	Webb Tract - Station 630+00 Full Reservoir w/ no Pumping	2.3.3	- ½	-0.0167	-8 ½	0.0208	-13	NA
3	Webb Tract - Station 630+00 Full Reservoir w/ Pumping	2.3.3	-15	0.0759 (pumping)	-15 ½	0.0071	-17	12
4	Webb Tract - Station 260+00 Existing Conditions	2.3.4	-10	0.0163	-9	0.0142	-9	NA
5	Webb Tract - Station 260+00 Full Reservoir w/ no Pumping	2.3.5	-3 ½	-0.0076	-8 ½	0.0167	-9	NA
6	Webb Tract - Station 260+00 Full Reservoir w/ Pumping	2.3.5	-10	0.0660 (pumping)	-9	0.0149	-9	10 ½

Table 2.3.2 continued

Case	Description	Figure Number	Head in Sand at Near Levee CL (feet)	Flow at Near Levee CL (gpm/ft)	Head in Sand at Far Levee CL (feet)	Flow at Far Levee CL (gpm/ft)	Water Table At Far Toe of Far Levee (feet)	Pumping Rate Required for Wells at 160' (gpm)
7	Bacon Island - Station 220+00 Existing Conditions	2.3.6	-14	0.0080	-14	0.0078	-17	NA
8	Bacon Island - Station 220+00 Full Reservoir w/ no Pumping	2.3.7	2	-0.0069	-9 ½	0.0118	-13	NA
9	Bacon Island - Station 220+00 Full Reservoir w/ Pumping	2.3.7	-14	0.0527 (pumping)	-14	0.0076	-17	8 ½
10	Bacon Island - Station 665+00 Existing Conditions	2.3.8	-14	0.0010	-14	0.0010	-9	NA
11	Bacon Island - Station 665+00 Full Reservoir w/ no Pumping	2.3.9	- ½	-0.0057	-9	0.0049	-9	NA
12	Bacon Island - Station 665+00 Full Reservoir w/ Pumping	2.3.9	-14	0.0333 (pumping)	-14	0.0011	-9	5

Table 2.3.2 continued

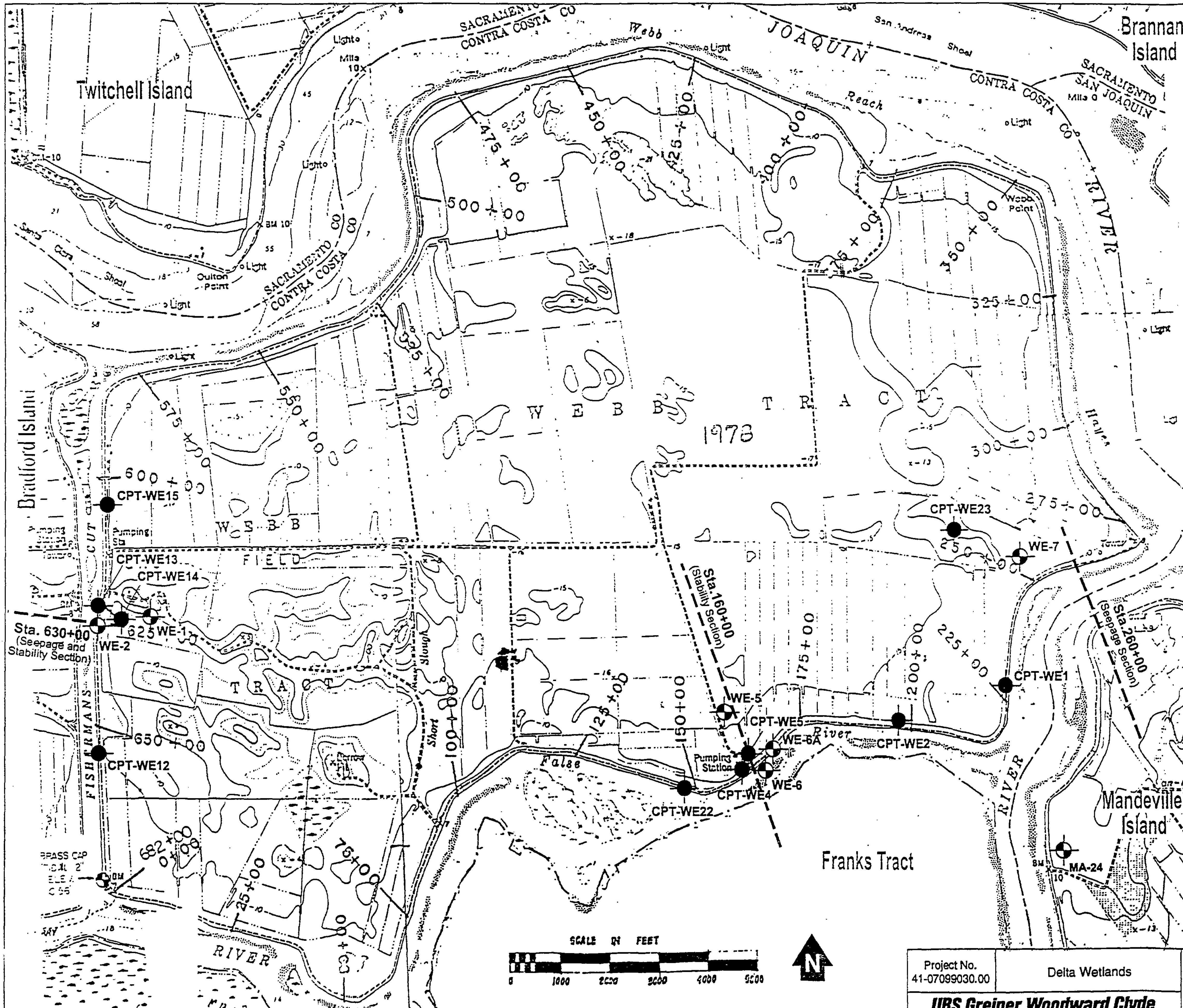
Case	Description	Figure Number	Head in Sand at Near Levee CL (feet)	Flow at Near Levee CL (gpm/ft)	Head in Sand at Far Levee CL (feet)	Flow at Far Levee CL (gpm/ft)	Water Table At Far Toe of Far Levee (feet)	Pumping Rate Required for Wells at 160' (gpm)
SENSITIVITY ANALYSES								
S1	Webb Tract - Station 630+00 Existing Conditions (Channel Silt at $5x10^{-6}$ cm/s)	2.3.10	-10 ½	0.0159	-11	0.0165	-13	NA
S2	Webb Tract - Station 630+00 Full Reservoir w/ no Pumping (Channel Silt at $5x10^{-6}$ cm/s)	2.3.11	+2	-0.0134	-7.5	0.0242	-13	NA
S3	Webb Tract - Station 630+00 Full Reservoir w/ Pumping (Channel Silt at $5x10^{-6}$ cm/s)	2.3.11	-10	0.0681 (pumping)	-10 ½	0.0168	-14	11
S4	Webb Tract - Station 630+00 Existing Conditions (Aquifer Sand at $5x10^{-3}$cm/s)	2.3.12	-18 ½	0.0085	-18 ½	0.0086	-18 ½	NA
S5	Webb Tract - Station 630+00 Full Reservoir w/ no Pumping (Aquifer Sand at $5x10^{-3}$cm/s)	2.3.13	-1 ½	-0.0702	-9 ½	0.0758	-11	NA

Table 2.3.2 continued

Case	Description	Figure Number	Head in Sand at Near Levee CL (feet)	Flow at Near Levee CL (gpm/ft)	Head in Sand at Far Levee CL (feet)	Flow at Far Levee CL (gpm/ft)	Water Table At Far Toe of Far Levee (feet)	Pumping Rate Required for Wells at 160' (gpm)
S6	Webb Tract - Station 630+00 Full Reservoir w/ Pumping (Aquifer Sand at $5x10^{-3}$cm/s)	2.3.13	-18 ½	0.2384 (pumping)	-18 ½	0.0092	-18 ½	38
S7	Webb Tract - Station 630+00 Existing Conditions (Peat Thickness reduced from 6 ft to 3 ft)	2.3.14	-15	0.0063	-15	0.0069	-16	NA
S8	Webb Tract - Station 630+00 Full Reservoir w/ no Pumping (Peat Thickness reduced from 6 ft to 3 ft)	2.3.15	1	-0.0169	-8 ½	0.0208	Above -13	NA
S9	Webb Tract - Station 630+00 Full Reservoir w/ Pumping (Peat Thickness reduced from 6 ft to 3 ft)	2.3.15	-15	0.0819 (pumping)	-15	0.0070	-16	13

Table 2.3.2 continued

Case	Description	Figure Number	Head in Sand at Near Levee CL (feet)	Flow at Near Levee CL (gpm/ft)	Head in Sand at Far Levee CL (feet)	Flow at Far Levee CL (gpm/ft)	Water Table At Far Toe of Far Levee (feet)	Pumping Rate Required for Wells at 160' (gpm)
BORROW AREA ANALYSIS								
BA1	Webb Tract - Station 630+00 Full Reservoir w/ Pumping	2.3.16	-15	0.0738 (pumping)	-15	0.0071	-16	12
BA2	Webb Tract - Station 630+00 Full Reservoir w/ Pumping (Borrow Area 400' from Levee Toe)	2.3.16	-15	0.0745 (pumping)	-15	0.0071	-16	12



LEGEND

Approximate Borehole Location

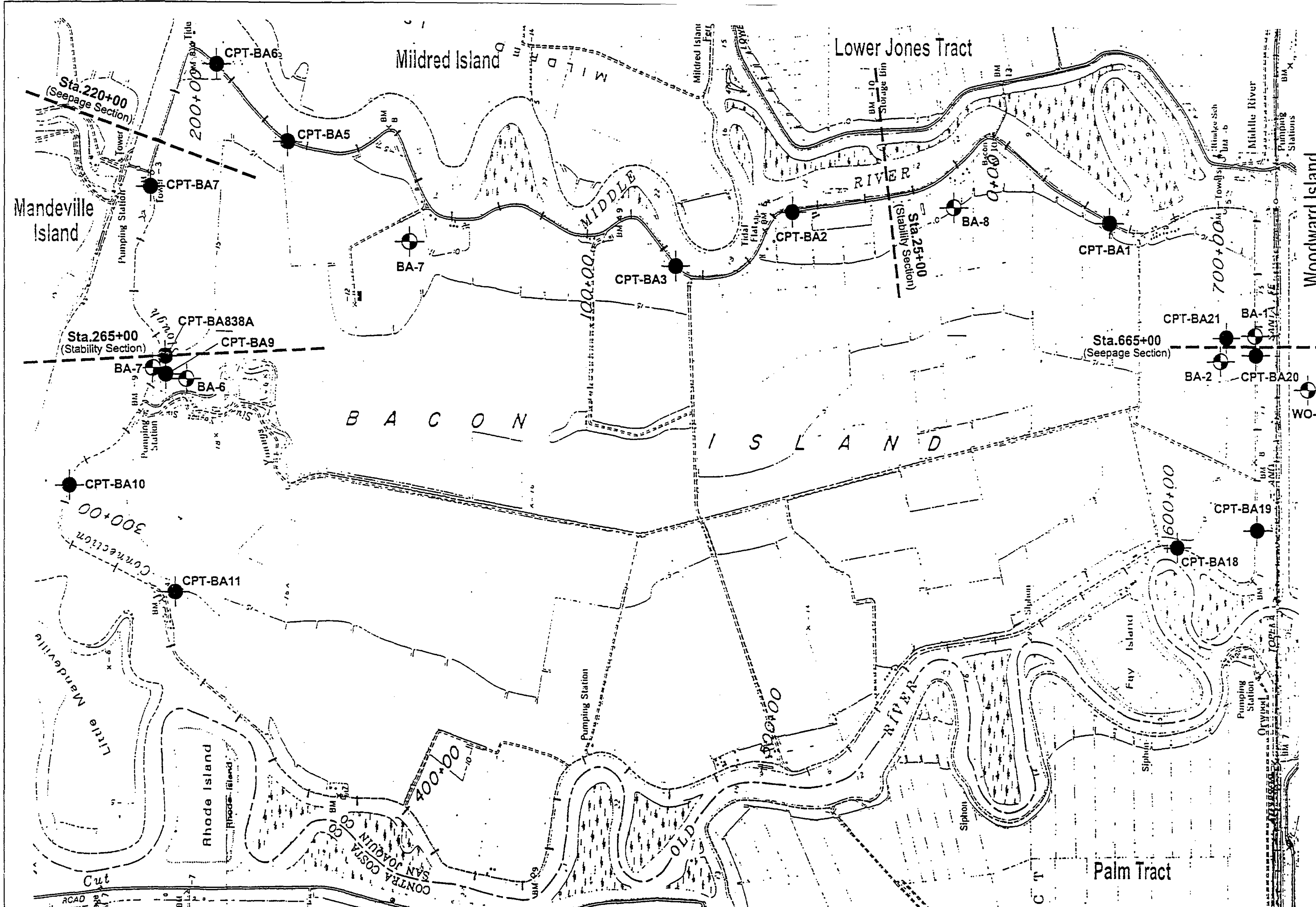
Approximate Cone Penetration Test Sounding Location

Notes: Only Boring Locations in Vicinity of Analysis Sections (both Seepage and Stability) are shown. See HLA (1989) for Logs of Borings and CPTs.

Seepage Analysis Sections at Stations 260+00 and 630+00. Stability Analysis Sections at Stations 160+00 and 630+00.

Project No. 41-07099030.00	Delta Wetlands	WEBB TRACT BASE MAP	Figure 2.2.1
URS Greiner Woodward Clyde			

41-07099030.00-00003/120999/gos



LEGEND

- Approximate Borehole Location
- Approximate Cone Penetration Test Sounding Location

Notes:

Only Boring Locations in Vicinity of Analysis Sections (both Seepage and Stability) are shown. See HLA (1989) for Logs of Borings and CPTs.

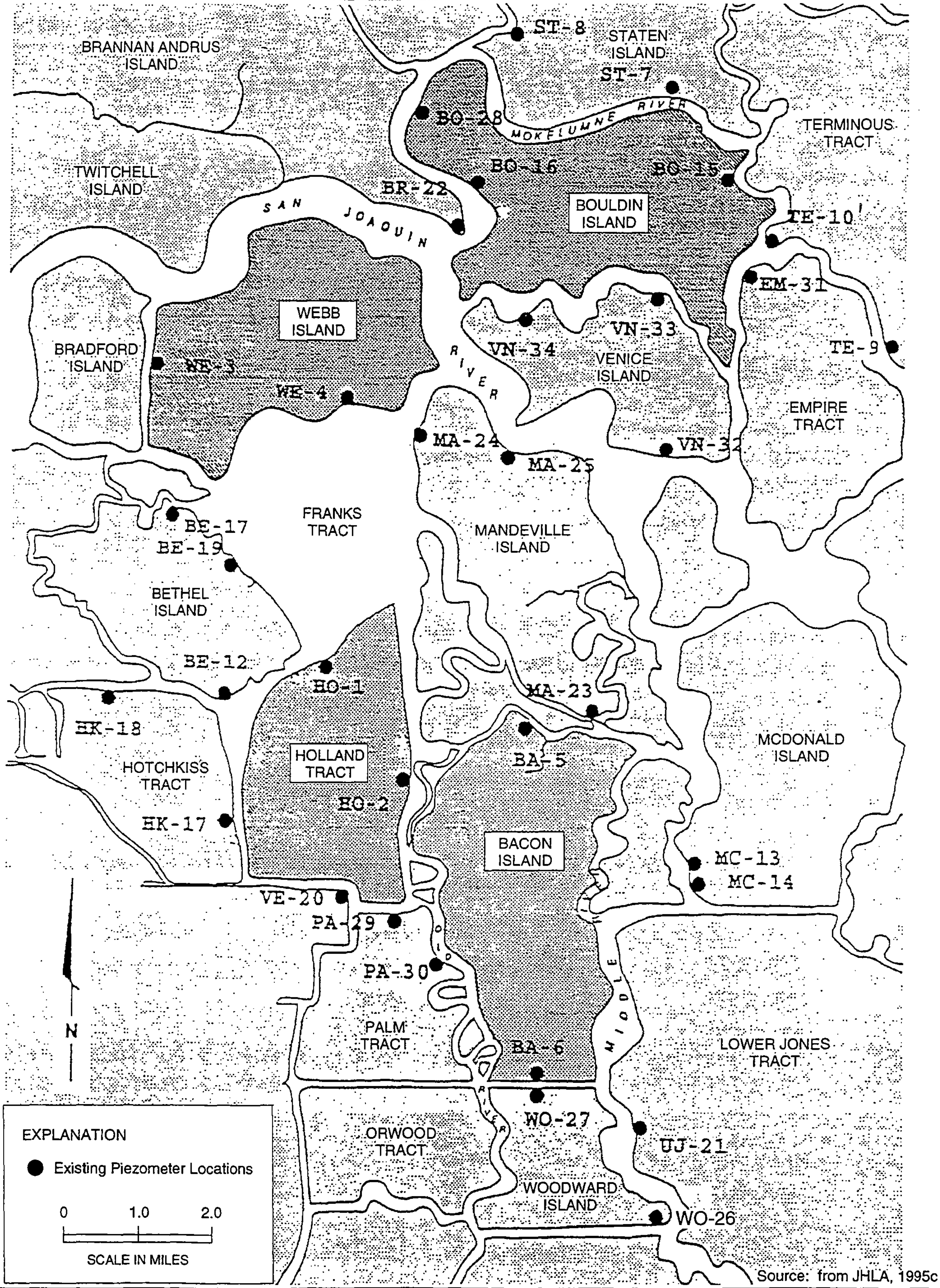
Seepage Analysis Sections at Stations 220+00 and 665+00. Stability Analysis Sections at Stations 25+00 and 265+00.

N

0 1000 2000 3000
SCALE IN FEET

Project No. 41-07099030.00	Delta Wetlands	BACON ISLAND BASE MAP	Figure 2.2.2
URS Greiner Woodward Clyde			

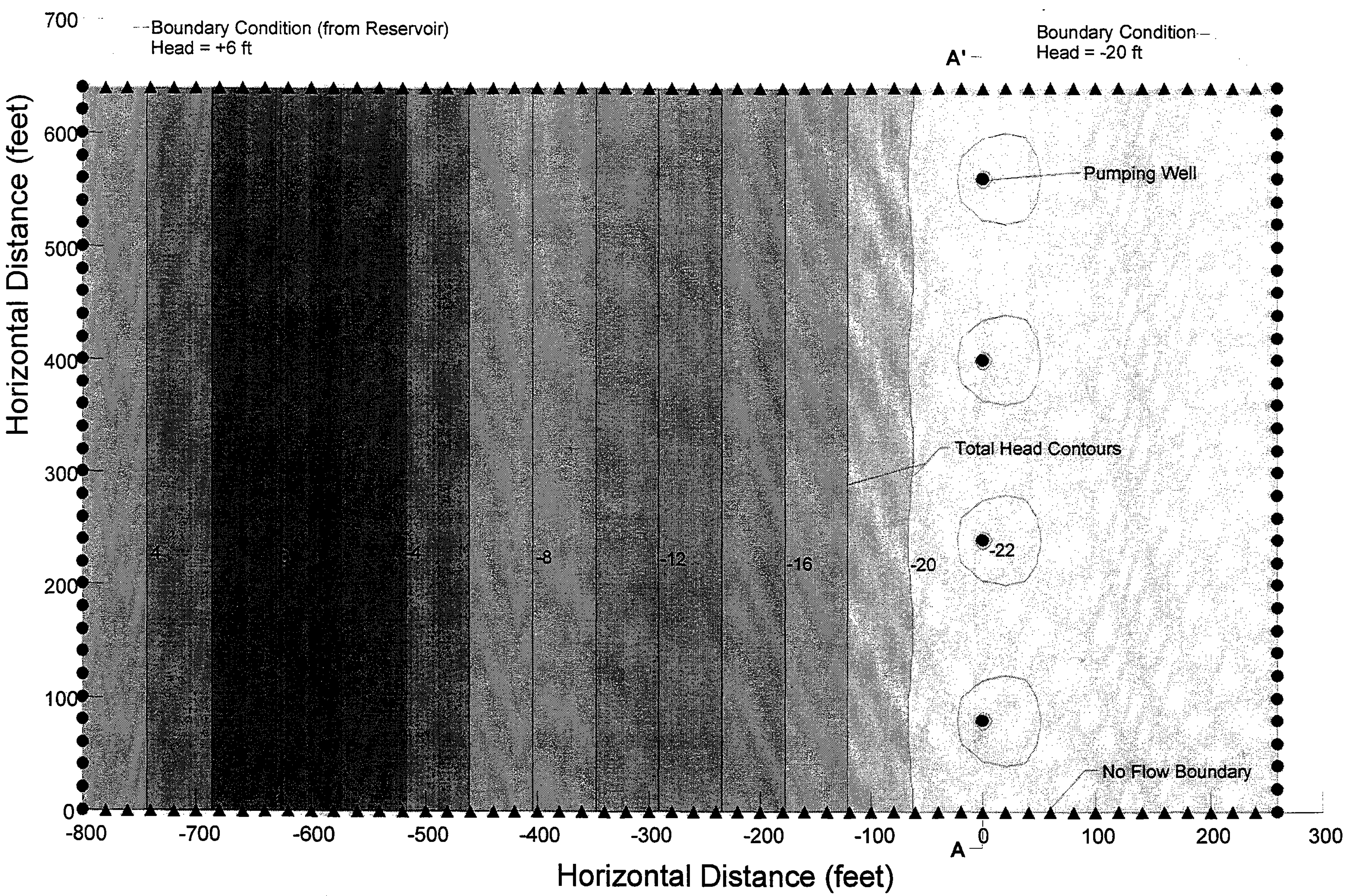
41-07099030.00-00003/120999/gos



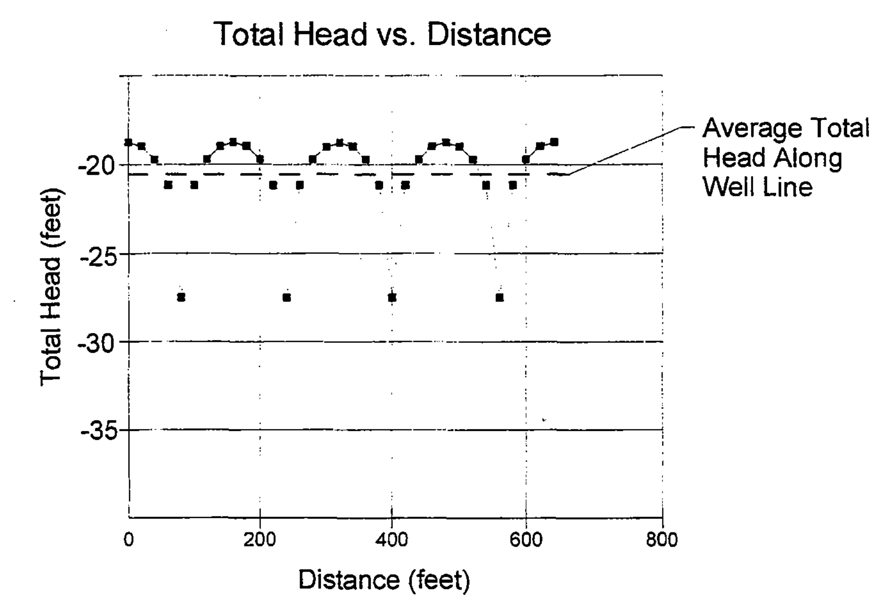
Source: from JHLA, 1995c

Project No. 41-07099030.00	Delta Wetlands	LOCATIONS OF EXISTING BACKGROUND GROUNDWATER MONITORING WELLS	Figure 2.2.3
URS Greiner Woodward Clyde			

41-07099030.00-00003/051800/gos

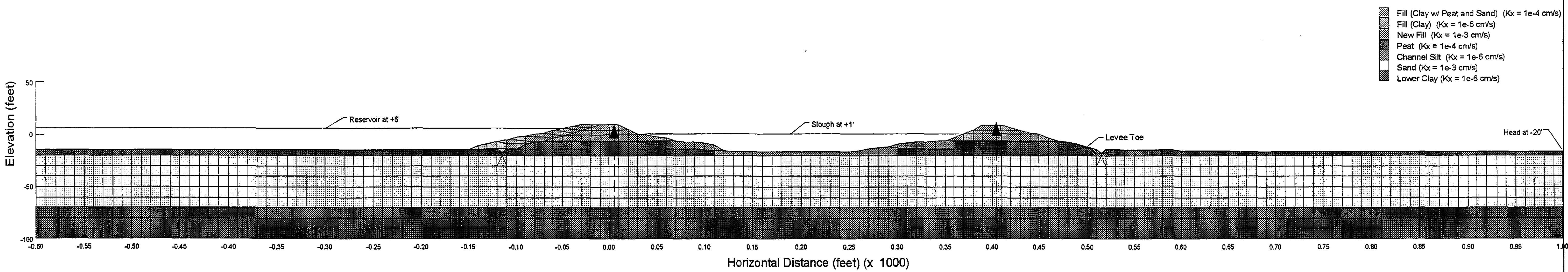


EXAMPLE OF PLAN VIEW MODEL APPROACH

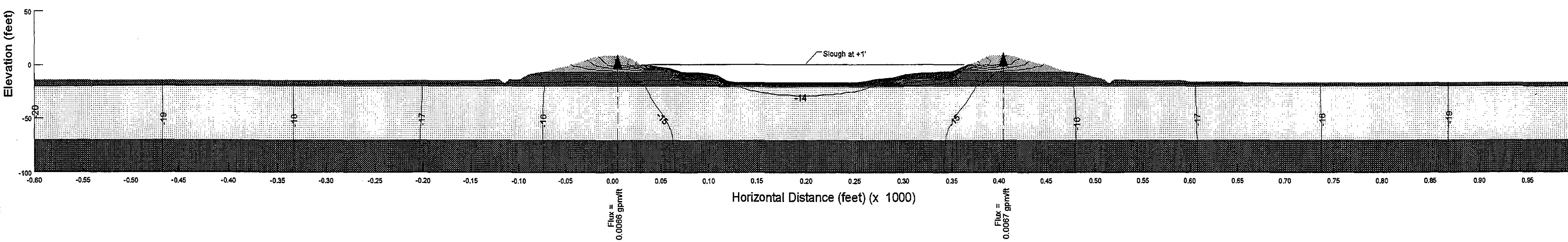


TOTAL HEAD ALONG WELL LINE (SECTION A-A') 160' WELL SPACING

DELTA WETLANDS PROJECT	WEBB TRACT STATION 630+00 SEEPAGE ANALYSIS APPROACH PLAN VIEW MODEL	FIGURE 2.3.1
URS GREINER WOODWARD CLYDE		

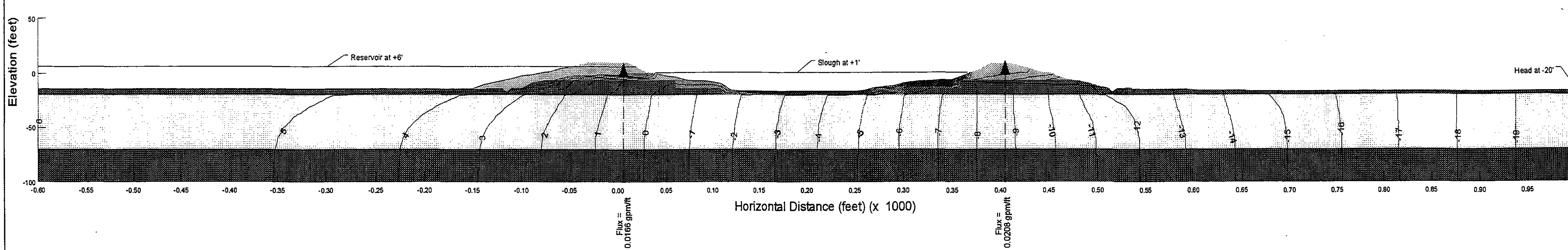


A. Stratigraphy and Model Mesh

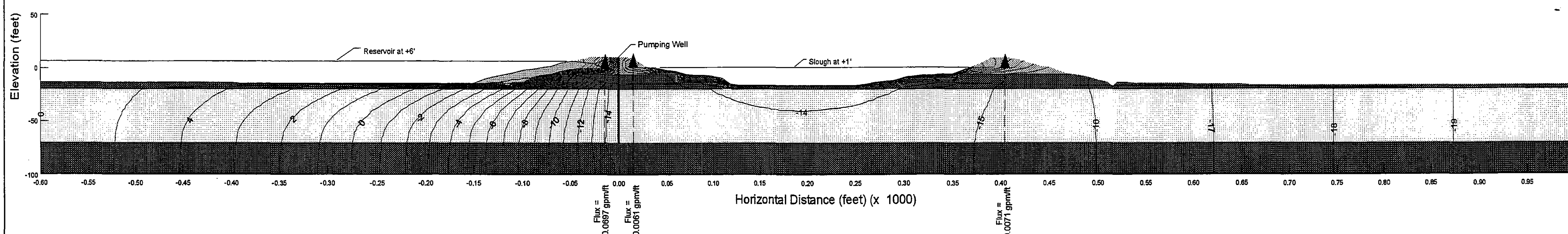


B. Existing Seepage Conditions
Total Head Contours

DELTA WETLANDS PROJECT	**WEBB TRACT STATION 630+00 STRATIGRAPHY AND EXISTING SEEPAGE CONDITIONS**	**FIGURE 2.3.2**
URS GREINER WOODWARD CLYDE		

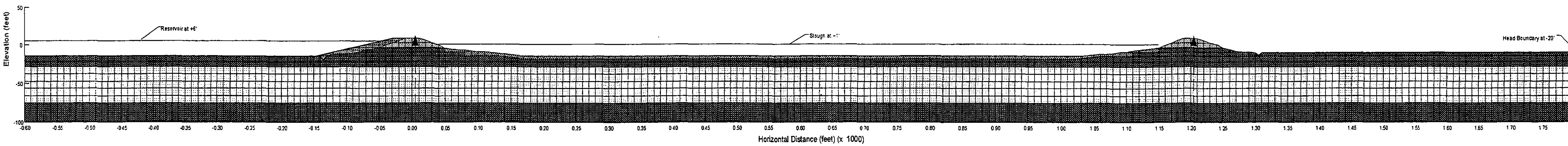


A. Seepage Condition - Full Reservoir, No Pumping
Total Head Contours

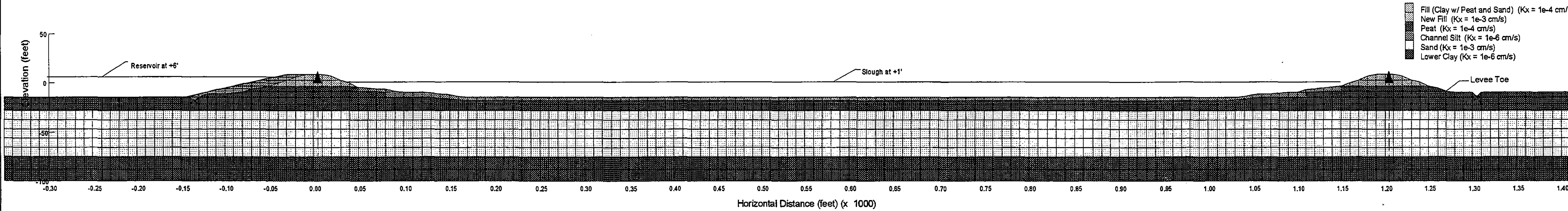


B. Seepage Condition - Full Reservoir with Pumping
Total Head Contours

DELTA WETLANDS PROJECT	WEBB TRACT STATION 630+00 SEEPAGE CONDITIONS WITH FULL RESERVOIR	FIGURE 2.3.3
URS GREINER WOODWARD CLYDE		

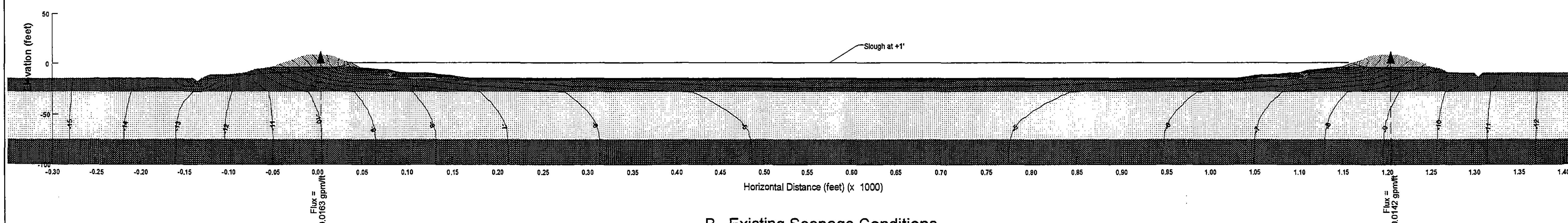


Full Model



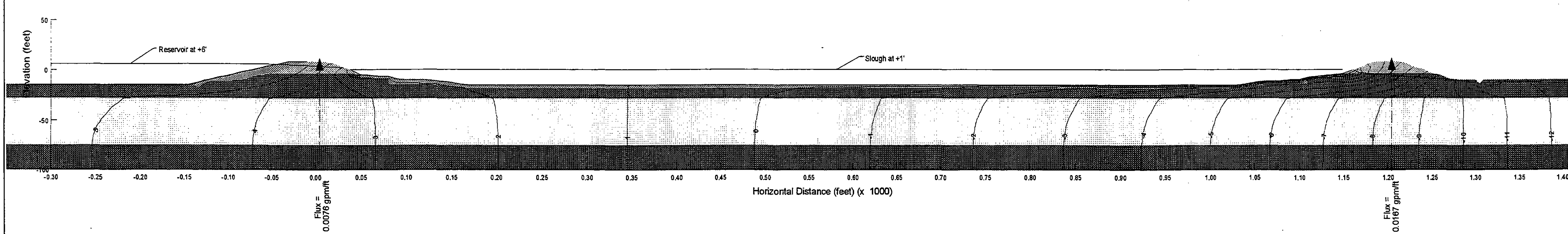
Partial Model

A. Stratigraphy and Model Mesh

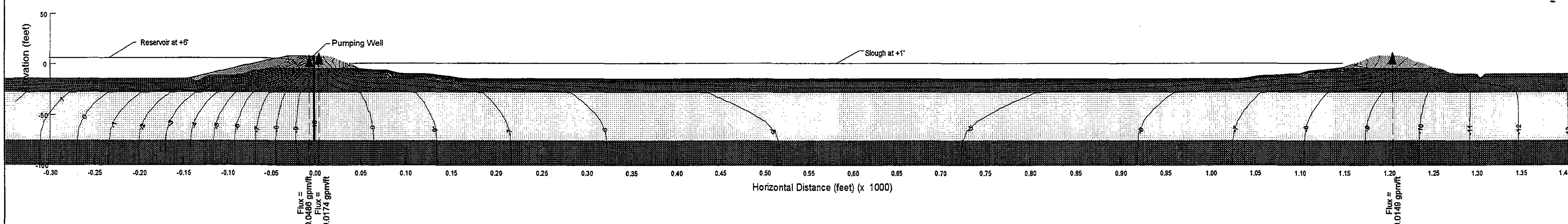


B. Existing Seepage Conditions
Total Head Contours

DELTA WETLANDS PROJECT	WEBB TRACT STATION 260+00 STRATIGRAPHY AND EXISTING SEEPAGE CONDITIONS	FIGURE 2.3.4
URS GREINER WOODWARD CLYDE		

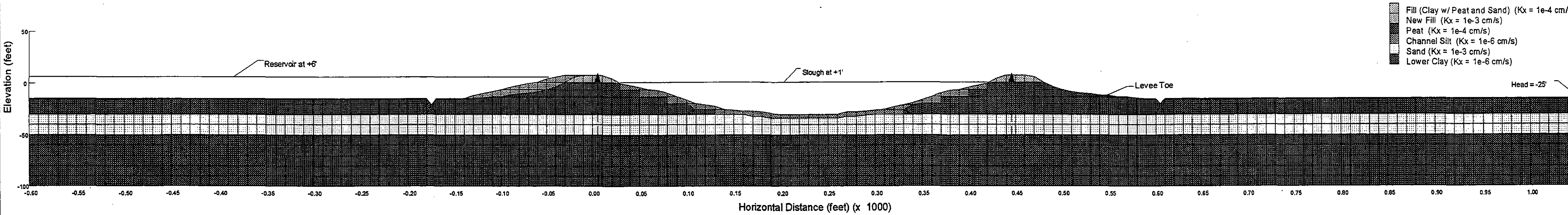


A. Seepage Condition - Full Reservoir, No Pumping
Total Head Contours

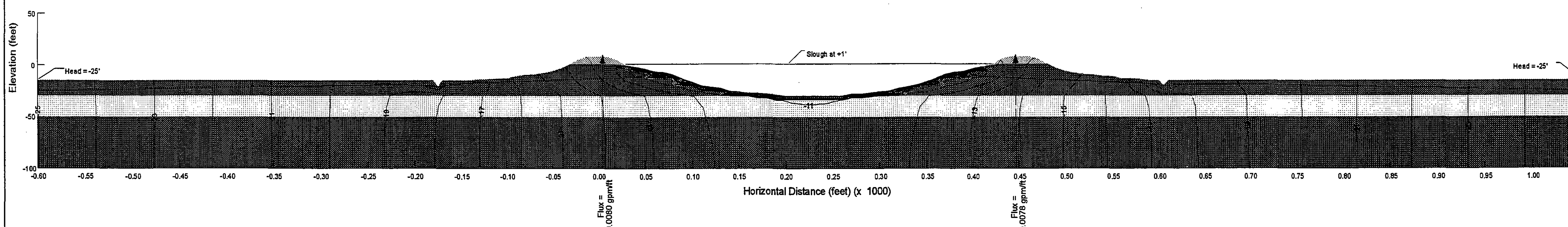


B. Seepage Condition - Full Reservoir with Pumping
Total Head Contours

DELTA WETLANDS PROJECT	WEBB TRACT STATION 260+00 SEEPAGE CONDITIONS WITH FULL RESERVOIR	FIGURE 2.3.5
URS GREINER WOODWARD CLYDE		

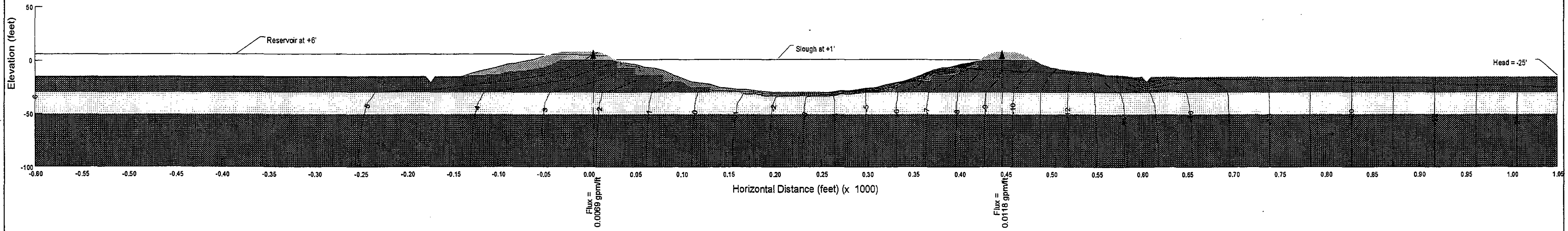


A. Stratigraphy and Model Mesh

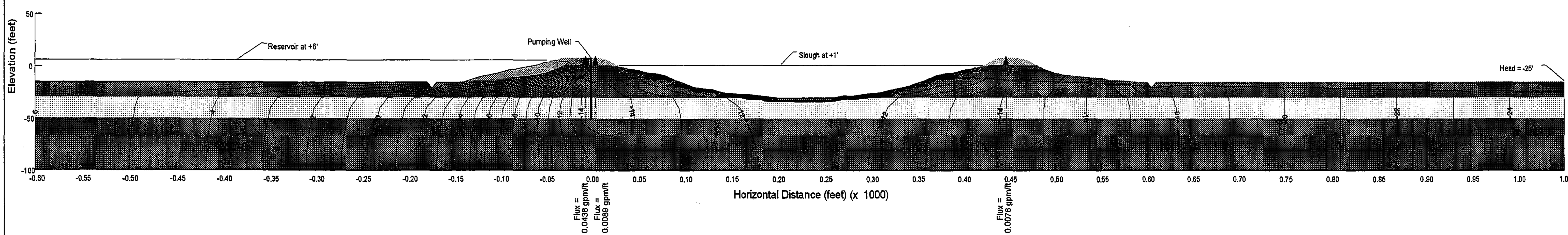


B. Existing Seepage Conditions
Total Head Contours

DELTA WETLANDS PROJECT	BACON ISLAND STATION 220+00 STRATIGRAPHY AND EXISTING SEEPAGE CONDITIONS	FIGURE 2.3.6
URS GREINER WOODWARD CLYDE		

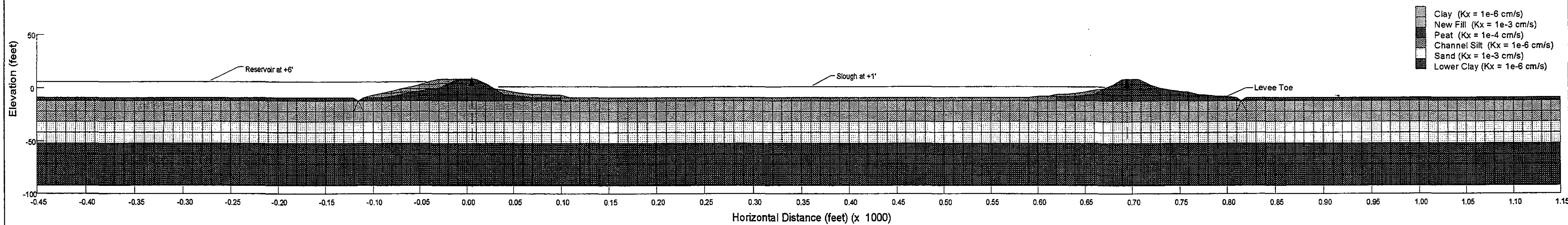


A. Seepage Condition - Full Reservoir, No Pumping
Total Head Contours

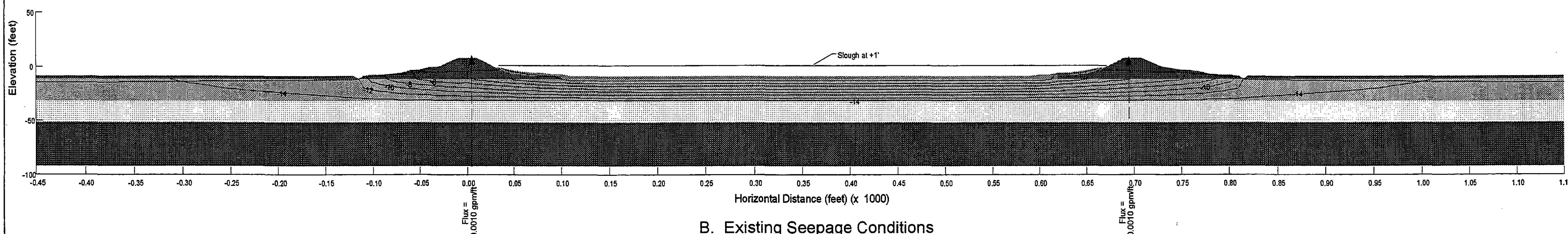


B. Seepage Condition - Full Reservoir with Pumping
Total Head Contours

DELTA WETLANDS PROJECT	BACON ISLAND STATION 220+00 SEEPAGE CONDITIONS WITH FULL RESERVOIR	FIGURE 2.3.7
URS GREINER WOODWARD CLYDE		

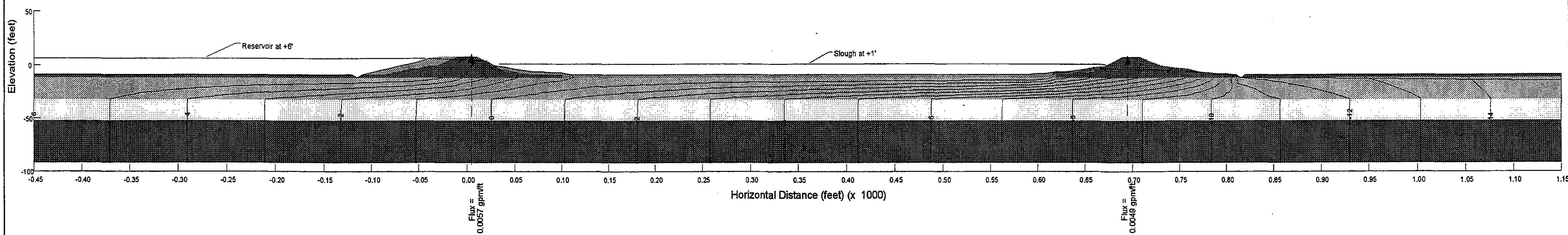


A. Stratigraphy and Model Mesh

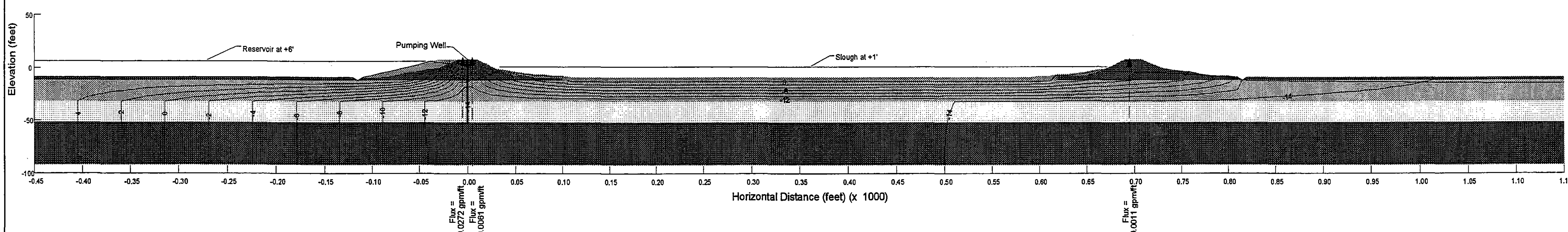


B. Existing Seepage Conditions
Total Head Contours

DELTA WETLANDS PROJECT	BACON ISLAND STATION 665+00 STRATIGRAPHY AND EXISTING SEEPAGE CONDITIONS	FIGURE 2.3.8
URS GREINER WOODWARD CLYDE		

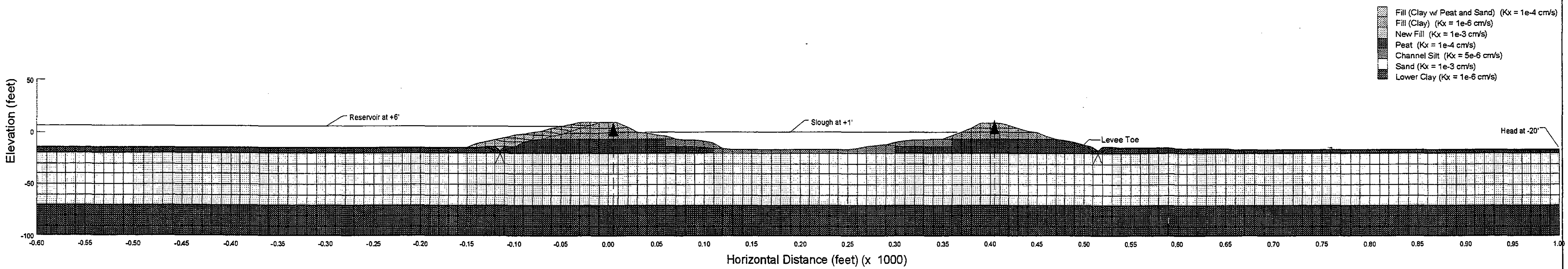


A. Seepage Condition - Full Reservoir, No Pumping
Total Head Contours

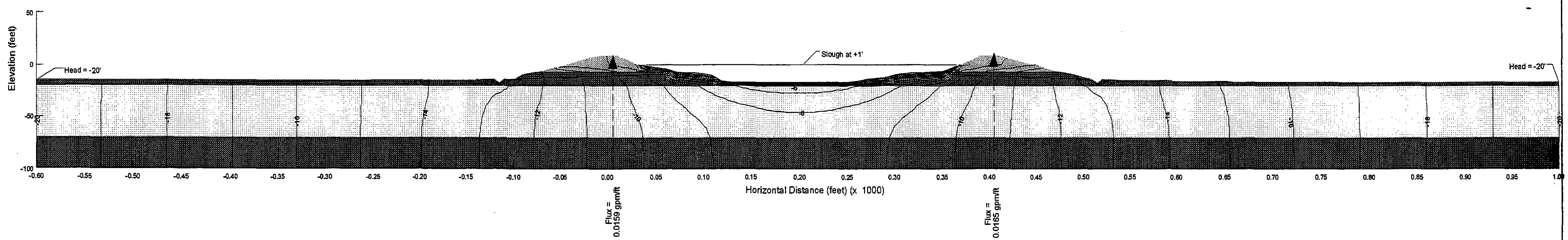


B. Seepage Condition - Full Reservoir with Pumping
Total Head Contours

DELTA WETLANDS PROJECT	BACON ISLAND STATION 665+00 SEEPAGE CONDITIONS WITH FULL RESERVOIR	FIGURE 2.3.9
URS GREINER WOODWARD CLYDE		

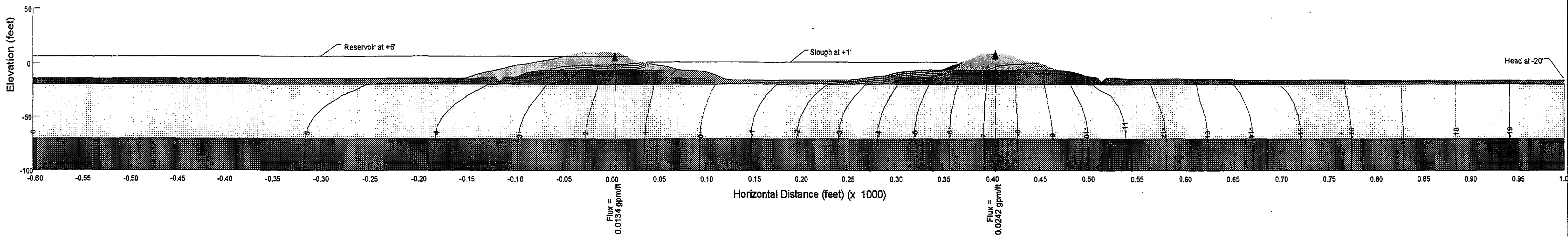


A. Stratigraphy and Model Mesh

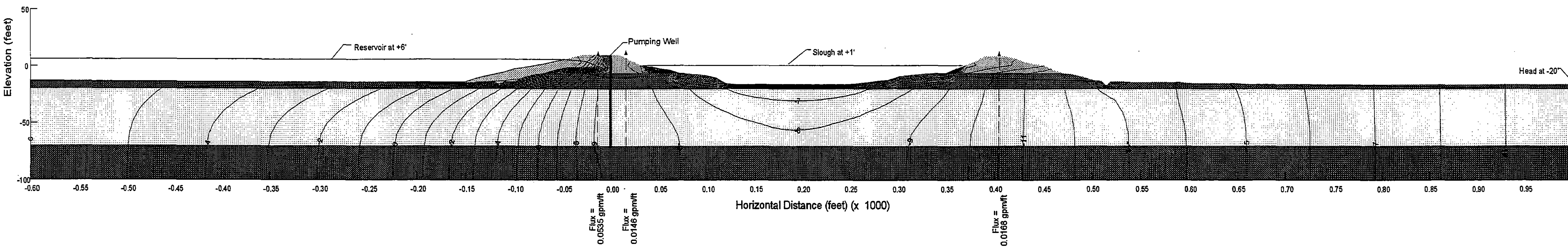


B. Existing Seepage Conditions
Total Head Contours

DELTA WETLANDS PROJECT	WEBB TRACT STATION 630+00 STRATIGRAPHY AND EXISTING SEEPAGE CONDITIONS (Channel Silt at 5e-6 cm/s)	FIGURE 2.3.10
URS GREINER WOODWARD CLYDE		

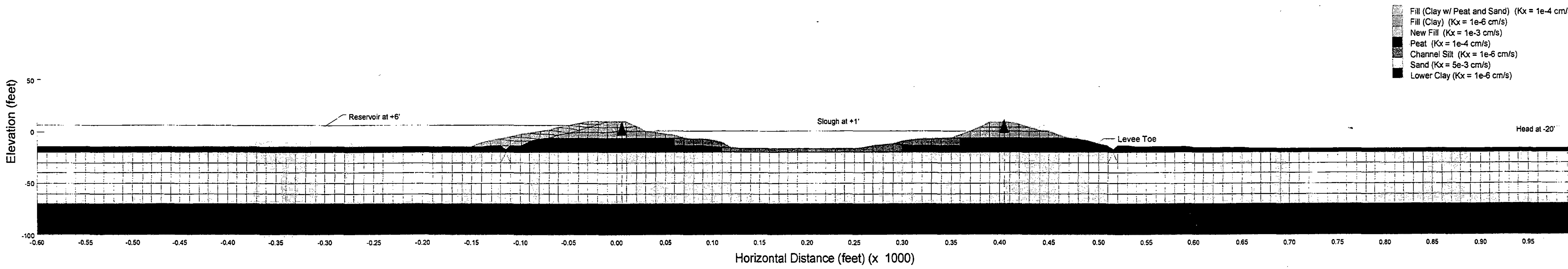


A. Seepage Condition - Full Reservoir, No Pumping
Total Head Contours

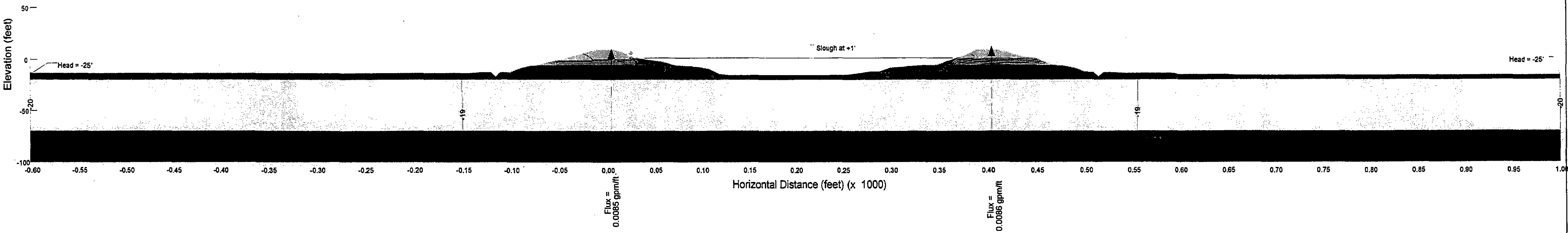


B. Seepage Condition - Full Reservoir with Pumping
Total Head Contours

DELTA WETLANDS PROJECT	WEBB TRACT STATION 630+00 SEEPAGE CONDITIONS WITH FULL RESERVOIR (Channel Silt at 5e-6 cm/s)	FIGURE 2.3.11
URS GREINER WOODWARD CLYDE		

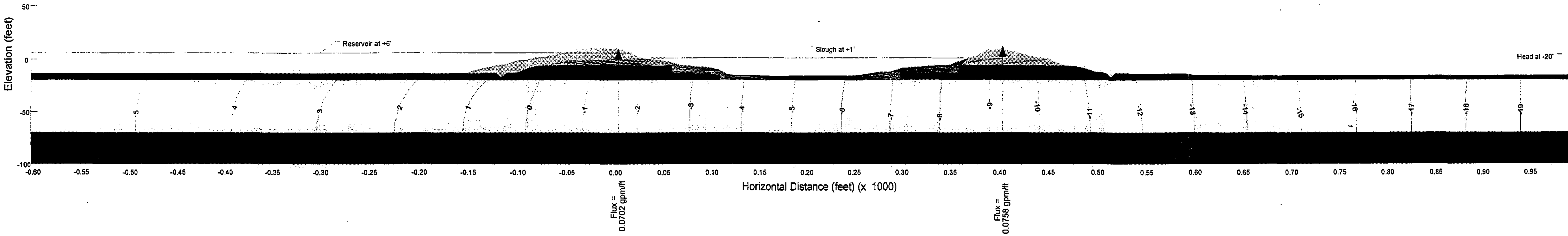


A. Stratigraphy and Model Mesh

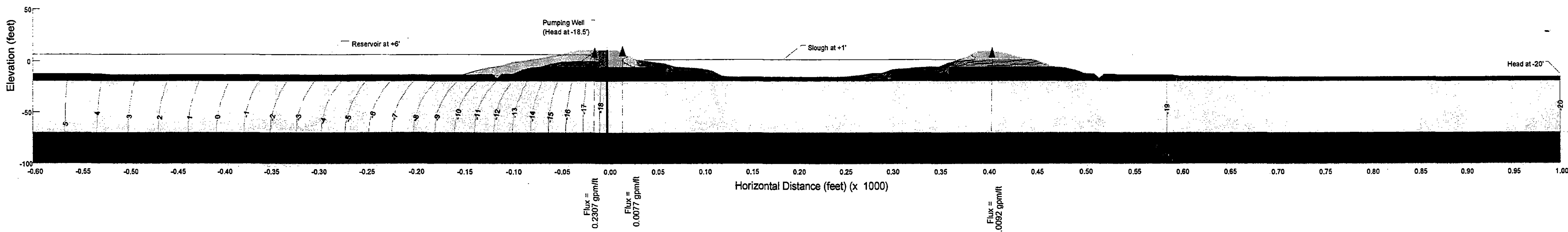


B. Existing Seepage Conditions
Total Head Contours

DELTA WETLANDS PROJECT	**WEBB TRACT STATION 630+00** **STRATIGRAPHY AND EXISTING SEEPAGE CONDITIONS** **(Aquifer Sand at 5e-3 cm/s)**	**FIGURE** **2.3.12**
URS GREINER WOODWARD CLYDE		

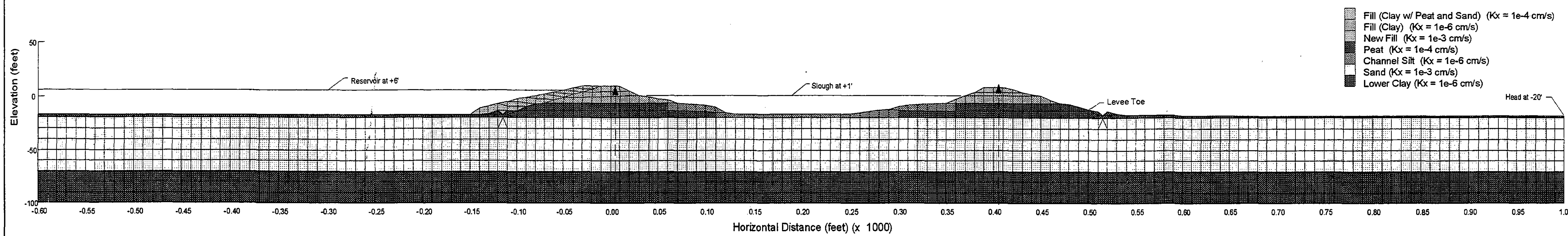


A. Seepage Condition - Full Reservoir, No Pumping
Total Head Contours

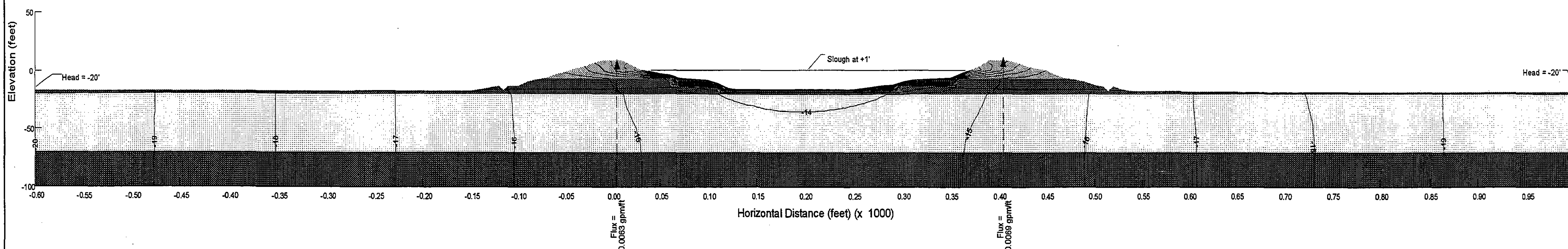


B. Seepage Condition - Full Reservoir with Pumping
Total Head Contours

DELTA WETLANDS PROJECT	WEBB TRACT STATION 630+00 SEEPAGE CONDITIONS WITH FULL RESERVOIR (Aquifer Sand at 5e-3 cm/s)	FIGURE 2.3.13
URS GREINER WOODWARD CLYDE		

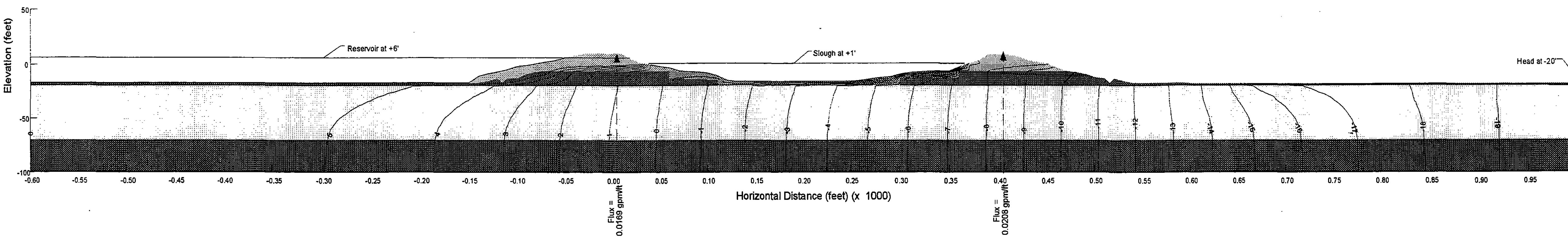


A. Stratigraphy and Model Mesh

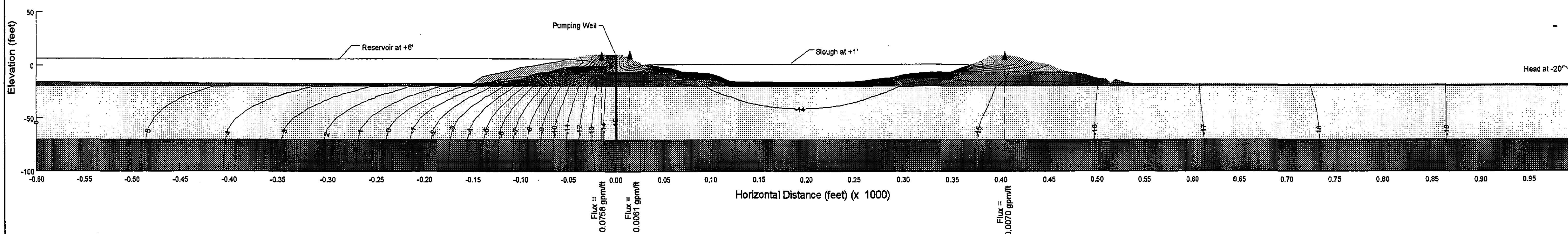


B. Existing Seepage Conditions
Total Head Contours

DELTA WETLANDS PROJECT	WEBB TRACT STATION 630+00 STRATIGRAPHY AND EXISTING SEEPAGE CONDITIONS (Peat thickness reduced from 6 feet to 3 feet)	FIGURE 2.3.14
URS GREINER WOODWARD CLYDE		

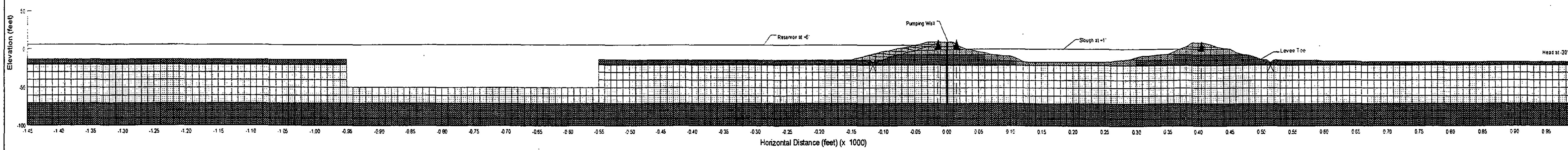


A. Seepage Condition - Full Reservoir, No Pumping
Total Head Contours

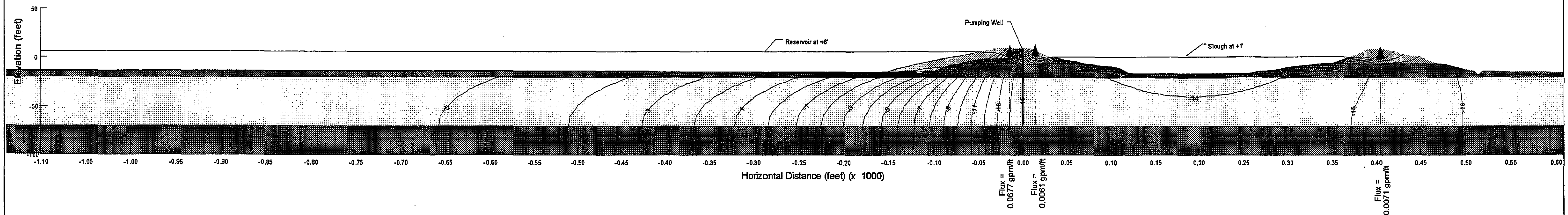


B. Seepage Condition - Full Reservoir with Pumping
Total Head Contours

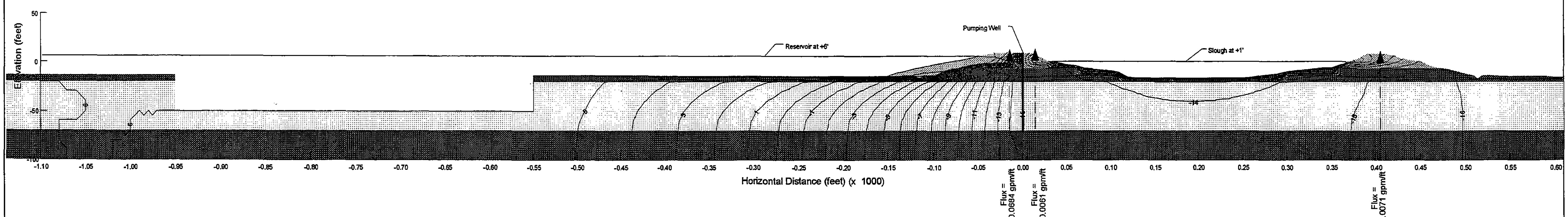
DELTA WETLANDS PROJECT	WEBB TRACT STATION 630+00 SEEPAGE CONDITIONS WITH FULL RESERVOIR (Peat thickness reduced from 6 feet to 3 feet)	FIGURE
URS GREINER WOODWARD CLYDE		2.3.15



A. Stratigraphy and Extended Model Mesh

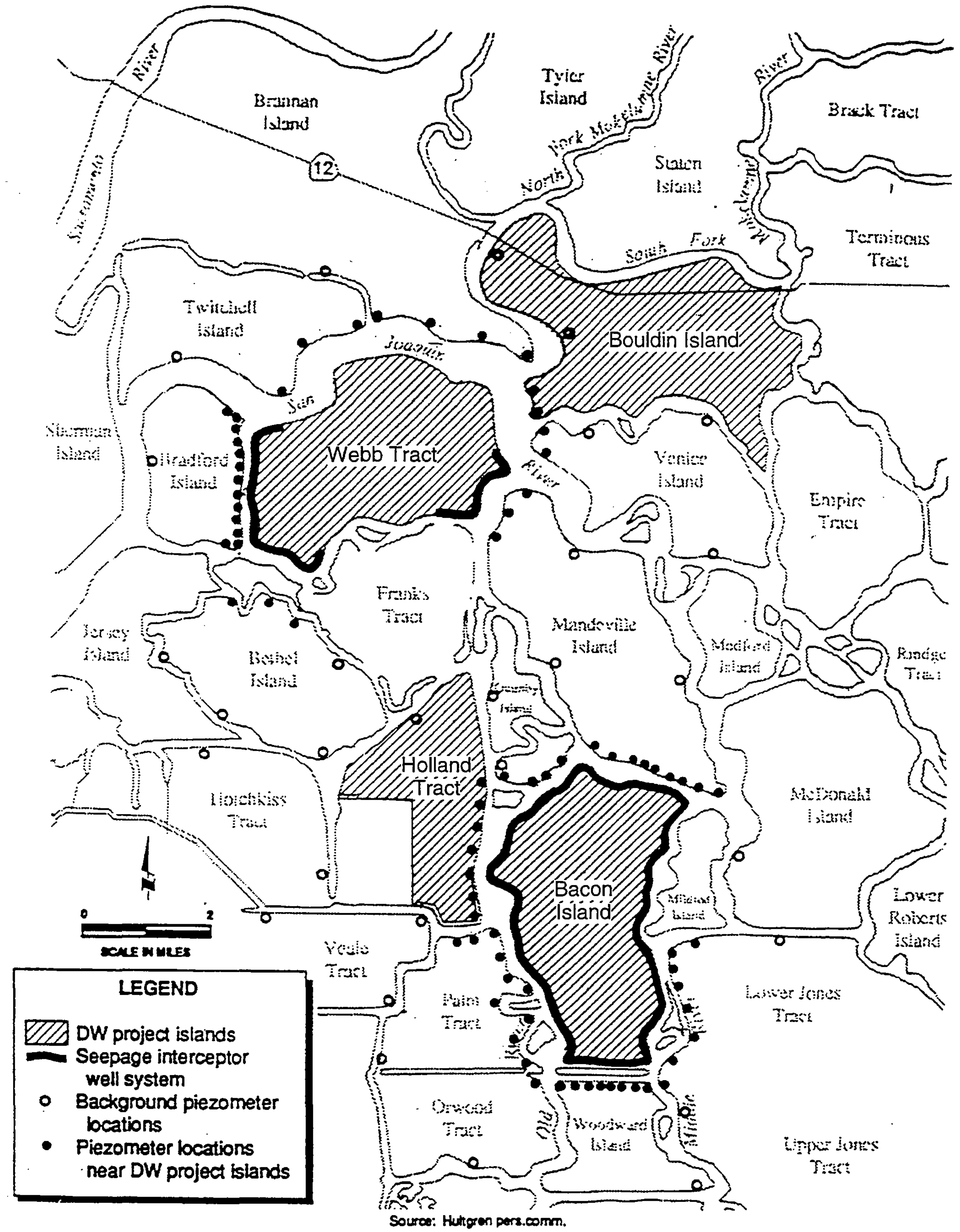


B. Seepage Condition - Full Reservoir with Pumping
Total Head Contours under Existing Conditions



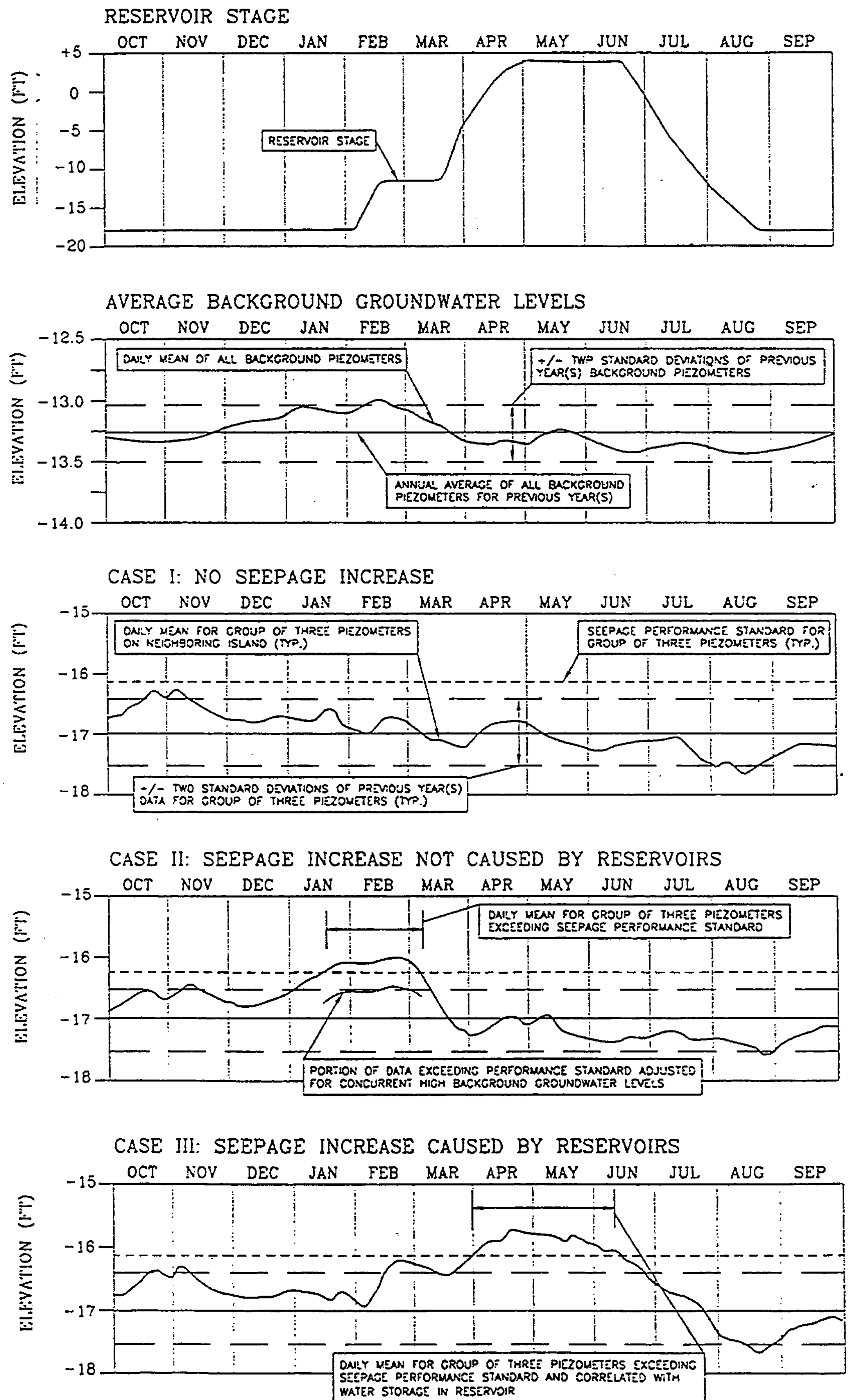
C. Seepage Condition - Full Reservoir with Pumping
Total Head Contours with Borrow Area

DELTA WETLANDS PROJECT	**WEBB TRACT STATION 630+00 SEEPAGE CONDITIONS WITH FULL RESERVOIR (With Effects of Borrow Area)**	**FIGURE** **2.3.16**
URS GREINER WOODWARD CLYDE		



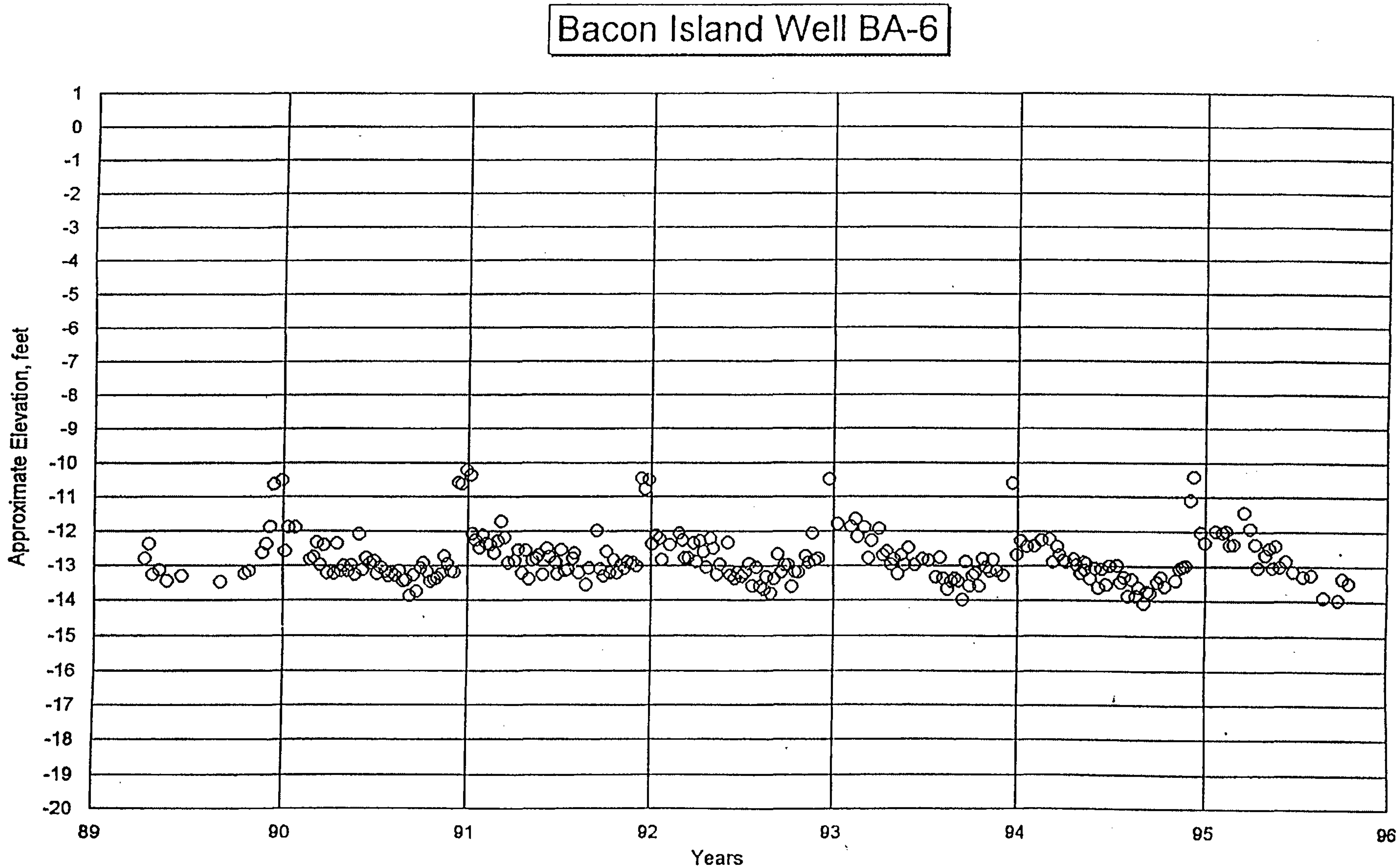
Source: from Jones and Stokes, 1995

Project No. 41-07099030.00	Delta Wetlands	PROPOSED LOCATIONS OF SEEPAGE MONITORING PIEZOMETERS	Figure 2.4.1
URS Greiner Woodward Clyde			



Source: from Hultgren, 1997a

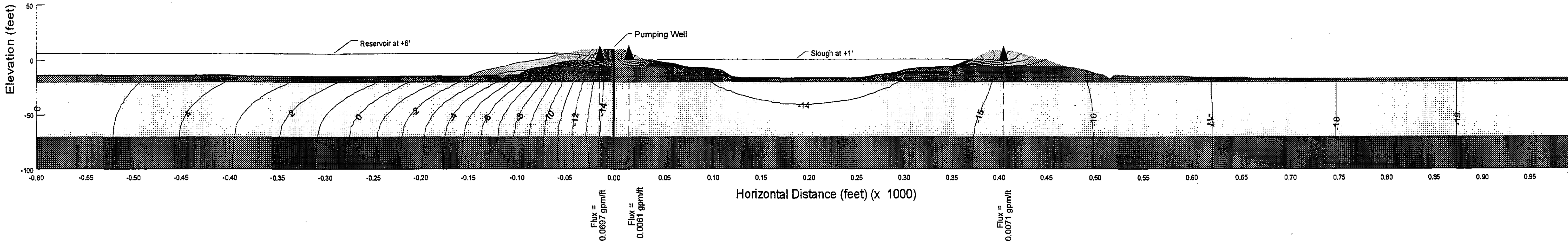
Project No. 41-07099030.00	Delta Wetlands	HYPOTHETICAL PATTERNS OF SEEPAGE RELATIVE TO PERFORMANCE STANDARDS	Figure 2.4.2
URS Greiner Woodward Clyde			



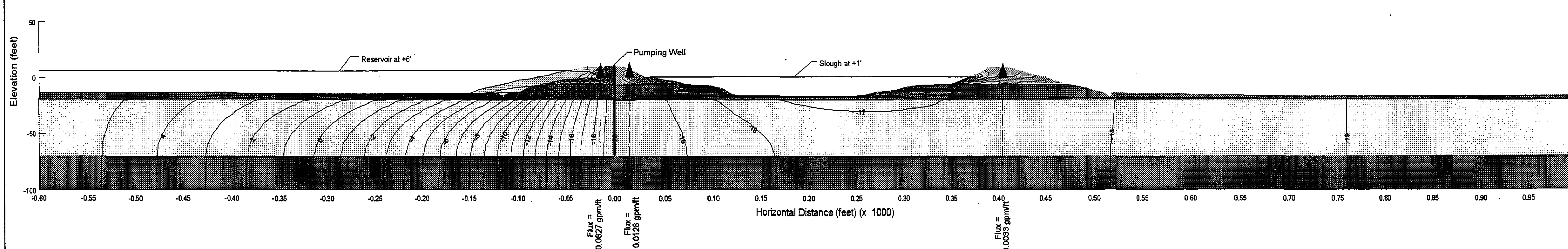
Source: from HLA 1995c

Project No. 41-07099030.00	Delta Wetlands	WATER LEVEL DATA FROM BACKGROUND MONITORING WELL BA-6	Figure 2.4.3
URS Greiner Woodward Clyde			

41-07099030.00-00003/120999/gos



A. Seepage Condition - Full Reservoir with Pumping
Total Head Contours
Head in Pumping Well at -15 ft.



B. Seepage Condition - Full Reservoir with Pumping
Total Head Contours
Head in Pumping Well at -20 ft.

DELTA WETLANDS PROJECT	WEBB TRACT STATION 630+00 SEEPAGE CONDITIONS WITH FULL RESERVOIR ANALYSIS OF INADVERTENT WATER DIVERSIONS	FIGURE 2.6.1
URS GREINER WOODWARD CLYDE		

3.1 OBJECTIVES

The main objective of the stability analysis was to evaluate the proposed levee strengthening scheme for Webb Tract and Bacon Island in the Delta Wetlands (DW) Project. In particular, the adequacy of the proposed levee configuration in relation to static and dynamic slope stability of the levee was studied. Additionally, other performance conditions were evaluated including bearing capacity, slope deformations and settlement and their effects on levee stability, and potential effects associated with geologic and seismic hazards (e.g., liquefaction).

As part of this study, we performed the tasks listed below:

- Evaluated analysis results and soil engineering parameters used in previous studies conducted on levee stability;
- Assessed assumptions made related to subsurface soil and groundwater conditions used in slope stability analysis;
- Conducted additional static slope stability analyses for the existing conditions and the proposed strengthened levee configurations for various scenarios including end-of-construction, long-term, sudden drawdown, and seismic performance (quasi-static);
- Reviewed previous and relevant ground motion studies for the project area;
- Developed and updated dynamic soil parameters based on recent findings and published data;
- Developed site-specific design response spectra, and acceleration time histories for additional dynamic analyses;
- Conducted two-dimensional dynamic analyses of the proposed levee configuration and assessed post-seismic deformation;
- Assessed the liquefaction potential at the site, and estimated the potential liquefaction-induced settlement, and its effect on the performance of the proposed levee design; and
- Evaluated the borrow needs for the levee strengthening, including volume estimation and borrow sources.

3.2 REVIEW OF PREVIOUS SLOPE STABILITY ANALYSES

A number of geotechnical studies that include slope stability analyses and other issues related to the overall stability of the Delta levees and their performance have been conducted by Harding Lawson Associates (HLA), Hultgren Geotechnical Engineers and Hultgren Tillis Engineers for the DW Project. We reviewed the geotechnical data, assumptions made, and results from stability analyses contained in those reports. The principal reports in connection with levee slope stability analysis include HLA (1989), HLA (1992e) and HLA (1993a).

HLA (1989) contains results of a preliminary geotechnical investigation conducted by HLA for the DW project. The report describes the subsurface soil conditions encountered during a field investigation that included drilling, standard penetration testing (see Glossary), sampling, and cone penetration test (CPT) sounding. The field work was performed in Webb Tract, Bacon Island and in the neighboring Bouldin Island and Holland Tract. For our slope stability analysis, we relied on the geotechnical data encountered in borings and CPT soundings. The HLA (1989) report also presents engineering soil properties determined in a laboratory testing program conducted on a limited number of samples from the borings. Soil tests included particle size analyses, consolidation tests, moisture content, dry density, shear strength, and permeability tests. The report also contains results of slope stability analyses for the proposed strengthened levee configuration. They analyzed the stability of slopes facing the reservoir islands and the channel and evaluated potential settlements.

HLA (1992e) discusses geotechnical investigations and design for Wikerson Dam on Bouldin Island. The report contains useful geotechnical data.

The HLA (1993a) letter report discusses further issues regarding slope stability of the levee improvements.

The above reports indicate that in the interior of the proposed reservoir islands (Webb Tract and Bacon Island) the subsurface soil conditions consist of a top layer of peat underlain successively by silty sand, stiff clay and silt, and sand. The peat is fibrous, soft, and highly compressible and has a variable thickness ranging from 10 to 20 feet under the levee. The silty sand underlying the peat is dense to very dense and is encountered in a layer 30 feet to 35 feet thick below Webb Tract and 20 feet to 25 feet thick below Bacon Island. The levees typically are built of an approximately 10-foot-thick layer of sandy to clayey fill at the top, which overlies a mixture of clayey peat and peat fill that overlies the naturally occurring peat layer. Because the levee surface has been subsiding over decades, the levees have been raised periodically. The natural peat layer is underlain by a thick sand layer, which itself is underlain by a clay layer.

3.3 ANALYSIS PARAMETERS

We performed independent slope stability analyses to assess the stability and adequacy of the proposed levee strengthening scheme at four cross sections, two for each island being considered as reservoir islands. Details regarding the loading conditions, the ground topography at the selected sections, the selection of material parameters, ground water levels on slough and reservoir sides, and the types of analyses performed are described below.

3.3.1 Cases Considered For Slope Stability Analysis

Because critical conditions may arise on the slopes facing the channel (slough) side as well as the reservoir island side, the margins of safety against instability for both slopes were assessed. The following analysis conditions were considered for each slope.

a) Existing Conditions

For this case, we considered the present levee, island and channel geometry without stored water. Water levels on the island and slough sides were selected to produce a representatively critical, though not the most critical case. (For instance, the highest water stage is taken at +6 feet, even though maximum flood stages may be somewhat higher for short periods.) The specific water elevations used are shown in the table on page 3-3 and discussed for each case.

b) End-of-Construction

The end-of-construction scenario is the condition occurring immediately after placement of the new fill on the reservoir island side of the levee, as illustrated in Figure 3.3.1 for one case. The fill will be placed in compacted layers. Immediately after the placement of the fill, fine-grained soils such as peat in the levee and foundation will not have had sufficient time to drain the construction-induced excess pore pressures, and consequently will not develop higher shear strengths due to the added surcharge. As a result, at the end of construction, pre-construction undrained shear strengths are used to characterize the cohesive soils of the levee and foundation. Water levels on the island and slough sides were selected to produce a critical case; see Section 3.3.3.

If placement of the new fill is done in several stages, as is typically the case for fills on soft foundation soils, the stability should be evaluated after the application of each stage, to ensure adequate calculated stability for each stage. These calculations, together with field monitoring of fill and foundation performance, would allow safe stage levels and consolidation periods between stages to be selected. The stability analysis for the end-of-construction using multiple stages was not calculated in this report, because this type of construction requires to be detailed in the final design.

c) Long-Term

The analysis of long-term levee stability involves the post construction conditions when strength gain has occurred and normal operations of the reservoir are in place. Water levels on the island and slough sides were selected to produce a critical case.

d) Sudden Drawdown

The sudden drawdown case is the condition occurring on the reservoir island slope when the level of the stored water drops rapidly (e.g., reservoir drawdown during an emergency). Because this drop can occur at a relatively rapid rate, the peat and other fine-grained soils do not have enough time to drain, and undrained strengths are used.

e) Pseudo-Static (Determination of Yield Acceleration)

The stability of slopes during seismic loading is analyzed to determine the yield accelerations. The use of the calculated yield acceleration to estimate earthquake-induced deformation of the levees systems is discussed in Section 3.6. Water levels on the island and slough sides were selected to produce critical cases. However, for the seismic condition toward the island, the water table in the slough was taken at the average elevation of +2 feet; it is customary to assume that the highest flood and the design earthquake do not occur simultaneously.

3.3.2 Sections Selected for Analysis

The criteria used in selecting the most critical analysis sections were the highest elevation differential between the crest and the island or slough side toe and the soil conditions affecting stability results. Based on these criteria, four representative cross sections, two from each island being considered for water impoundment, were selected for stability analysis. The locations of these sections are shown in Figure 2.2.1. The section at Webb Tract Sta. 630+00 crosses Fishermans Cut toward Bradford Island. The section at Webb Tract Sta. 160+00 crosses False River toward Franks Tract. The levee geometry and stratigraphy of the sections at stations 160+00 and 360+00 are depicted in Figures 3.3.1 and 3.3.2, respectively.

The section at Bacon Island Sta. 25+00 crosses Middle River toward Lower Jones Tract. The section at Bacon Island Sta. 265+00 crosses Connection Slough toward Mandeville Island. The levee geometry and stratigraphy of the sections at stations 25+00 and 265+00 are depicted in Figures 3.3.3 and 3.3.4, respectively.

Each section is representative of a reach of levee with similar geometry, levee, and foundation materials. Subsurface conditions were described in the HLA (1989) report. The levee materials generally consist of dredged sand, silt, clay, and peat. The thickness of this fill typically varies between 6 to 10 feet. Beneath the levee is a thick layer of peat down to approximately elevation -30 feet. The thickness of the peat layer varies typically between 15 and 35 feet in these two islands. Underlying the peat is a thick layer of dense sand, below which is typically a stiff clay or dense silt. A typical present condition on the islands is a 20-foot wide crest at approximately elevation +8.5 (all elevations in NGVD), with a 2:1 (H:V) slough side slope and a 4:1 reservoir side slope. It was judged that these four cross sections were representative of the more severe slope stability situations of the levees of both reservoir islands.

Two configurations for the planned new fills were proposed by HLA.

(a) The first configuration consists of a uniform reservoir side slope inclined at about 5:1 from the levee crest to toe.

(b) The second configuration consists of an interior slope at about 3:1 from the levee crest down to near elevation –3 feet and then flattening to a 10:1 slope extending toward the island interior.

Both configurations involved raising the levee crest to about elevation +9 feet and widening it to about 35 feet. This wide levee crest would allow future levee raises without widening the levee. The first configuration of levee strengthening was considered for each analysis section. In addition, the second configuration was considered for one section on Webb Tract only.

3.3.3 Water Table Elevations

At each section and case analyzed, we used reservoir island and slough side water levels that would produce critical cases. For the analysis of the existing condition of the slope toward the island, we considered the water level in the slough to be at flood elevation of +6 feet. The maximum peak flood elevation corresponding to a 100-year flood condition is +7.5 feet. After inspection of a number of gauge recordings and historical data at this site, we noted that the maximum peak flood occurs over a very short period of time and hence will not lead to a steady state condition. Therefore, we considered that a flood elevation of +6 feet was a reasonable and conservative representation of the high stage during the flood event. In the case of the stability of the slope facing the slough, the water level in the slough was considered to be at low tide (i.e., elevation 0 feet). Again, elevation 0 was a reasonable and conservative condition, though not the most conservative possible but rarely occurring short-term condition. In both these existing conditions, the water level in the reservoir island was assumed to be at about 2 feet below the existing ground surface.

We assumed that water would be stored up to elevation +6 feet on both reservoir islands. For the analysis of the end-of-construction toward the island slope, we considered the water level in the slough to be at flood elevation of +6 feet. For Webb Tract Sta. 630+00, two different water levels in the slough were considered for comparison purposes. They were elevations +6 feet and +2 feet, corresponding to flood stage and high tide, respectively. Normally, construction takes place in summer and water level in the slough would be unlikely to reach the flood stage. However, late fall construction and early winter precipitation could cause a condition of little consolidation before a flood stage. The various water levels considered on the island and slough sides are summarized in the table below for different analysis conditions.

WATER ELEVATIONS USED IN SLOPE STABILITY ANALYSES

Condition	Water Elevation (ft)		Side Slope Considered for Analysis
	Slough	Island	
Existing	+6 0	-16 -16	Island Slough
End of Construction	+2 and +6	-16	Island
Long-term Condition	+6 0	-14 +6	Island Slough
Seismic, K_y	+2 0	-14 +6	Island Slough
Sudden Drawdown	0	+6 to -14	Island

3.3.4 Soil Parameters

The HLA (1989) report presents geotechnical data obtained from the field exploration and laboratory testing programs in the Delta Wetlands islands. These data were the main source used to derive soil parameters for the slope stability analyses. To further validate the selected material properties used in the analysis, we reviewed published literature regarding the geotechnical properties of peat (e.g., Marachi et al. 1983 and Dhowian et al. 1980). The sands and sandy silts, which are free draining materials, were represented by their effective strength envelopes, consisting mainly of the effective friction angle obtained from correlation with SPT blow counts (Lambe and Whitman, 1969). A summary of the generalized soil strengths used in the various analyses is presented in the table below.

The HLA (1992e) report presents the results of geotechnical investigation and design studies conducted for Wilkerson Dam on Bouldin Island. The report presents an undrained shear strength envelope for peat based on data collected mainly from undrained triaxial shear tests on soil samples acquired from Bouldin Island. We used this envelope to calculate the variation of undrained shear strength of peat soils as a function of effective consolidation pressure.

SOIL PARAMETERS USED IN SLOPE STABILITY ANALYSES

Material	Total (wet) Unit Weight, γ_s (pcf)	Effective Friction Angle, Φ' (degrees)	Effective Cohesion Intercept, c' (psf)	Undrained Friction Angle, Φ^t (degrees)	Undrained Cohesion Intercept, c (psf)
Existing clay fill with peat and sand	110	27	80	12	135
Existing sand fill	110	32	0	-	-
Existing silty sand fill with fat clay	110	32	0	-	-
Planned fill	120	34	0	-	-
Clay with peat	80	28	100	12	135
Peat under levee	70	28	50	12	135
Free-field peat	70	26	50	12	135
Deep sand	125	36	0	-	-

3.4 METHODS OF STATIC SLOPE STABILITY ANALYSIS

The stability of the levees was analyzed using the limit equilibrium method based on Spencer's procedure of slices as coded in the computer program UTEXAS3 (Wright, 1990). In Spencer's procedure all side forces acting on a slice interface are assumed to have the same inclination and all requirements for static equilibrium are satisfied. The trial-and-error solution involves successive assumptions for the factor of safety and side force inclination until both force and moment equilibrium conditions are satisfied. UTEXAS3 can be used to compute factors of safety using either circular or general shaped, noncircular shear surfaces.

UTEXAS3 is capable of performing two-stage and three-stage computations to simulate rapid undrained loading following a period of consolidation of the soil. The end-of-construction case was analyzed using both the two-stage procedure and an undrained-strength (Su) analysis. The two-stage procedure requires the input of both the effective strength (S-envelope) and total strength (R-envelope) envelopes for the cohesive materials, such as peat. The undrained-strength analysis used undrained shear strengths based on the HLA strength envelope discussed in Section 3.3.4. The sudden drawdown cases were analyzed using the three-stage method as described in the user's manual for UTEXAS3 by Duncan et al. (1990). The three-stage method requires the input of both the effective and total strength envelopes for the peat and the effective strength envelope for the sand.

The presence of rip-rap on both faces of the levee was not considered in the slope stability analyses, because the rip-rap represents only a small portion of the levee mass. If anything, the rip-rap will strengthen the levee.

3.5 RESULTS OF STATIC SLOPE STABILITY ANALYSIS

3.5.1 Webb Tract

The soil parameters used in the analysis are presented in Section 3.3.4 of this report. Table 3.5.1 summarizes the results of the slope stability analyses for station 630+00 using the first configuration of the new fill; i.e., uniform 5:1 slope. Cross sections showing various conditions along with the potential failure surfaces toward the island and the slough are shown in Figures 3.5.1 through 3.5.11. It is noted that these cross sections were prepared to represent stability conditions conservatively, and do not necessarily agree with cross sections at the same locations prepared for seepage analyses.

The calculated factors of safety for the existing condition toward the island and toward the slough were 1.40 and 1.34, respectively (Figure 3.5.1 and 3.5.2). The calculated factor of safety for the end-of-construction condition toward the island, assuming that all fill were placed in one stage (which we do not advocate), was below 1.0 by both methods (Figures 3.5.3 and 3.5.4). This result indicates, as expected, that the placement of levee fill will have to be done in multiple stages (see next paragraph below). We did not analyze the stability of the slope facing the slough for this condition because it would be similar to the existing condition described previously. The calculated factor of safety for the long-term post-construction condition toward the island was 1.82 (Figure 3.5.5). It is noted that, for potential failure surface through the lower portion of the island side slope, a factor of safety of 1.56 was calculated for this long-term condition. For the long-term post construction condition we performed an additional analysis using a lower water table in the peat layer under the levee. The reason for selecting this case was to model a situation where the free-field peat layer is so pervious that water runs through it and into the lower sand layer rather than runs across the peat layer under the levee. The factor of safety increased by about 45% over the higher water table case. The calculated factor of safety for the long-term post-construction stability toward the slough was 1.12 (Figure 3.5.6). The calculated factor of safety for the sudden drawdown condition toward the island was 1.18 (Figure 3.5.9). The results of pseudo-static stability analyses were K_y values of 0.027g toward the slough (Figure 3.5.8) and 0.151g toward the island (Figure 3.5.7).

To review end-of-construction stability further, we also calculated a factor of safety for a first-stage fill to elevation –2 feet. This case had an end-of-construction factor of safety just below 1.0 (Figure 3.5.10), demonstrating that a somewhat lower first stage fill could be designed to have adequate stability.

Table 3.5.2 summarizes the results of the slope stability analyses for station 630+00 on Webb Tract using the second configuration of the new fill; i.e., 3:1 initial slope flattening to 10:1 slope at elevation –3 feet. Cross sections showing various conditions along with the potential failure surfaces toward the island and the slough are shown in Figures 3.5.12 through 3.5.18. The calculated factor of safety for the end-of-construction condition toward the island was 1.12. This result indicates that this fill configuration is more stable than the first fill configuration in regard to end-of-construction stability. The factors of safety calculated for the other conditions are comparable to those calculated for the first configuration.

Table 3.5.3 summarizes the results of the slope stability analyses for station 160+00 on the Webb Tract using the first configuration of the new fill; i.e., uniform 5:1 slope. Cross sections showing various conditions along with the potential failure surfaces toward the island and the slough are shown in Figures 3.5.19 through 3.5.27. The calculated factors of safety for the existing condition toward the island and toward the slough were 1.24 and 1.29, respectively. The calculated factor of safety for the end-of-construction condition toward the island was below 1.0. This result is consistent with the previous results. The calculated factor of safety for the long-term post-construction condition toward the island was 1.57. The calculated factor of safety for the sudden drawdown condition toward the island was 0.88. Calculated K_y values were similar to those for the section at Station 630+00.

3.5.2 Bacon Island

The soil parameters used in the analysis are presented in Section 3.3.4 of this report. Table 3.5.4 summarizes the results of the slope stability analyses for station 25+00 using the first configuration of the new fill; i.e., uniform 5:1 slope. Cross sections showing various conditions along with the potential failure surfaces toward the island and the slough are shown in Figures 3.5.28 through 3.5.36. The calculated factors of safety for the existing condition toward the island and slough were 1.23 and 1.48, respectively. The calculated factor of safety for the end-of-construction condition toward the island was below 1.0. This result is consistent with the previous results. The calculated factor of safety for the long-term post-construction condition toward the island was 1.63. It is noted that, for a potential failure surface through the lower portion of the island side slope, a factor of safety of 1.40 was calculated for this long-term condition. The calculated factor of safety for the sudden drawdown condition toward the island was 1.07.

Table 3.5.5 summarizes the results of the slope stability analyses for station 265+00 using the first configuration of the new fill; i.e., uniform 5:1 slope. Cross sections showing various conditions along with the potential failure surfaces toward the island and the slough are shown in Figures 3.5.37 through 3.5.45. The calculated factors of safety for this section were comparable to those calculated for the section at Sta. 25+00.

For both stations 25+00 and 265+00, K_y values were computed for two different crest widths as shown in Tables 3.5.4. and 3.5.5. As expected, higher K_y values were computed for the wider crest. The K_y values of the slope facing the slough were identical for the two crest widths.

3.5.3 Summary of Static Slope Stability Analyses Results

A summary of the calculated factors of safety for the four representative cross sections and various conditions is presented in Table 3.5.6.

The factors of safety calculated for the existing condition toward the reservoir island range between 1.2 and 1.4. The lowest and highest factors of safety were calculated for Bacon Island Sta. 265+00 and Webb Tract Sta. 630+00, respectively. The results of the analyses indicate that the factor of safety decreases with increasing thickness of the peat layer. The factors of safety calculated for the existing condition toward the slough ranged between 1.3 and 1.5.

End-of-construction stability was evaluated to check whether the levee strengthening could be constructed in a single stage. As expected, most of the calculated factors of safety were below 1.0. These results indicate, as expected, that placement of the levee-strengthening fill will have to be done in several stages to prevent slope failures. One calculation made for a first-stage fill for a multi-slope construction showed a higher factor of safety than that for single-stage construction. The fill construction stages and their scheduling will have to be carefully selected during final design to prevent stability failures during construction.

The analyses of the long-term post construction conditions indicate that on the reservoir side the four representative sections had calculated factors of safety in the range of 1.6 to 1.8. The factor of safety increased by about 30% by widening the crest and flattening the slope to 5:1 when compared to the existing slope configuration. For the second fill configuration; i.e., 3:1 initial slopes flattening to 10:1 slope at elevation –3 feet, the factor of safety increased by about 20% over the existing slope configuration. It is noted that lower island-side factors of safety were calculated for potential failure surfaces through the lower portion of the interior slope of the sections. However, this type of failure does not significantly affect the integrity of the levee system. Therefore, we did not include these factors of safety in Table 3.5.6.

The long-term with-project condition toward the slough for the four representative sections had calculated factors of safety in the range of 1.1 to 1.3. The factor of safety with project was about 15% lower than for the present condition. A similar result was calculated for the second fill configuration. This reduction in factor of safety is due primarily to raising the reservoir water level up to elevation +6 feet, which creates seepage forces toward the slough.

The analyses of the sudden drawdown condition for the four representative sections toward the reservoir island indicated calculated factors of safety in the range of 0.9 to 1.2. It is noted that based on the proposed reservoir operation an instantaneous water drawdown is not feasible except in an emergency drawdown. Hence, the calculated factors of safety for the sudden drawdown condition are conservative.

We calculated the yield acceleration, K_y, which corresponds to a pseudo-static force producing a factor of safety of unity, for the representative sections. K_y values for the slopes facing the slough and the interior island were calculated. The water level conditions used in this analysis are presented in Section 3.3.3 of this report. The K_y values obtained are summarized in Table 3.5.6. The calculated K_y values toward the slough were between 0.017 and 0.048, while K_y values toward the island were between 0.114 and 0.151. The lower K_y values toward the slough are consistent with the lower factors of safety calculated for the slough side. This is generally due to the fact that the slopes on the slough side are steeper and irregular due to erosion effects; also, the reservoir water creates seepage forces toward the slough.

3.5.4 Static Stability Criteria and their Application to DW Project

Numerical criteria for the calculated factors of safety for static stability from several sources are summarized in Table 3.5.7. Geometric criteria from several other sources are presented in Figure 3.5.46.

It is not obvious which criterion or set of criteria should be used to judge the adequacy of the stability of the Delta Wetlands reservoir islands at this stage. It could be judged on the basis of (in order of increasing conservatism):

- the PL84-99 geometric criteria, or
- the Corps of Engineers' Delta-specific criteria,

- the Corps' non-Delta-specific criteria, or
- Criteria of Association of State Dam Safety Officials (ASDSO).

The selection of applicable criteria could be based on the significance of the project; the consequences of failure (economic, environmental and other); the jurisdictional status of the reservoir under California Division of Safety of Dams (DSOD); and possibly other factors.

This is a significant project, in terms of the land area it encompasses, the investments in it, and the environmental and water-supply implications.

The consequences of failure depend on the type of failure that might occur. The most likely types (though all are unlikely) include:

- Failure of the reservoir island levee into the channel, slough or river, with full reservoir
- Failure of the reservoir island levee into the reservoir island, with the reservoir low or empty
- Failure of the adjacent island's levee due to seepage effects attributable to the reservoir island.

The first type of failure is judged least consequential. The loss is largely limited to the DW project in the form of loss of sellable water and required repair of the damages. In addition, development of a levee breach and sudden outflow of the stored waters into the channel may impact the adjacent island's levee and structures floating in the channel. This eventuality is discussed in Section 3.11.

Potential causes of an outward failure of the reservoir levee with full reservoir are long-term stability failure toward the slough, and potential earthquake effects with full reservoir. We judge that the factors of safety for the long-term failure toward the slough are marginal, and that the potential earthquake displacements in this direction are larger than what is generally considered as acceptable (see Section 3.6). One method to improve these situations is to flatten or otherwise strengthen the slough-side slope. However, this would require disturbing that slope, which may be difficult to have permitted because of environmental issues. Another potential method is to construct a rock toe buttress in the slough. A third method, that we recommended, is to provide a wide levee crest, such that slumping off of a section, say of 10 feet, would still leave enough levee crest width to provide a capable levee until repairs could be made.

The other two potential levee failures would have serious environmental consequences due to the large inflow of brackish water into the Delta, beside significant economic losses due to large repair costs and loss of beneficial use. These events clearly should be protected against with a significant margin.

The second type of failure, failure of the reservoir levee with reservoir empty, is considered adequately protected against, with high factors of safety for long-term failure into the reservoir island and adequate factors of safety for sudden drawdown at most locations. At some locations the levee geometry may need to be adjusted to provide an adequate factor of safety against sudden drawdown. Further, a large-scale stability failure during levee strengthening construction must be avoided by carefully-controlled staged construction.

Failure of the adjacent island's levee would be due to seepage effects and must be protected against by rigorous monitoring combined with application of the significance criteria. This is discussed in Sections 2.4 and 2.5. The monitoring methods and application of significance criteria should be periodically reevaluated and adjusted as may be indicated.

In addition to these long-term failures, it is important that end-of-construction failures be avoided. Such failures, although they would be unlikely to lead to levee breaches, would require significant extra effort to repair and would have the potential to delay construction.

3.6 SEISMIC-INDUCED LEVEE DEFORMATIONS AND GEOLOGIC HAZARDS

3.6.1 Objective

This section summarizes the analysis results of the seismic-induced levee deformations and geologic hazards for the proposed reservoir islands of the Delta Wetlands project. The analysis was performed for the proposed levee final design.

The study included the evaluation of the levees' seismic responses and deformations and the assessment of geologic hazard under the design earthquake ground motions. The details of the analysis approaches and results are presented in Appendix A.

3.6.2 Design Earthquake Ground Motions

Two horizontal earthquake acceleration time histories recorded during past earthquakes were selected for the analysis. These records were from the 1992 Landers and the 1987 Whittier Narrows earthquakes. The following table lists these selected motions along with the names of the recording stations, their closest distances from the rupture planes and recorded peak accelerations.

Summary of the Earthquake Records Used in the Dynamic Response Analysis

Earthquake	M_w	Recording Station			Comp	Recorded PGA (g)
		Distance (km)	Station #	Site Condition		
1987 Whittier Narrows	6.0	18	24402[b]	Soil[a]	90°	0.15
1992 Landers	7.3	64	24577[c]	Soil[a]	0°	0.11

Note : a = Deep Stiff Soil Site
b = Altadena – Eaton Canyon Station
c = Fort Irwin Station

The selected acceleration time histories were then modified to match the design earthquake response spectrum. Results from the recent CALFED study on the seismic hazard and levee failure probability of the Delta project were used to construct the design response spectrum (CALFED, 1999). A hazard exposure level corresponding to a 10% probability of exceedance in 50 years was selected for the design ground motions. This hazard exposure level results in a return period of about 475 years (or annual frequency of occurrence of 2.1×10^{-3}) and is consistent with the requirement adopted by the 1997 Uniform Building Code (UBC).

For the assessment of geologic hazards, two earthquake design criteria were used: earthquakes with magnitude (M_w) 6 and peak ground acceleration of 0.25g, and magnitude (M_w) 7.7 and peak ground acceleration of 0.13g. These ground motions represent the local and distant controlling seismic events and are consistent with the results of the CALFED study (CALFED, 1999).

3.6.3 Earthquake-Induced Levee Deformations

3.6.3.1 Dynamic Response Analysis

Four levee cross sections were analyzed for the two proposed reservoir islands: two cross sections for Webb Tract and two cross sections for Bacon Island. These selected cross sections are those used in the static and pseudo-static slope stability analyses (see Section 3.3.2). The results of dynamic response analysis are presented in terms of the average horizontal accelerations, which represent the seismic-induced inertia accelerations acting on the sliding masses and were used in the deformation analysis.

The computed average horizontal accelerations (K_{ave}) for the critical slide masses are shown in Figures A.6.11 and A.6.12, Figures A.6.16 and A.6.17, Figures A.6.21 and A.6.22, and Figures A.6.26 and A.6.27 of Appendix A. The peak values of these average horizontal accelerations (K_{max}) are tabulated in the following table.

Calculated Seismic-induced Slope Deformations

Critical Slide	K_y (g)	K_{max} (g)	Max Deformation (ft) Newmark[1]	Max Deformation (ft) Makdisi & Seed[2]
Webb Tract at St. 160+00				
Reservoir-side Slope				
Crest Slide	0.114	0.40	2.0	0.5-1.5
Slough-side Slope				
Crest Slide	0.025	0.21	3.5	0.5-3.5
Webb Tract at St. 630+00				
Reservoir-side Slope				
Crest Slide	0.151	0.36	1.5	0-1.0
Slough-side Slope				
Crest Slide	0.027	0.26	4.0	1.0-4.0
Bacon Island at St. 25+00				
Reservoir-side Slope				
Upper Toe Slide	0.148	0.47	3.5	0.5-1.0
Slough-side Slope				
Crest Slide	0.048	0.31	3.5	0.5-3.0

Critical Slide	K_y	K_{max}	Max Deformation (ft)	
	(g)	(g)	Newmark[1]	Makdisi & Seed[2]
Bacon Island at St. 265+00				
Reservoir-side Slope				
Crest Slide	0.133	0.36	1.5	0.5-1.0
Slough-side Slope				
Crest Slide	0.0385	0.28	3.5	0.5-3.0

Note: 1: Newmark Double Integration Method (1965)
2: Makdisi and Seed Simplified Method (1978)

3.6.3.2 Levee Deformations

The calculated deformations of the selected critical slide masses of the levees on the Webb Tract and Bacon Island are tabulated in Table 3.6.2. These deformations were estimated using both the Newmark Double Integration Method (Newmark, 1965) and the Simplified Procedure of Makdisi and Seed (Makdisi and Seed, 1978) for comparison. In estimating the deformation, we rounded the calculated deformation to the nearest ½ foot.

The results of analysis indicate that the slough-side slopes may experience up to about 4 feet of deformations. Smaller deformations can be expected for the reservoir-side slopes, due to the increased stability provided by the proposed new fills, and flatter slopes.

3.6.4 Earthquake-Induced Geologic Hazards

The seismic-induced geologic hazards assessed for this study included liquefaction, loss of bearing capacity, settlement and levee overtopping.

3.6.4.1 Liquefaction

We used the data from HLA's exploratory borings (HLA, 1987) to assess the potential for liquefaction during the occurrence of the design ground motions.

The evaluation procedure for liquefaction susceptibility proposed by the National Center for Earthquake Engineering Research (NCEER) Workshop (Youd and Idriss,1997) was utilized for this study. We applied the corrections to the measured penetration blow counts, as recommended by the NCEER procedure.

The results of the analyses indicate that a few pockets of potentially liquefiable soil deposit may exist in the levees and foundation soils. We believe, however, that these liquefiable soil pockets are confined in limited areas and therefore are expected to have negligible adverse effects on the stability of the levees.

3.6.4.2 Loss of Bearing Capacity

Seismic-induced bearing capacity loss/reduction is associated mainly with the occurrence of liquefaction or pore water pressure generation. The reduction may be substantial for shallow foundations supported on or near the liquefied soils. Based on the results of the liquefaction evaluation and the absence of shallow foundations at the project site, we judge that the risk of loss of bearing capacity that may affect levee performance is insignificant.

3.6.4.3 Dynamic Soil Compaction

Similar to the seismic-induced bearing capacity loss, the dynamic soil compaction would only be significant following the occurrence of extensive liquefaction. Since the potential for liquefaction at the project islands is limited to a few isolated pockets, we judge that the potential for dynamic soil compaction (settlement) at these islands is negligible.

3.6.4.4 Levee Overtopping During Seismic-Induced Seiche

Earthquakes can cause overtopping of levee due to three primary mechanisms: Landslide generated waves, static displacement of the reservoir or dynamic displacement of the reservoir. Both the landslide induced waves and static displacement of the reservoir are not expected to occur at the project reservoirs.

Records for past occurrences of seiche are generally incomplete. The largest seiche reported in the United States was in Lake Ouachita in Arkansas with a maximum amplitude of about 0.44 m (1.5 feet). We have estimated the amplitudes of seismic-induced waves (dynamic displacement of reservoir water) using the procedure of United States Committee on Large Dams (USCOLD, 1995). The results of the analysis indicate a negligible amplitude of seismic-induced wave (less than 1 foot). It should be noted that this procedure was developed for a limited body of water (tanks, dams) and has been assumed to be applicable to the DW Project reservoirs.

3.7 EXPECTED SETTLEMENTS AND EFFECTS ON STABILITY

A settlement analysis was performed for the section at Sta. 630+00 in Webb Tract to study the effect of consolidation settlement on stability and to estimate the required fill volume. Two types of settlements resulting from the levee strengthening were estimated. The first consists of the long-term consolidation settlement that corresponds to the slow volume change associated with the dissipation of excess pore pressures as the soil is subjected to a sustained load. The second consists of the secondary consolidation settlement that corresponds to the long-term creep of peat.

The consolidation settlement was estimated using analysis based on laboratory one-dimensional consolidation tests. The tests were performed by HLA on peat samples acquired from Delta Wetlands Islands, presented in HLA (1989), Appendices A & B, Vol. 2. The evaluation of the total consolidation settlement was based on relevant parameters including preconsolidation pressure, stress increase due to added fill, in-situ stress conditions, and compression indices for the virgin loading curve and the unloading-reloading curve. The coefficient of consolidation was obtained from the laboratory time rate of consolidation tests for various levels of load increments. A summary of the consolidation parameters used in the analysis is presented in the table below:

SUMMARY OF CONSOLIDATION PARAMETERS FOR PEAT

Material	C_c	C_r	e_o	C_α	c_v (ft^2/yr)	σ_p' (psf)
Peat	3.8	0.69	8.428	0.17	75	300

where

- C_c is the compression index for the virgin loading curve, calculated from a one-dimensional consolidation test on a peat sample from 30-foot depth at Webb Tract (see Plate 13 of HLA 1989) and validated by comparison to similar data.
- C_r is the compression index for the reloading curve.
- C_α is the secondary compression index, calculated using a C_α / C_c ratio of 0.045.
- e_o is the initial void ratio, calculated from the initial water content of the peat.
- c_v is the coefficient of consolidation corresponding to a vertical effective stress of about 1000 psf (Plate 13, HLA [1992e]).
- σ_p' is the average preconsolidation pressure of peat, estimated at 300 psf based on laboratory tests.

We assumed that fill was placed instantaneously and that strength gain occurs as peat consolidates and pore pressure dissipates due to the load imposed by the fill. The consolidation settlement in the peat under the fill load will require the addition of fill to maintain the required fill height as settlement occurs. The settlement analysis for the fill construction was made iteratively until the final levee height was reached eventually. A table indicating the maximum consolidation settlements for each iterative step is presented below. Figure 3.7.1 shows the estimated settlement profile after the first stage of load application. We assumed settlement due to secondary compression would take place only after final construction is completed.

EXPECTED MAXIMUM SETTLEMENT

Iteration #	Expected Maximum Settlement (feet)
1	5.10
2	2.25
3	1.00
Expected Total	9.0

While the settlement calculation was based on instantaneous loading, the actual construction will be performed in stages to prevent adverse stability conditions. We anticipate that three to four stages of construction will be required to place the additional fill material. Each construction stage will take about one to two years to achieve required consolidation settlement and gain in strength to allow the next stage to be constructed. Therefore, the projected construction time to raise and widen the levee may be 4 to 6 years.

We then calculated the factors of safety for the long-term condition using the deformed geometry. The cross sections showing water conditions on both slough and island sides along with the potential failure surfaces toward the island and the slough are shown in Figures 3.7.2 and 3.8.3. The calculated factor of safety increased by about 6% for the slope toward the island when using the deformed levee cross section. There was no change in the calculated factor of safety for the slope toward the slough which remained at 1.12.

3.8 WAVE HEIGHT ESTIMATES AND EROSION ASSESSMENT OF LEVEES

Wave runup analyses for Bacon Island and Webb Tract were made to evaluate freeboard and erosion potential characteristics for the levees when the islands are used as storage reservoirs. Wave runup is defined as the vertical height above stillwater level to which water from an incident wave will run up the face of a structure. The analyses involved estimating wave runup characteristics from wind velocities, reservoir fetch, and levee geometry.

Wind velocities for the "fastest mile of record" were obtained from generalized charts published by the U.S. Army Corps of Engineers (USACE, 1976) and U.S. Bureau of Reclamation (USBR, 1981). These data indicate that the estimated fastest mile of record wind velocities over land at elevation 25 feet for winter, spring, summer, and fall are 58, 52, 40, and 60 miles per hour, respectively. The effective fetch, F, of the islands were calculated using procedures in USACE's "Shore Protection Manual" (1984). The largest effective fetch for Bacon Island and Webb Tract are 3.15 miles and 2.83 miles, respectively. Analyses were made assuming levee bank slopes of 3H:1V and 5H:1V on the reservoir side of the levees. Rip-rap on the face of the levee was considered in the calculations.

An estimate of the reservoir setup resulting from winds was also made. Reservoir setup is a general tilting of the reservoir surface due to shear stresses caused by winds.

Using the procedures presented above, wave runup for Bacon Island and Webb Tract for the most severe wind conditions (Fall) were calculated to be 6.4 feet and 6.1 feet, respectively, for the 3H:1V levee bank slope and 4.0 feet and 3.8 feet, respectively, for the 5H:1V levee bank slope. Wave runup of these magnitudes will pose a significant potential for erosion of the levees absent erosion protection. If rip-rap is used on the bank slopes, runup would be reduced to about 55% of these values and would also greatly reduce the potential for erosion.

In addition to runup, wind shear will also cause a setup in the reservoir. Setup for Bacon Island and Webb Tract was calculated to be 0.38 feet and 0.34 feet, respectively.

Results of these analyses were compared to general wave runup estimates published in the California Department of Water Resources' Bulletin 192-82 (DWR, 1982) and are consistent with them.

3.9 BORROW REQUIREMENTS

We estimate that as much as 4 million cubic yards of fill may be needed at Webb Tract, and slightly more than that at Bacon Island, to bring and maintain the islands' levees to the strengthened cross section. These estimates include not only the initial fill quantity but also the additional quantities required later to restore and continue restoring the levees to the specified configuration to compensate for long-term settlement.

DW plans to use on-island borrow material. The seepage considerations described in Section 2.3 have indicated that borrow pits can be excavated down to and into the underlying sand layer without any discernible effect on seepage conditions that might affect neighboring islands if the borrow area is at least 800 to 1000 feet set back from the levee.

We understand that there are numerous sand mounds on Webb Tract, which could be used as borrow, if necessary with some fines blended in. Assuming that five percent of the island's area of about 5500 acres has surficial sand and is located more than 1000 feet from the levee, a borrow depth of about 9 feet would be sufficient to provide the needed borrow volume. It is obvious that enough borrow is available, either in the sand mounds or below the peat layer, to borrow the required fill quantity.

We are not aware of sand mounds on Bacon Island. Approximately 3600 acres of the island's total land area of about 5500 acres is located more than 1000 feet from the levee. Using one tenth of this area for borrow would require a borrow depth into the sand of about 7.5 feet to generate the required fill quantity. This type of borrowing could be done with relatively simple dewatering.

It is concluded that it will be easy to mobilize the required amounts of borrow fill needed to upgrade the levees on each island, with nominal dewatering.

3.10 EFFECT OF INTERCEPTOR WELLS ON SLOPE STABILITY

The results of the evaluation of the interceptors wells presented in Section 2.3 indicated that 6-inch diameter wells spaced at about 160 feet or larger were generally adequate to mitigate the potential underseepage and flooding at the neighboring islands. From a stability viewpoint the wells' size and spacing is such that the ratio of the area occupied by the well over the tributary area of the levee is very small or insignificant. Therefore, the presence of the wells would not have any significant impact on the stability of the levees and supporting foundation.

However, the high rate of continuous pumping during reservoir operation should be considered carefully in relation to potential internal erosion/piping. An inadequately designed and constructed filter system may cause internal erosion and piping which may create cavities under the levees and possibly result in the formation of sink holes and deterioration of the levee foundation. The design, construction, and quality control during installation and development of the interceptor wells should be addressed carefully in the design and implementation of the wells system. Of particular interest are the reliability and compatibility of the filter packing between the base soil (aquifer gradation) and the well screen's schedule. This may require a careful site-specific characterization of the aquifer properties (grain size distribution at various locations and various depths). Standard procedures with detailed guidelines for design and construction of pumping wells are widely available and used in the industry. The documentation of the wells' design details should be provided in the design phase for the DW project.

One effect of internal soil erosion around extraction wells is a gradual silting up of the wells, which reduces their hydraulic effectiveness. This effect can be controlled by re-developing the well. This may be done periodically or in response to evidence of lack of effectiveness of the well. For this reason it would be advisable to be able to measure flow rates in individual wells, such that lack of performance can be identified and corrected.

A second set of related potential effects of internal soil erosion around extraction wells may occur, if the internal erosion process is ongoing for an extended time. This can lead to potential settlements in the vicinity of the well and potential development of a meta-stable (half-stable) soil structure, which could suddenly collapse, with or without provocation, and cause significant levee settlement and potential levee instability. This is a major reason why silting up of wells cannot be tolerated on this project. Measures against this occurring, after well construction, are monitoring of individual wells' flows to judge well pumping efficiency, and tracking of redevelopment of wells; if it were to occur at frequent intervals, it would be a sign of loss of fines. In severe cases the well may have to be abandoned and rebuilt using appropriate construction methods and materials to minimize soil loss in the future.

3.11 LEVEE BREACH ANALYSIS AND PROJECT ABANDONMENT

In this section the potential consequences of a sudden levee breach and project abandonment on adjacent Delta islands are discussed. It is noted that a levee breach has a very low likelihood of occurring, provided seepage and stability issues are addressed as discussed in this report.

The following is a summary of the hydraulic analysis that was conducted to determine maximum bank velocities along the downstream levee opposite the breach opening between Webb Tract and Bradford Island in Delta Wetlands:

- The breach analysis location between Webb Tract and Bradford Island was selected because it is one of the shortest distances between a reservoir island and a neighboring island (it represents the most adverse impact from a levee break).
- The assumed water elevation in the adjacent slough was considered to be at –2 feet, while the reservoir level in the island was at elevation +6 feet.

To judge the potential effects of a failure of the reservoir island (filled to the maximum elevation of +6 feet) into the channel, the hydraulic effects of a potential levee breach were analyzed. For assumed breach widths of 40, 80, 200 and 400 feet, respectively, the maximum resulting flow velocities along the opposite bank of the channel were calculated as 2, 9, 12 and 16 feet per second, respectively. The pattern of the calculated flow velocities for the 400-foot breach is illustrated in Figure 3.11.1. A 400-foot breach width is the widest expected breach width for this situation, based on breaching characteristics of dam failures (MacDonald and Langridge-Monopolis, 1984).

The 400-foot breach would cause a water level runup on the opposite shore up to elevation + 5.2 feet. This elevation would not present an overtopping threat. Further, this breach would have a calculated discharge rate of water out of the reservoir island of 123,000 cubic feet per second. At this discharge rate, the water surface elevation in the larger of the two reservoir islands would drop at an approximate rate of 1.6 feet per hour. Consequently, the highest flow velocity in the channel would be sustained for about 30 to 40 minutes, and would gradually decrease as the water level in the reservoir island dropped and the discharge rate decreased.

The flow rate of 16 feet per second along the opposite bank sustained for that duration would be expected to cause erosion of unprotected levee slopes, but would likely not cause severe damage to a rip-rapped levee slope. Floating structures and boats moored in the channel near the location of the levee breach would probably experience damages.

Abandonment of the project by its sponsors would leave project facilities designed for the planned use. Following are some thoughts on potential consequences of such abandonment. First and foremost, we do not expect an immediate threat to adjacent islands. Longer-term levee maintenance must be continued. The project's facilities could probably be converted back to serve traditional island uses. There would clearly be considerable time and effort required to re-start agriculture on the island. It is believed that the expense of this effort would be less than the land value of the island. Similarly, should the project be abandoned with a full reservoir, the value of the stored water should pay for discharging it to the Delta channels (using the project's facilities). The most unfavorable case would be if the project were abandoned after failure of a levee. The conversion in this case would require repairing the levee and pumping out the island in addition to the cost of any other damage that the levee breach may have caused. At any rate, it appears that project abandonment should be followed by re-conversion to agricultural use, that it is likely that such conversion could be done at no cost to the public, and that after conversion the new operators would maintain the levees to minimize the potential for future levee failures. This topic of project abandonment will deserve more detailed evaluation, primarily economic, to assess all probable eventualities.

Table 3.5.1
Results of Slope Stability Analyses
for Webb Tract Sta. 630+00
Fill with 5:1 Slope

Condition	Factor of Safety: Toward Slough	Factor of Safety: Toward Island	Remarks
Existing	-	1.40	Drained analysis
	1.34	-	
End of Construction, One Stage[a]	-	0.92	Two-stage analysis
	-	0.85	S_u profile calculated using HLA's design curve for peat
Long-Term Condition	-	1.56[c]	Drained analysis
		1.82[d]	
	1.12	-	
Seismic Loading	-	1.00 K_y= 0.151	Two-stage analysis
	1.00 K_y= 0.027	-	
Sudden Drawdown	-	1.18	Three-stage analysis
Staged loading, 1st Stage to Elev. –2 ft			
End of Construction[b]	-	0.96	Two-stage analysis
	-	1.02	S_u profile calculated using HLA's design curve for peat

Notes:

[a] Assuming one-stage construction, which we do not advocate. The factors of safety for the multiple-stage construction have not been calculated because these criteria need to be established during final design as to stage fill thickness and time sequencing.

[b] Result for first stage of multi-stage construction

[c] For small toe circle

[d] For large circle

Table 3.5.2
Results of Slope Stability Analyses
for Webb Tract Sta. 630+00
Fill with 3:1 Slope Flattening to 10:1 Slope at Elev. –3 Feet

Condition	Factor of Safety		Remarks
	Toward slough	Toward island	
Existing	- 1.34	1.40 -	Drained analysis (same as 5:1 slope)
End of Construction[a]	- -	1.32 1.12	Two-stage analysis S_u profile calculated using HLA's design curve for peat
Long-term	- 1.12	1.26[b] 1.71[c] -	Drained analysis
Seismic Loading	- 1.00 K_y= 0.017	1.00 K_y= 0.144 -	Two-stage analysis
Sudden Drawdown	-	1.04	Three-stage analysis

Notes:
[a] Assuming one-stage construction, which we do not advocate. The factors of safety for the multiple-stage construction have not been calculated because these criteria need to be established during final design as to stage fill thickness and time sequencing.
[b] For small toe circle
[c] For large circle

Table 3.5.3
Results of Slope Stability Analyses
for Webb Tract Sta. 160+00
Fill with 5:1 Slope

Condition	Factor of Safety		Remarks
	Toward Slough	Toward Island	
Existing	- 1.29	1.24 -	Drained analysis
End of Construction[a]	- -	0.58 0.65	Two-stage analysis S_u profile calculated using HLA's design curve for peat
Long-term	- 1.13	1.36[b] 1.57[c] -	Drained analysis
Seismic Loading	- 1.00 K_y= 0.025	1.00 K_y= 0.114 -	Two-stage analysis
Sudden Drawdown	-	0.88	Three-stage analysis

Notes:
[a] Assuming one-stage construction, which we do not advocate. The factors of safety for the multiple-stage construction have not been calculated because these criteria need to be established during final design as to stage fill thickness and time sequencing.
[b] For small toe circle
[c] For large circle

Table 3.5.4
Results of Slope Stability Analyses
for Bacon Island Sta. 25+00
Fill with 5:1 Slope

Condition	Factor of Safety: Toward Slough	Factor of Safety: Toward Island	Remarks
Existing	- 1.48	1.23 -	Drained analysis
End of Construction[a]	- -	0.88 0.91	Two-stage analysis S_u profile calculated using HLA's design curve for peat
Long-term	- 1.33	1.40[b] 1.63[c] -	Drained analysis
Seismic Loading	- 1.00 K_y= 0.048	1.00 K_y= 0.128 K_y= 0.148 -	Two-stage analysis Crest width = 35 feet Crest width = 45 feet
Sudden Drawdown	-	1.07	Three-stage analysis

Notes:

[a] Assuming one-stage construction, which we do not advocate. The factors of safety for the multiple-stage construction have not been calculated because these criteria need to be established during final design as to stage fill thickness and time sequencing.

[b] For small toe circle

[c] For large circle

Table 3.5.5
Results of Slope Stability Analyses
for Bacon Island Sta. 265+00
Fill with 5:1 Slope

Condition	Factor of Safety: Toward Slough	Factor of Safety: Toward Island	Remarks
Existing	- 1.49	1.21 -	Drained analysis
End of Construction[a]	- -	0.90 0.81	Two-stage analysis S_u profile calculated using HLA's design curve for peat
Long-term	- 1.23	1.31[b] 1.64[c] -	Drained analysis
Seismic Loading	- 1.00 K_y= 0.038	1.00 K_y= 0.115 K_y= 0.133 -	Two-stage analysis Crest width = 35 feet Crest width = 45 feet
Sudden Drawdown	-	0.98	Three-stage analysis

Notes:

[a] Assuming one-stage construction, which we do not advocate. The factors of safety for the multiple-stage construction have not been calculated because these criteria need to be established during final design as to stage fill thickness and time sequencing.

[b] For small toe circle

[c] For large circle

TABLE 3.5.6
SUMMARY RESULTS OF SLOPE STABILITY ANALYSES

FILL WITH 5:1 SLOPE

Island Profile	Existing Condition		End of Construction[b]	Long-term Condition		Sudden Drawdown	K_y	
	Toward Island	Toward Slough	Toward Island	Toward Island	Toward Slough	Toward Island	Toward Island	Toward Slough
Webb Tract Sta. 160+00	1.24	1.29	0.62	1.57	1.12	0.88	0.114	0.025
Webb Tract Sta. 630+00	1.40	1.34	0.89	1.82	1.12	1.18	0.151	0.027
Bacon Sta. 25+00	1.23	1.48	0.90	1.63	1.33	1.07	0.128	0.048
Bacon Sta. 265+00	1.21	1.49	0.86	1.64	1.23	0.98	0.115	0.038

FILL WITH 3:1 SLOPE FLATTENING TO 10:1 SLOPE AT ELEV. –3 FEET

Webb Tract Sta. 630+00	1.40	1.34	1.22	1.71	1.12	1.04	0.144	0.017

Notes:

[a] Assuming one-stage construction, which we do not advocate. The factors of safety for the multiple-stage construction have not been calculated because these criteria need to be established during final design as to stage fill thickness and time sequencing.

[b] average of the two methods (two-stage method and S_u/p' method)

Table 3.5.7
Stability Criteria for Levees and
Factors of Safety for Dam Safety Evaluations

Case	Design Condition	Factors of Safety for Dam Safety Evaluations[1]	Minimum Levee Factor of Safety by USACE[2]	DWR Criteria for Levee Rehabs[4]	PL84-99 for Non-Federal Levees[5]
1	Immediately Following Construction	-	1.3	-	-
2	Sudden Drawdown	1.25	1.0	-	-
4	Long-term, Steady-State at Flood Stage	1.5	1.4	1.3	1.25
5	Seismic Loading (Pseudo-Static Analysis)	1.2 [3]	1.0	-	-

Notes:

1. From ASDSO (1989).
2. From USACE (1978).
3. Deformation criteria are also used to satisfy that no excessive deformations occur.
4. From California DWR (1989).
5. From USACE (1988)

Table 3.6.1
Dynamic Soil Parameters Used in the Response Analysis

Description	Moist Unit Weight pcf	K_{2max}	Shear Wave Velocity ft/sec	Modulus and Damping Curves
Levee Materials				
New fills: sand	120	80	-	Sand[3]
Fills: sand	105-110	25	-	Sand[3]
Fills: soft clay	70	-	250	Clay[1]
Fills: silty sand with fat clay	110	25	-	Sand[3]
Fills: clay with peat	80	-	300	Clay[1]
Fills: silty clay with sand	110		450	Clay[2]
Peat	70	-	250	Peat[4]
Foundation Materials				
Sand	120-125	80	-	Sand[3]
Clay	127	-	700	Clay[2]

Note : 1: Relationships of Vucetic and Dobry (1991) for PI = 100
2: Relationships of Vucetic and Dobry (1991) for PI = 50
3: Relationships of Seed and Idriss (1970) for mean
4: Relationships of Boulanger et al (1997)

Table 3.6.2
Summary of the Earthquake Records Used in the Dynamic Response Analysis

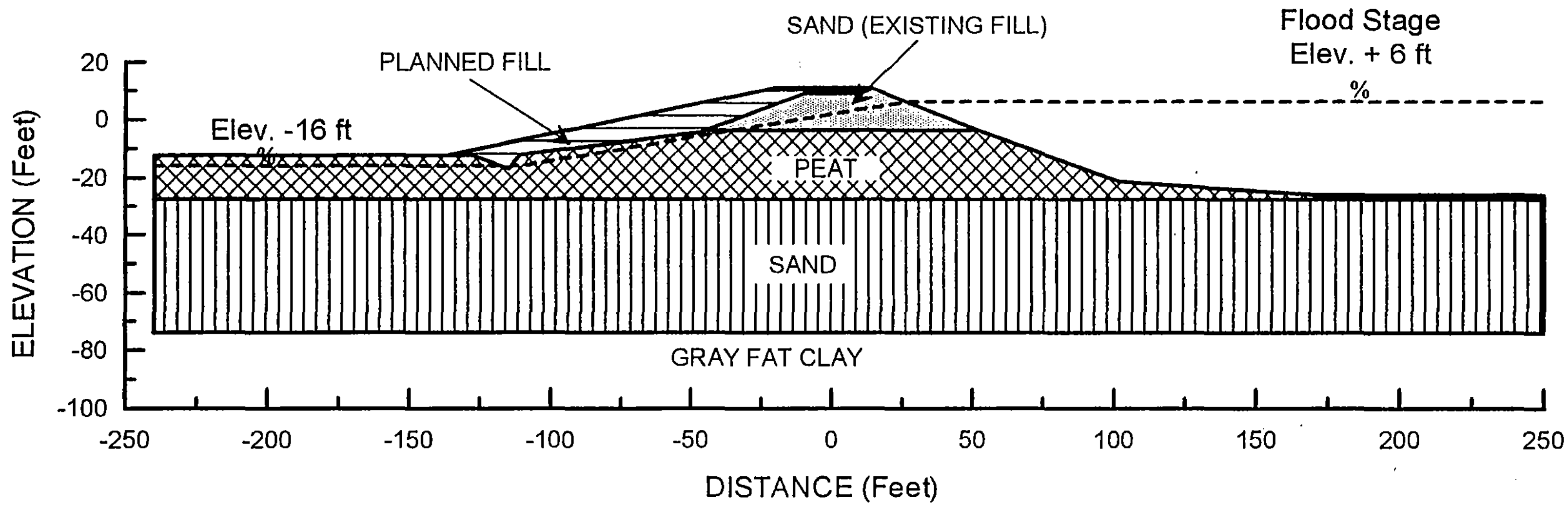
Earthquake	M_w	Recording Station: Distance (km)	Recording Station: Station #	Recording Station: Site Condition	Comp	Recorded PGA (g)
1987 Whittier Narrows	6.0	18	24402[b]	Soil[a]	90°	0.15
1992 Landers	7.3	64	24577[c]	Soil[a]	0°	0.11

Note : a = Deep Stiff Soil Site
b = Altadena – Eaton Canyon Station
c = Fort Irwin Station

Table 3.6.3
Calculated Seismic-induced Slope Deformations

Critical Slide	K_y (g)	K_{max} (g)	Max Deformation (ft)	
			Newmark[1]	Makdisi & Seed[2]
Webb Tract at St. 160+00				
Reservoir-side Slope				
Crest Slide[3]	0.114	0.40	2.0	0.5-1.5
Slough-side Slope				
Crest Slide[3]	0.025	0.21	3.5	0.5-3.5
Webb Tract at St. 630+00				
Reservoir-side Slope				
Crest Slide[4]	0.151	0.36	1.5	0-1.0
Slough-side Slope				
Crest Slide[4]	0.027	0.26	4.0	1.0-4.0
Bacon Island at St. 25+00				
Reservoir-side Slope				
Upper Toe Slide[5]	0.148	0.47	3.5	0.5-1.0
Slough-side Slope				
Crest Slide[5]	0.048	0.31	3.5	0.5-3.0
Bacon Island at St. 265+00				
Reservoir-side Slope				
Crest Slide[6]	0.133	0.36	1.5	0.5-1.0
Slough-side Slope				
Crest Slide[6]	0.0385	0.28	3.5	0.5-3.0

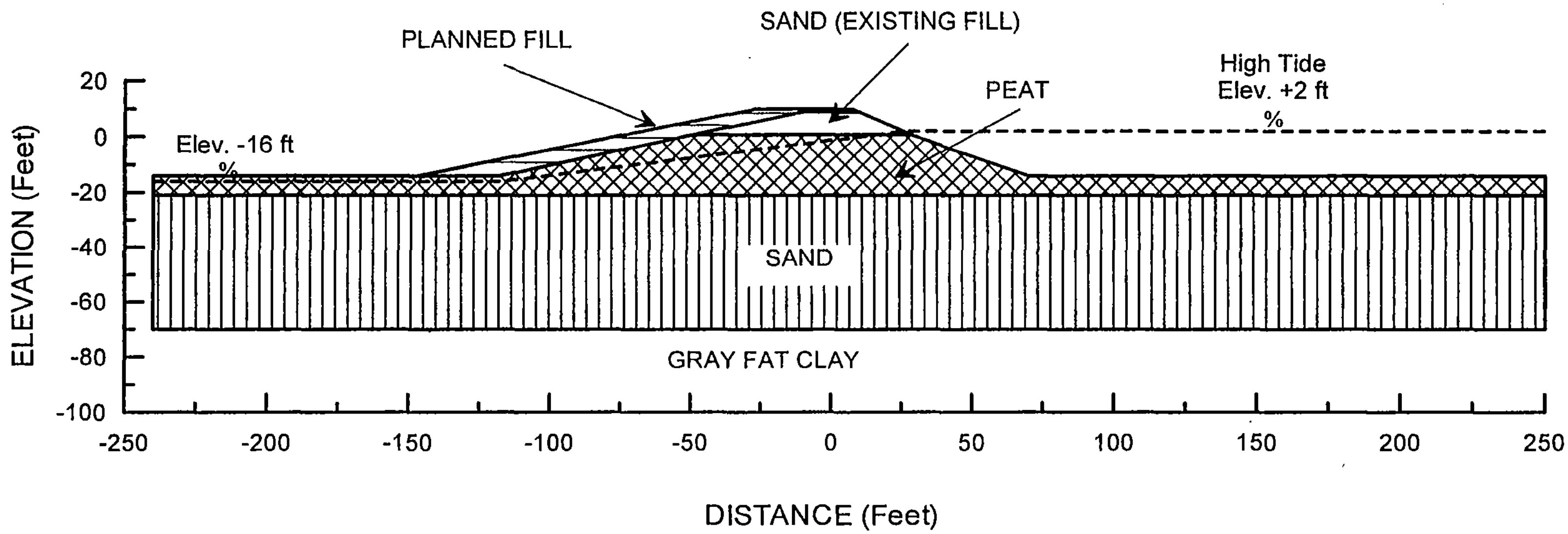
Note:
1: Newmark Double Integration Method (1965)
2: Makdisi and Seed Simplified Method (1978)
3: Refer to Figures 3.5.25 and 3.5.26.
4: Refer to Figures 3.5.7 and 3.5.8.
5: Refer to Figures 3.5.34 and 3.5.35.
6: Refer to Figures 3.5.43 and 3.5.44.



Soil Properties			
Material	γ_s (pcf)	c' (psf)	ϕ' (deg)
Clay with Peat and Sand	110	80	27
Peat	70	50	28
Sand	125	0	36
Planned Fill	120	0	34

DELTA WETLANDS PROJECT	WEBB TRACT STA. 160+00 CROSS SECTION FOR STABILITY ANALYSIS	FIGURE 3.3.1
URS GREINER WOODWARD CLYDE		

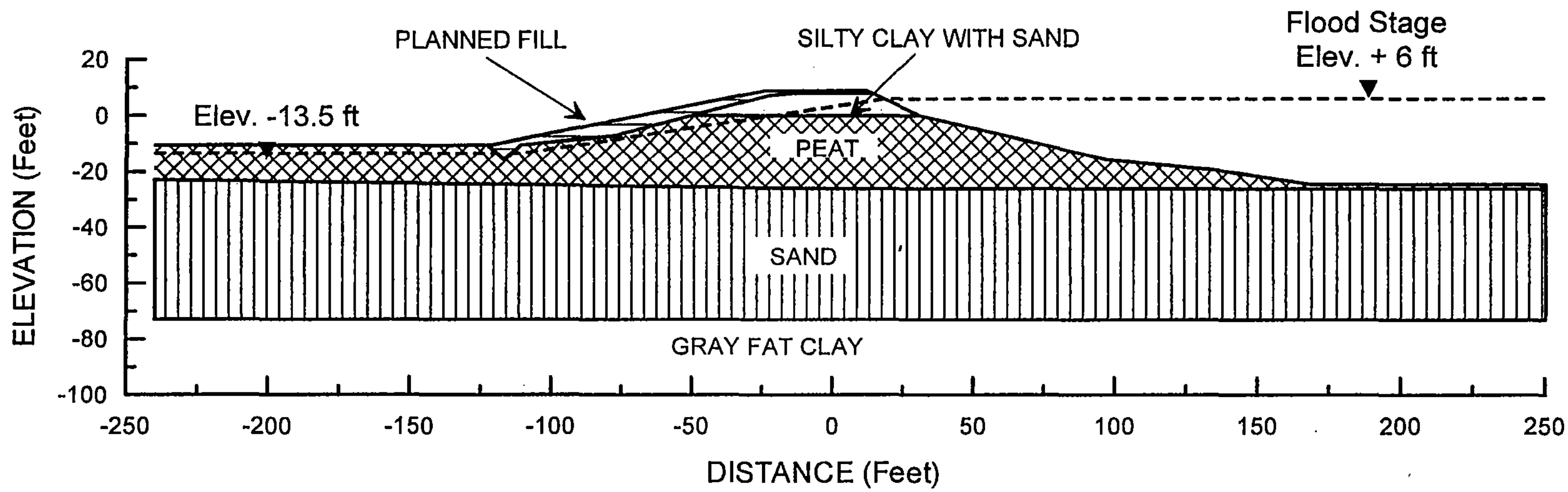
x:/ARLLNA/deltawetland/websta160.grf 3/16/00



Soil Properties			
Material	γ_s (pcf)	c' (psf)	ϕ' (deg)
Sand Fill	110	0	32
Soft Clay Fill or Peat	70	50	28
Sand	125	0	36
Planned Fill	120	0	34

DELTA WETLANDS PROJECT	WEBB TRACT STA. 630+00 CROSS SECTION FOR STABILITY ANALYSIS	FIGURE 3.3.2
URS GREINER WOODWARD CLYDE		

x:/ARULNA/deltawetland/webb630/w630.grf 3/16/00



Soil Properties			
Material	γ_s (pcf)	c' (psf)	ϕ' (deg)
Silty Clay with Sand	110	80	27
Peat	70	50	28
Sand	125	0	36
Planned Fill	120	0	34

DELTA WETLANDS PROJECT *URS GREINER WOODWARD CLYDE*	**BACON ISLAND STA. 25+00 CROSS SECTION FOR STABILITY ANALYSIS**	**FIGURE 3.3.3**

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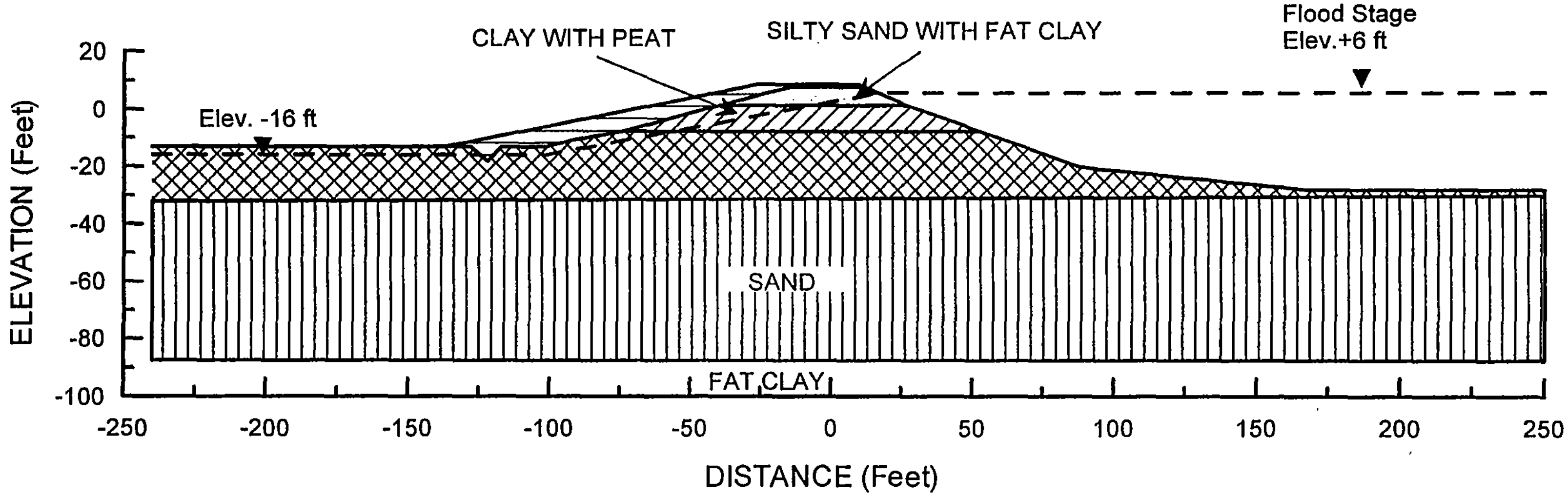

Soil Properties			
Material	γ_s (pcf)	c' (psf)	ϕ' (deg)
Silty sand with Fat Clay	110	0	32
Clay with Peat	80	100	28
Peat	70	50	28
Sand	120	0	37
Planned Fill	120	0	34

DELTA WETLANDS PROJECT	BACON ISLAND STA. 265+00 CROSS SECTION FOR STABILITY ANALYSIS	FIGURE 3.3.4
URS GREINER WOODWARD CLYDE		

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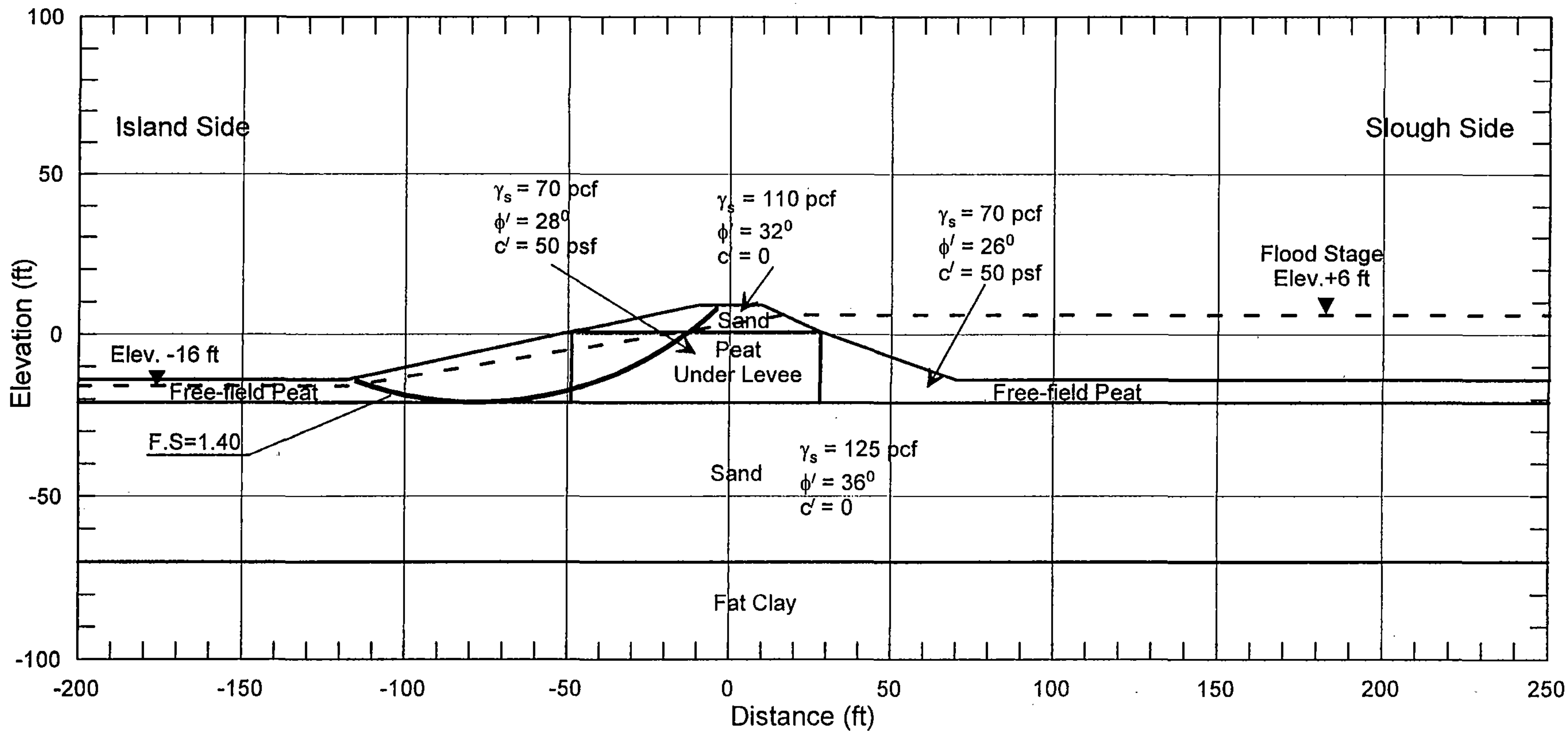

DELTA WETLANDS PROJECT	WEBB TRACT STA. 630+00 STABILITY ANALYSIS EXISTING CONDITION-INTO ISLAND	FIGURE 3.5.1
URS GREINER WOODWARD CLYDE		

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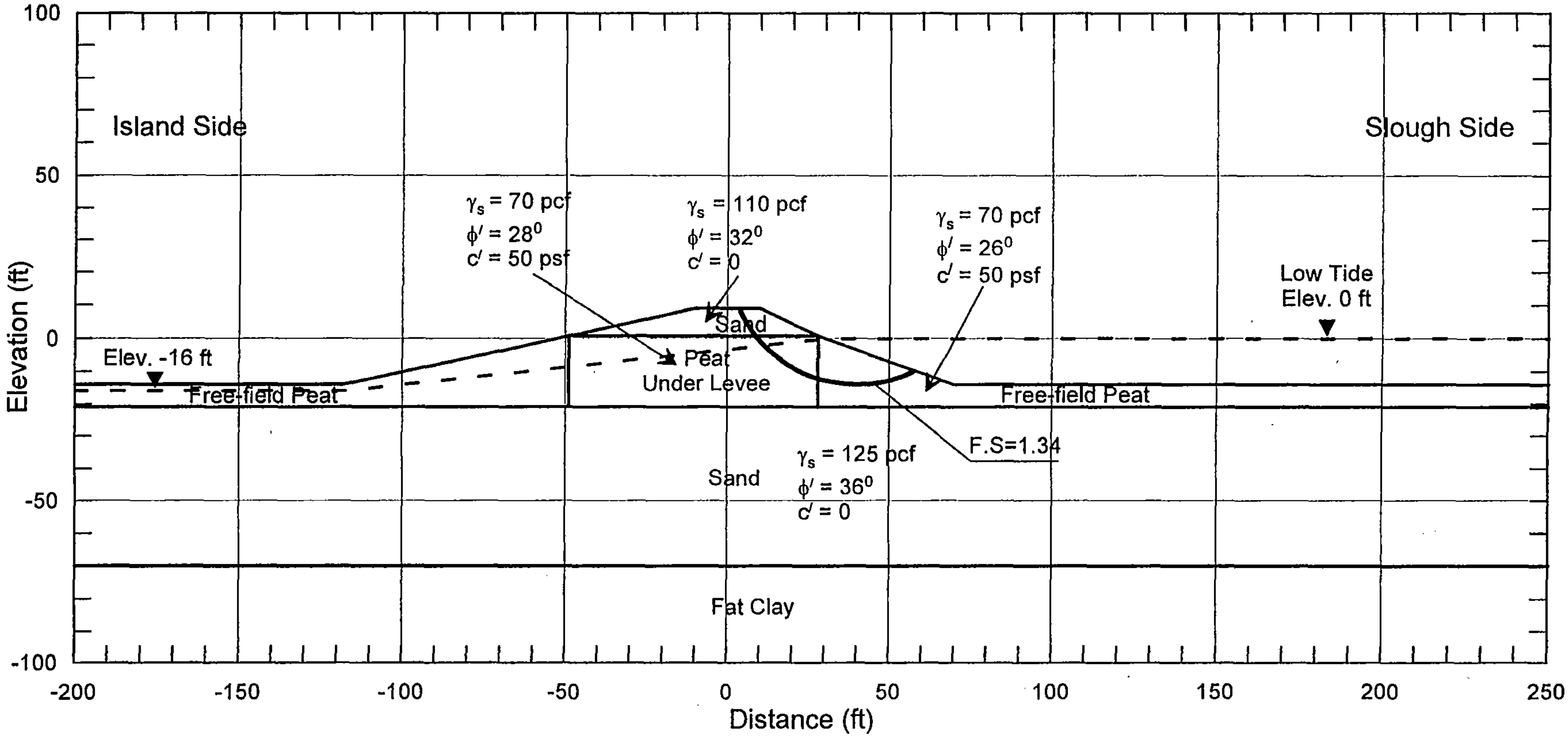

DELTA WETLANDS PROJECT	WEBB TRACT STA. 630+00 STABILITY ANALYSIS EXISTING CONDITION- TOWARD SLOUGH	FIGURE 3.5.2
URS GREINER WOODWARD CLYDE		

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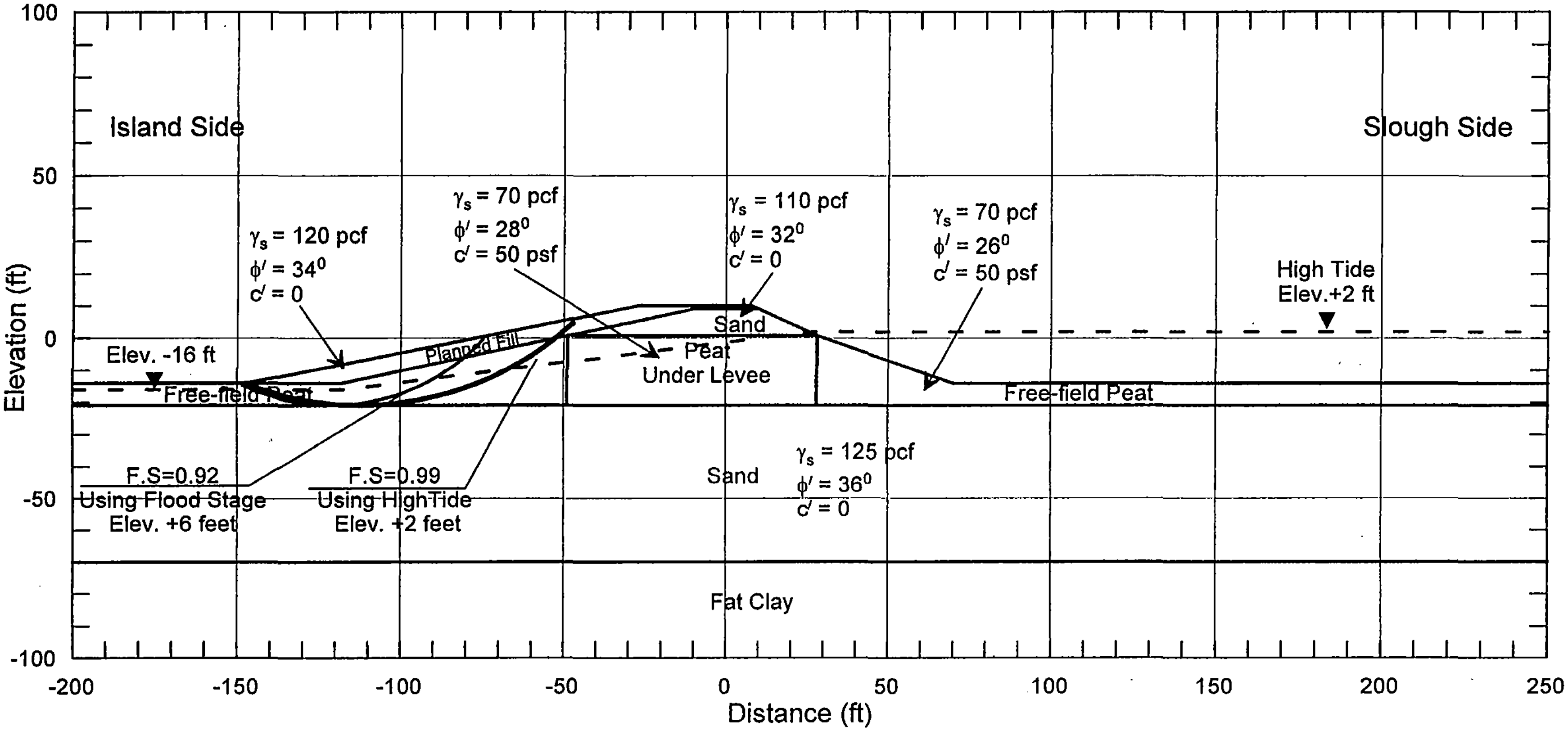

DELTA WETLANDS PROJECT	WEBB TRACT STA. 630+00 STABILITY ANALYSIS, TWO-STAGE END OF CONSTRUCTION- INTO ISLAND	FIGURE 3.5.3
URS GREINER WOODWARD CLYDE		

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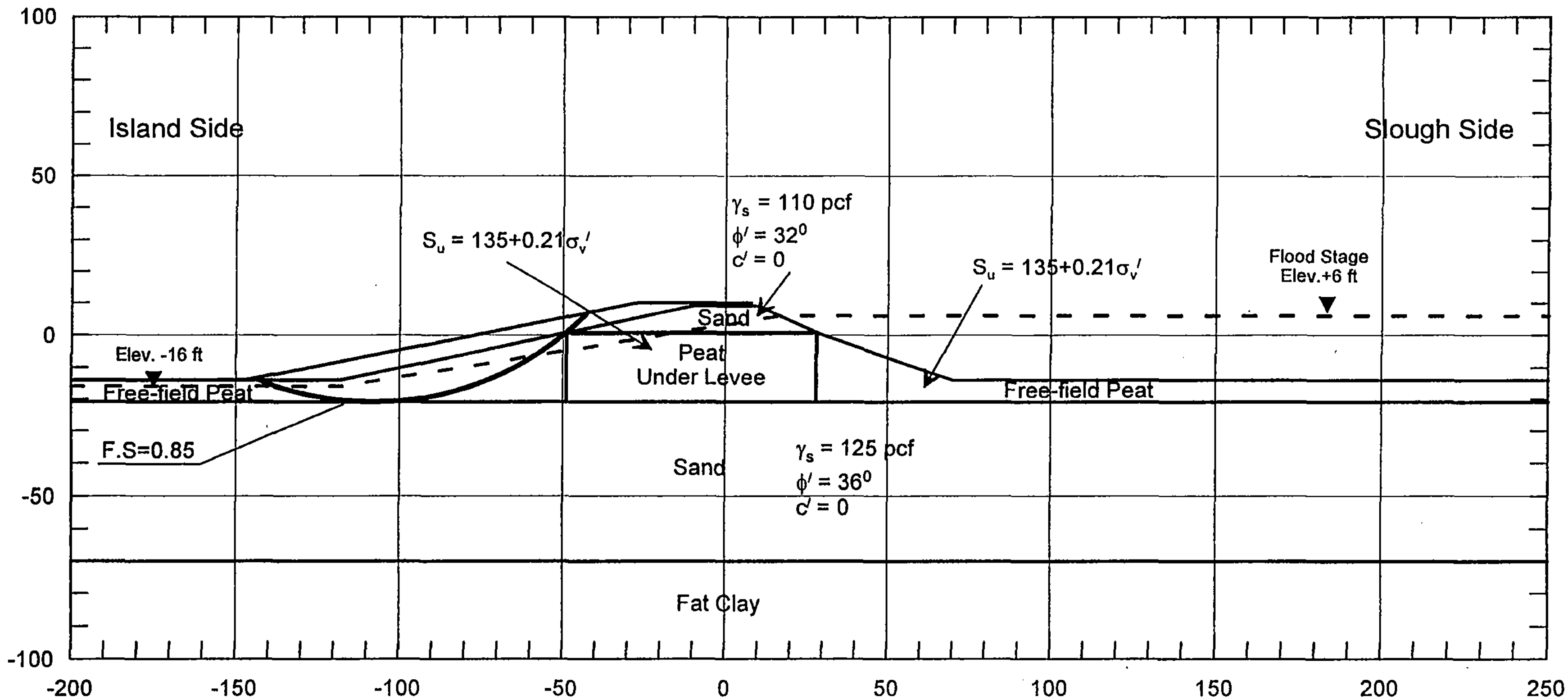

DELTA WETLANDS PROJECT	WEBB TRACT STA. 630+00 STABILITY ANALYSIS, S_u PROFILE END OF CONSTRUCTION- INTO ISLAND	FIGURE 3.5.4
URS GREINER WOODWARD CLYDE		

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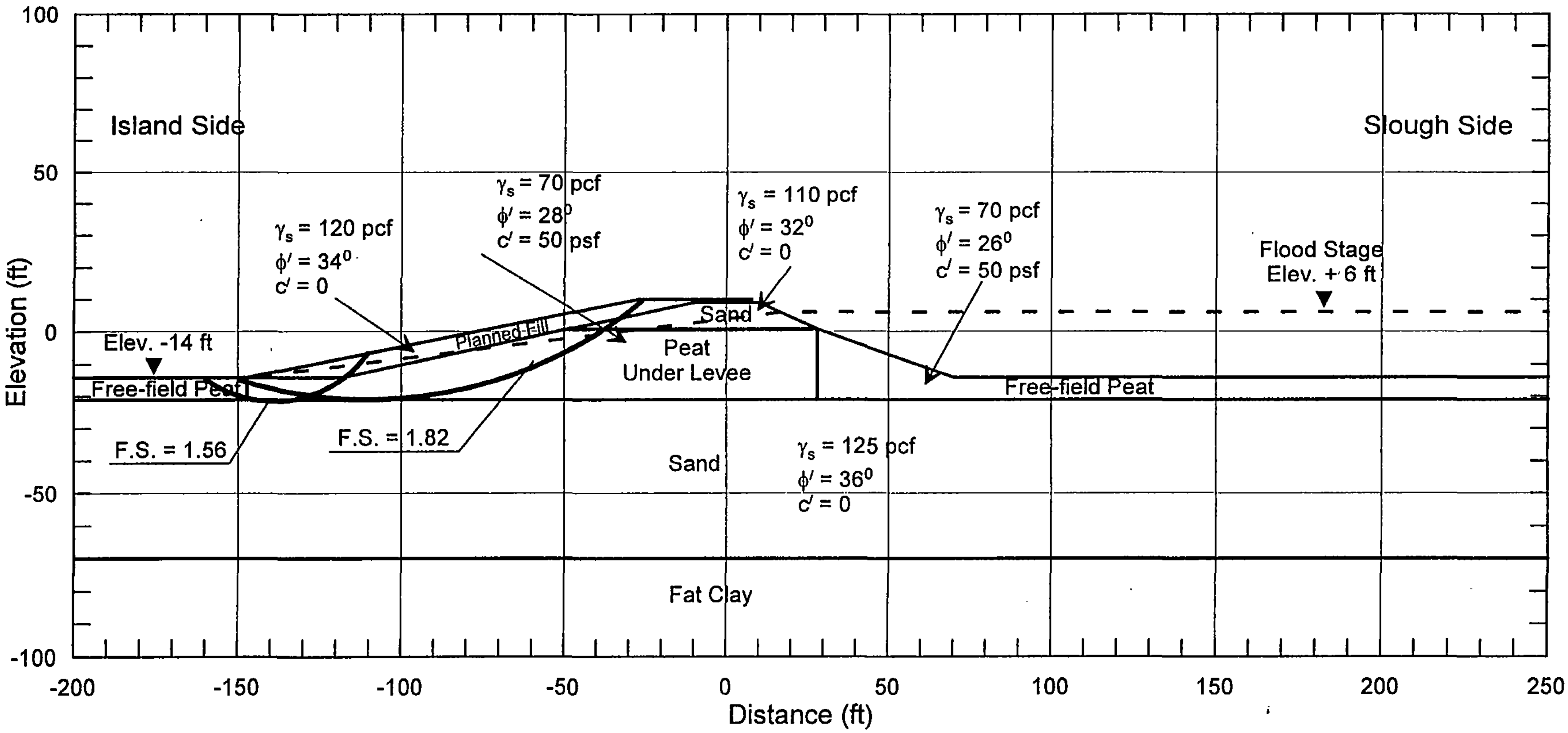

DELTA WETLANDS PROJECT	WEBB TRACT STA. 630+00 STABILITY ANALYSIS LONG-TERM CONDITION- INTO ISLAND	FIGURE 3.5.5
URS GREINER WOODWARD CLYDE		

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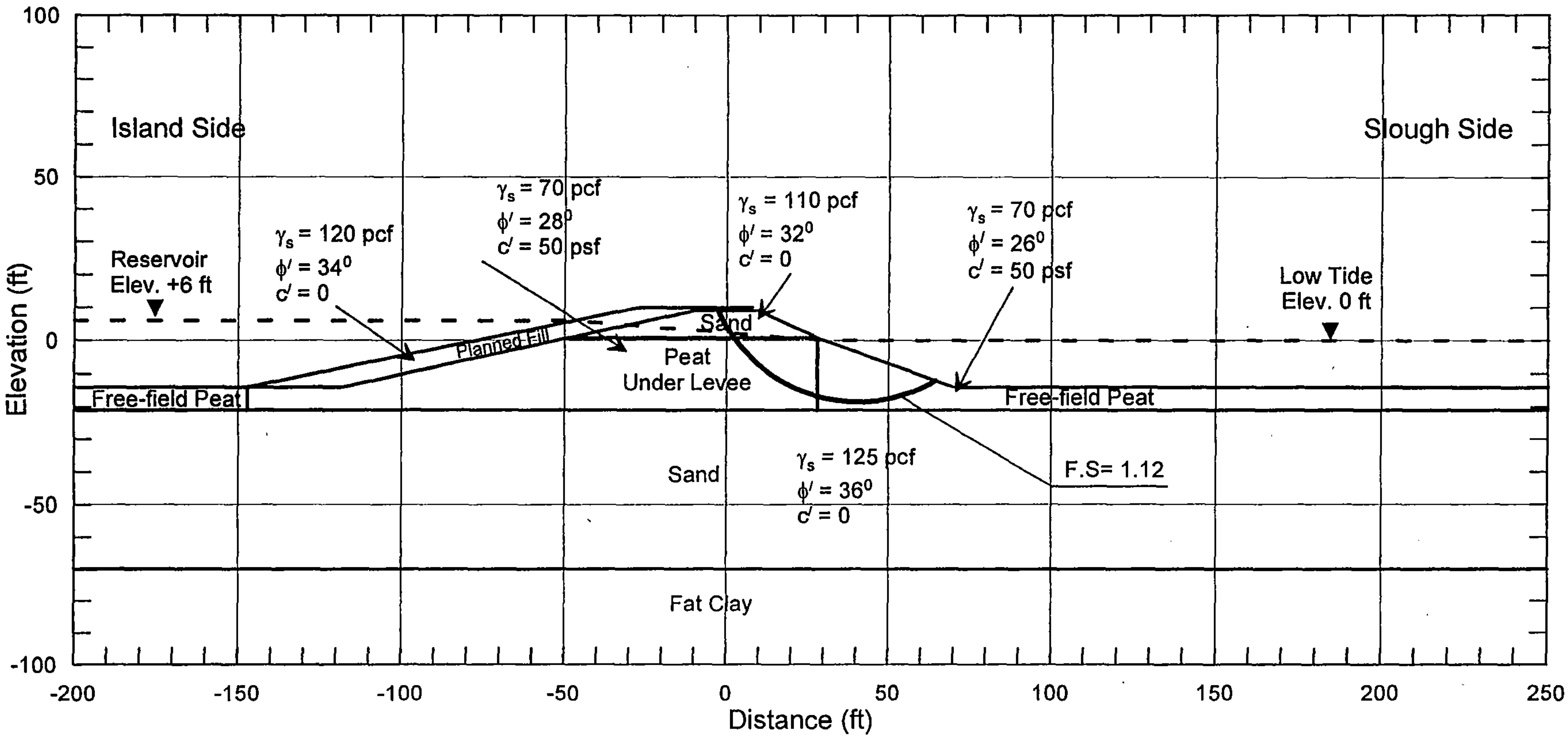

DELTA WETLANDS PROJECT	WEBB TRACT STA. 630+00 STABILITY ANALYSIS LONG-TERM CONDITION- TOWARD SLOUGH	FIGURE 3.5.6
URS GREINER WOODWARD CLYDE		

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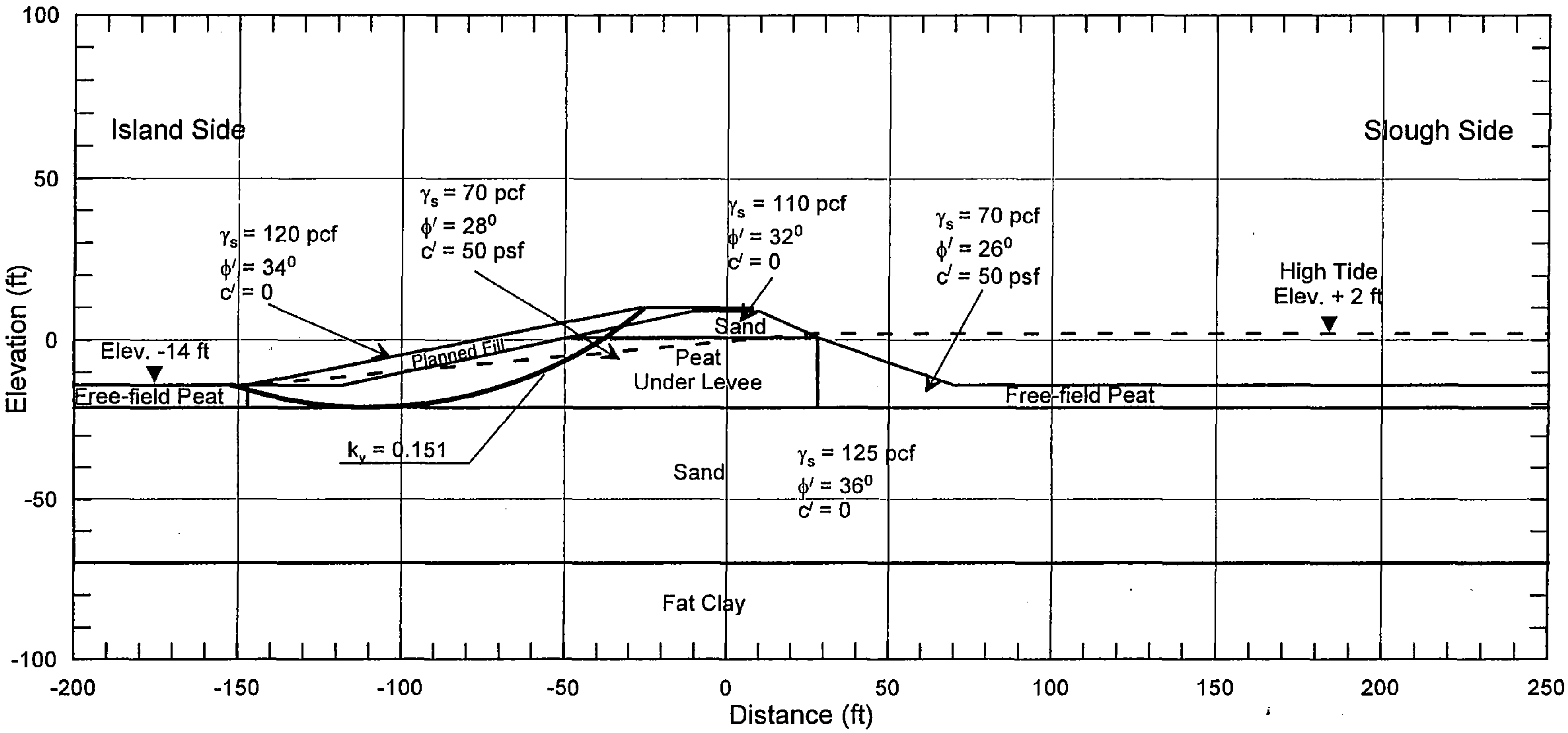

DELTA WETLANDS PROJECT	WEBB TRACT STA. 630+00 STABILITY ANALYSIS SEISMIC CONDITION- INTO ISLAND	FIGURE 3.5.7
URS GREINER WOODWARD CLYDE		

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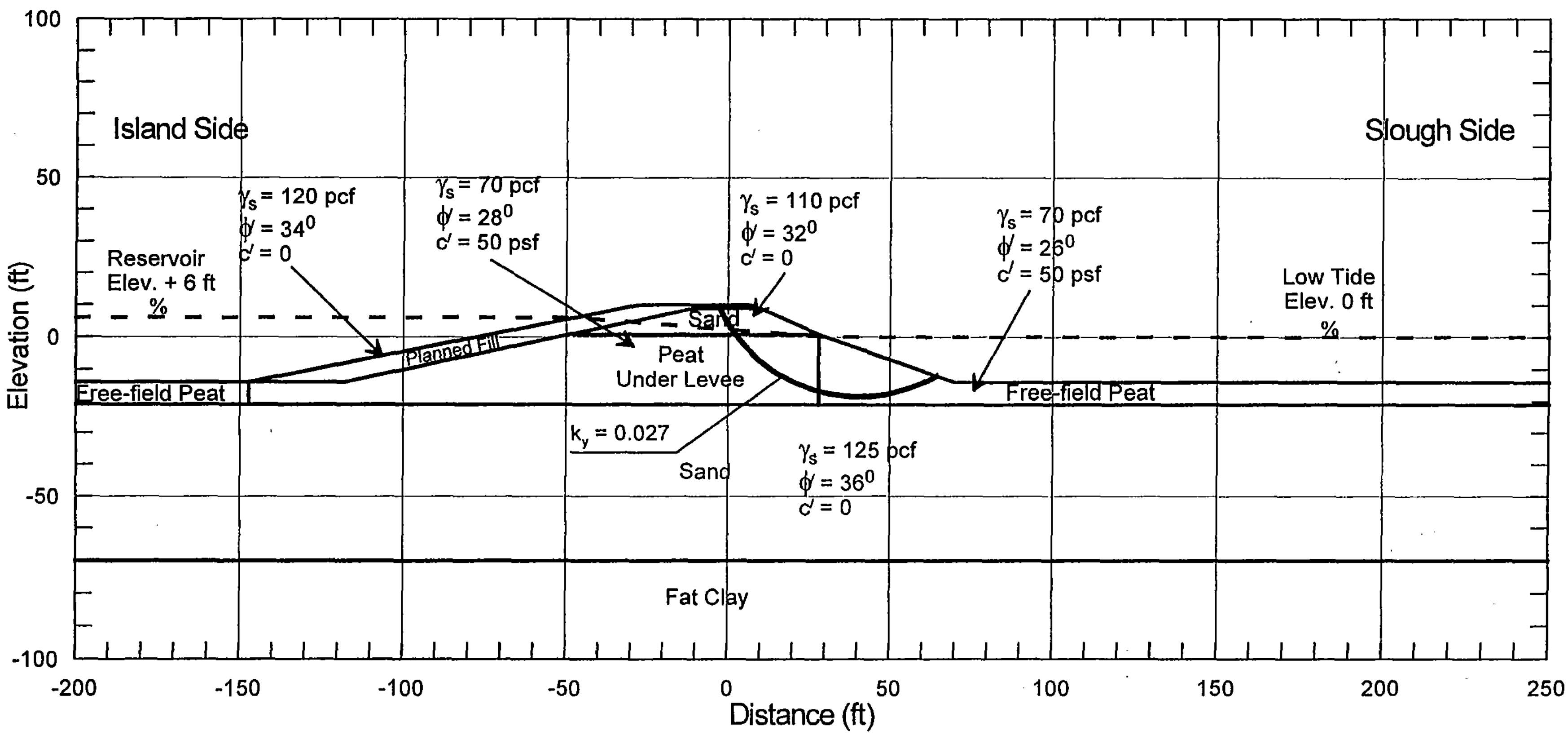
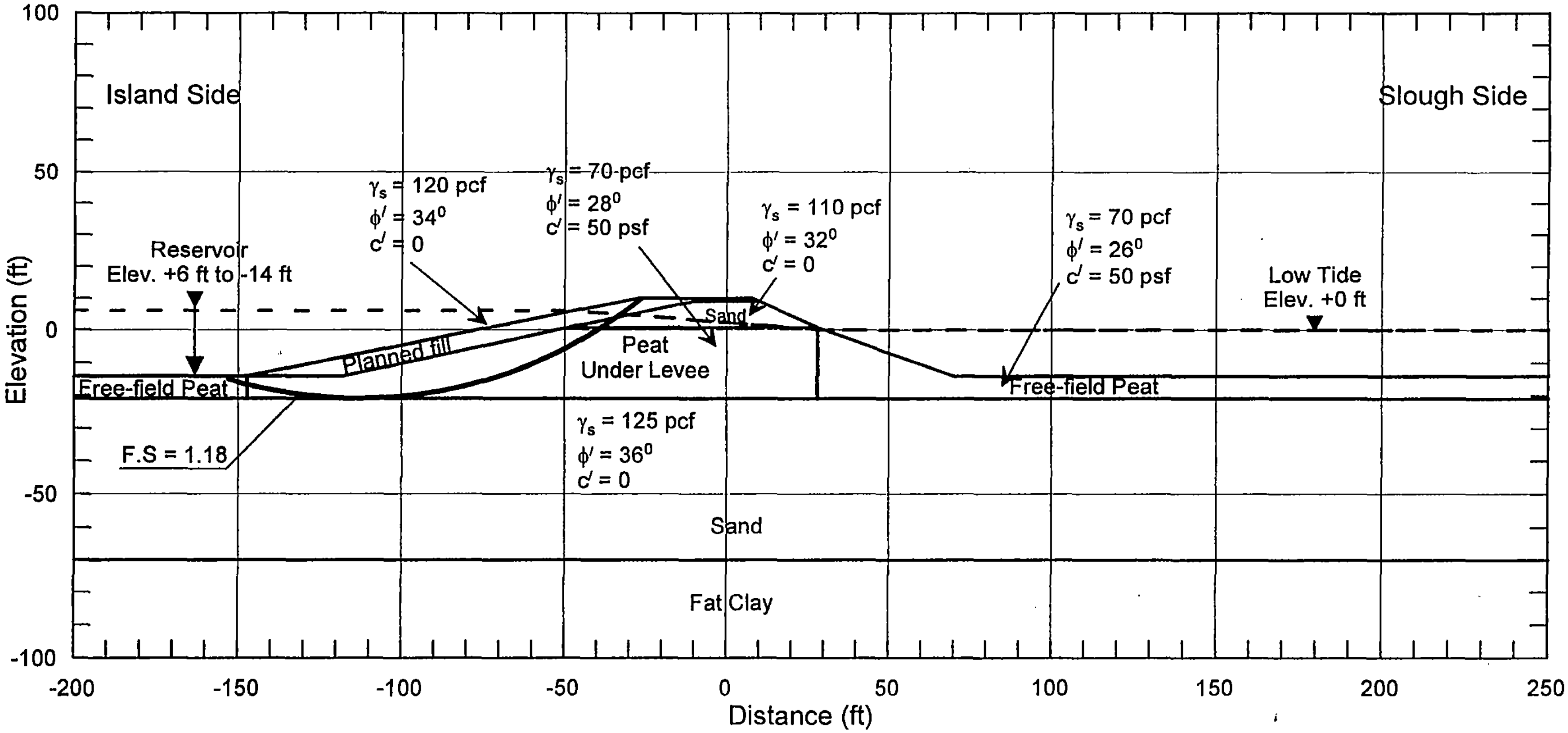


DELTA WETLANDS PROJECT	WEBB TRACT STA. 630+00 STABILITY ANALYSIS SEISMIC CONDITION TOWARD SLOUGH	FIGURE 3.5.8
URS Greiner Woodward Clyde		

x:/ARULNA/deltawetland/webb630/w6sesl.grf 12/13/99



DELTA WETLANDS PROJECT

URS GREINER WOODWARD CLYDE

**WEBB TRACT STA. 630+00
STABILITY ANALYSIS, THREE-STAGE
SUDDEN DRAWDOWN CONDITION
- INTO ISLAND**

**FIGURE
3.5.9**

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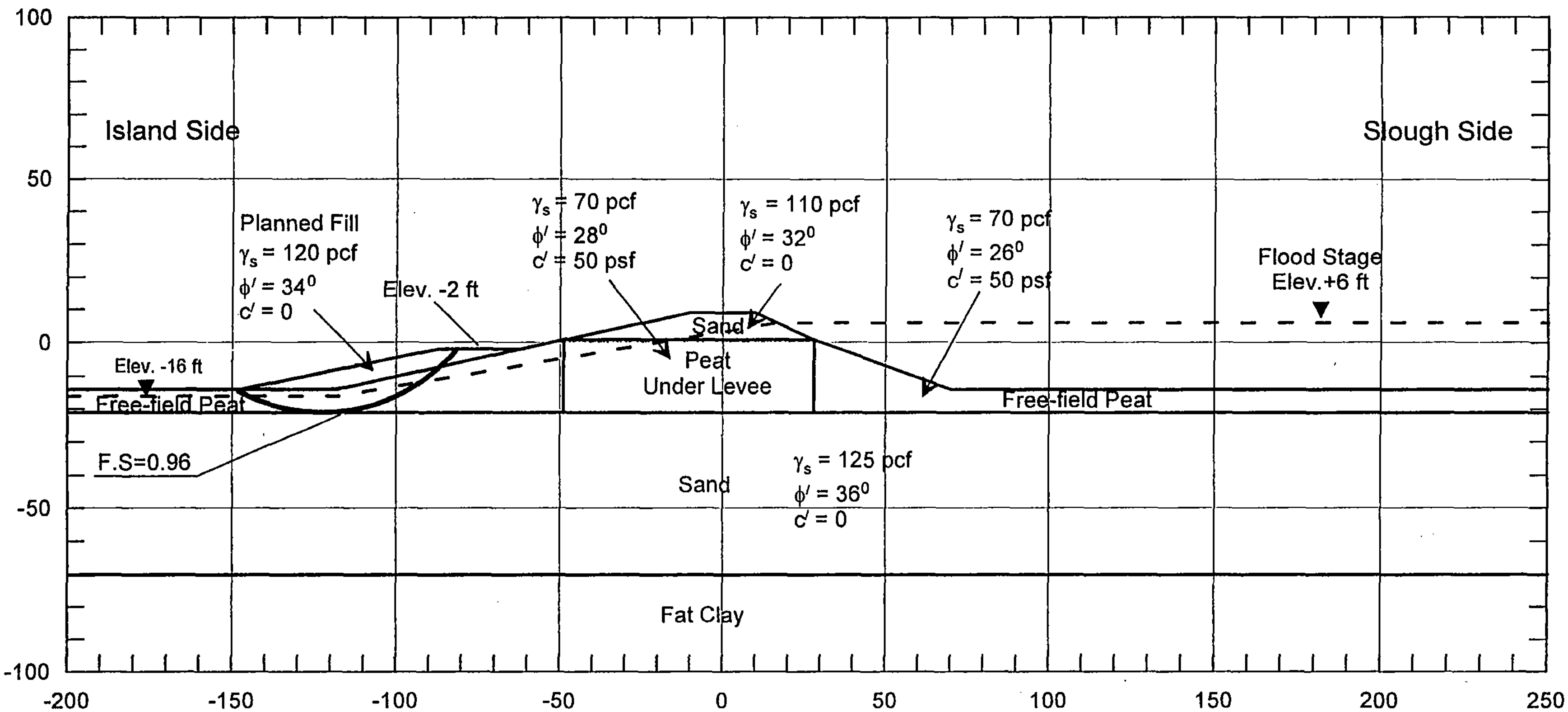
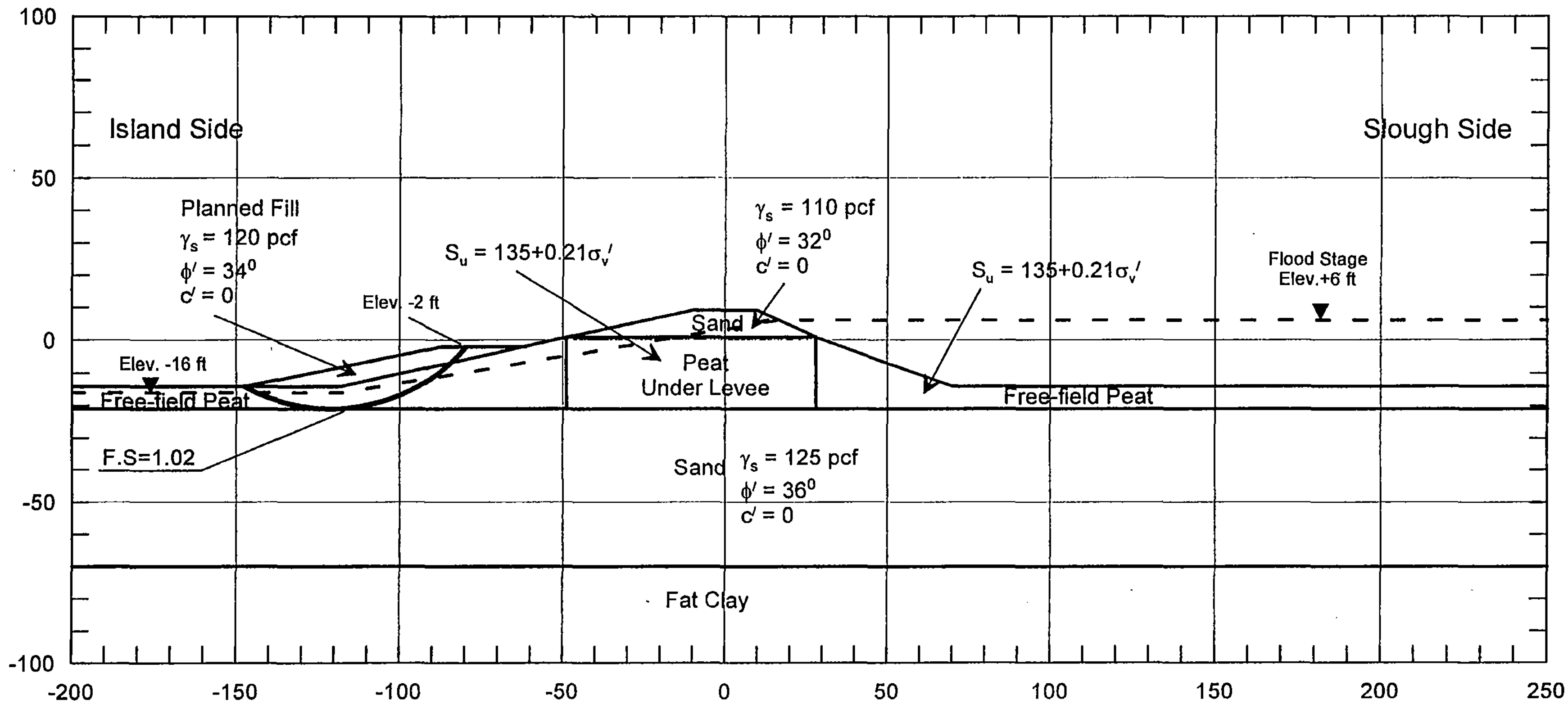


DELTA WETLANDS PROJECT	WEBB TRACT STA. 630+00 STABILITY ANALYSIS, TWO-STAGE END OF FIRST STAGE CONSTRUCTION - INTO ISLAND	FIGURE 3.5.10
URS GREINER WOODWARD CLYDE		

x:/ARULNA/deltawetland/webb630/w6half2s.grf 12/2/99



DELTA WETLANDS PROJECT	WEBB TRACT STA. 630+00 STABILITY ANALYSIS, Su PROFILE END OF FIRST STAGE CONSTRUCTION - INTO ISLAND	FIGURE 3.5.11
URS GREINER WOODWARD CLYDE		

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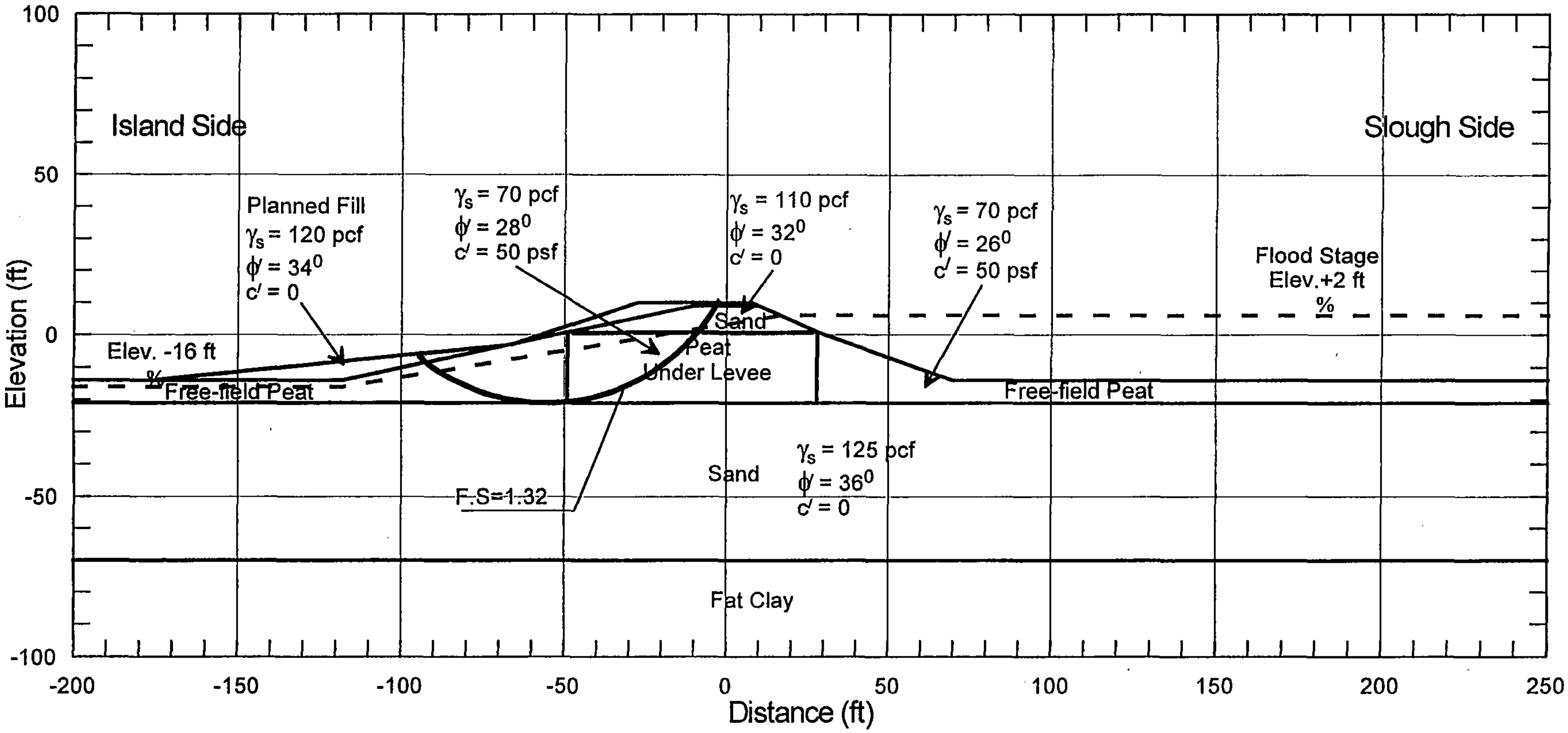

DELTA WETLANDS PROJECT	WEBB TRACT STA. 630+00 ALTERNATIVE GEOMETRY STABILITY ANALYSIS, TWO-STAGE END OF CONSTRUCTION- INTO ISLAND	FIGURE 3.5.12
URS GREINER WOODWARD CLYDE		

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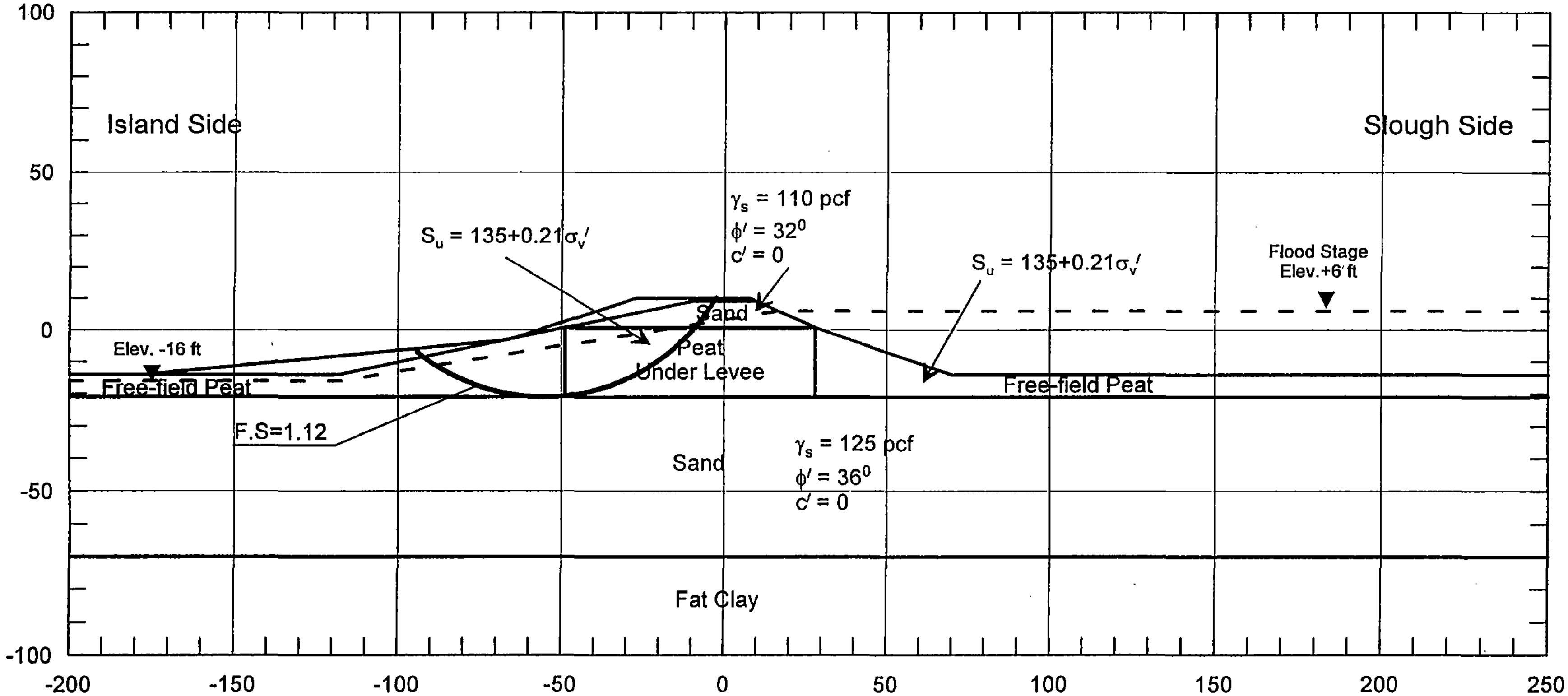

DELTA WETLANDS PROJECT	WEBB TRACT STA. 630+00 STABILITY ANALYSIS, S_u PROFILE END OF CONSTRUCTION- INTO ISLAND	FIGURE 3.5.13
URS GREINER WOODWARD CLYDE		

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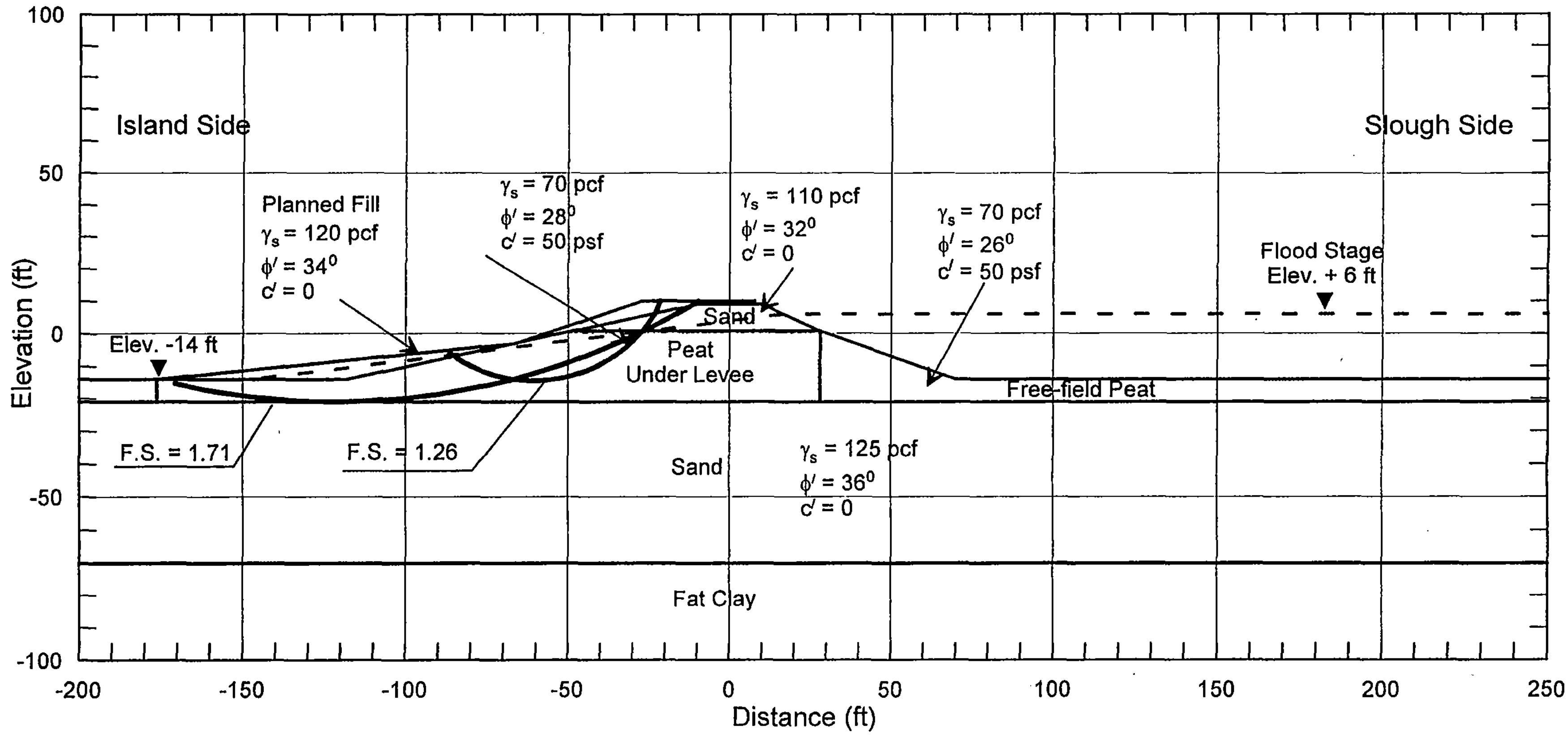
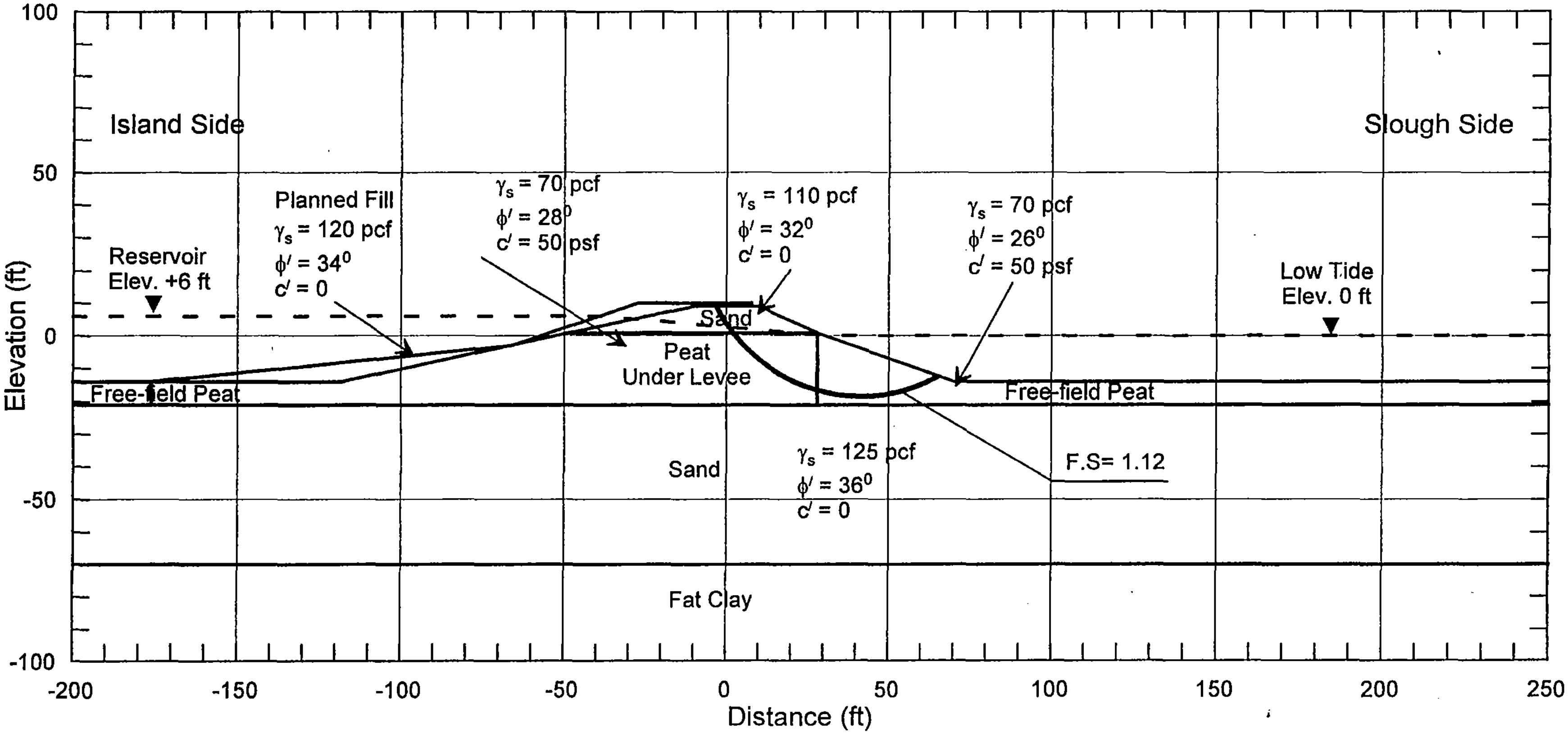


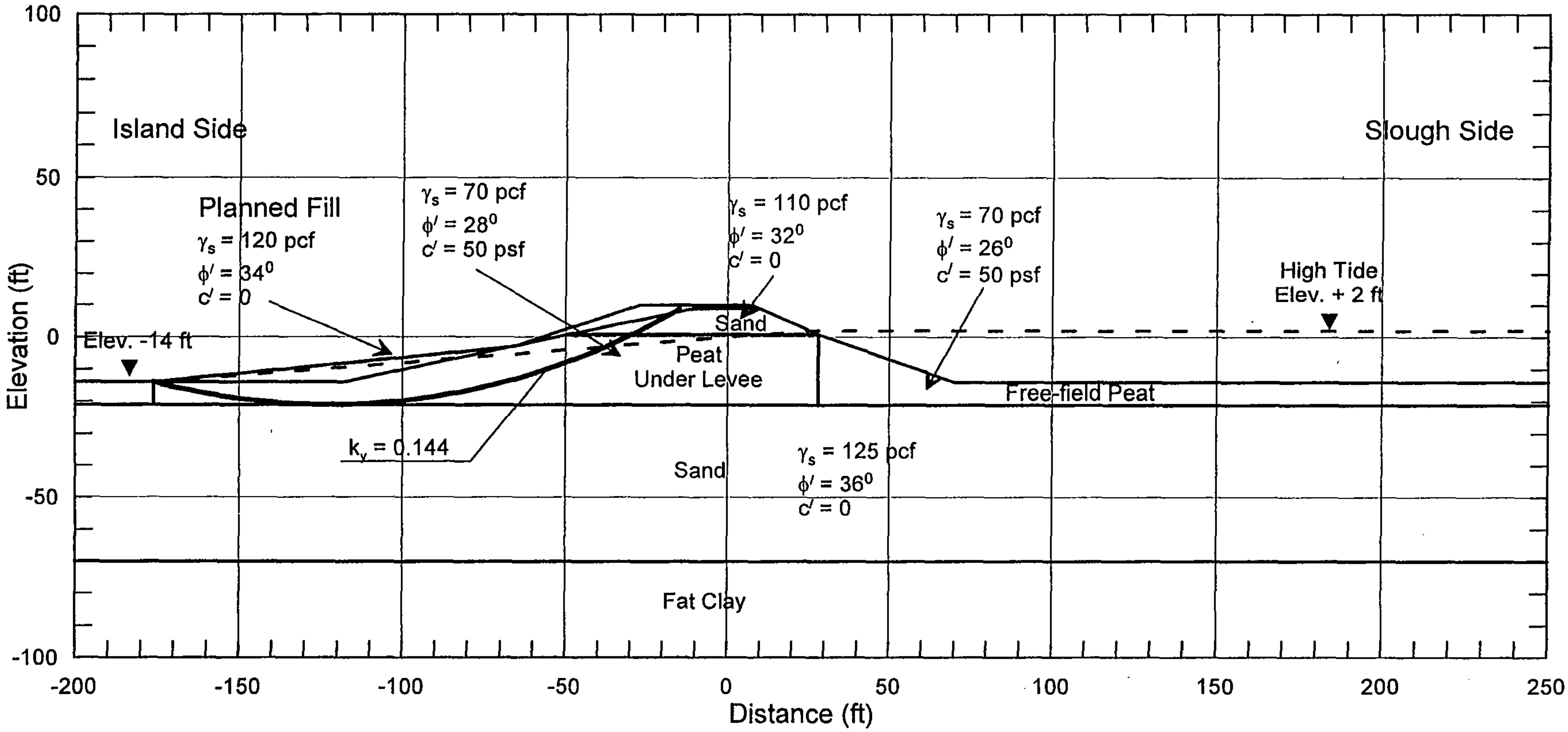
DELTA WETLANDS PROJECT	WEBB TRACT STA. 630+00 STABILITY ANALYSIS LONG-TERM CONDITION- INTO ISLAND	FIGURE 3.5.14
URS GREINER WOODWARD CLYDE		

x:/ARULNA/deltawetland/webb630/w31long.grf 12/2/99



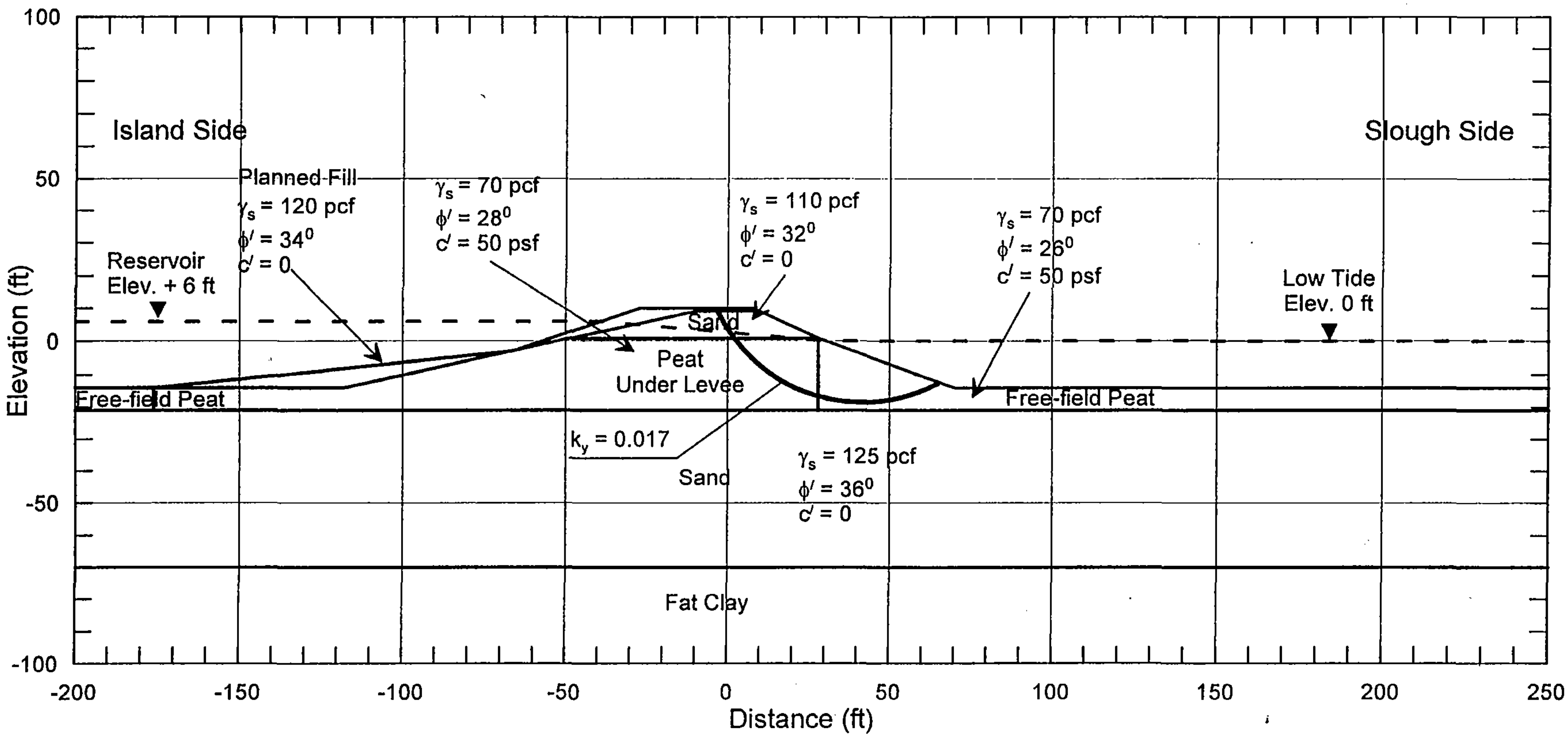
DELTA WETLANDS PROJECT	WEBB TRACT STA. 630+00 STABILITY ANALYSIS LONG-TERM CONDITION- TOWARD SLOUGH	FIGURE 3.5.15
URS GREINER WOODWARD CLYDE		

x:/ARULNA/deltawetland/webb630/w31lons.grf 12/2/99



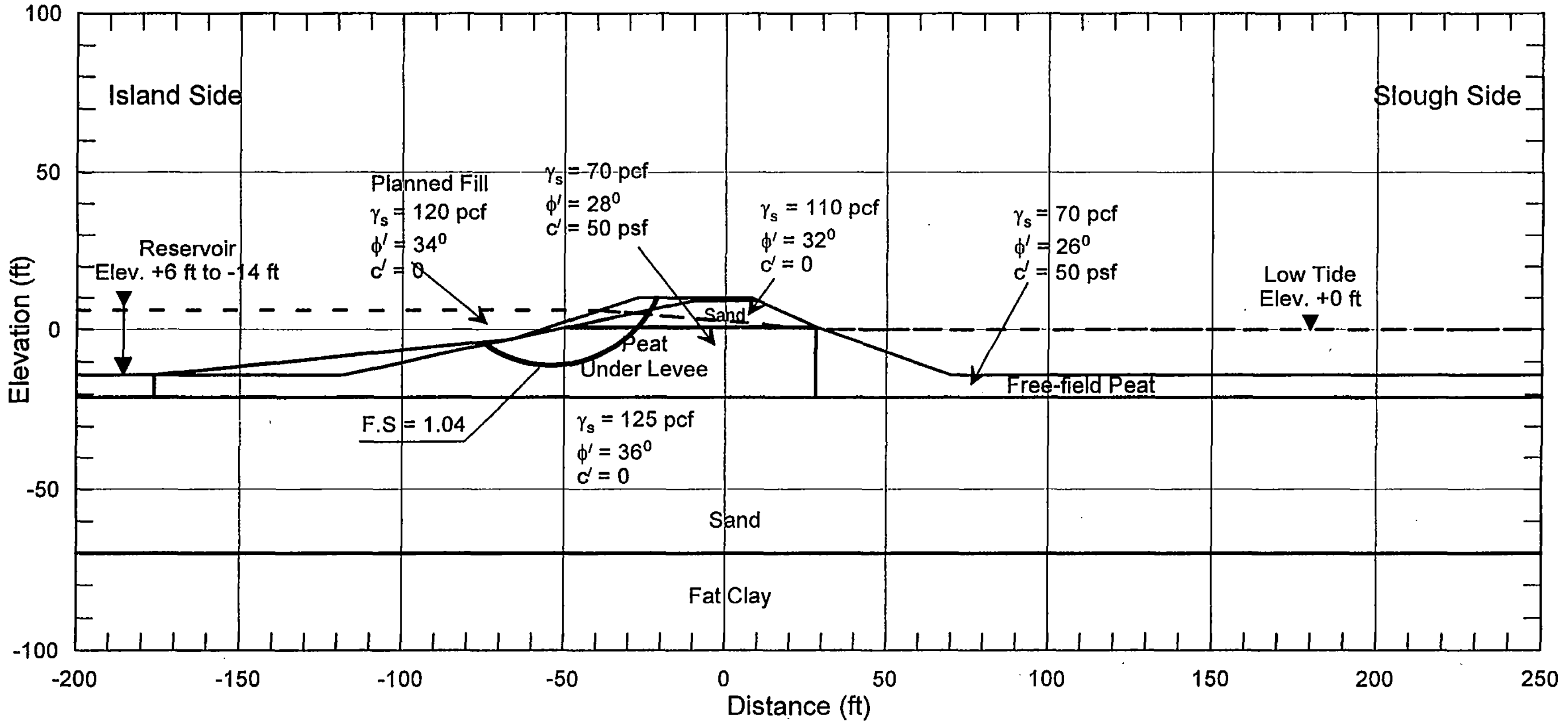
DELTA WETLANDS PROJECT	WEBB TRACT STA. 630+00 STABILITY ANALYSIS SEISMIC CONDITION- INTO ISLAND	FIGURE 3.5.16
URS GREINER WOODWARD CLYDE		

x:/ARULNA/deltawetland/webb630/w31lose.grf 12/2/99



DELTA WETLANDS PROJECT	WEBB TRACT STA. 630+00 STABILITY ANALYSIS SEISMIC CONITION TOWARD SLOUGH	FIGURE 3.5.17
URS Greiner Woodward Clyde		

x:/ARULNA/deltawetland/webb630/w31sesl.grf 12/2/99



DELTA WETLANDS PROJECT	WEBB TRACT STA. 630+00 STABILITY ANALYSIS, THREE-STAGE SUDDEN DRAWDOWN CONDITION - INTO ISLAND	FIGURE 3.5.18
URS GREINER WOODWARD CLYDE		

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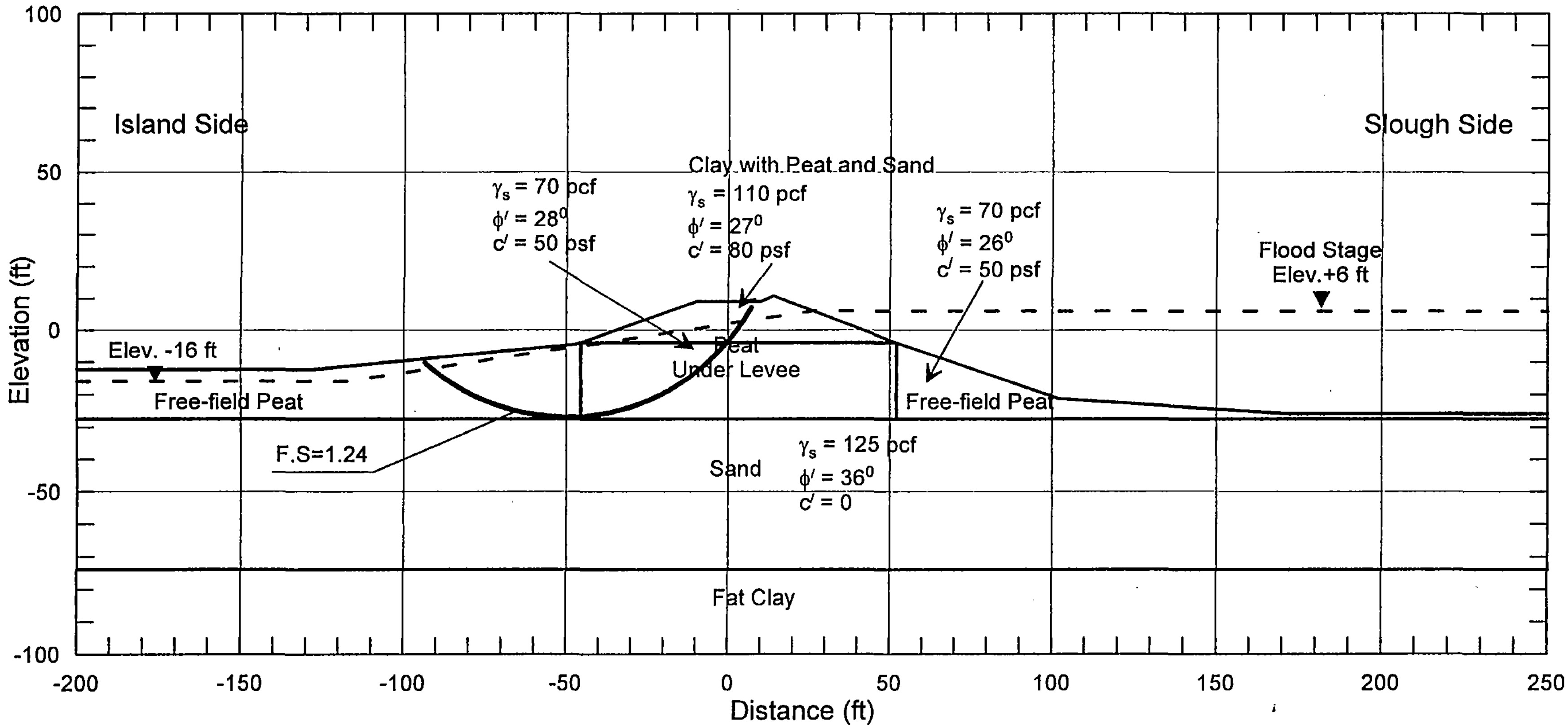

DELTA WETLANDS PROJECT	WEBB TRACT STA. 160+00 STABILITY ANALYSIS EXISTING CONDITION-INTO ISLAND	FIGURE 3.5.19
URS GREINER WOODWARD CLYDE		

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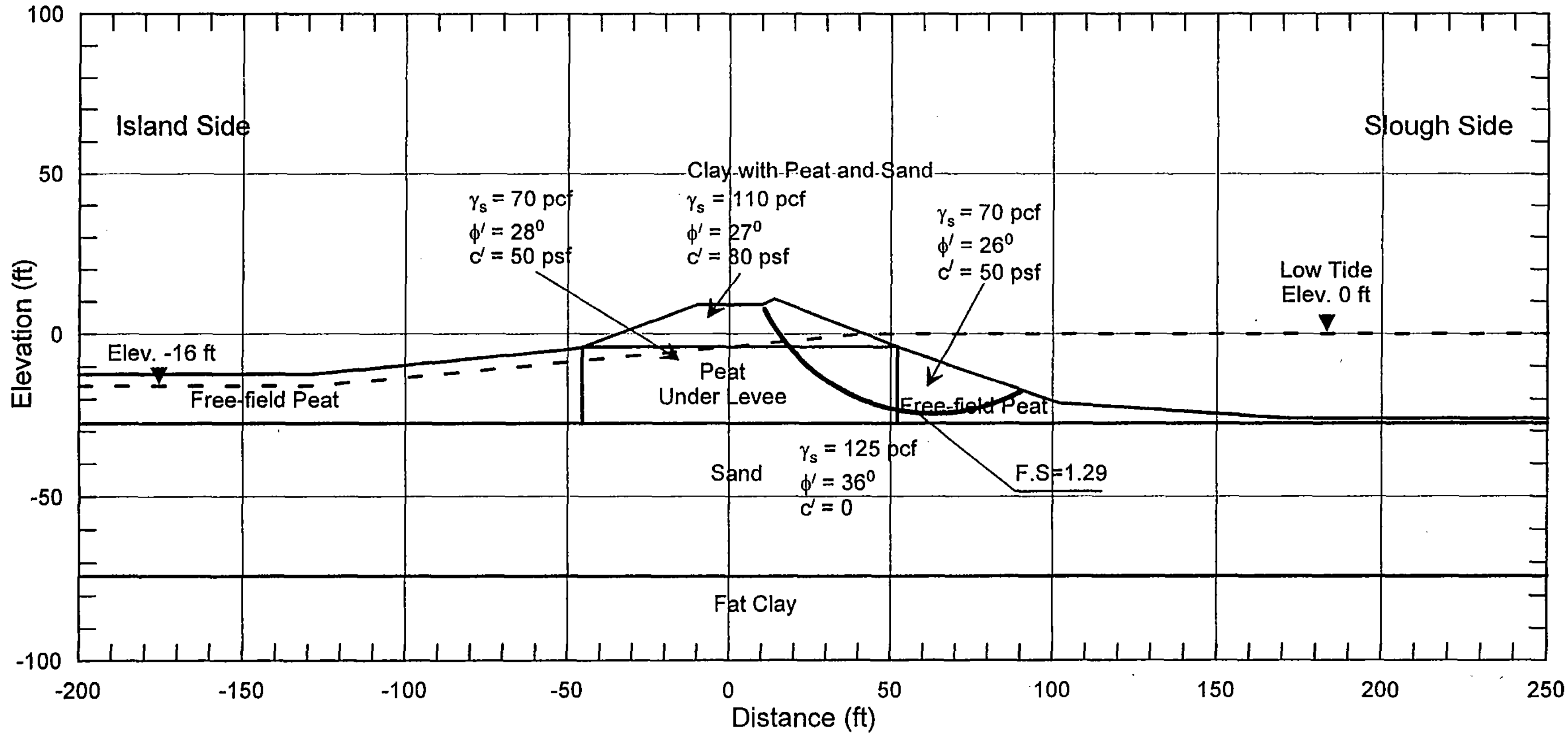
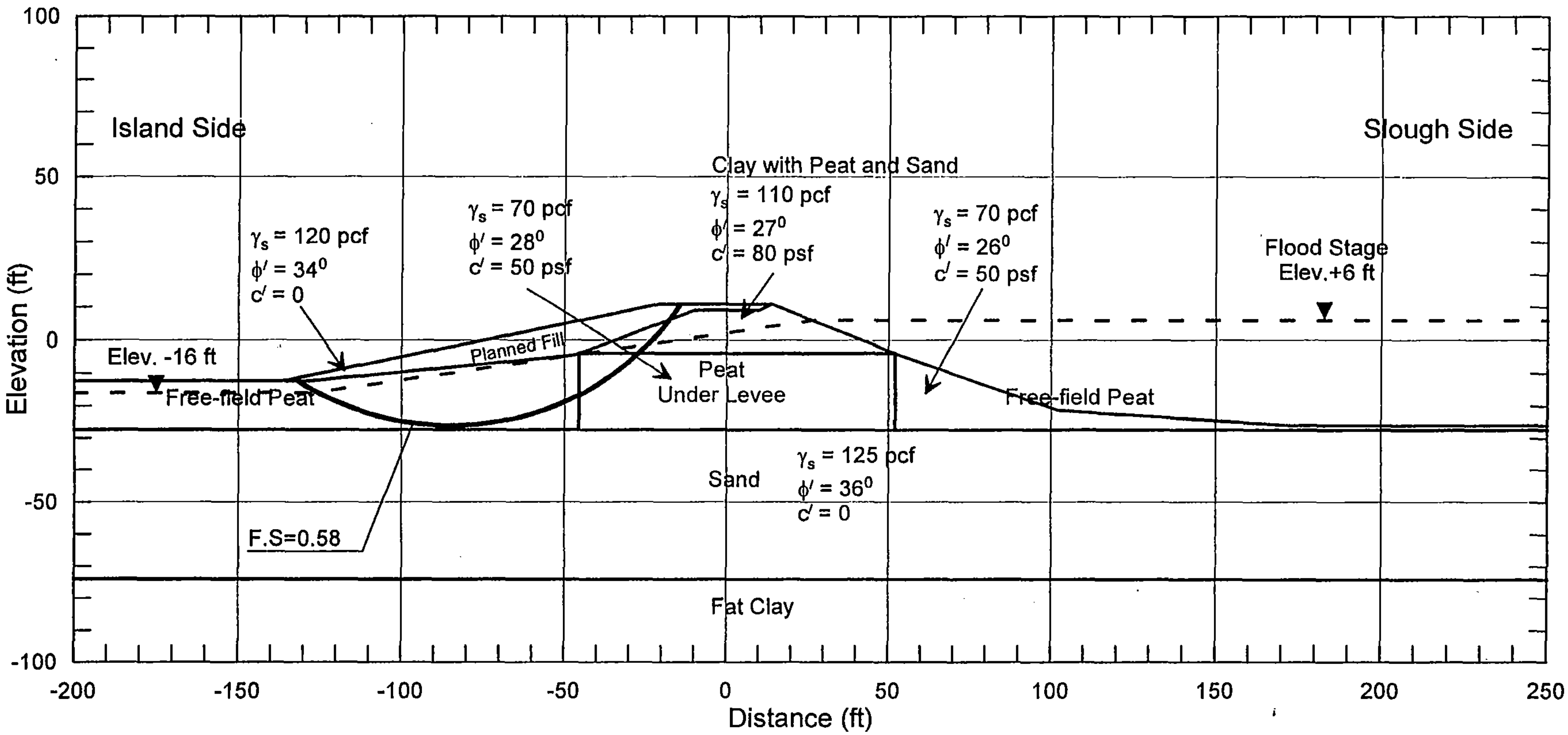


DELTA WETLANDS PROJECT	WEBB TRACT STA. 160+00 STABILITY ANALYSIS EXISTING CONDITION- TOWARD SLOUGH	FIGURE 3.5.20
URS GREINER WOODWARD CLYDE		

x:/ARULNA/deltawetland/webb160/w160slo.grf 12/2/99



DELTA WETLANDS PROJECT	WEBB TRACT STA. 160+00 STABILITY ANALYSIS, TWO-STAGE END OF CONSTRUCTION- INTO ISLAND	FIGURE 3.5.21
URS GREINER WOODWARD CLYDE		

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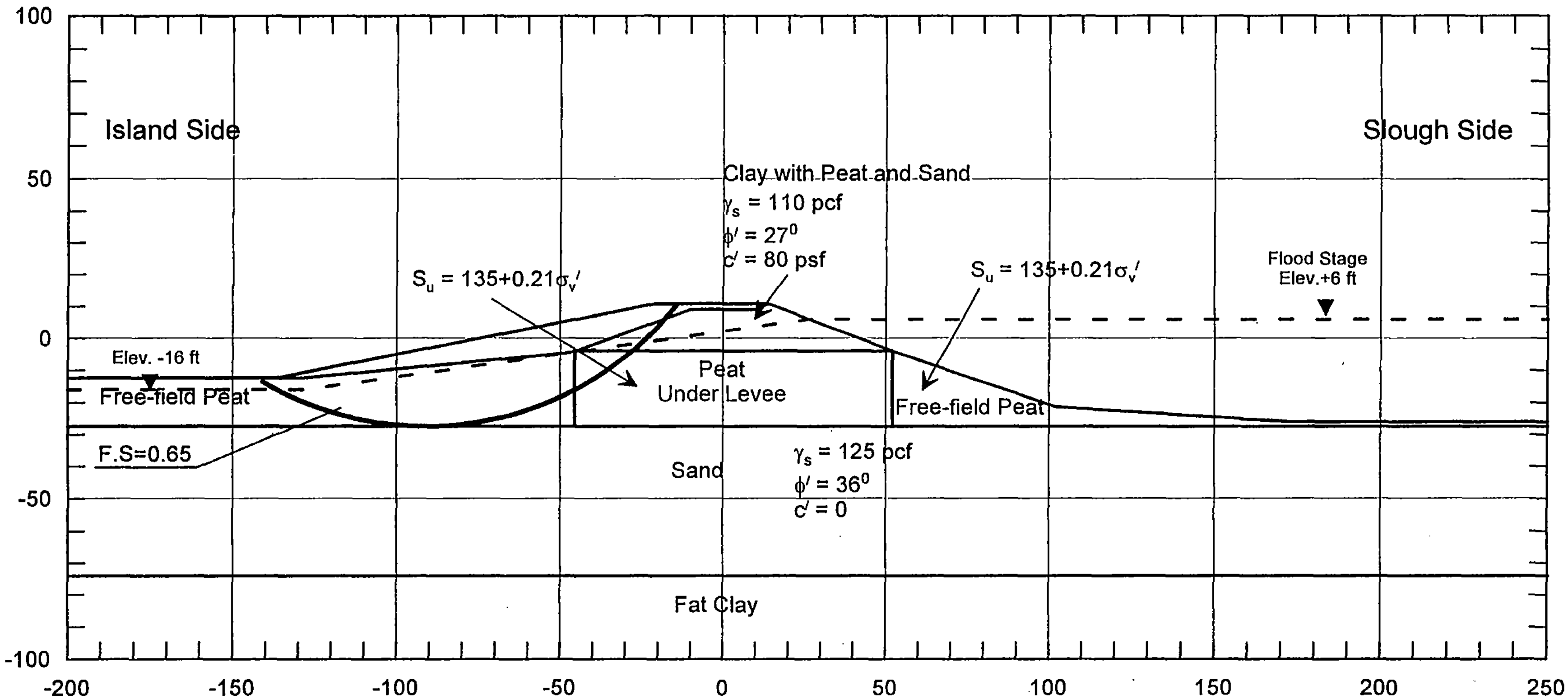

DELTA WETLANDS PROJECT	**WEBB TRACT STA. 160+00** **STABILITY ANALYSIS, S_u PROFILE** **END OF CONSTRUCTION- INTO ISLAND**	**FIGURE** **3.5.22**
URS GREINER WOODWARD CLYDE		

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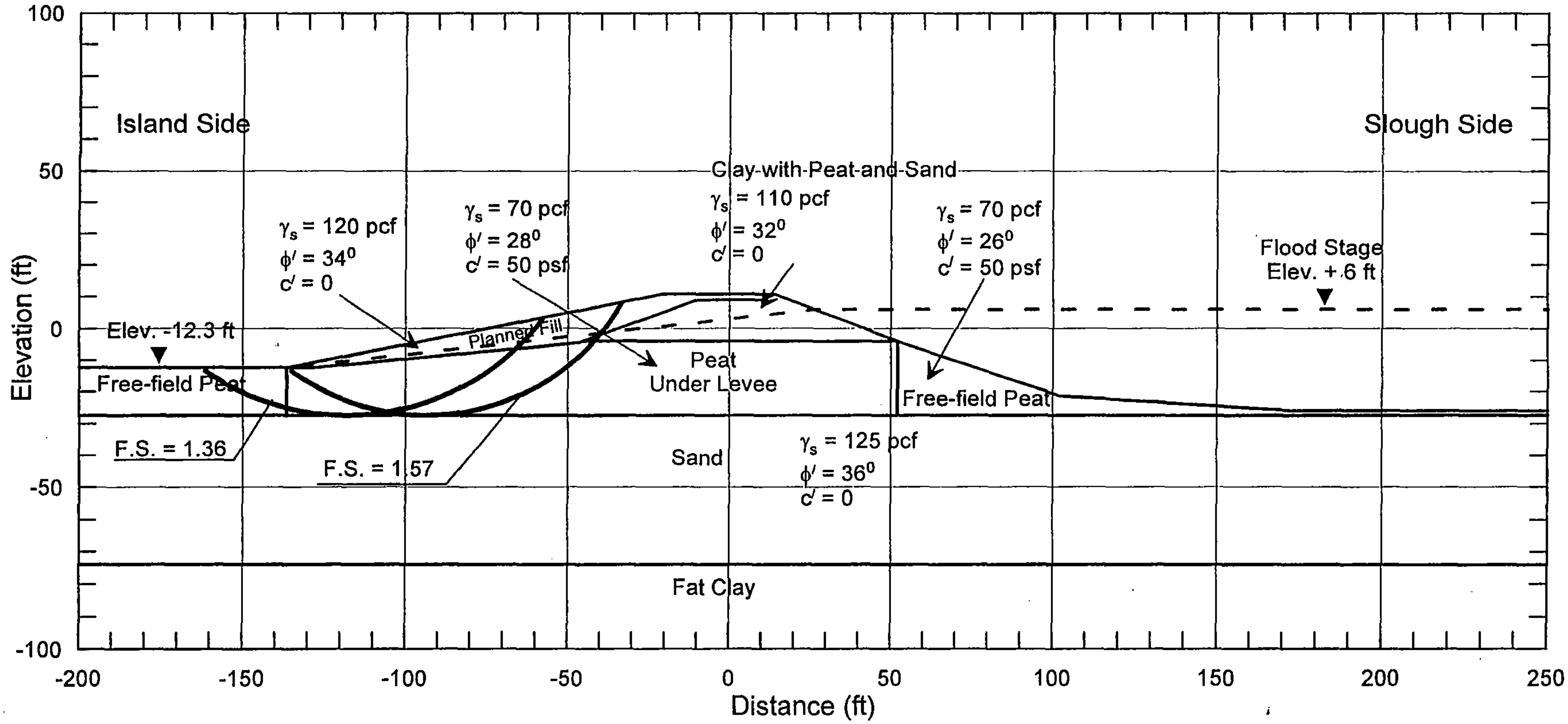

DELTA WETLANDS PROJECT	WEBB TRACT STA. 160+00 STABILITY ANALYSIS LONG-TERM CONDITION- INTO ISLAND	FIGURE 3.5.23
URS GREINER WOODWARD CLYDE		

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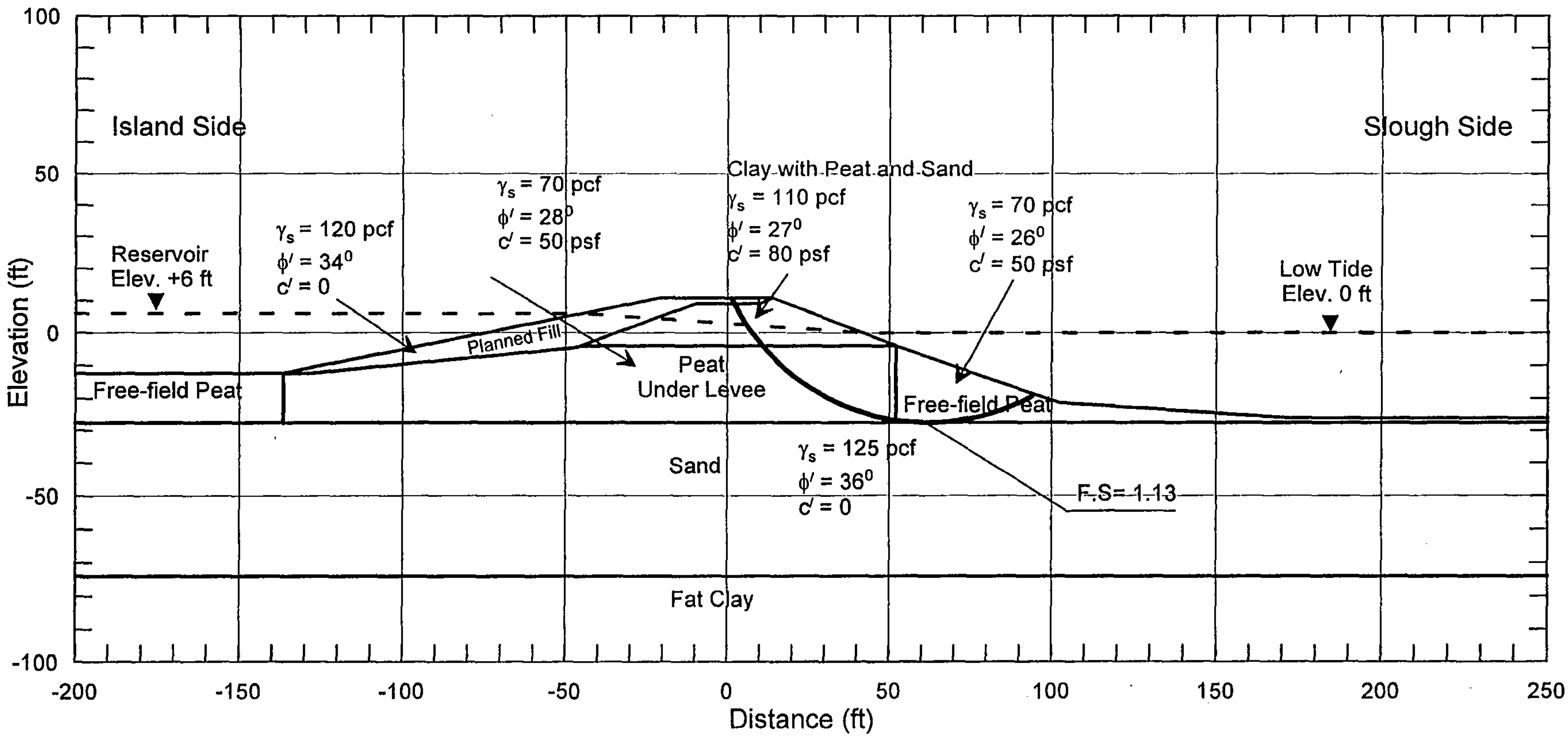

DELTA WETLANDS PROJECT *URS GREINER WOODWARD CLYDE*	WEBB TRACT STA. 160+00 STABILITY ANALYSIS LONG-TERM CONDITION- TOWARD SLOUGH	FIGURE 3.5.24

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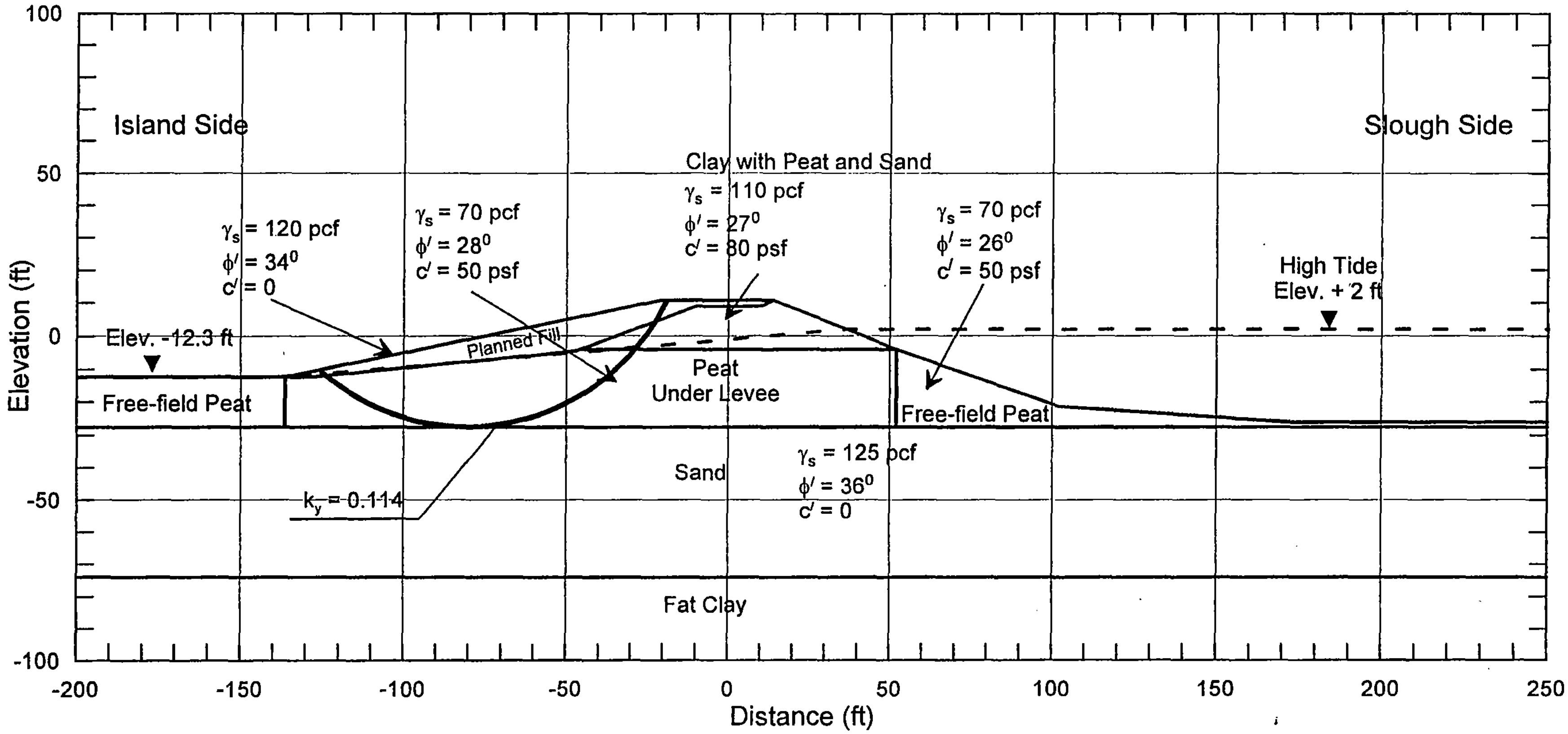

DELTA WETLANDS PROJECT	WEBB TRACT STA. 160+00 STABILITY ANALYSIS SEISMIC CONDITION- INTO ISLAND	FIGURE 3.5.25
URS GREINER WOODWARD CLYDE		

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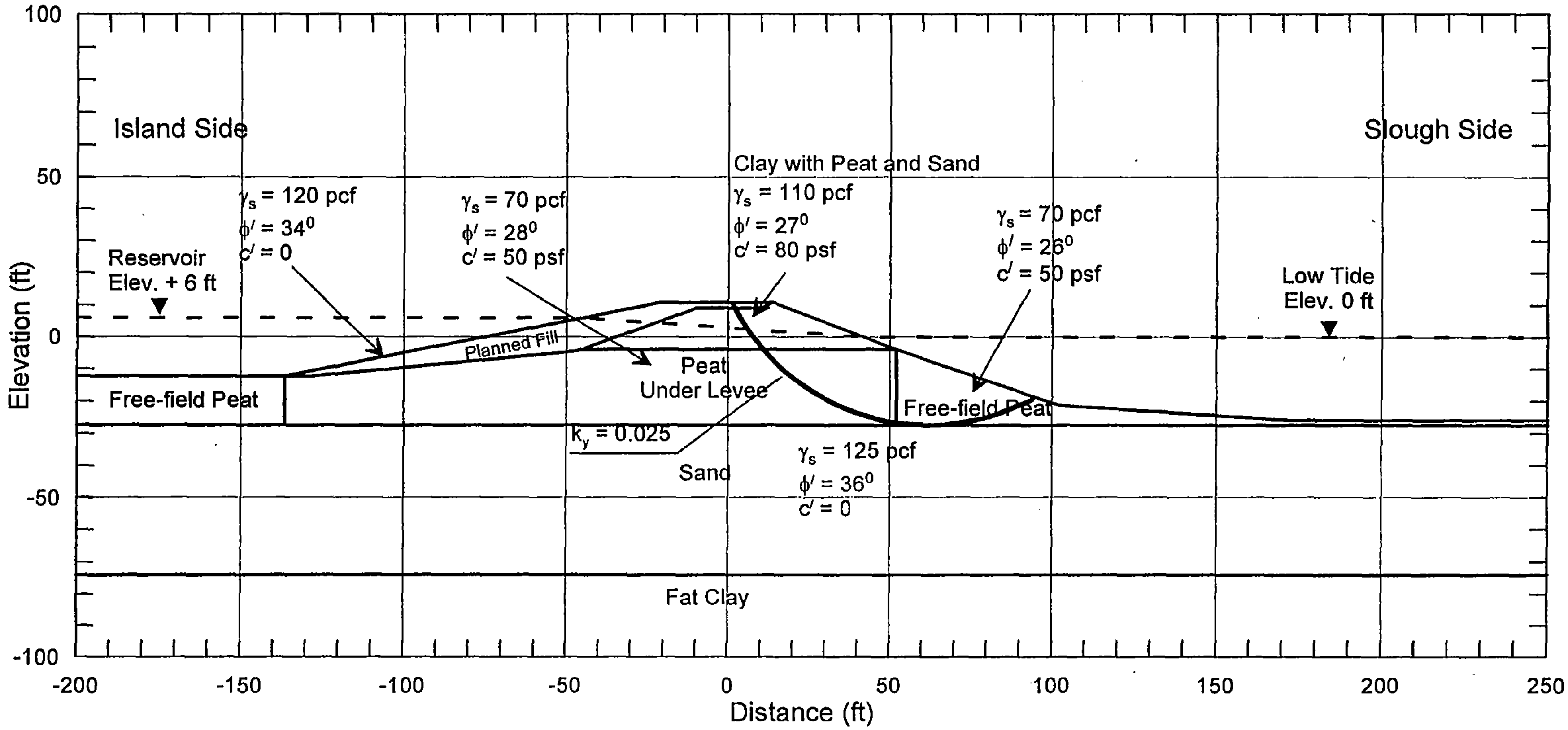

DELTA WETLANDS PROJECT	WEBB TRACT STA. 160+00 STABILITY ANALYSIS SEISMIC CONITION TOWARD SLOUGH	FIGURE 3.5.26
URS Greiner Woodward Clyde		

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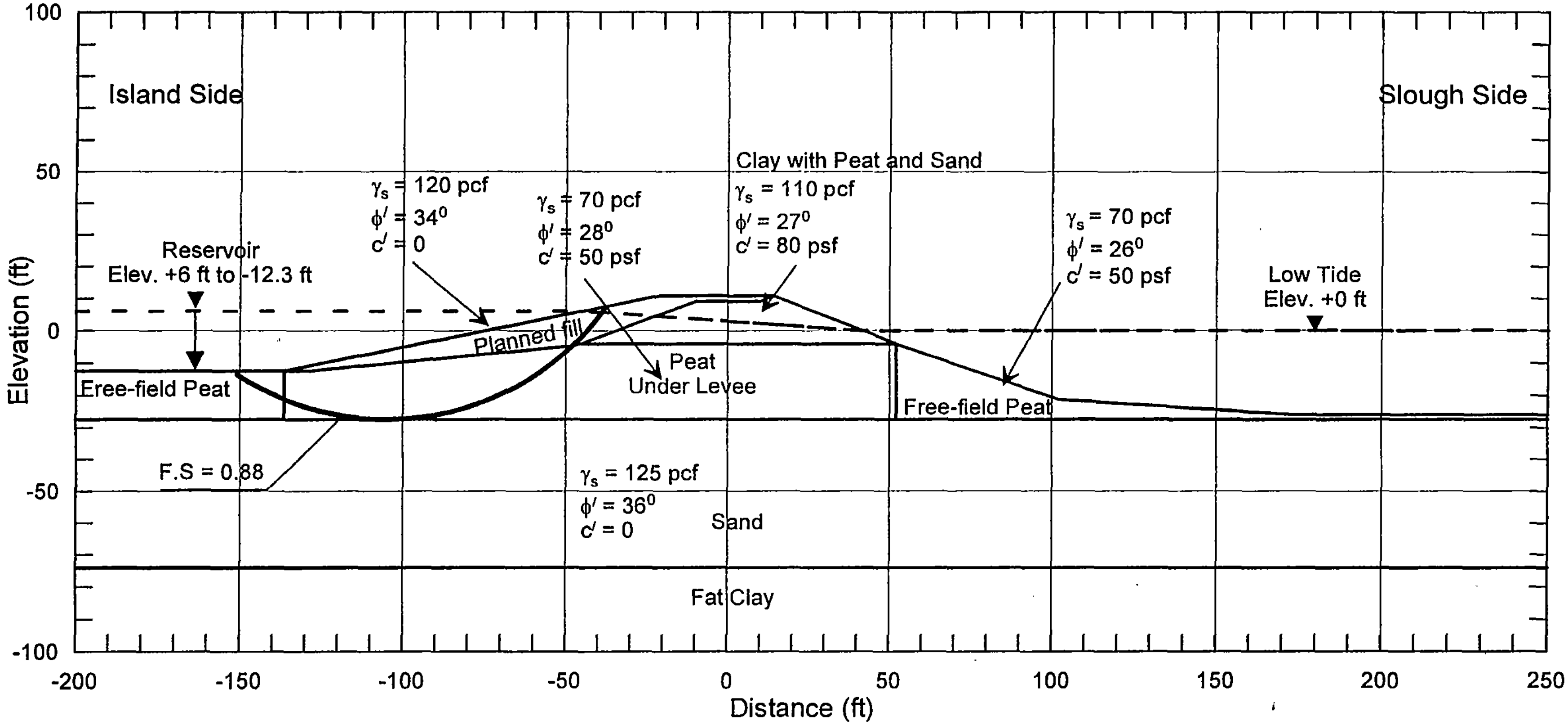

DELTA WETLANDS PROJECT	WEBB TRACT STA. 160+00 STABILITY ANALYSIS, THREE-STAGE SUDDEN DRAWDOWN CONDITION - INTO ISLAND	FIGURE 3.5.27
URS GREINER WOODWARD CLYDE		

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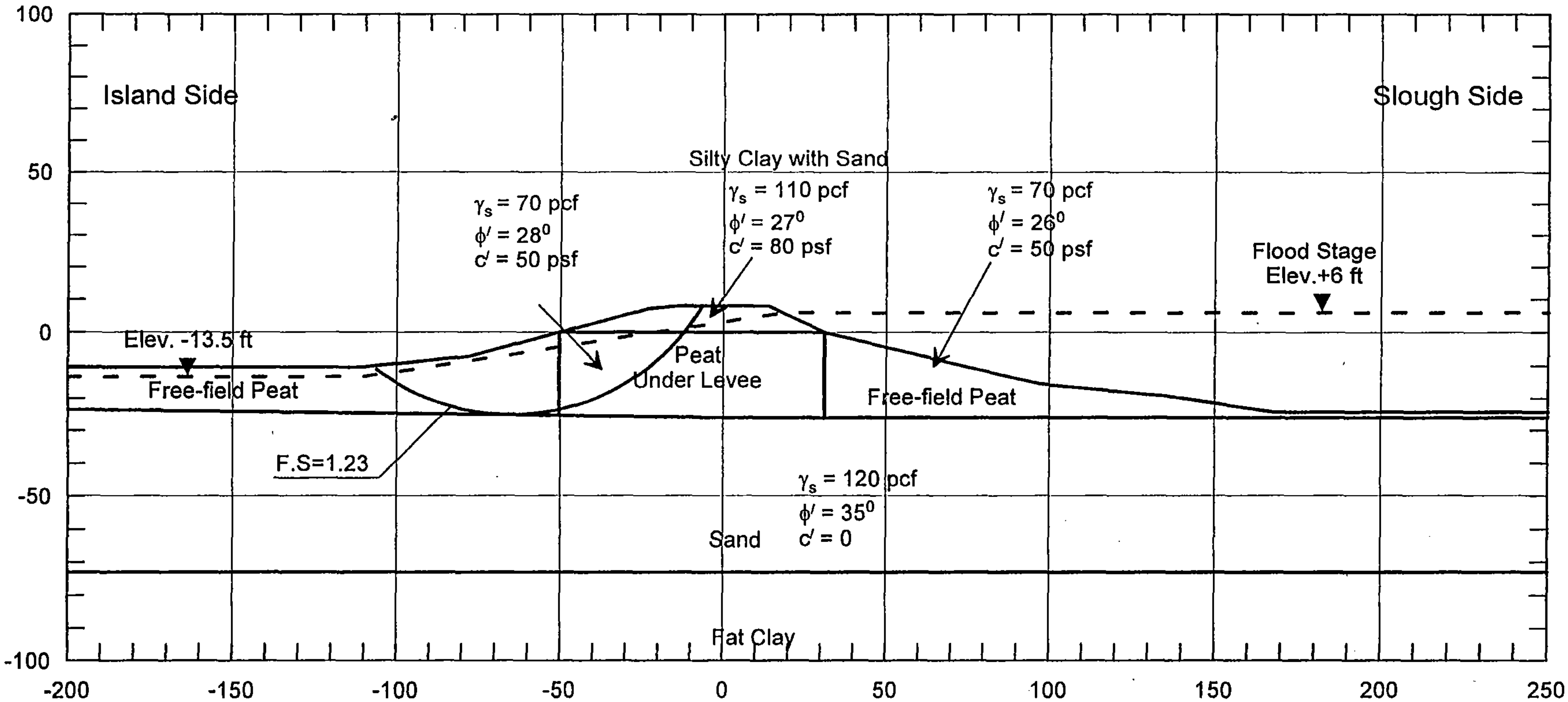

DELTA WETLANDS PROJECT	BACON ISLAND STA. 25+00 STABILITY ANALYSIS EXISTING CONDITON- INTO ISLAND	FIGURE 3.5.28
URS GREINER WOODWARD CLYDE		

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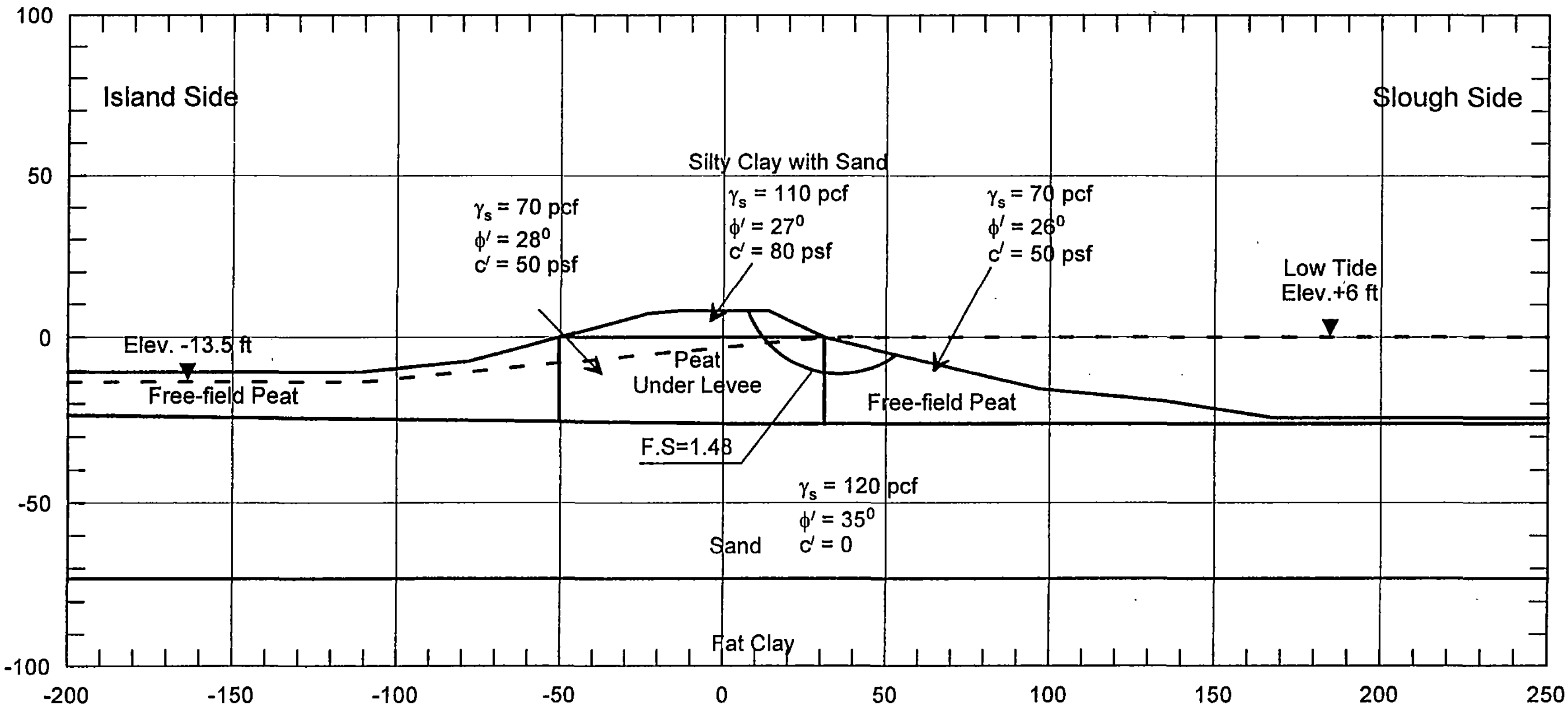

DELTA WETLANDS PROJECT	BACON ISLAND STA. 25+00 STABILITY ANALYSIS EXISTING CONDITON- TOWARD SLOUGH	FIGURE 3.5.29
URS GREINER WOODWARD CLYDE		

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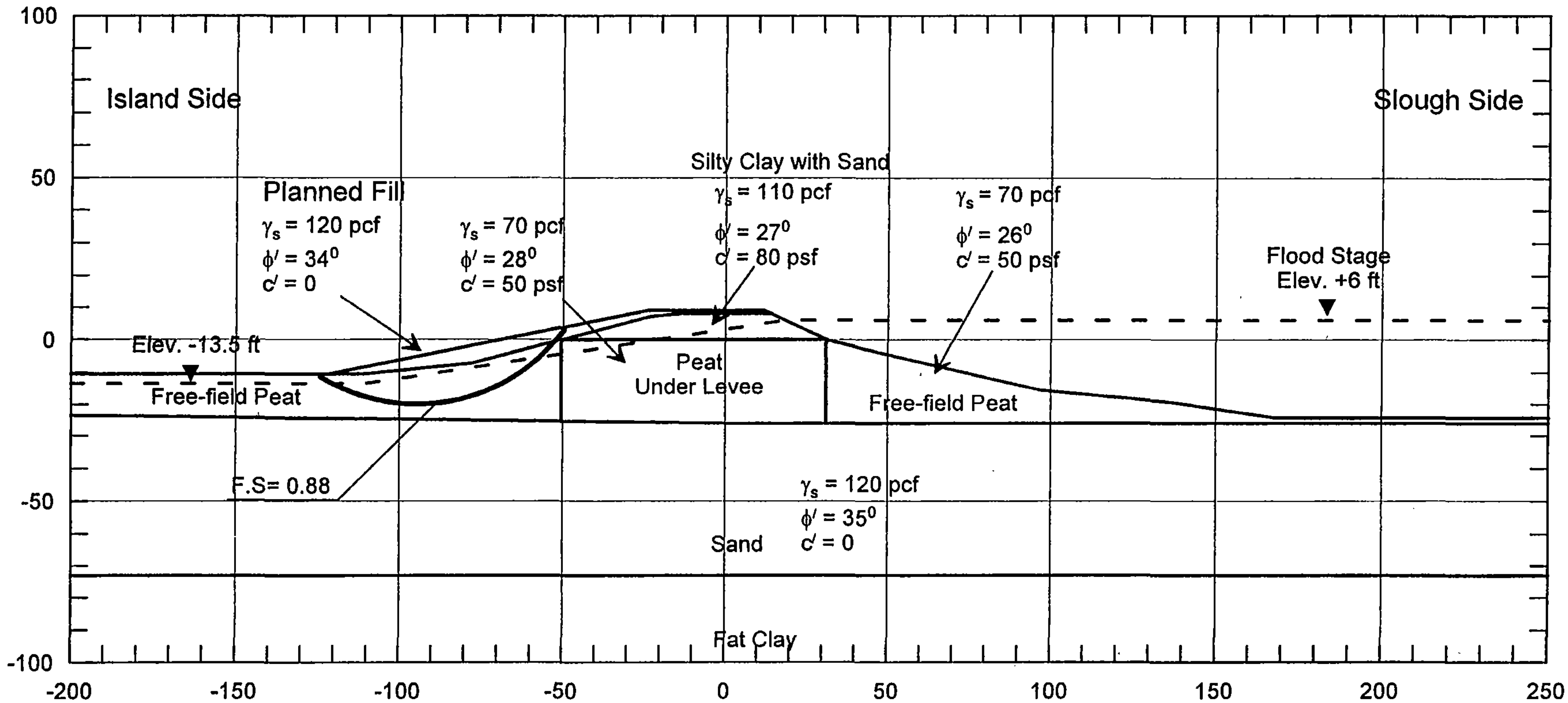

DELTA WETLANDS PROJECT	BACON ISLAND STA. 25+00 STABILITY ANALYSIS, TWO-STAGE END OF CONSTRUCTION- INTO ISLAND	FIGURE 3.5.30
URS GREINER WOODWARD CLYDE		

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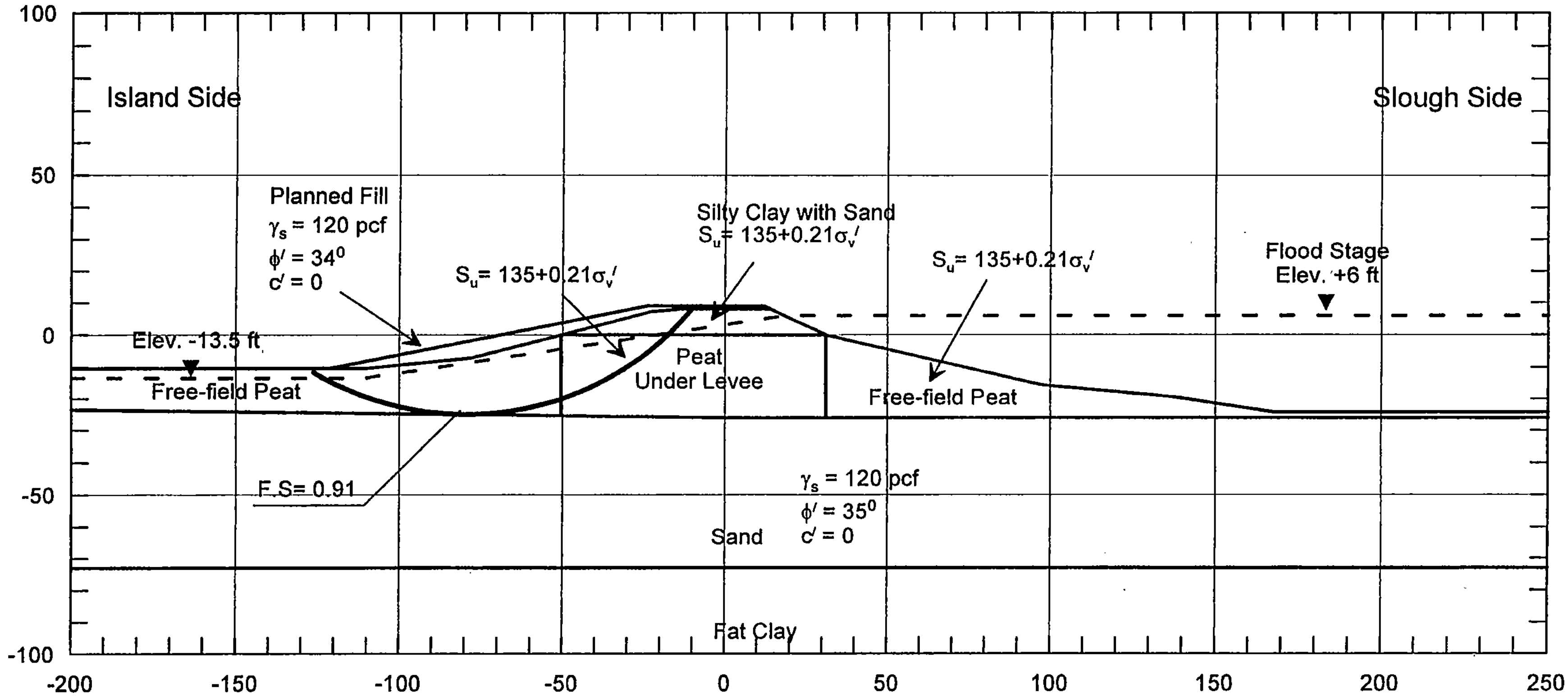

DELTA WETLANDS PROJECT	BACON ISLAND STA. 25+00 STABILITY ANALYSIS, S_u PROFILE END OF CONSTRUCTION- INTO ISLAND	FIGURE 3.5.31
URS GREINER WOODWARD CLYDE		

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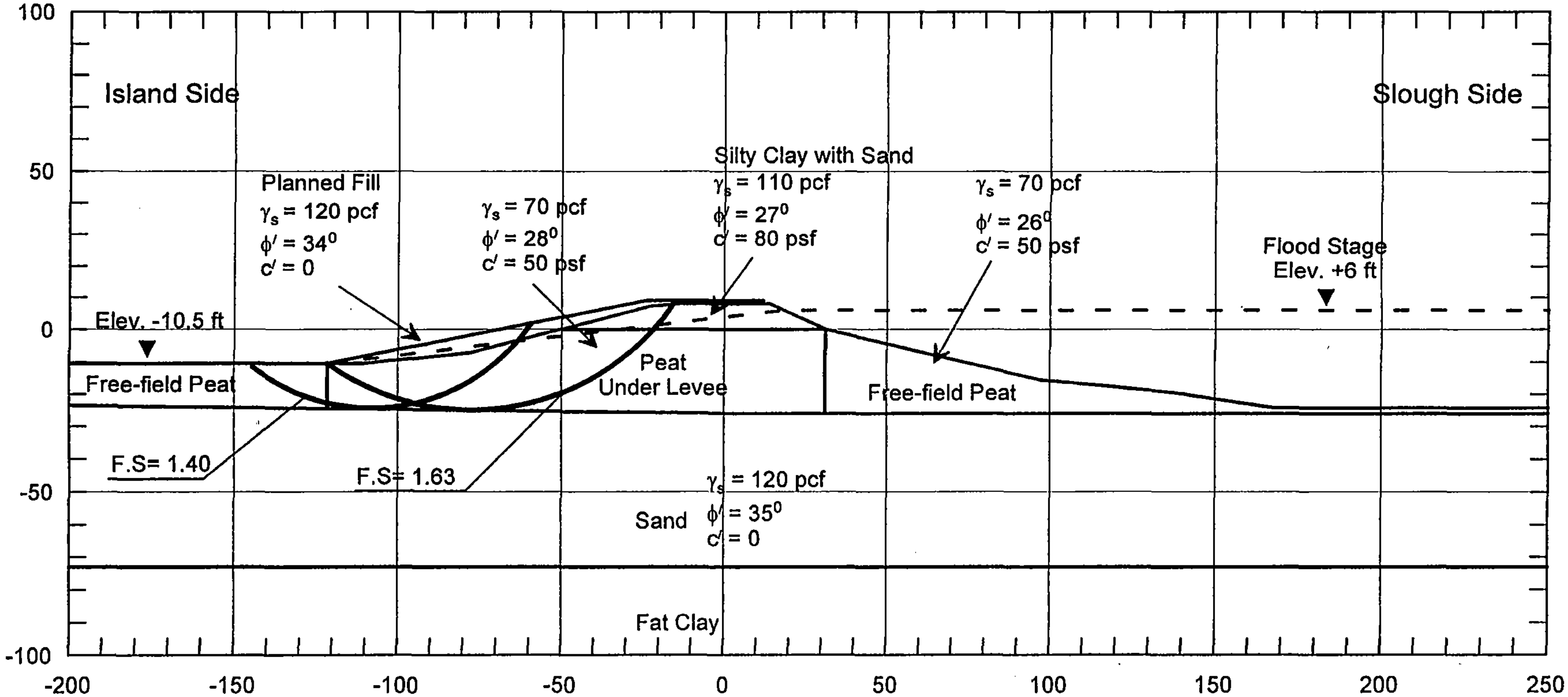

DELTA WETLANDS PROJECT	BACON ISLAND STA. 25+00 STABILITY ANALYSIS LONG-TERM CONDITION- INTO ISLAND	FIGURE 3.5.32
URS GREINER WOODWARD CLYDE		

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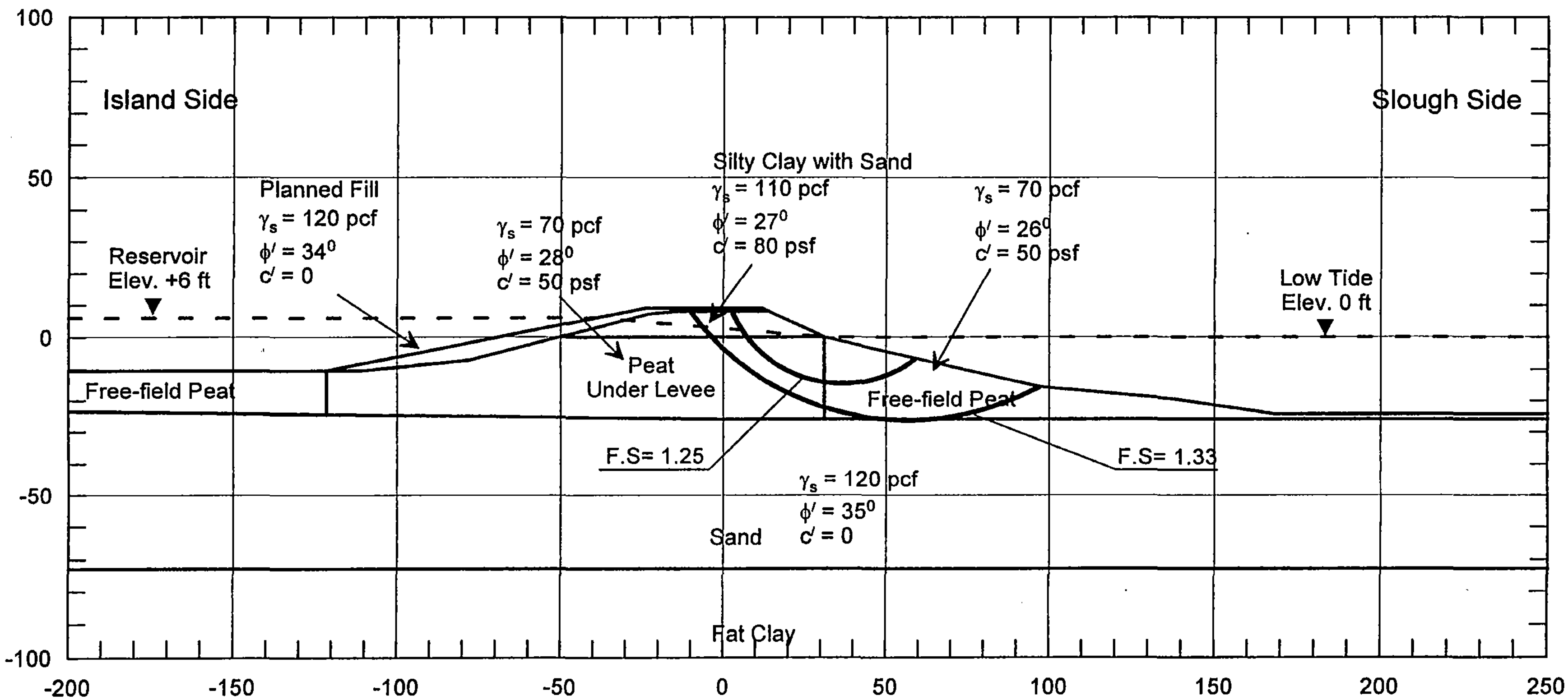

DELTA WETLANDS PROJECT	BACON ISLAND STA. 25+00 STABILITY ANALYSIS LONG-TERM CONDITION- TOWARD SLOUGH	FIGURE 3.5.33
URS GREINER WOODWARD CLYDE		

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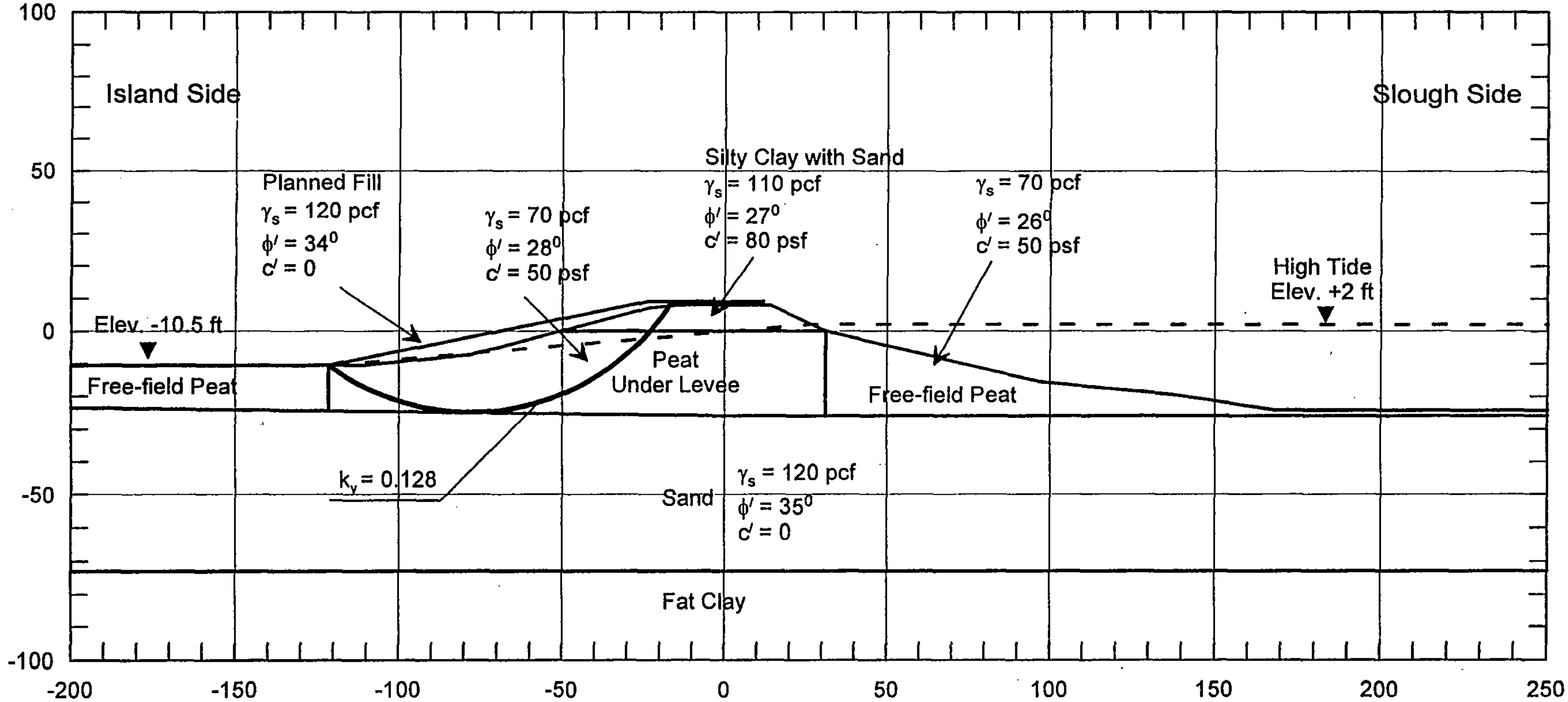
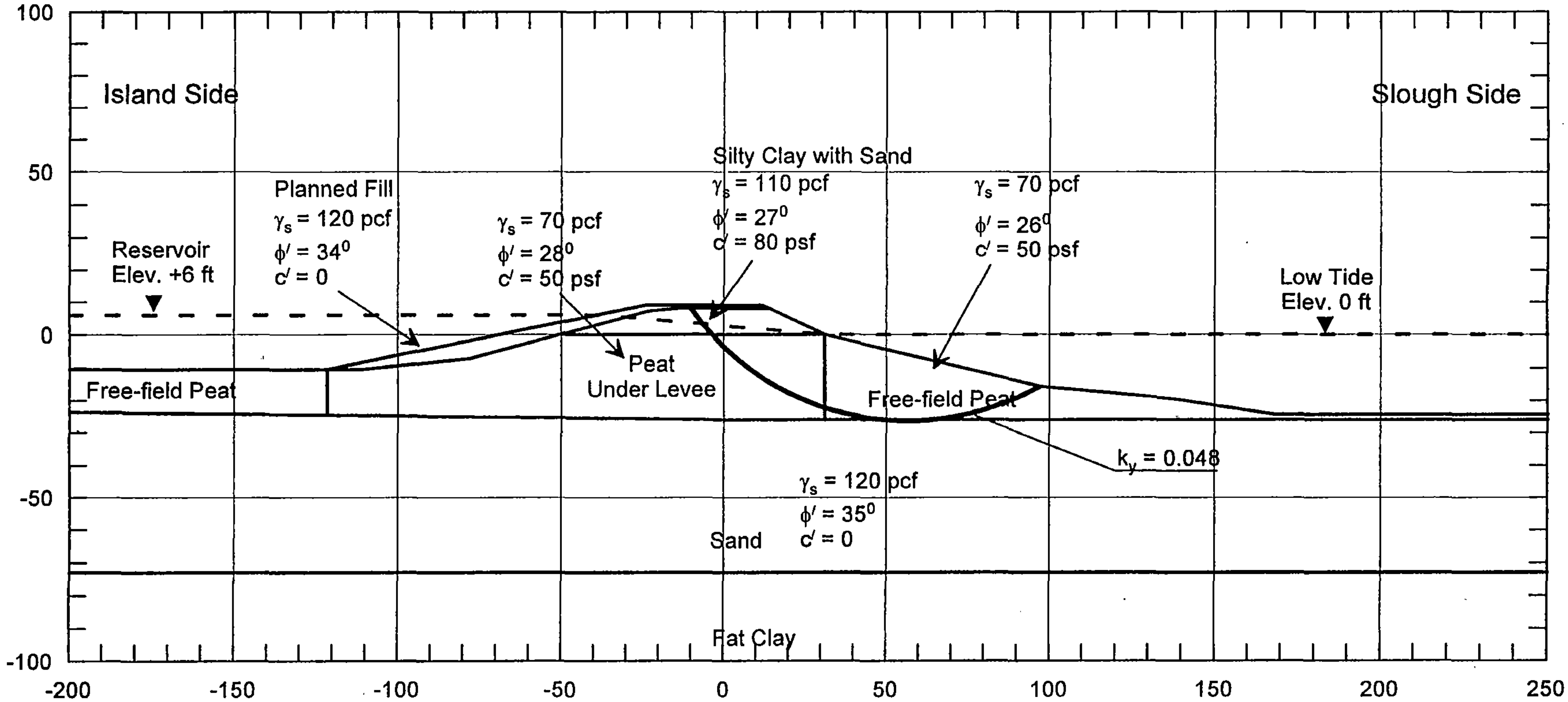


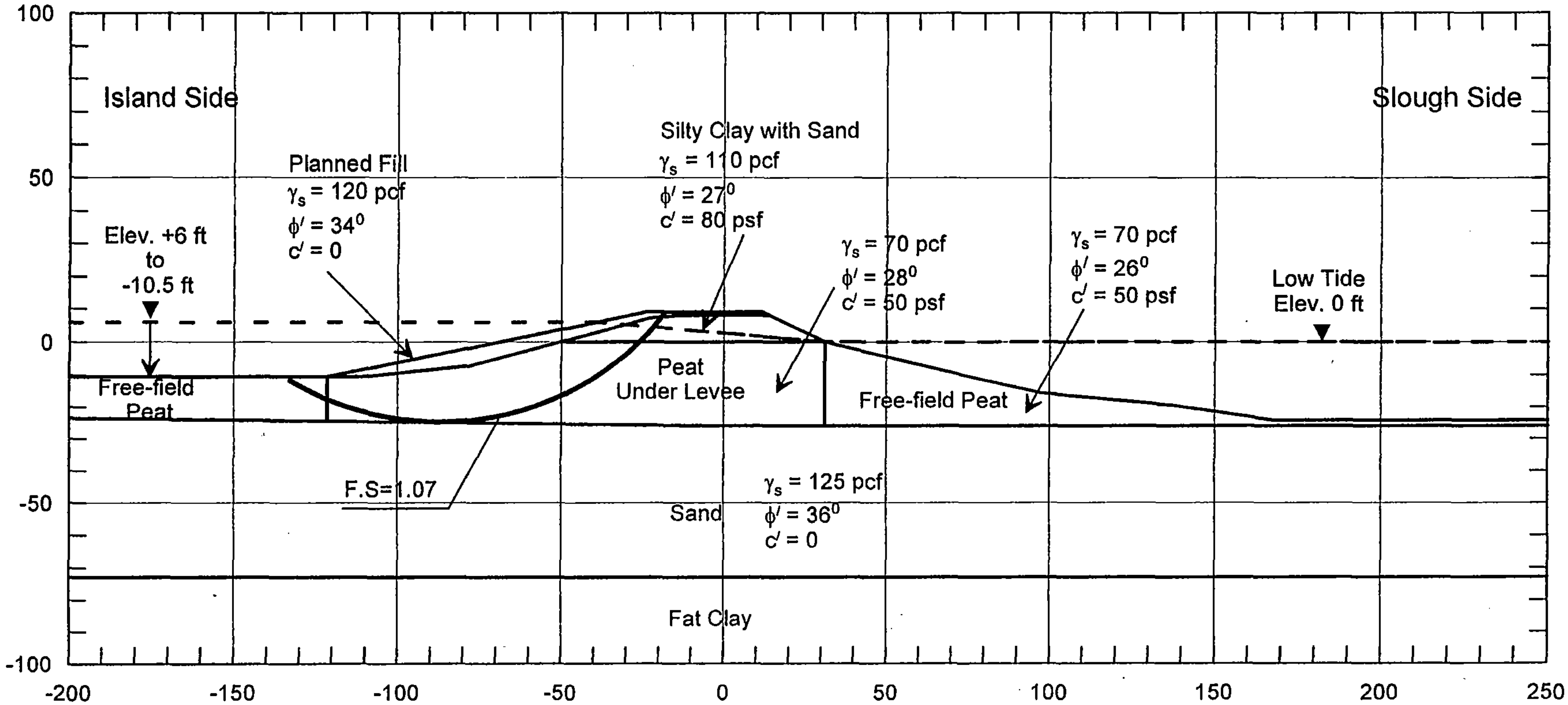
DELTA WETLANDS PROJECT	BACON ISLAND STA. 25+00 STABILITY ANALYSIS SEISMIC CONDITION- INTO ISLAND	FIGURE 3.5.34
URS GREINER WOODWARD CLYDE		

x:/ARULNA/deltawetland/Bacon25/ba25seis.grf 12/2/99



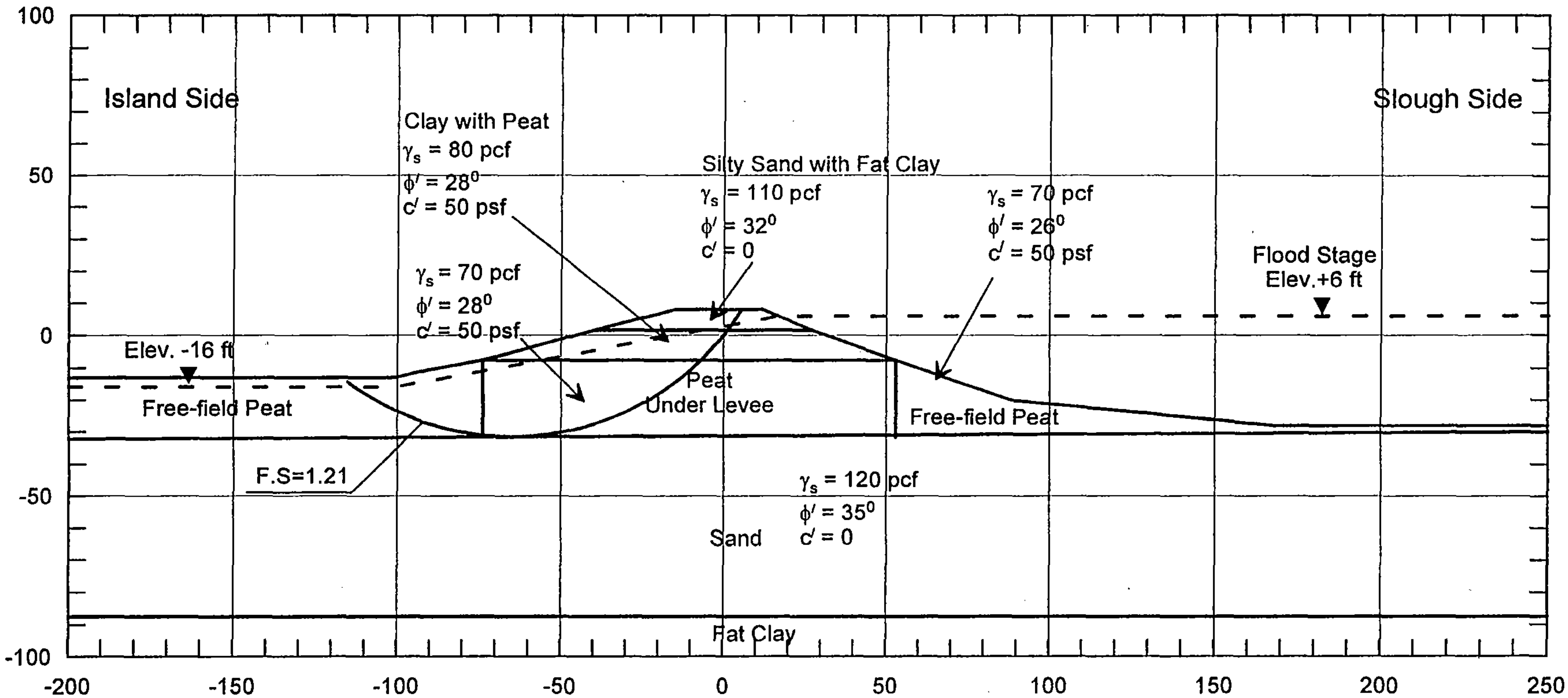
DELTA WETLANDS PROJECT	BACON ISLAND STA. 25+00 STABILITY ANALYSIS SEISMIC CONDITION- TOWARD SLOUGH	FIGURE 3.5.35
URS GREINER WOODWARD CLYDE		

x:/ARULNA/deltawetland/Bacon25/ba25sesl.grf 12/2/99



DELTA WETLANDS PROJECT	BACON ISLAND STA. 25+00 STABILITY ANALYSIS, THREE-STAGE SUDDEN DRAWDOWN CONDITION - INTO ISLAND	FIGURE 3.5.36
URS GREINER WOODWARD CLYDE		

x:/ARULNA/deltawetland/Bacon25/ba25rap.grf 12/2/99



DELTA WETLANDS PROJECT	BACON ISLAND STA. 265+00 STABILITY ANALYSIS EXISTING CONDITON- INTO ISLAND	FIGURE 3.5.37
URS GREINER WOODWARD CLYDE		

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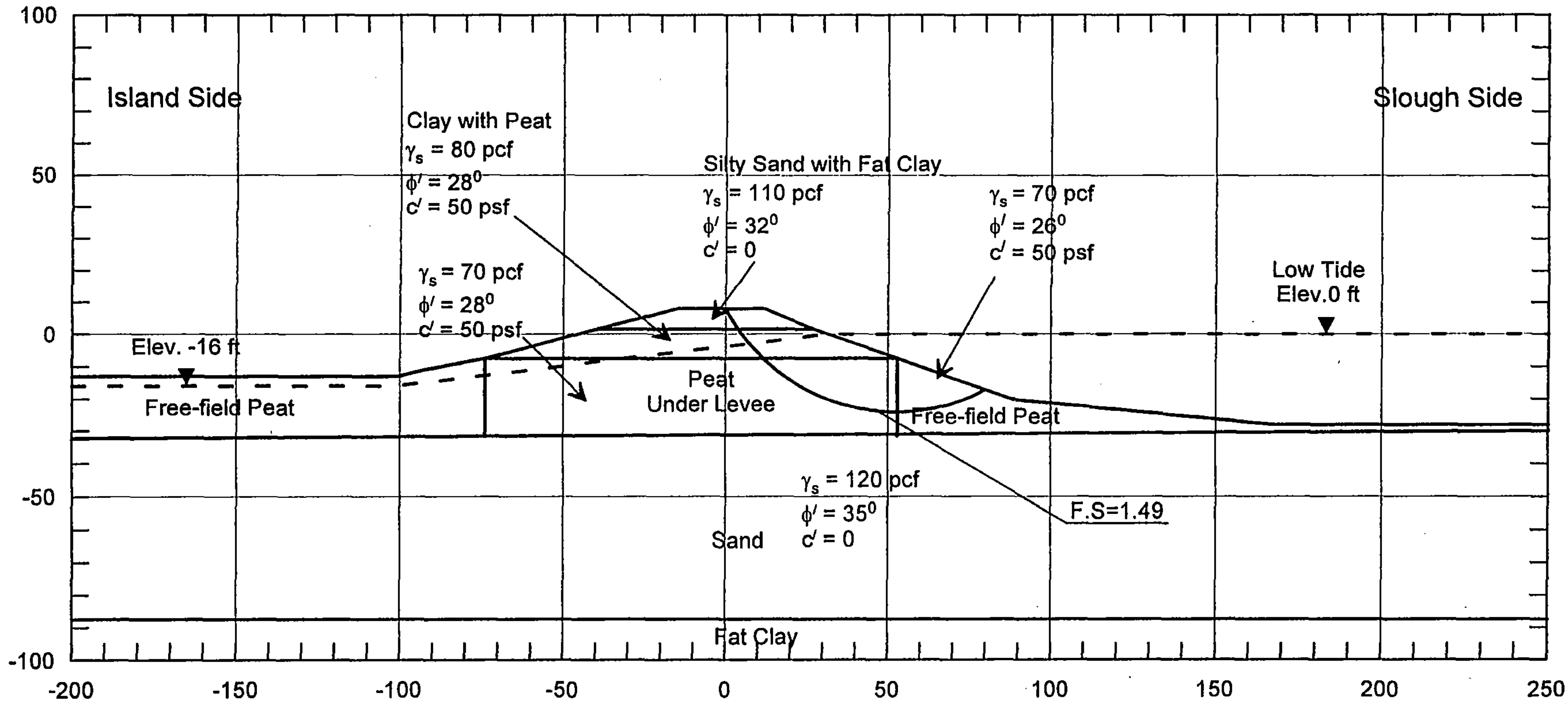

DELTA WETLANDS PROJECT	**BACON ISLAND STA. 265+00 STABILITY ANALYSIS EXISTING CONDITON- TOWARD SLOUGH**	**FIGURE 3.5.38**
URS GREINER WOODWARD CLYDE		

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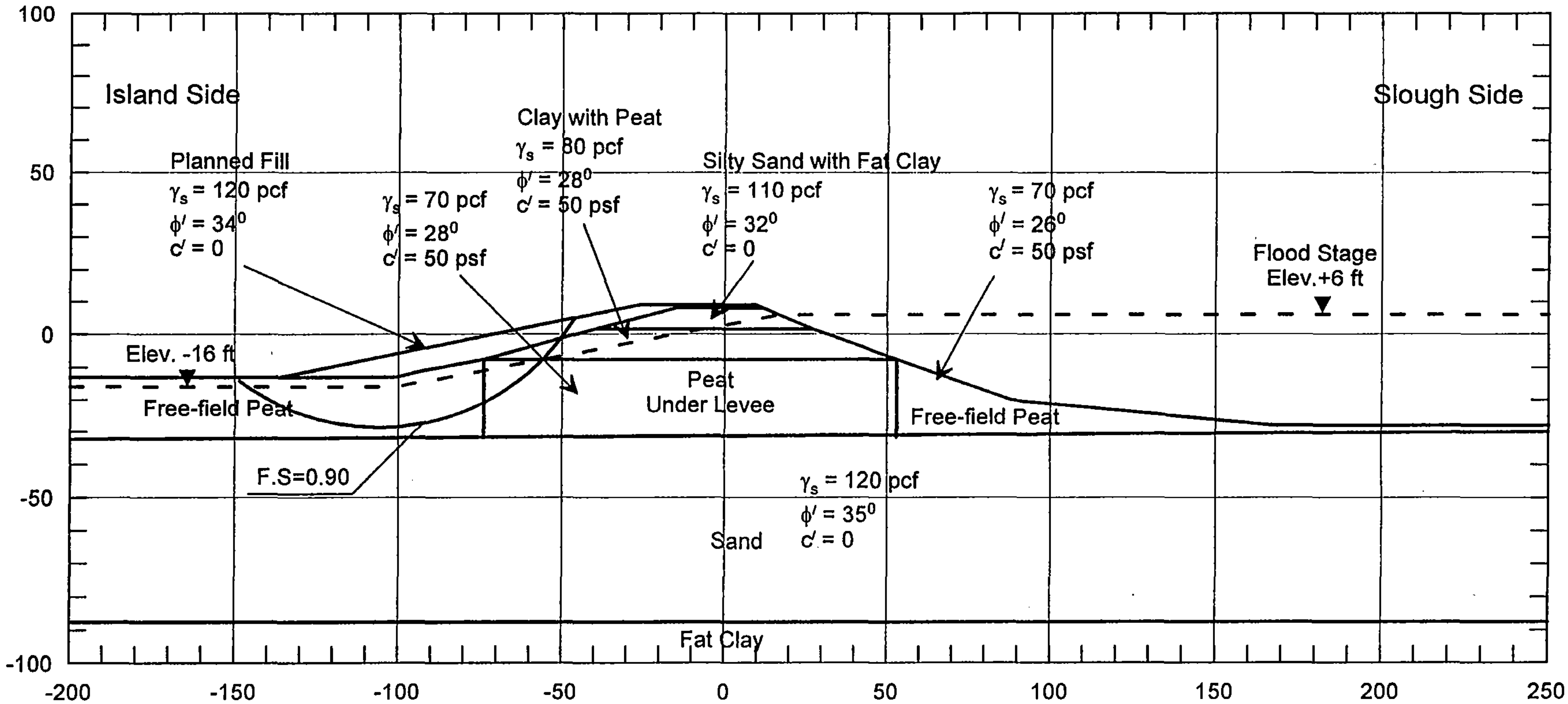

DELTA WETLANDS PROJECT	BACON ISLAND STA. 265+00 STABILITY ANALYSIS, TWO-STAGE END OF CONSTRUCTION- INTO ISLAND	FIGURE 3.5.39
URS GREINER WOODWARD CLYDE		

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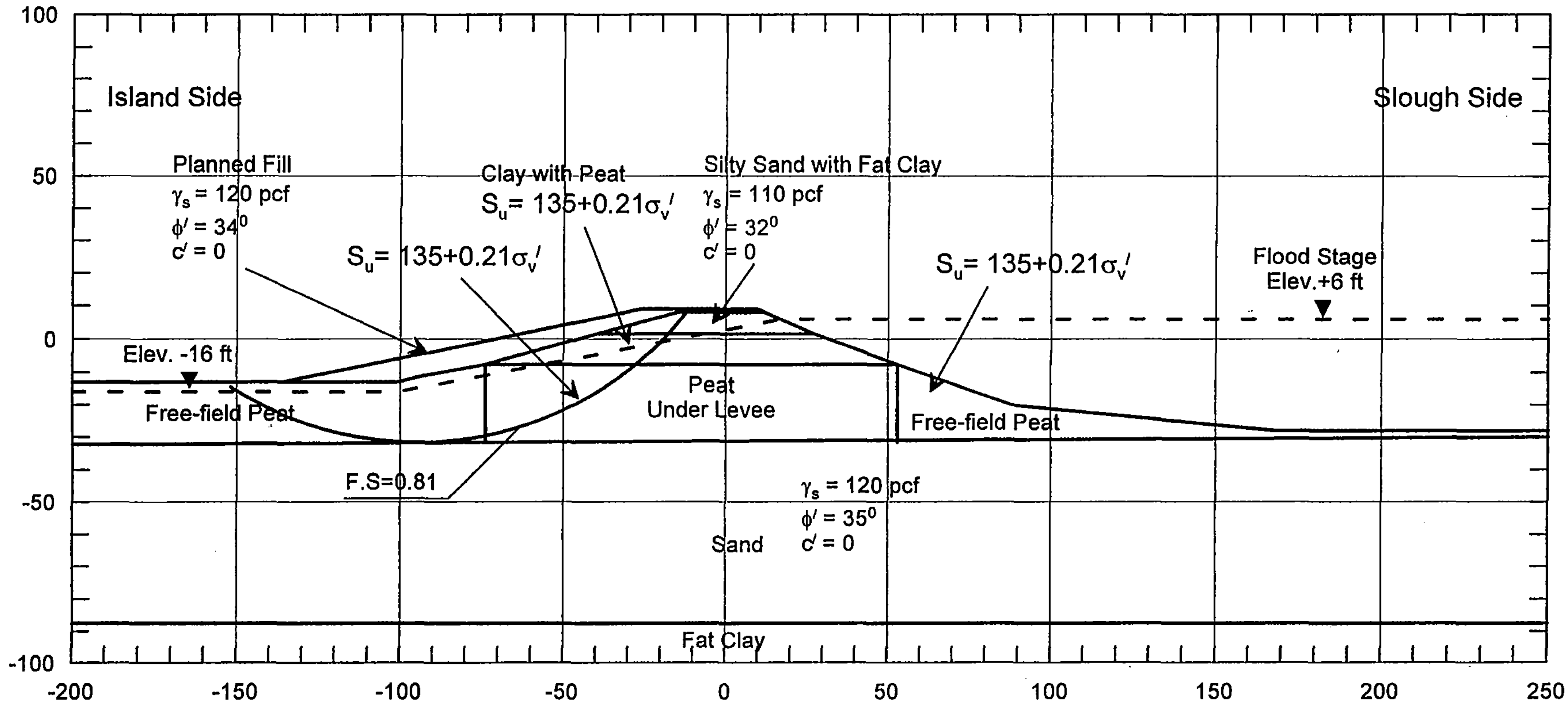

DELTA WETLANDS PROJECT	**BACON ISLAND STA. 265+00 STABILITY ANALYSIS, S_u PROFILE END OF CONSTRUCTION- INTO ISLAND**	**FIGURE 3.5.40**
URS GREINER WOODWARD CLYDE		

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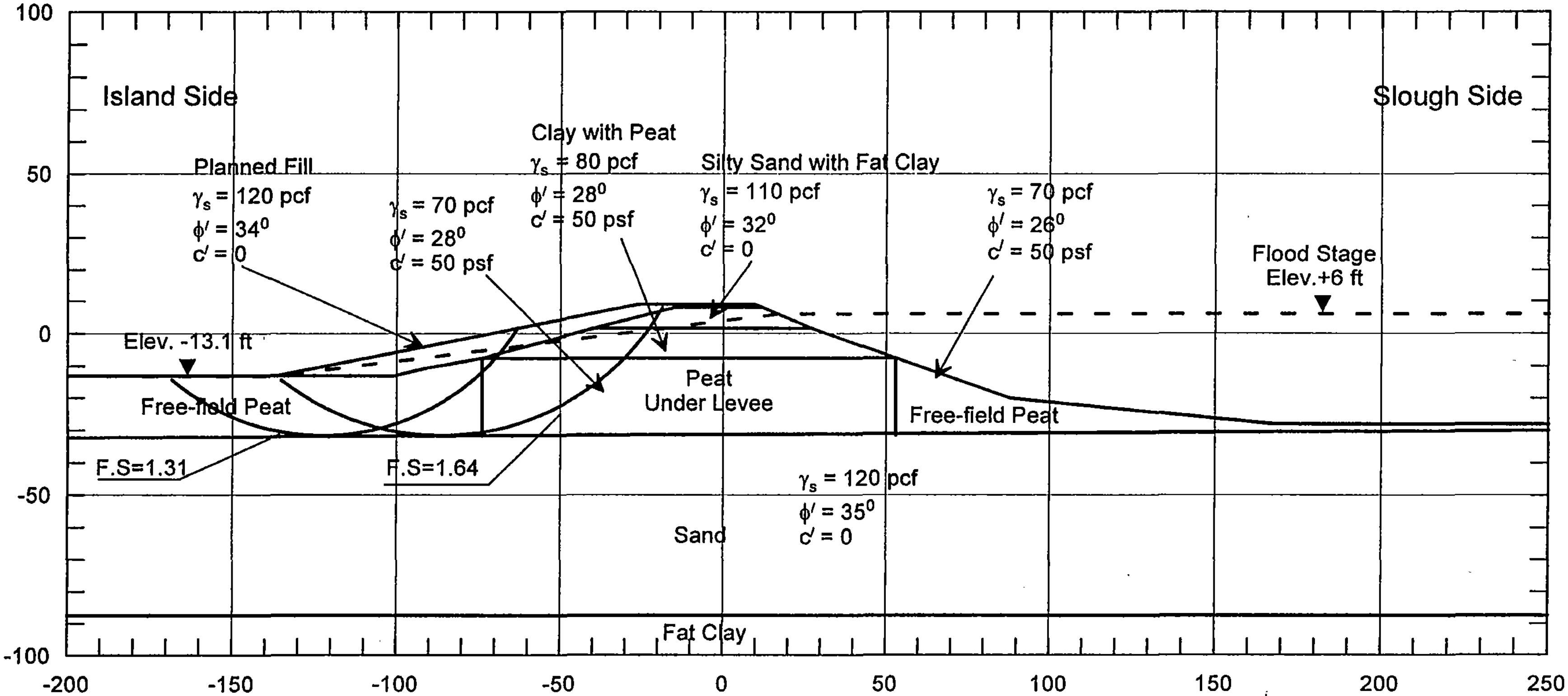

DELTA WETLANDS PROJECT	BACON ISLAND STA. 265+00 STABILITY ANALYSIS LONG-TERM CONDITION- INTO ISLAND	FIGURE 3.5.41
URS GREINER WOODWARD CLYDE		

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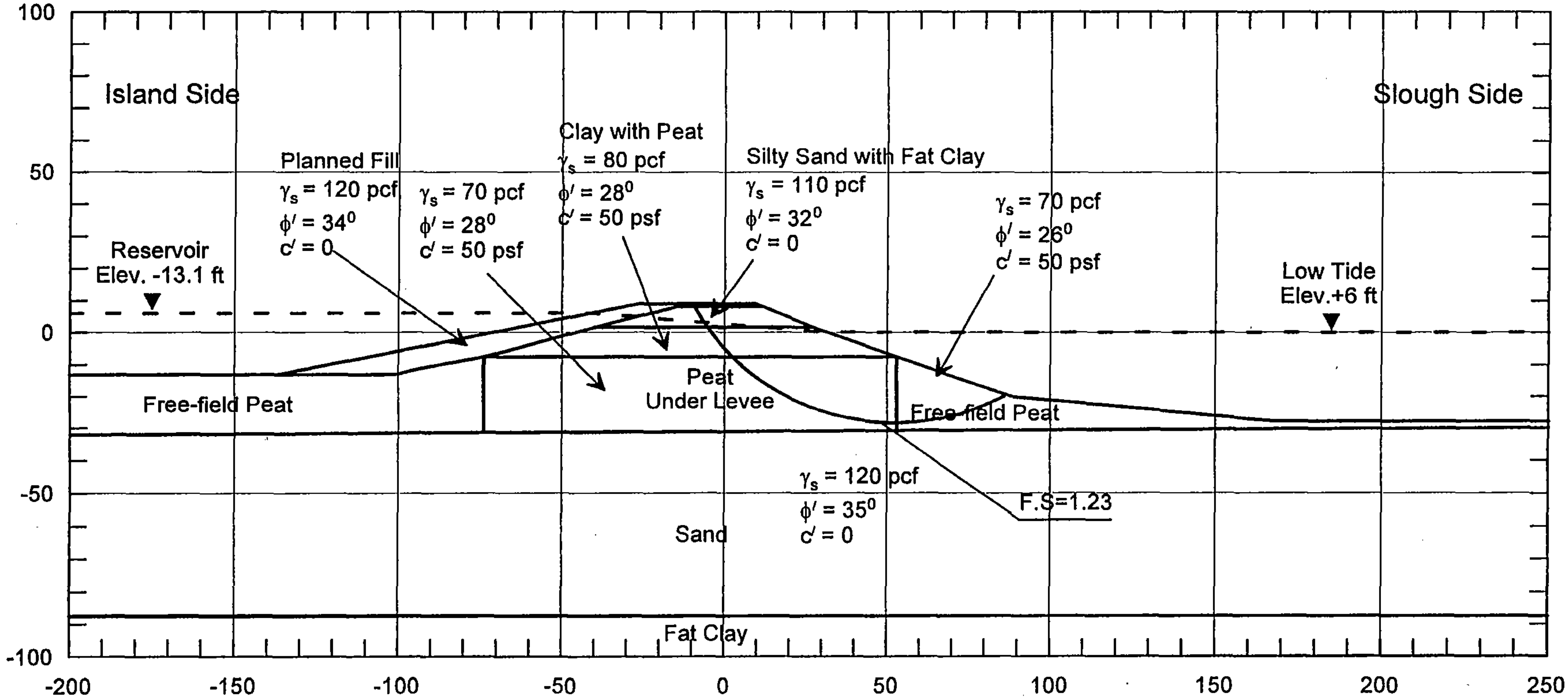

DELTA WETLANDS PROJECT

URS GREINER WOODWARD CLYDE

BACON ISLAND STA. 265+00
STABILITY ANALYSIS
LONG-TERM CONDITION- TOWARD SLOUGH

FIGURE 3.5.42

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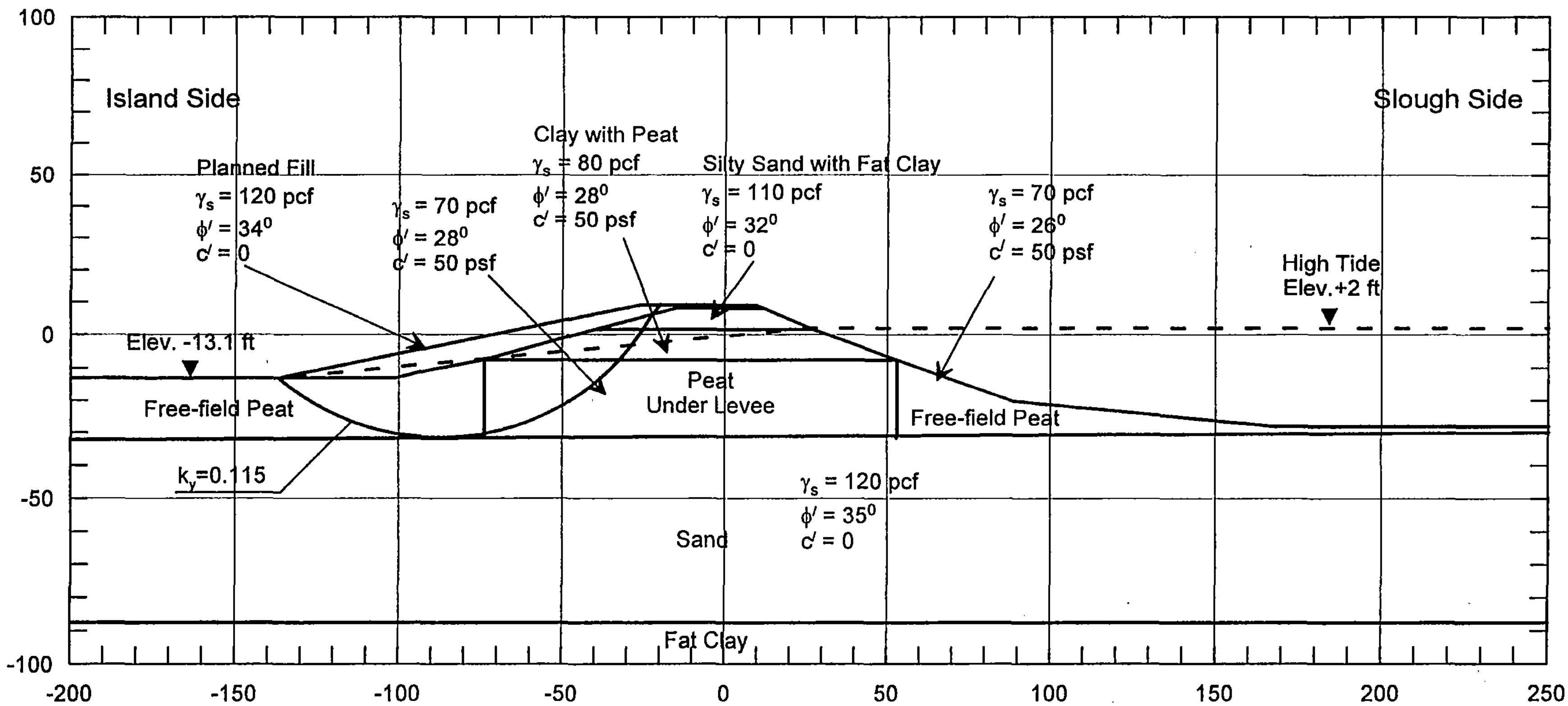
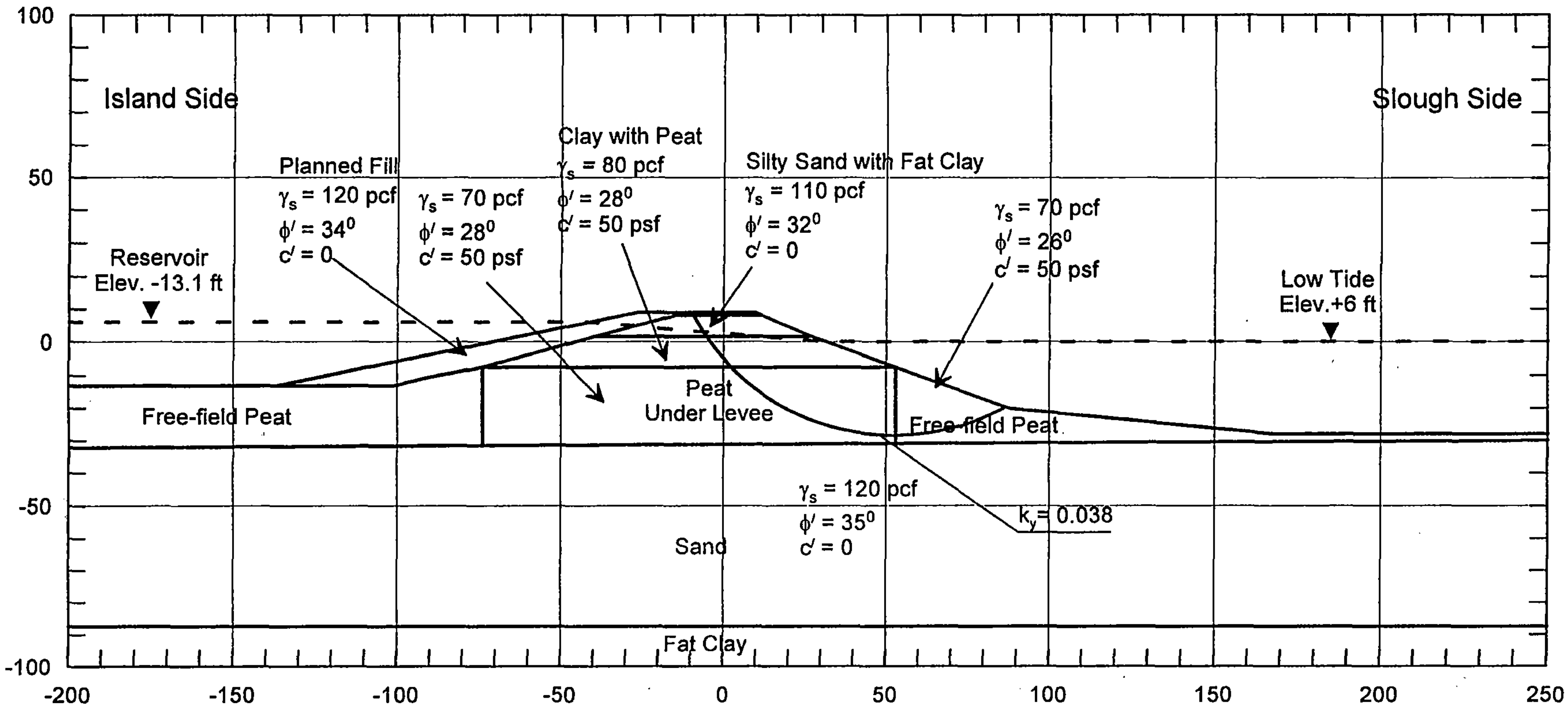


DELTA WETLANDS PROJECT	BACON ISLAND STA. 265+00 STABILITY ANALYSIS SEISMIC CONDITION- INTO ISLAND	FIGURE 3.5.43
URS GREINER WOODWARD CLYDE		

x:/ARULNA/deltawetland/Bacon265/ba2seis.grf 12/2/99



DELTA WETLANDS PROJECT	BACON ISLAND STA. 265+00 STABILITY ANALYSIS LONG-TERM CONDITION- TOWARD SLOUGH	FIGURE 3.5.44
URS GREINER WOODWARD CLYDE		

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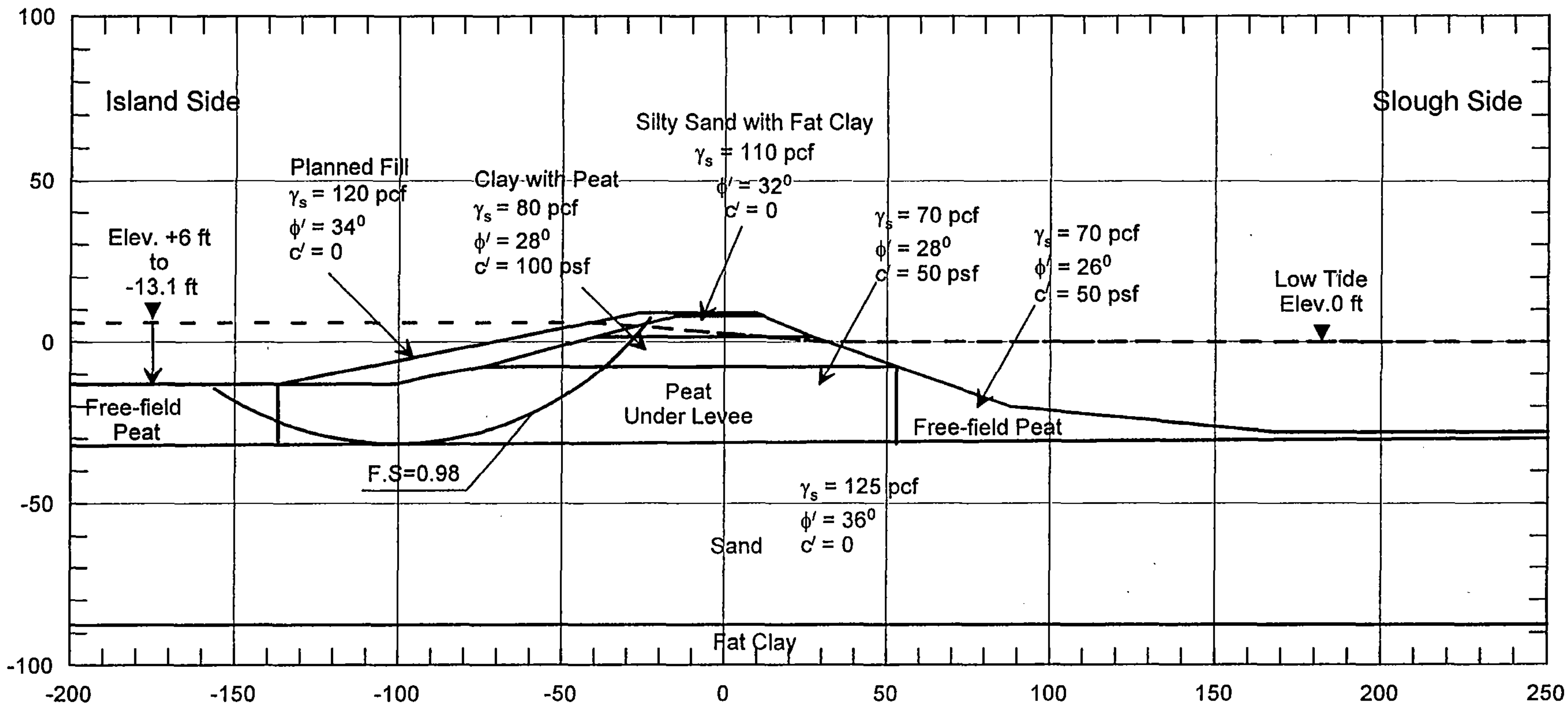
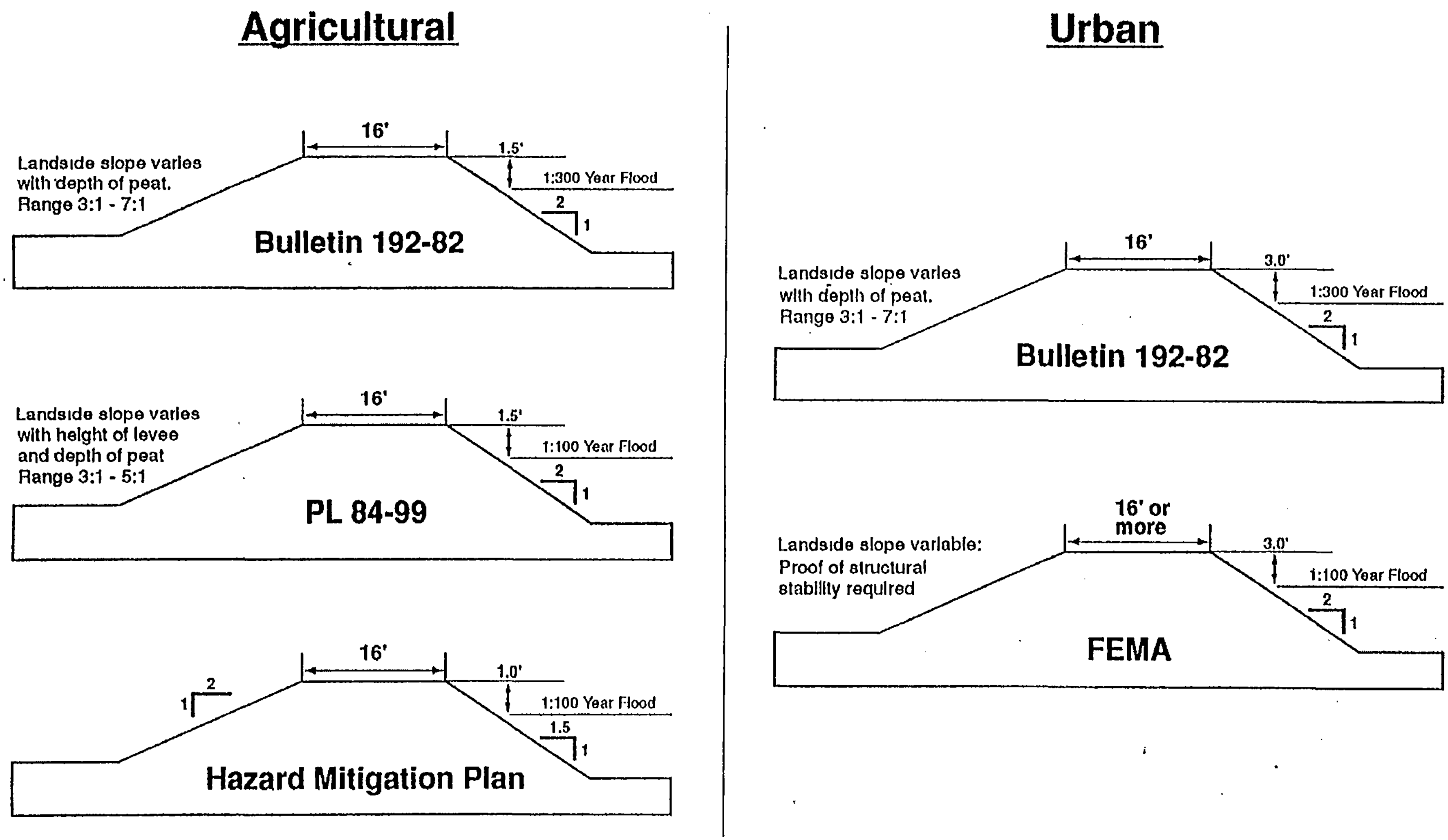


DELTA WETLANDS PROJECT

URS GREINER WOODWARD CLYDE

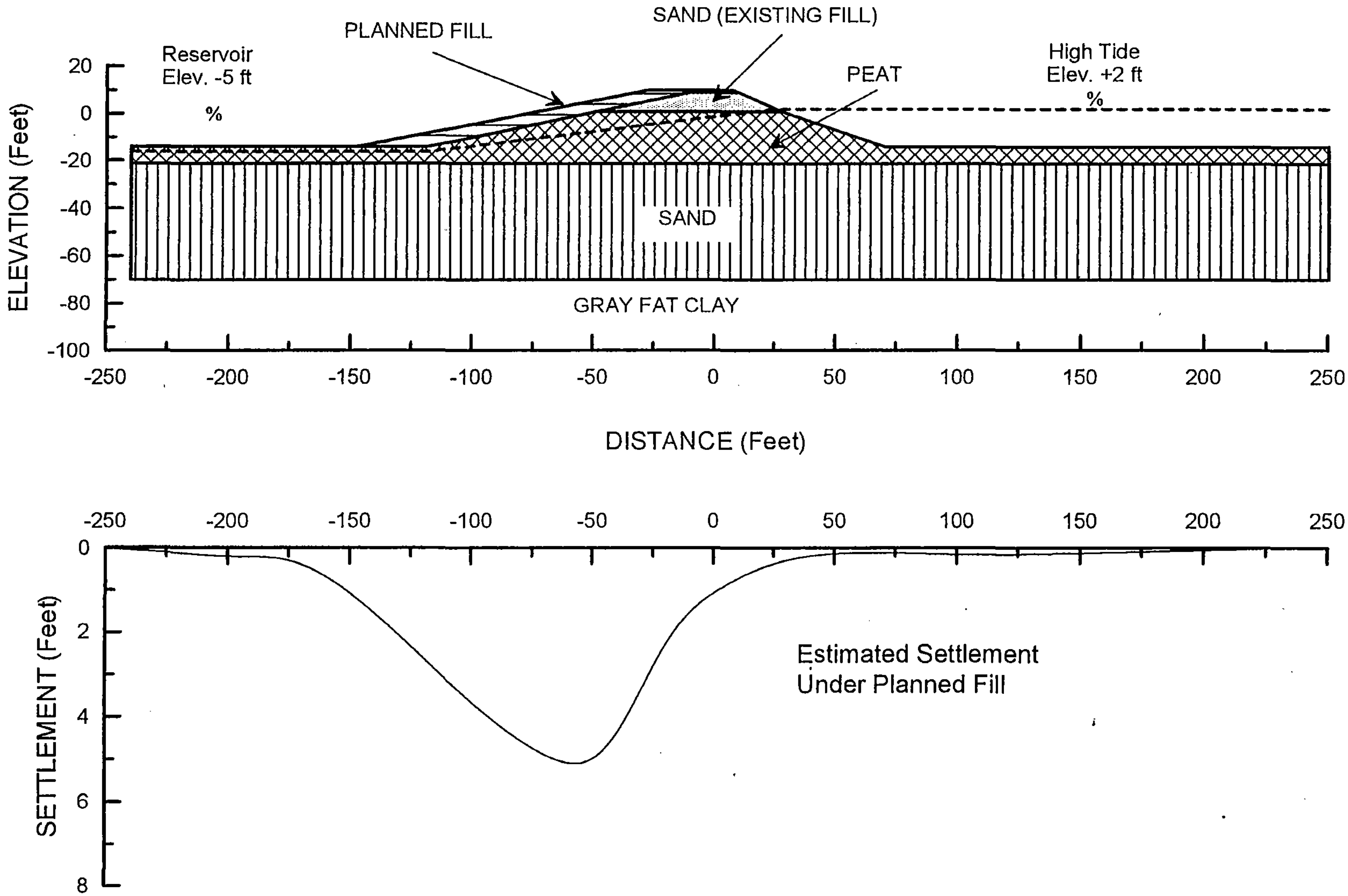
BACON ISLAND STA. 265+00
STABILITY ANALYSIS, THREE-STAGE
SUDDEN DRAWDOWN CONDITION
- INTO ISLAND

FIGURE
3.5.45



Project No. 41-07099030.00	Delta Wetlands	LEVEE GEOMETRIC STANDARDS	Figure 3.5.46
URS Greiner Woodward Clyde			

41-07099030.00-[illegible]3/120999/gos



DELTA WETLANDS PROJECT	WEBB TRACT STA. 630+00 SETTLEMENT ANALYSIS
URS GREINER WOODWARD CLYDE	**FIGURE 3.7.1**

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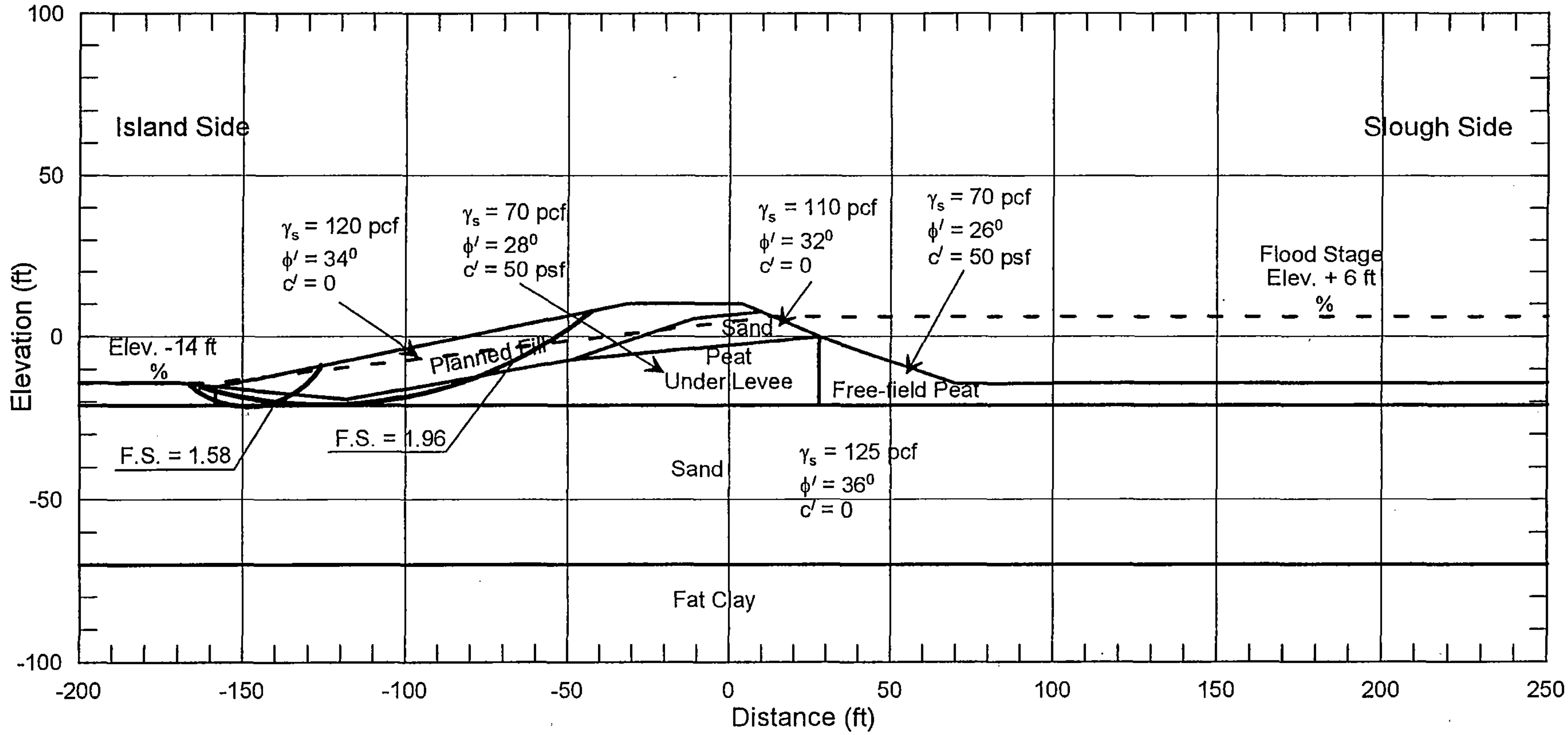
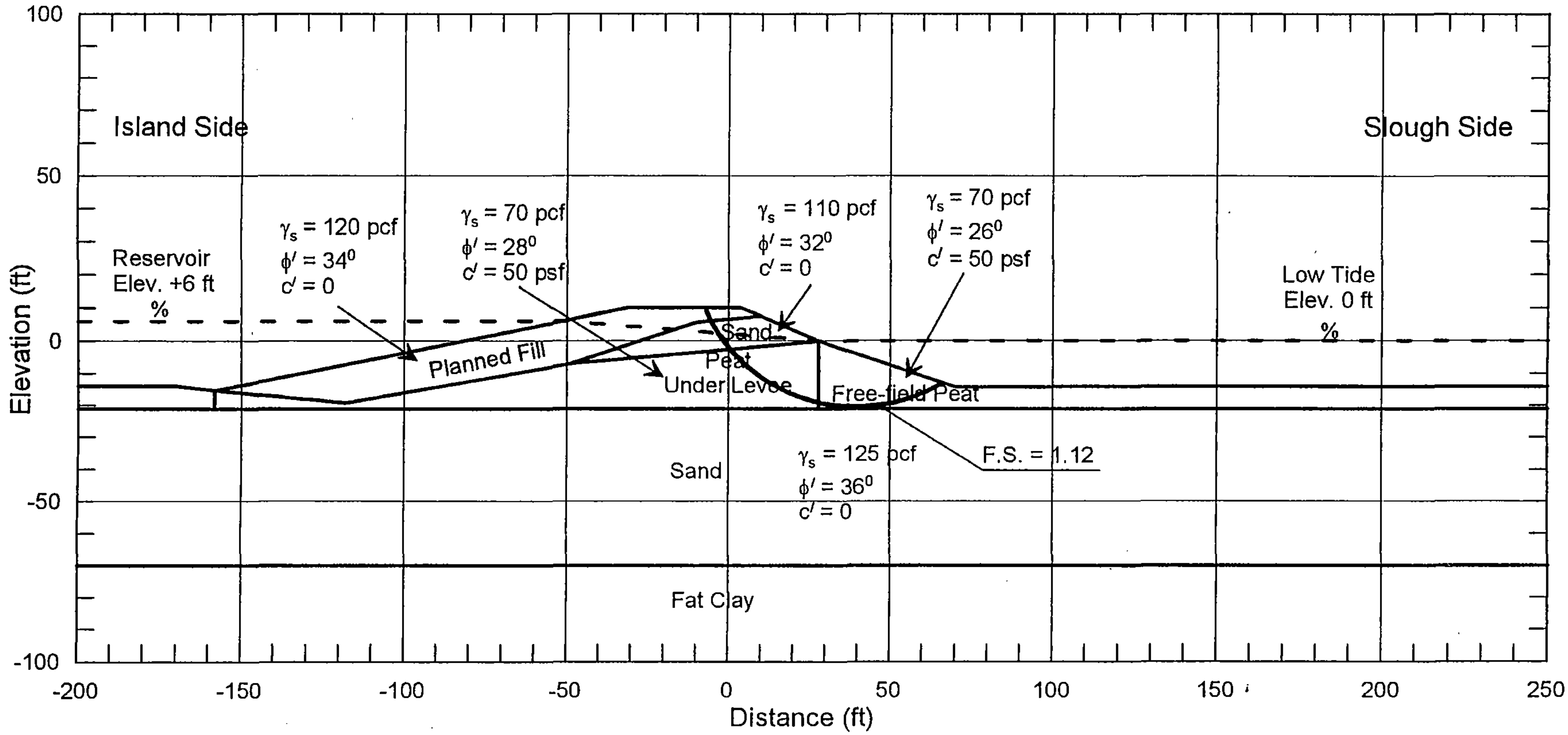


DELTA WETLANDS PROJECT	WEBB TRACT STA. 630+00 STABILITY ANALYSIS LONG-TERM CONDITION USING DEFORMED GEOMETRY- INTO ISLAND	**FIGURE 3.7.2**
URS GREINER WOODWARD CLYDE		

x:/deltawetland/2000files/fig372.grf 3/15/00



DELTA WETLANDS PROJECT	WEBB TRACT STA. 630+00 STABILITY ANALYSIS LONG-TERM CONDITION USING DEFORMED GEOMETRY- TOWARD SLOUGH	FIGURE 3.7.3
URS GREINER WOODWARD CLYDE		

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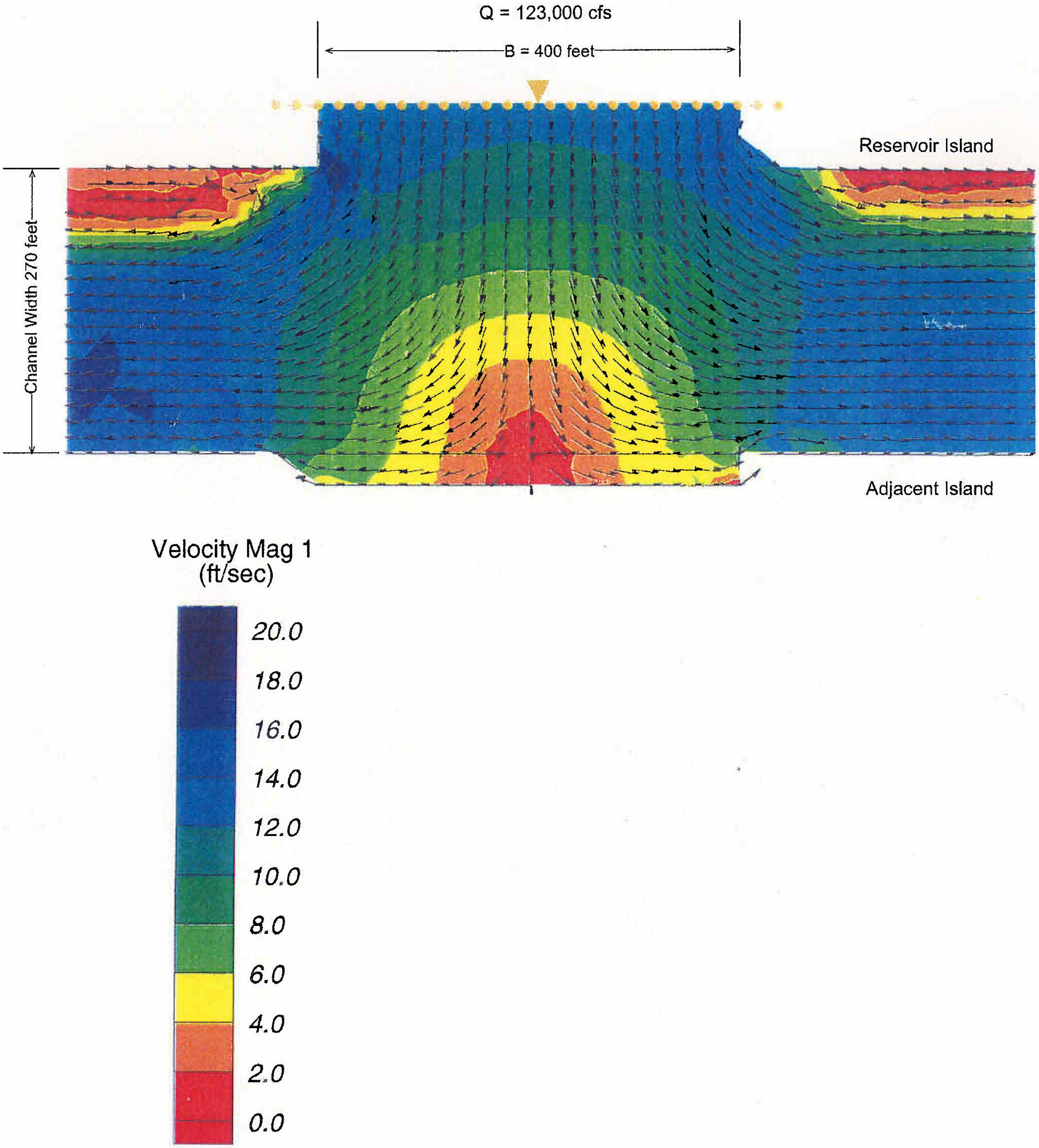

Project No. 41-07099030.00	DELTA WETLANDS PROJECT	RESULTS OF LEVEE BREACH ANALYSIS	Figure 3.11.1
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The main findings from the seepage and stability evaluations are summarized below.

4.1 SEEPAGE ISSUES

The findings from the seepage analysis were based on two representative cross section for each island. The cross sections at each island were selected for the "narrowest" and "widest" slough width across reservoir island and neighboring island. These cross sections represent somewhat of a bounding of the seepage conditions. The following major findings emerged from the seepage evaluations.

- The proposed reservoir islands can have undesirable seepage flooding effects on adjacent islands if seepage mitigation measures are not considered.
- Seepage control by interceptor wells placed on the levees of the reservoir islands, as proposed by DW, appears effective to control undesirable seepage effects. Required well spacings and pumping rates appear to be reasonable and manageable.
- Interceptor well pumping must be carefully monitored by observation wells and application of "significance criteria."
- Use of a combination of seepage monitoring wells and background wells, as proposed by DW, combined with the use of "significance criteria," appears suitable to control the interceptor well pumping. Additional rows of shallow monitoring wells are recommended across each neighboring island. Well readings by means of automatic data acquisition are appropriate.
- Significance criteria have been developed by DW in consultation with others to apply the monitoring results to trigger seepage mitigation, consisting in the first place in pumping from the interceptor wells. The concept and format of the significance criteria appear appropriate, but some changes in the criteria appear desirable.
- The significance criteria should be re-evaluated and updated periodically.
- A system of checking the performance of individual wells and of well maintenance needs to be developed and implemented. Well maintenance should be documented and tracked, to identify wells requiring excessive maintenance.
- It appears that the most effective pumping of the interceptor wells, combined with return of some of the pumped water back into the channel (max 8% of total pump volume), will not lead to water diversion from the channel into the island.
- Operation of the reservoir islands will lead to only small additional settlements, smaller than the settlements that the islands would experience with continued use as farmland.
- Wind-induced waves during reservoir operation are expected to be significant enough to require scour and erosion protection of the inner levee slopes.
- A minimum of 800 to 1,000 feet offset form the levee toe should be maintained for the location of borrow sites. With this offset, there is no discernible effect of the borrow areas on seepage.

- The sensitivity analysis considered the channel silt permeability, aquifer permeability, and the thickness of the peat layer within the reservoir island. The results indicated that the permeabilities of the channel silt and the aquifer have a significant impact on the seepage conditions and required pumping volume, while the peat thickness has little effect.

4.2 STABILITY ISSUES

The stability of the project's levees has been evaluated by extensive stability analyses of sections selected to be representative of the more severe stability situations expected at the reservoir islands. The calculated factors of safety have been compared to various published stability criteria, and judgments were made of the adequacy of the proposed project in regard to levee stability. The resulting conclusions and recommendations are:

- The levee strengthening measures conceptually proposed by DW are generally appropriate and adequate to provide adequate stability of the reservoir islands' levees, except as noted below.
- Similarly, the seepage monitoring and control measures are generally adequate to avoid reducing the stability of adjacent islands' levees, provided the measures noted in Section 4.1. are implemented.
- Construction of the levee strengthening fills must be implemented in a manner to prevent stability failures due to the new fill loads. This will require carefully planned and timed multi-stage construction, and monitoring to observe the behaviors as the fill is placed. The staged construction will require a construction period estimated to extend over 4 to 6 years, depending on final design.
- Long-term stability toward the slough side will be reduced by the construction and reservoir filling to an excessive degree. Measures should be provided to improve this stability. Some conceptual slope stabilization measures may include:
  - Flattening the slough side levee slope
  - Widening of the levee crest to provide redundant levee width
  - Rock buttressing the levee toe on the slough side
- There may be potential environmental impact resulting from slough sideslope failure. These are outside the scope of this work and consequently are not addressed in this report.
- Stability with respect to sudden drawdown of the water in the reservoir may be inadequate at some locations. This potential failure mode should be considered carefully, and remedial measures (such as flattening of levee slopes) implemented where locally needed.
- The seismic stability evaluation of the reservoir islands levees indicates that as much as 2 feet of downslope deformation on the reservoir side and 4 feet of deformation on the slough side could be experienced during a probable earthquake in the region. The measures noted above to improve the slough side stability will also mitigate the slough-side deformation.
- As indicated by DW, it is planned, as a part of final design, to implement extensive and detailed subsurface exploration programs along the reservoir island levees, followed by stability evaluations and site-specific detailed design and construction to provide adequate

levee stability. These steps will be essential to achieve adequate safety and effectiveness of the proposed levee system.

4.3 OVERALL FINDINGS

Taking a broader view, we consider the overall findings of this reevaluation of geotechnical issues of the proposed Delta Wetlands Project to be as follows:

- The seepage mitigation design proposed by DW appears appropriate and has the potential to be effective, provided that
  - the interceptor well system is appropriately designed, constructed and operated;
  - the monitoring system consisting of seepage monitoring wells and background wells is appropriately designed, constructed and operated;
  - the significance criteria are rigorously applied and continually updated based on experience.
- The levee strengthening conceptually proposed by DW appears appropriate, except that measures need to be developed to improve the stability of the raised levee stoward the slough.
- Because conditions around the islands' perimeter vary, it will be essential that a "mile-by-mile" geotechnical exploration and, based on it, a detailed final design, be implemented. The exploration should consist of borings and soundings spaced closely enough that adverse conditions extending over some distance would be identified. Appropriate detailed geotechnical laboratory tests, in particular grain size, permeability and strength tests, should be made on recovered samples. Final design of seepage control and monitoring, and levee strengthening, should consider the specific conditions identified on a site-specific basis.
- Construction of the improvements will require detailed geotechnical construction oversight, construction quality control and quality assurance, and documentation of as-built features, to maximize the chances that unexpected conditions are identified and accommodated, that construction will be implemented to satisfy the intent of the design, and that construction is documented.
- In particular, extraction well design, construction and operation will be critical not only to maximize the reliability of the seepage control system, but also to minimize the possibility of flushing fine particles out of the levee foundation, which could over time lead to weakened levee foundations and potential settlement and stability problems. Experience has shown that this can be achieved.
- It is recognized that pumping from the crest of the reservoir levee to mitigate seepage effects across the slough in the adjacent island is not the most effective way to achieve the seepage mitigation. It has been selected because of ownership and access issues. Other measures to achieve the seepage mitigation could be developed. In particular, pumping from the adjacent island's levee across the slough from the reservoir island would be hydraulically more efficient, and would likely require fewer wells and lower pumping volume. Passive or active relief wells or trenches on the adjacent island would also be effective. A continuous cutoff around the reservoir islands would also be effective, but would likely be cost prohibitive.

The supplemental geotechnical evaluations described in this report had a number of limitations. We made only reconnaissance-type visits to the two islands considered for reservoir islands that we evaluated. No additional site and subsurface investigations were made. Consequently, our work was based on existing, widely spaced borings and cone penetration tests; and on available laboratory tests made by Harding Lawson Associates. Most of the laboratory tests were also made more than 10 years ago and may not have used most current testing procedures. Thus, we had to rely for levee geometries, levee and subsurface soil conditions, and soil seepage and strength properties on information developed by others. We also relied on survey data by others.

Our evaluations were made on two cross sections on each proposed reservoir island. These cross sections, which were mostly different for seepage and stability evaluations, were selected based on available data to be reasonably representative but on the conservative side for seepage and stability issues, respectively. The most severe conditions that may be encountered may not have been considered. Nevertheless, the results for the sections that were analyzed suggested in all cases that more severe conditions could be accommodated with suitable changes in the design. Such accommodation will need to be considered in the final design.

Finally, this project was implemented with the care normally associated with work of this kind in this area at the present time. No other warranty is given or implied.

An Annotated List of Geotechnical Reports Prepared for the DW Project by Harding Lawson Associates between February 1989 and November 1993 is contained in Appendix D1 to the Draft EIR/EIS (Jones and Stokes, 1995). This annotated list is attached to this report at the end of Section 6.0. The references contained in the annotated list are not repeated in the Section 6.0 listing. They are referred to in the text of the report by the standard method (e.g., HLA 1992a). All other references are listed below.

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Appendix D1. Annotated List of Geotechnical Reports Prepared for the DW Project

Harding Lawson Associates, Inc. 1989. Preliminary geotechnical investigation for the Delta Wetlands project. By K. Tillis, E. Hultgren, and C. Wood. February 15, 1989. (HLA No. 18749,001.03.) Concord, CA. Prepared for Delta Wetlands, Lafayette, CA.

This report presents the results of a preliminary geotechnical investigation performed by Harding Lawson Associates (HLA) for the Delta Wetlands (DW) project. The investigation was to provide preliminary geotechnical design for the project. The report describes the results of collecting available data on soil conditions and physical properties of Delta levees and foundation materials and of exploring subsurface conditions to define site stratigraphy and obtain soil samples for visual observation and laboratory testing. The report also provides preliminary conclusions and recommendations regarding geotechnical engineering concerns.

HLA's field investigations consisted of drilling, logging, and sampling exploratory borings; performing cone penetration test soundings; and installing and monitoring piezometers at representative locations around the island perimeters. Soil samples were collected and analyzed from levees and levee foundations on each of the project islands. Soil tests included particle size analyses, consolidation tests, and the determination of soil moisture content, dry density, shear strength, and permeability. The effects of levee reconstruction on levee settlement were estimated from the boring data, soil sample consolidation test results, and published data on settlement of fill material placed on peat soils of the Delta. HLA analyzed slope stability toward island interiors and toward Delta channels for the existing, after-construction, and long-term conditions.

__________. 1990a. Project status report: McDonald Island drawdown demonstration. By K. Tillis, D. Holloway, and E. Hultgren. February 22, 1990. (HLA No. 18749,013.03.) Concord, CA. Prepared for Delta Wetlands, Lafayette, CA.

This report summarizes results of the McDonald Island drawdown demonstration study. The purpose of the investigation was to demonstrate that hydraulic head within the sand aquifer can be lowered by pumping through a groundwater relief well system, and that similar systems would be viable options for controlling seepage resulting from the operation of DW reservoirs. HLA conducted a field investigation to confirm stratigraphy and install observation piezometers and the relief well system between July 10 and September 1, 1989. Water levels were then monitored before, during, and after the pumping phase of the demonstration (November 14, 1989, to January 24, 1990). The report concludes that pumping is effective in controlling essentially all seepage into the island, as indicated by the flattening of the hydraulic grade line beneath the island interiors.

__________. 1990b. Groundwater data transmittal, Delta Wetlands monitoring program. By D. Holloway, K. Tillis, and E. Hultgren. April 12, 1990. (HLA No. 18749,007.03.) Concord, CA. Prepared for Delta Wetlands, Lafayette, CA.

This report presents groundwater monitoring data collected through March 1990 for a groundwater monitoring program performed by HLA for the DW project. The groundwater monitoring program is to provide baseline information on existing groundwater levels in the Delta. Data were obtained from a network of piezometers installed to monitor pore pressure (i.e., hydraulic head) within the sand aquifer at varying locations on the DW islands and other Delta islands. Water levels were measured weekly during spring 1989, and from fall 1989 through March 1990. To supplement manual measurements, water-level data were continuously recorded for 1-2 weeks at a time. The report presents boring logs, results of grain size analyses, well completion diagrams for 27 piezometers, and data on groundwater level.

__________. 1990c. Project status report: McDonald drawdown demonstration Phase II. By K. Tillis, D. Holloway, and E. Hultgren. November 19, 1990.

(HLA No. 18749,013.03.) Concord, CA. Prepared for Delta Wetlands, Lafayette, CA.

This report presents results of a Phase II drawdown demonstration study performed by HLA for the DW project. The purpose of the Phase II study was to demonstrate that artesian head in the sand aquifer can be lowered by a groundwater gravity dewatering system for seepage control. Between June and mid-July 1990, the existing relief well system (pump system) was converted to a gravity-flow system, in which groundwater flows from wells into seepage ditches by artesian pressure in the sand aquifer. The report concludes that, based on groundwater level monitoring, the gravity flow system shows results that are similar to those of the pumped well system.

__________. 1991a. Groundwater data transmittal No. 2, Delta Wetlands monitoring program. By D. Holloway, K. Tillis, and E. Hultgren. January 7, 1991. (HLA No. 18749,007.03.) Concord, CA. Prepared for Delta Wetlands, Lafayette, CA.

This report presents the status of the groundwater monitoring program described above (HLA 1990b). This report presents data collected from March to December 1990. Seven additional piezometers were installed in September 1990, resulting in a total of 34 piezometers on 17 Delta islands. Groundwater data for the piezometers from March through December 1990 are presented in this report.

__________. 1991b. Interceptor well modeling for the Delta Wetlands project. By D. Holloway, K. Tillis, and E. Hultgren. (HLA No. 18749,016.03.) Concord, CA. Prepared for Delta Wetlands, Lafayette, CA.

This report presents the results of HLA's groundwater modeling effort for the DW project. The model simulated various pumping well systems located on DW island levees for controlling groundwater flow off the island. The purpose of the study was to establish parametric relationships that could serve as the basis for conceptual design of pumping and interceptor well systems on DW islands. The goal of the modeling was to simulate groundwater withdrawal required to offset the increase in head in the sand aquifer, keeping groundwater levels on neighboring islands unaffected by water storage on the DW islands. The report describes the modeling approach and procedures and results of three conceptual aquifer system models. Results of the study provide a range of well spacing distances for corresponding ranges of aquifer properties, system dimensions, and pumping rates.

__________. 1991c. Groundwater monitoring plan for the Delta Wetlands project. By D. Holloway, K. Tillis, and E. Hultgren. January 23, 1991. (HLA No. 18749,007.03.) Concord, CA. Prepared for Delta Wetlands, Lafayette, CA.

This document presents a seepage monitoring plan for the DW project. The report describes the rationale for spacing of piezometers on neighboring islands. The proposed piezometer locations are shown on a regional map. Piezometers are planned for all levee reaches located across from DW reservoir islands. Additional piezometers are proposed at locations remote from the reservoirs to provide data on general Delta-wide groundwater level variations for comparison with water level fluctuations near DW reservoirs during project operation. The report describes methods for evaluating the groundwater level and outlines criteria for determining whether a net seepage impact is occurring.

__________. 1991d. Seepage control program for the Delta Wetlands project. By D. Holloway, K. Tillis, and E. Hultgren. January 24, 1991. (HLA No. 18749,007.03.) Concord, CA. Prepared for Delta Wetlands, Lafayette, CA.

This report summarizes existing conditions on and adjacent to the DW project islands and outlines a seepage control program for the DW project. The program is based on information and recommendations presented in HLA's preliminary geotechnical investigation, McDonald Island drawdown demonstration project status reports, groundwater data transmittals, and interceptor well modeling reports. The report describes potential seepage effects of farming, wetland management, and reservoir management and outlines potential measures to control seepage, including cutoff walls, interceptor wells, and relief wells.

__________. 1992a. Wave erosion monitoring and mitigation for the Delta Wetlands project. By K. Tillis and E. Hultgren. January 6, 1992. (HLA No. 18749,007.03.) Concord, CA. Prepared for Delta Wetlands, Lafayette, CA.

This report describes measurable performance standards, monitoring, and mitigation measures for wave erosion on the interior slopes of the DW project levees. This report assumes a spending beach design for the interior levees. (The current project description for this environmental impact report/environmental impact statement [EIR/EIS] does not include spending beach design.)

__________. 1992b. Monitoring and mitigation of geotechnical impacts on State Route 12 for the Delta Wetlands project. By K. Tillis and E. Hultgren. January 7, 1992. (HLA No. 18749, 007.03.) Concord, CA. Prepared for Delta Wetlands, Lafayette, CA.

This report presents a proposed design for a new dam to impound a reservoir south of State Route 12 on Bouldin Island. The report describes proposed drainage structures, performance standards for settlement and shallow groundwater, potential and anticipated geotechnical effects of the new dam, and monitoring needs. This proposal is for the four-island, maximum fill alternative (Alternative 3).

__________. 1992c. Seepage monitoring and mitigation for the Delta Wetlands project. By K. Tillis and E. Hultgren. January 8, 1992. (HLA No. 18749,007.03.) Concord, CA. Prepared for Delta Wetlands, Lafayette, CA.

This report provides an overview of seepage issues that affect Delta islands and how water storage on one island may affect an adjacent island. This report proposes a seepage monitoring plan and measures to mitigate seepage.

__________. 1992d. Phreatic surface in perimeter levees for the Delta Wetland project. Letter report by K. Tillis and E. Hultgren to J. Winther, President, Delta Wetlands. January 9, 1992. (HLA No. 18749,007.03.) Concord, CA. Prepared for Delta Wetlands, Lafayette, CA.

This letter report addresses the anticipated level of phreatic surface within the buttressed perimeter levees on the DW project islands. The phreatic surface (free water surface) is the level below which groundwater would seep into an excavation, boring, or well. To estimate the phreatic surface, HLA created flow nets to assess seepage through the levee. The report describes factors affecting the phreatic surface and results of analyses conducted on Holland Tract. The report concludes that the phreatic surface would rise as fill is placed for levee reconstruction.

__________. 1992e. Geotechnical investigation and design for the Wilkerson Dam on Bouldin Island. By K. Tillis, S. Vahdani, and K. Bergman. May 27, 1992. (HLA No. 11472-008.) Concord, CA. Prepared for Delta Wetlands, Lafayette, CA.

This report presents the results of a geotechnical investigation and design studies for Wilkerson Dam on Bouldin Island. The purpose of the investigation was to develop design criteria appropriate for a dam that falls under the jurisdiction of the State of California (California Department of Water Resources' Division of Safety of Dams). The report describes site conditions, design considerations, and several analyses performed to design Wilkerson Dam. Two alignments were investigated in detail as part of the study.

The study included an extensive field investigation using cone penetration test probes, borings, piezometers, down-hole seismic techniques, and a test fill constructed on peat. Laboratory tests were also conducted to evaluate strength and compressibility characteristics of soft marsh deposits, grain size distribution of sandy soils, permeability of planned fill and in situ soils, and basic index properties. Results of these analyses were used to develop engineering parameters for design. This proposal is for the four-island, maximum fill alternative (Alternative 3).

__________. 1992f. Groundwater data transmittal No. 3 Delta Wetlands monitoring program. By K. Tillis and E. Hultgren. June 25, 1992. (HLA No. 18749,007.03 [11471.007].) Concord, CA. Prepared for Delta Wetlands, Lafayette, CA.

This report presents the status of the groundwater monitoring program described above (HLA 1990b). This report presents data collected from December 1990 to October 1991. Groundwater data for the 34 piezometers discussed above are presented in this report.

__________. 1993a. Geotechnical evaluation of perimeter levees for the Delta Wetlands project. Letter report by K. Tillis and E. Hultgren to J. Winther, President, Delta Wetlands. November 16, 1993. (HLA No. 11471,007.) Concord, CA. Prepared for Delta Wetlands, Lafayette, CA.

This letter report discusses the results of the geotechnical evaluation for perimeter levee improvements planned in response to revisions to the DW project and alternatives description. The impact of planned levee improvements on slope stability were evaluated for two different existing levee conditions. Changes in the factor of safety from existing conditions were computed for the revised levee reconstruction design.

_________. 1993b. Description of Wilkerson Dam on Bouldin Island for the Delta Wetlands project. Letter report by K. Tillis and E. Hultgren to J. Winther, President, Delta Wetlands. November 17, 1993. (HLA No. 11471,007.) Concord, CA. Prepared for Delta Wetlands, Lafayette, CA.

This report describes in conceptual terms the size and nature of Wilkerson Dam under the revised four-island, maximum storage alternative (Alternative 3). This information is presented in Appendix E1, "Design and Construction of Wilkerson Dam South of SR 12 on Bouldin Island".

Appendix A
Seismic-Induced Levee Deformations and Geologic Hazards

A.1 OBJECTIVE

This section presents the results of the seismic evaluation of the levees for the proposed reservoir islands of the Delta Wetlands project. The reservoir islands analyzed for this study are the Webb Tract and Bacon Island. The seismic evaluation analysis was performed for the levees' final configuration, which includes strengthening of the levee slope. New buttresses will be constructed on the reservoir-side levee slopes of the islands to increase the safety margin of the levees.

The analyses included dynamic finite element analysis and seismic geologic hazard assessment to evaluate the seismic performances and deformations of the levees under design earthquake ground motions. The analyses presented in this section were performed in accordance with the scope of services presented in Task 3, Levee Stability, of our proposal to Jones & Stokes Associates, Inc, dated July 06, 1999.

The objectives of these analyses were to: 1) review previous studies on dynamic soil properties, earthquake ground motions and dynamic levee responses; 2) review and use existing seismic hazard studies in the region and corresponding ground motions; 3) evaluate levee dynamic responses to the design earthquake motions; 4) estimate the potential deformations induced by the design earthquake; and 5) assess the potential of seismic geologic hazards.

A.2 REVIEW OF PREVIOUS STUDIES

Previous studies of the seismic hazards for the Delta Wetlands project were performed by Harding Lawson Associates (HLA, 1992e including Appendices). These studies included, among others data, the development of design earthquake ground motions, characterization of dynamic soil properties, and analysis of levee dynamic responses (site response analysis). The studies were performed for the proposed Wilkerson Dam on Bouldin Island, which is located east-northeast and north of Webb Tract and Bacon Island, respectively.

A series of field investigations was conducted at Bouldin Island (HLA, 1992e). These field investigations consisted of 65 test borings, 169 cone penetration tests and 12 downhole geophysical surveys. Laboratory tests on soil samples recovered from the test borings were also performed to evaluate the static and dynamic soil characteristics. From these results, shear modulus reduction and damping curves were developed for the soils encountered in the borings. The downhole geophysical surveys also provided direct measurements of the in-situ shear wave velocities of the various foundation soils and levee materials. The results indicated a shear wave velocity range of 110-230 ft/sec for the soft peat.

A more recent study of the dynamic soil properties of the organic soil (peat) in the Delta Region was conducted by Boulanger et al (1997). Laboratory dynamic tests were performed on soil samples obtained in Shelby tubes on Sherman Island, which is located west and northwest of Webb Tract and Bacon Island, respectively. The resulting shear modulus reduction and damping curves for the peat were developed. A shear wave velocity range of 265-290 ft/sec was also obtained from testing the in-situ peat samples. These dynamic characteristics for the peat were shown to be consistent with those developed by other researchers for similar soils (Boulanger et al, 1998).

Figure A.1 compares the shear modulus reduction (G/G_{max}) and damping curves developed by HLA (1992e), and Boulanger et al (1997). The figure shows that the shear modulus decreases more rapidly with shear strain for the HLA (1991) model than the Boulanger, et al (1997) model. The damping curves are consistent for the two models, except for the larger shear strains (larger than about 1% shear strain) where HLA (1991) model gives higher damping values.

HLA (1990 and 1992e) identified three main seismic sources that control the seismic hazard at the Bouldin Island: 1) a magnitude 8.3 earthquake on the San Andreas fault that is capable of generating peak acceleration of 0.15g at the site; 2) a magnitude 7 earthquake on the Antioch fault that is capable of generating peak acceleration of 0.21g at the site; and 3) a magnitude 6.5 local earthquake that is capable of generating peak acceleration of 0.28g at the site.

A total of four earthquake time histories from past earthquakes were also selected for the dynamic response analyses (HLA, 1992e). These selected records were two rock motions recorded at U.C. Santa Cruz and Yerba Buena Island during the 1989 Loma Prieta earthquake and two artificial ground motion records developed by Seed et al (1972) for the San Andreas and Hayward fault events.

More recently (CALFED, 1999), probabilistic seismic hazard analysis and levee failure probabilistic evaluations were conducted for the Sacramento/San Joaquin Delta levees by the Seismic Vulnerability Sub-Team of CALFED's Levees and Channels Technical Team. In this study, the Delta Region was divided into four groups based on their expected seismic ground motions and the levee fragility to failure. Estimates for levee failure due to scenario earthquake events from nearby dominant seismic sources were also developed.

The results of the above probabilistic analysis indicate that local seismic sources in the Delta Region dominate the high frequency ground motions, including peak ground acceleration. Average peak accelerations at a 475-year return period of about 0.26g and 0.25g were calculated for Webb Tract and Bacon Island, respectively. The 475-year return period corresponds to about 10% probability of exceedance in 50 years. No information on the longer period ground motions was presented in the report, although the San Andreas and Hayward faults are expected to dominate the long period motions, and also are capable of longer duration.

Incidentally, the 475-year return period event is generally comparable to the deterministic ground motions obtained by HLA (1992e) using the MCE events on both local and distance sources.

Permanent deformations of the levee on the Bouldin Island were estimated using the dynamic soil characteristics and earthquake ground motions described above (HLA, 1990, 1991, 1992). The calculated deformations can be summarized as follows (HLA, 1992):

1. Deformations of up to about 7 feet are expected if the maximum credible earthquake were to occur at the end of levee construction.

2. Deformations of less than about 1 foot are expected if the maximum credible earthquake were to occur 5 years after construction.

A.3 EARTHQUAKE-INDUCED LEVEE DEFORMATIONS

A.3.1 Analysis Approach

The analysis approach taken for this study consisted of the following steps:

1. Select representative levee cross sections and material properties for analyses.
2. Develop design earthquake ground motions.
3. Compute the dynamic responses of the levee induced by the design earthquake motions.
4. Evaluate deformations of the levee based on the results of step 3.

The discussions of these analysis steps are given in the following subsections.

A.3.2 Select Cross Sections and Dynamic Soil Parameters

Four levee cross sections were selected for stability analyses for the two proposed reservoir islands, two cross sections for Webb Tract and two for Bacon Island. These cross sections were selected because they represent the critical sections along the levee axis. The cross sections selected for dynamic analyses are the same as those used in the static and pseudo-static slope stability analyses (see Section 3.3.2).

The nonlinear dynamic behavior of the levee and foundation materials was modeled using the equivalent-linear method proposed by Seed and Idriss (1970). In this method, the dynamic stress-strain behavior of soil is represented by that of a viscoelastic material with elastic modulus and viscous damping which are compatible with the amplitude of induced dynamic shear strain. The analysis is performed in iterations until the shear modulus and damping used in the analysis are compatible with the computed shear strains.

The parameters required for the viscoelastic soil model are the total unit weight, shear modulus (G), fraction of critical damping and Poisson's ratio. For sandy materials, the shear modulus at small strain (G_{max}) was assumed to depend on the effective confining pressure in accordance with the following equation, as proposed by Seed and Idriss (1970):

$$G_{max} = 1000 K_{2max} \sqrt{\sigma'_m}$$

where G_{max} = shear modulus at small strain in psf
σ'_m = mean effective confining pressure in psf
K_{2max} = a factor which depends on relative density, maximum particle size, gradation and other parameters.

The value of G_{max} and the variation of G/G_{max} with strain define the variation of shear modulus (G) with strain. The variation of G/G_{max} with strain is known as the modulus reduction curve. The mean effective confining pressure was computed using the following equation:

$$\sigma'_m = \frac{1+2K_0}{3} \sigma'_v$$

in which the σ_v' is the effective vertical pressure and K_0 is the coefficient of earth pressure at rest.

For clayey soils, shear modulus was estimated from the shear wave velocity using the following equation:

$$G_{max} = \rho V_s^2$$

where ρ and V_s are the soil density and shear wave velocity, respectively.

Table A.1 presents the selected dynamic soil parameters used in the analyses. The unit weights are those used in the static analyses. The values of K_{2max} and V_s selected for the various foundation and levee materials were estimated based on the results of previous studies (HLA, 1991, 1992 and Boulanger, 1997), experience with similar soil conditions and engineering judgment.

Table A.1 also lists the damping and shear modulus reduction curves used for each levee and foundation materials. The shear modulus reduction and damping curves selected for the clayey soils were those developed by Vucetic and Dobry (1991) for clayey soils with Plasticity Index (PI) of about 50 and 100. Shear modulus reduction and damping curves (mean curves) developed by Seed and Idriss (1970) for sand were used for the sandy soils. For peat, we used the relationships developed by Boulanger (1997) for Sherman Island peat. The selected modulus reduction and damping curves are shown in Figure A.2, as a function of shear strain.

It was expected that the levee materials will control the overall dynamic behavior of the levee. Accordingly, for the dynamic response analysis, the underlying clay deposit was modeled as an elastic half space in order to properly account for its energy transmitting characteristics.

A.3.3 Design Earthquake Ground Motions

The approach used to develop the design earthquake ground motions can be summarized as follows:

1. Select an appropriate hazard exposure level for design and develop the design response spectrum consistent with the selected hazard exposure level.
2. Select earthquake acceleration time histories for input motions.
3. Spectrally modify selected acceleration time histories to match the design response spectrum developed in step 1.

These steps are discussed below, and the spectrally matched ground motions were used in the dynamic response analysis, as described in Section A.3.4.

Design Response Spectrum

We selected a hazard exposure level that corresponds to a 10% probability of exceedance in 50 years for the design. Assuming that earthquake occurrences follow a Poisson process, a 10% probability of exceedance in 50 years results in a return period of about 475 years (or annual frequency of occurrence of 2.1×10^{-03}). The 475-year return period hazard exposure level is consistent with the requirement adopted by the 1997 Uniform Building Code (UBC) and was used in a previous study conducted for the project (HLA, 1990).

A site-specific probabilistic seismic hazard analysis is beyond the scope of services of our current study. We have, therefore, developed the design response spectrum using the results of previous studies (CALFED, 1999; HLA, 1992e), supplemented by current understanding of regional seismic sources and the deterministic ground motion analysis. In developing the design response spectrum, we used the results of the recent probabilistic seismic hazard analysis conducted by the Seismic Vulnerability Sub-Team of CALFED's levees and channels Technical Team (1999) to identify controlling seismic sources. Accordingly, we considered two controlling seismic source groups: local and distant source groups. The local source group represents the seismic sources in the Delta Region while the distant source group represents the San Andreas and Hayward faults.

The results of the CALFED study indicate that the local seismic source group can be represented by an earthquake of magnitude (M_w) 6 at a distance of about 20 km, for the 475-year return period hazard exposure level. For the San Andreas and Hayward faults, earthquakes with M_w of 7.7 at a distance of about 85 km and M_w of 7.2 at a distance of about 56 km were used, respectively. The magnitudes of the San Andreas and Hayward faults were selected based on the current understanding of the fault characteristics that are consistent with the 475-year return period earthquake magnitudes (USGS Working Group of 1999). The peak accelerations corresponding to the local, San Andreas and Hayward seismic events were set at 0.26g, 0.13g and 0.11g, respectively, based on the results of the CALFED study.

Figure A.3 shows the 5% damped response spectra calculated for these controlling events, scaled to their respective peak accelerations, using the ground motion attenuation relationships developed by Abrahamson and Silva (1997) and Sadigh et al (1997) for stiff soils. The design response spectrum was then developed by smoothing and enveloping these response spectra, as shown in Figure A.3. The design response spectrum is applicable for a free-field stiff soil site condition with 5% damping ratio.

Selected Earthquake Time Histories

Two horizontal earthquake acceleration time histories recorded during past earthquakes were selected for the dynamic analysis. These records were from the 1992 Landers earthquake with M_w of 7.3, recorded at Fort Irwin station (station #24577), and the 1987 Whittier Narrows earthquake with M_w of 6, recorded at Altadena, Eaton Canyon station (station #24402). Table A.2 lists these selected motions along with their closest distances from the rupture planes and recorded peak accelerations. The site conditions at these recording stations are classified as stiff soil sites. Figures A.4 and A.5 show the time history plots of the acceleration, velocity and displacement of these selected earthquake time histories.

The record from the 1992 Landers earthquake was selected to represent the larger and more distant earthquakes on the San Andreas and Hayward faults. The 1987 Whittier Narrows earthquake was selected to represent the local seismic source group.

Spectrally Matched Earthquake Time Histories

The response spectral values calculated from the selected acceleration time histories (natural time histories) have peaks and valleys that deviate from the design response spectrum (target response spectrum). To develop acceleration time histories with overall characteristics that match the target response spectrum, modifications to the natural time histories were necessary.

The two pairs of selected acceleration time histories were spectrally matched to the design response spectrum using the method proposed by Lilhanand and Tseng (1988) and modified by Abrahamson (1993). The plots of the acceleration, velocity and displacement time histories of these spectrally matched motions are presented in Figures A.6 and A.7. The 5% damped response spectra for the natural and modified motions are shown in Figures A.8 and A.9 along with the target spectrum. It can be seen from these figures that the response spectra calculated from the modified time histories closely match the target spectrum and the general characteristics of the modified time histories resemble those of the natural motions.

A.3.4 Dynamic Response Analysis

The analysis for the levee response under the earthquake loads was carried out using the computer program QUAD4M (Hudson et al, 1994). QUAD4M is a two-dimensional plan-strain, finite element code for dynamic analysis. This program uses equivalent linear stress-strain relationships for soils. The program also uses a time domain integration scheme that allows the user to reassign different material properties at any time during the seismic shaking. QUAD4M incorporates a compliant base (energy-transmitting base) which can be used to model the elastic half-space.

The finite element models used for the dynamic analyses are shown in Figures A.10, A.15, A.20 and A.25 for the four selected levee cross sections. Compliant bases were used at the bottom of the finite element models to prevent total reflection of wave energy at the fixed bases. The shear wave velocity for the underlying elastic half space was taken equal to that of the clay deposit beneath the sand layer. Earthquake acceleration time histories were input to the finite element models at the base of the sand layer (i.e., at the interface between sand layer and clay deposit). These input acceleration time histories were obtained by deconvolving the spectrally matched time histories to an elevation corresponding to the base of the sand layer. We used the one-dimensional wave propagation computer program SHAKE (Schnabel et al, 1972) to deconvolve the ground motions.

Our review of the available subsurface data indicates that the levee materials and foundation soils are not susceptible to widespread liquefaction under the design earthquake ground motions (see Section A.4). Pockets of loose sand deposit exist within the levee and foundation soils. The data on subsurface soils, however, indicate that these loose sand pockets are limited in extent. Therefore, we do not expect that during the occurrence of the design earthquake significant liquefaction, and hence significant changes in dynamic soil properties and levee responses, will occur. As such, in carrying out the analyses, we did not account for the effects of softening (or reduction in shear modulus) of the sandy soils.

The dynamic response analyses were carried out to compute the average horizontal acceleration (K_{ave}) time histories of the potential (critical) slide masses within the levee. These critical slide masses were identified through the static slope stability analyses, as described in Section 3.5.

The critical slide masses analyzed for the dynamic responses are presented in Figures 3.5.25 and 3.5.26 for the Webb Tract levee at Station 160+00, Figures 3.5.7 and 3.5.8 for the Webb Tract levee at Station 630+00, Figures 3.5.34 and 3.5.35 for the Bacon Island levee at Station 25+00, and Figures 3.5.43 and 3.5.44 for the Bacon Island levee at Station 265+00. It is noted that the critical slide masses on the slough-side slopes were identified using groundwater conditions different from those used to identify critical slide masses on the reservoir-side slopes (see Section 3.3.3). The average horizontal acceleration was calculated by computing the dynamic response of the levee to the design earthquake ground motions and averaging various stresses within or close to the sliding surface.

Figures A.11 and A.12 show the computed average horizontal accelerations (K_{ave}) for the critical slide masses of the levee cross section at Station 160+00 of Webb Tract. Figures A.16 and A.17 show the computed average horizontal accelerations (K_{ave}) for the critical slide masses of the levee cross section at Station 630+00 of Webb Tract. Figures A.21 and A.22 show the computed average horizontal accelerations (K_{ave}) for the critical slide masses of the levee cross section at Station 25+00 of Bacon Island. Figures A.26 and A.27 show the computed average horizontal accelerations (K_{ave}) for the critical slide masses of the levee cross section at Station 265+00 of Bacon Island.

The peak average horizontal accelerations (K_{max}) for these critical masses were tabulated in Table A.3. These peak values will be used for estimating the levee deformations using the simplified method of Makdisi and Seed (1978), as discussed below.

A.3.5 Earthquake-induced Levee Deformations

Seismic-induced permanent deformations of the levee were estimated using both the Newmark Double Integration Method (1965) and the Makdisi and Seed Simplified Procedure (1978).

The Newmark Double Integration Method (1965) is based on the concept that deformations of an embankment will result from incremental sliding during the short periods when earthquake inertia forces in the critical slide mass exceed the available resisting forces. This method involves the calculation of the displacement (deformation) increment of a critical slide mass at each time step using the average horizontal acceleration (K_{ave}) and the value of yield acceleration (K_y) calculated for the slide mass. The displacement increment is calculated by double integrating the difference between K_{ave} and K_y values at time acting on the slide mass over time. The estimated permanent deformation of the slide mass is then taken as the sum of displacement increments at the end of ground shaking.

The Newmark method assumes that a well-defined failure surface will develop and that the materials will exhibit elastic-plastic behavior. Although these assumptions are only rough approximation on the true behavior of the slide mass under the earthquake shaking, the method has been shown to provide good estimates of the observed earthquake-induced deformations of dams (Makdisi and Seed, 1978).

Figures A.13 and A.14 show the computed permanent deformations for the critical slide masses of the levee cross section at Station 160+00 of Webb Tract. Figures A.18 and A.19 show the computed permanent deformations for the critical slide masses of the levee cross section at Station 630+00 of Webb Tract. Figures A.23 and A.24 show the computed permanent deformations for the critical slide masses of the levee cross section at Station 25+00 of Bacon

Island. Figures A.28 and A.29 show the computed permanent deformations for the critical slide masses of the levee cross section at Station 265+00 of Bacon Island. In these figures, we show the deformations calculated using the K_{ave} time histories applied in the "normal" and "reversed" directions. The "reserved" direction was obtained by flipping the time history about the time axis.

The simplified procedure of Makdisi and Seed (1978) was developed based on observations on dam performance during past earthquakes and analysis results. In this method, the inertia forces on the slide mass are represented by the peak average horizontal acceleration (K_{max}) induced by the design earthquake. Empirical relationships relating the ratio of the K_y and K_{max} (K_y/K_{max}) and the average deformation were then used to estimate the levee deformation.

The calculated deformations of the identified critical slide masses of the levees on the Webb Tract and Bacon Island are tabulated in Table A.3. Deformations estimated using the Newmark Double Integration Method and the simplified procedure of Makdisi and Seed are both listed for comparison. In estimating the deformation, we rounded up the calculated deformation to the nearest 0.5 ft. Also, the empirical relationships of Makdisi and Seed (1978) were developed for a magnitude range of 6.5 to 8.25. Since the 1987 Whittier Narrows earthquake had a magnitude of 6.0, we used the empirical relationships developed for magnitude 6.5 to estimate the deformations due to the 1987 Whittier Narrows earthquake.

Maximum calculated deformations are about 3-4 feet for the slough-side slopes. On the reservoir side, slope deformations of about 1.5-3.5 feet were estimated. The smaller deformations for the reservoir-side slopes are due to the increased stability provided by the proposed new fills. Both Newmark Double Integration Method and Makdisi and Seed simplified procedure give comparable results.

A.4 SEISMIC-INDUCED GEOLOGIC HAZARDS

A.4.1 Liquefaction

A liquefaction susceptibility evaluation was performed for Webb Tract and Bacon Island. We used the SPT blow counts from the exploratory borings to assess the potential for liquefaction during the occurrence of the design ground motions. The evaluation procedure for liquefaction susceptibility proposed by the NCEER Workshop (Youd and Idriss,1997) was utilized for this study.

Penetration blow counts were taken from the boring logs presented in a report by Harding Lawson Associates (HLA, 1989). We applied the corrections for the fines contents and overburden pressure to the measured blow counts. No corrections for the drilling procedure and testing equipment were applied due to the lack of specific details on equipment and drilling techniques used.

Two design ground motion criteria were selected for the analyses: earthquakes with magnitude (M_w) 6 and peak ground acceleration of 0.25g, and magnitude (M_w) 7.7 and peak ground acceleration of 0.13g. These ground motions represent the controlling events for the local and distant seismic sources and are consistent with those used in the dynamic response analyses, as described in Section A.3.

The results of the analyses indicate that a few pockets of potentially liquefiable soil deposit exist in the levees and foundation soils. We believe, however, that these liquefiable soil pockets are confined in limited areas and therefore are expected to have negligible adverse effects on the stability of the levees.

A.4.2 Loss of Bearing Capacity

Seismic-induced bearing capacity reduction is associated mainly with the occurrence of liquefaction or pore water pressure generation. The reduction may be substantial for shallow foundations supported on or near the liquefied soils. Based on the results of liquefaction evaluation and the absence of shallow liquifiable foundations layers at the project site, we judge that the risk of loss of bearing capacity that may affect levee performance is insignificant.

A.4.3 Dynamic Soil Compaction

Similar to the seismic-induced bearing capacity loss, the dynamic soil compaction would only be significant following the occurrence of extensive liquefaction and associated liquefaction-induced settlement. Since the potential for liquefaction at the project islands is limited to few isolated pockets, we judge that the potential for dynamic soil compaction (settlement) at these islands is negligible.

A.4.4 Levee Overtopping During Seismic-Induced Seiche

Earthquakes can cause overtopping of levees due to three primary mechanisms: landslide generated waves, static displacement of the reservoir or dynamic displacement of the reservoir. Both the landslide induced waves and static displacement of the reservoir are not expected to occur at the project reservoirs.

Records for past occurrences of seiche are generally incomplete. The largest seiche reported in the United States was in Lake Ouachita in Arkansas with a maximum amplitude of about 0.44 m (1.5 feet). We have estimated the amplitudes of seismic-induced waves (dynamic displacement of reservoir water) using the procedure of United States Committee on Large Dams (USCOLD, 1995). The results of analysis seem to indicate a negligible amplitude of seismic-induced wave (less than 1 foot). It should be noted that this procedure was developed for a limited body of water (tanks, dams) and has been assumed to be applicable to the DW project reservoirs.

Table A.1
Dynamic Soil Parameters Used in the Response Analysis

Description	Moist Unit Weight pcf	K_{2max}	Shear Wave Velocity ft/sec	Modulus and Damping Curves
Levee Materials				
New fills: sand	120	80	-	Sand[3]
Fills: sand	105-110	25	-	Sand[3]
Fills: soft clay	70	-	250	Clay[1]
Fills: silty sand with fat clay	110	25	-	Sand[3]
Fills: clay with peat	80	-	300	Clay[1]
Fills: silty clay with sand	110		450	Clay[2]
Peat	70	-	250	Peat[4]
Foundation Materials				
Sand	120-125	80	-	Sand[3]
Clay	127	-	700	Clay[2]

Note : 1: Relationships of Vucetic and Dobry (1991) for PI = 100
2: Relationships of Vucetic and Dobry (1991) for PI = 50
3: Relationships of Seed and Idriss (1970) for mean
4: Relationships of Boulanger et al (1997)

Table A.2
Summary of the Earthquake Records Used in the Dynamic Response Analysis

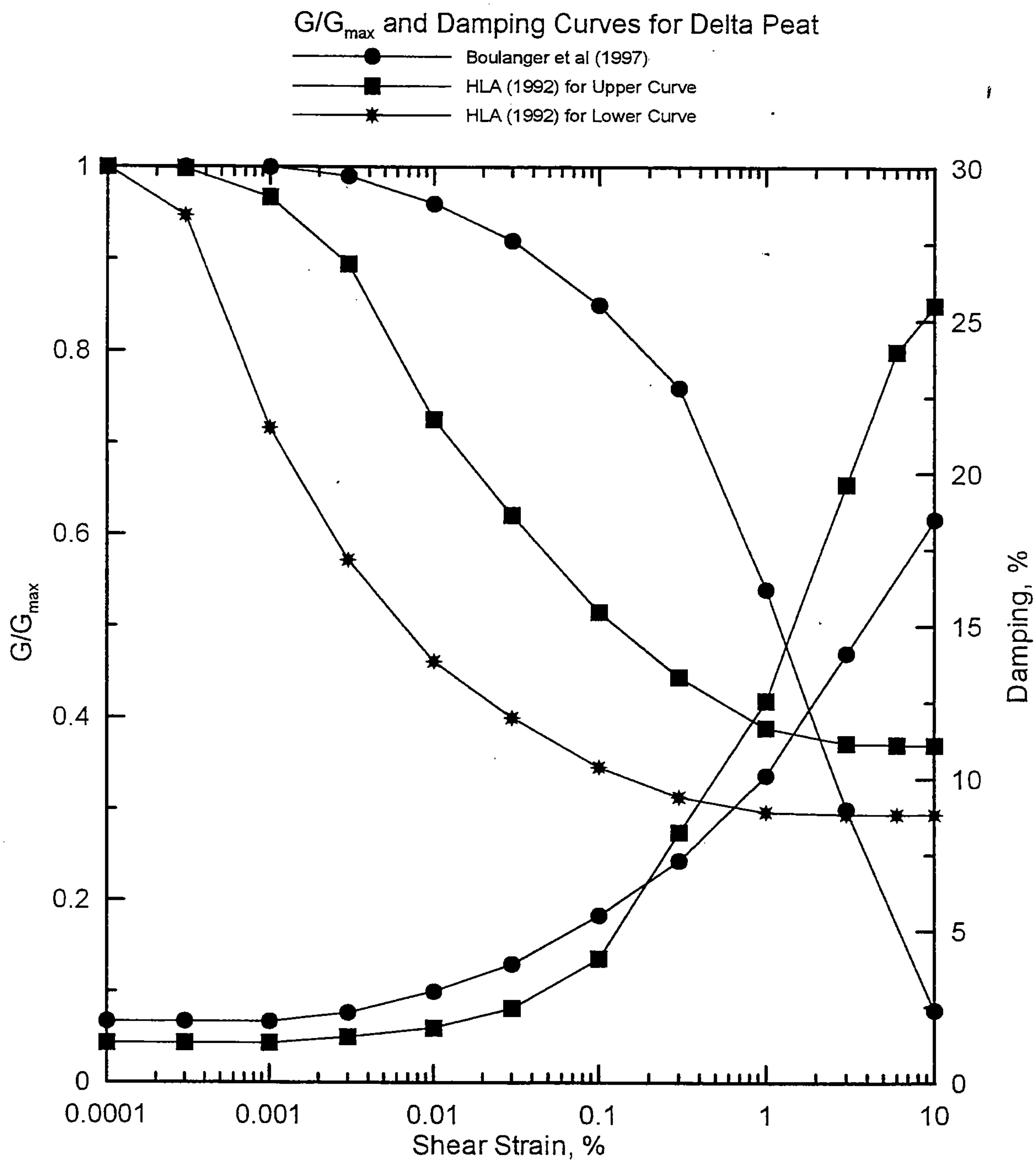
Earthquake	M_w	Recording Station			Comp	Recorded PGA (g)
		Distance (km)	Station #	Site Condition		
1987 Whittier Narrows	6.0	18	24402[b]	Soil[a]	90°	0.15
1992 Landers	7.3	64	24577[c]	Soil[a]	0°	0.11

Note : a = Deep Stiff Soil Site
b = Altadena – Eaton Canyon Station
c = Fort Irwin Station

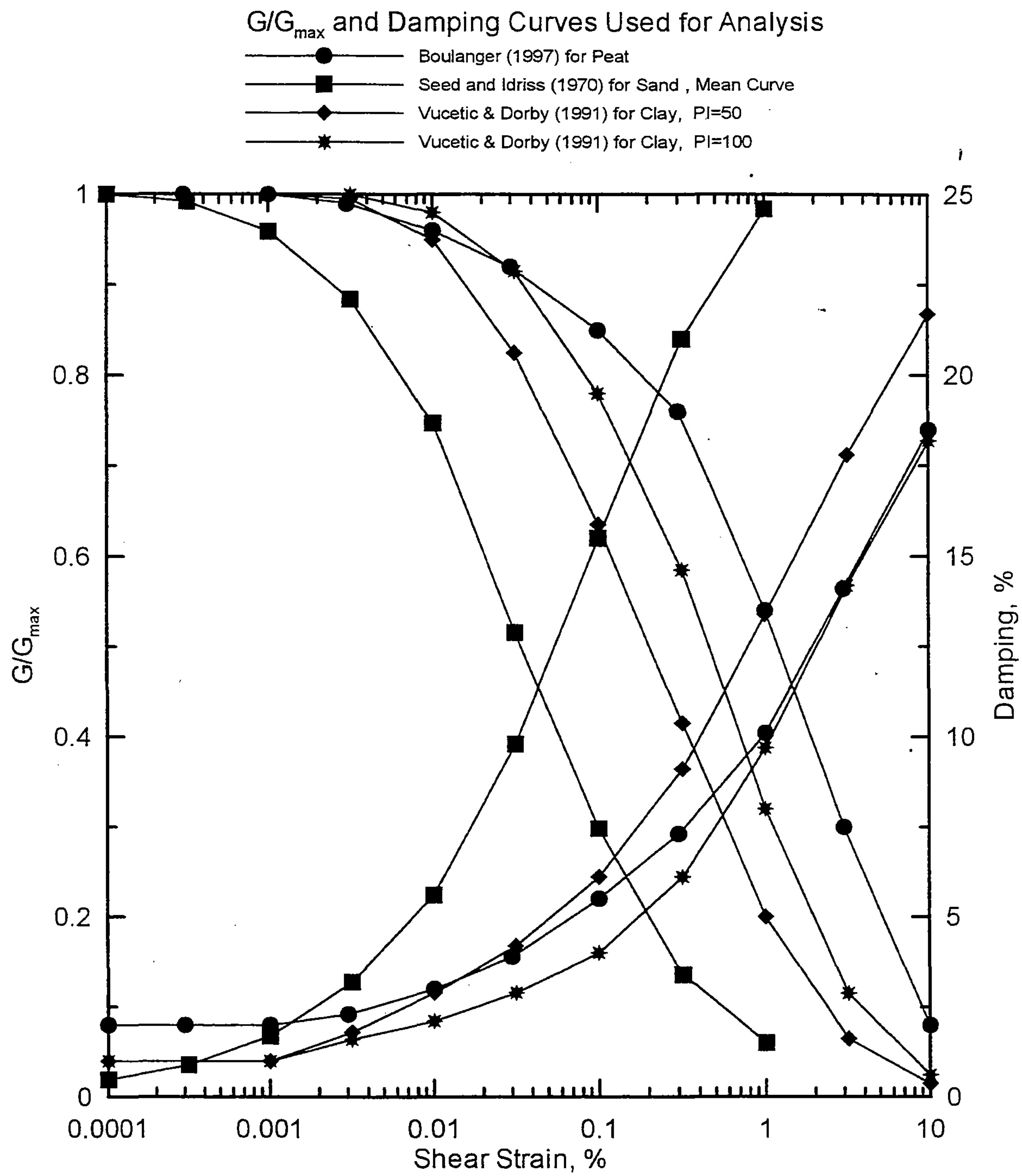
Table A.3
Calculated Seismic-induced Slope Deformations

Critical Slide	K_y (g)	K_{max} (g)	Max Deformation (ft)	
			Newmark[1]	Makdisi & Seed[2]
Webb Tract at St. 160+00				
Reservoir-side Slope				
Crest Slide[3]	0.114	0.40	2.0	0.5-1.5
Slough-side Slope				
Crest Slide[3]	0.025	0.21	3.5	0.5-3.5
Webb Tract at St. 630+00				
Reservoir-side Slope				
Crest Slide[4]	0.151	0.36	1.5	0-1.0
Slough-side Slope				
Crest Slide[4]	0.027	0.26	4.0	1.0-4.0
Bacon Island at St. 25+00				
Reservoir-side Slope				
Upper Toe Slide[5]	0.148	0.47	3.5	0.5-1.0
Slough-side Slope				
Crest Slide[5]	0.048	0.31	3.5	0.5-3.0
Bacon Island at St. 265+00				
Reservoir-side Slope				
Crest Slide[6]	0.133	0.36	1.5	0.5-1.0
Slough-side Slope				
Crest Slide[6]	0.0385	0.28	3.5	0.5-3.0

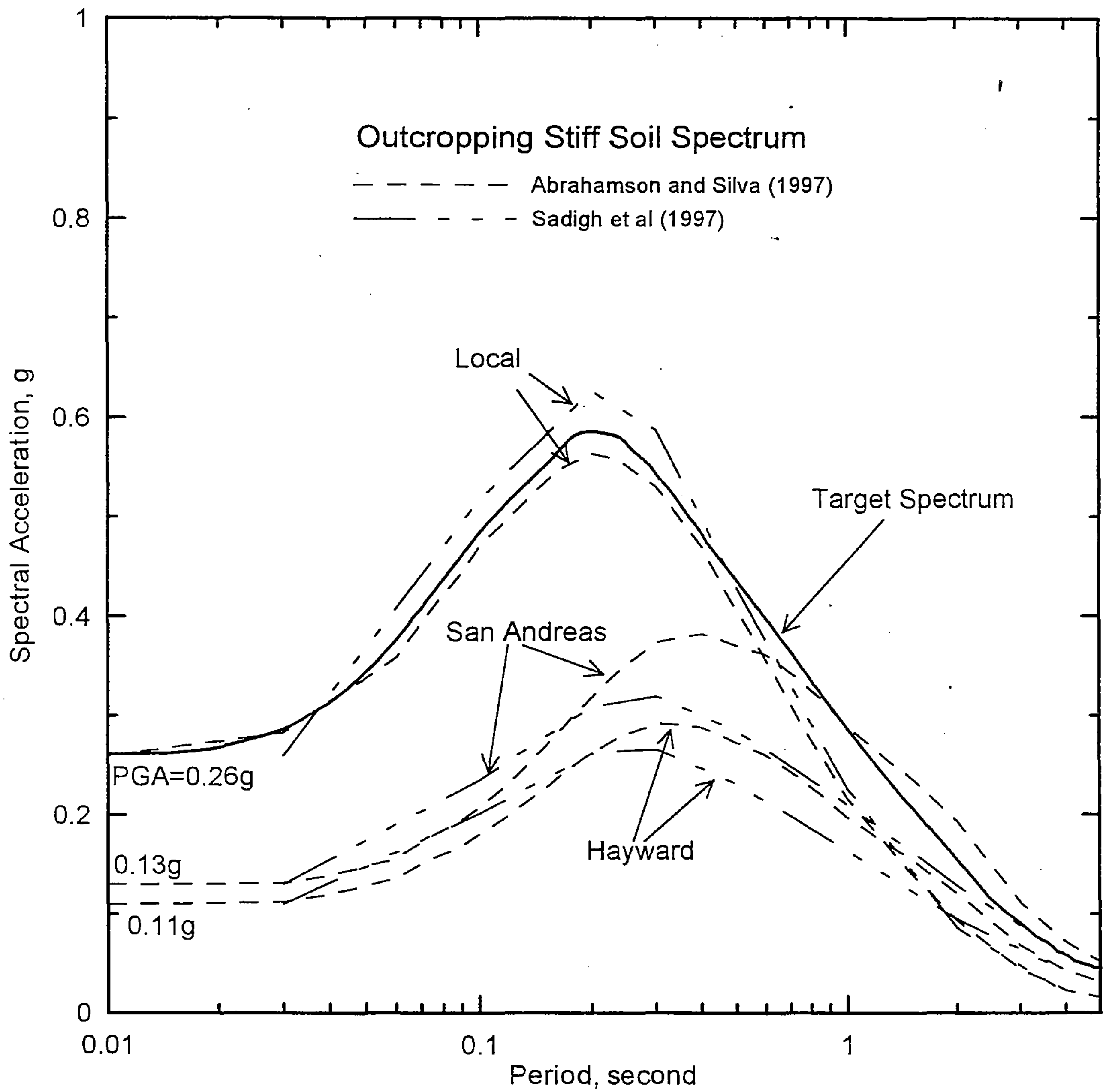
Note:
1: Newmark Double Integration Method (1965)
2: Makdisi and Seed Simplified Method (1978)
3: Refer to Figures 3.5.25 and 3.5.26.
4: Refer to Figures 3.5.7 and 3.5.8.
5: Refer to Figures 3.5.34 and 3.5.35.
6: Refer to Figures 3.5.43 and 3.5.44.



Project No. 410709903000	Delta Wetlands	Comparison of Shear Modulus Reduction and Damping Curves for Delta Peat	Figure A.1
URS Greiner Woodward Clyde			

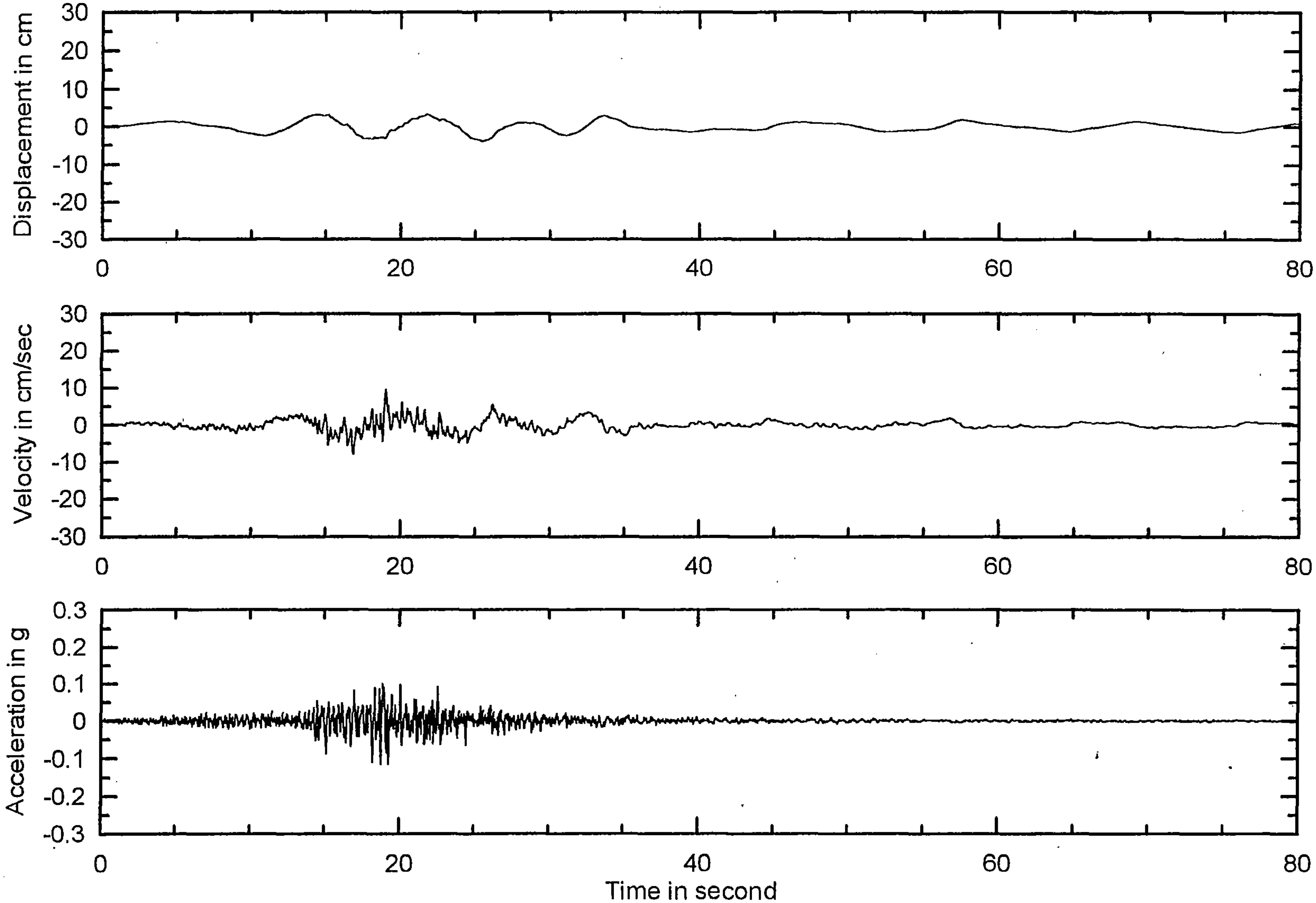


Project No. 410709903000	Delta Wetlands	Shear Modulus and Damping Curves Used for Dynamic Response Analysis	Figure A.2
URS Greiner Woodward Clyde			



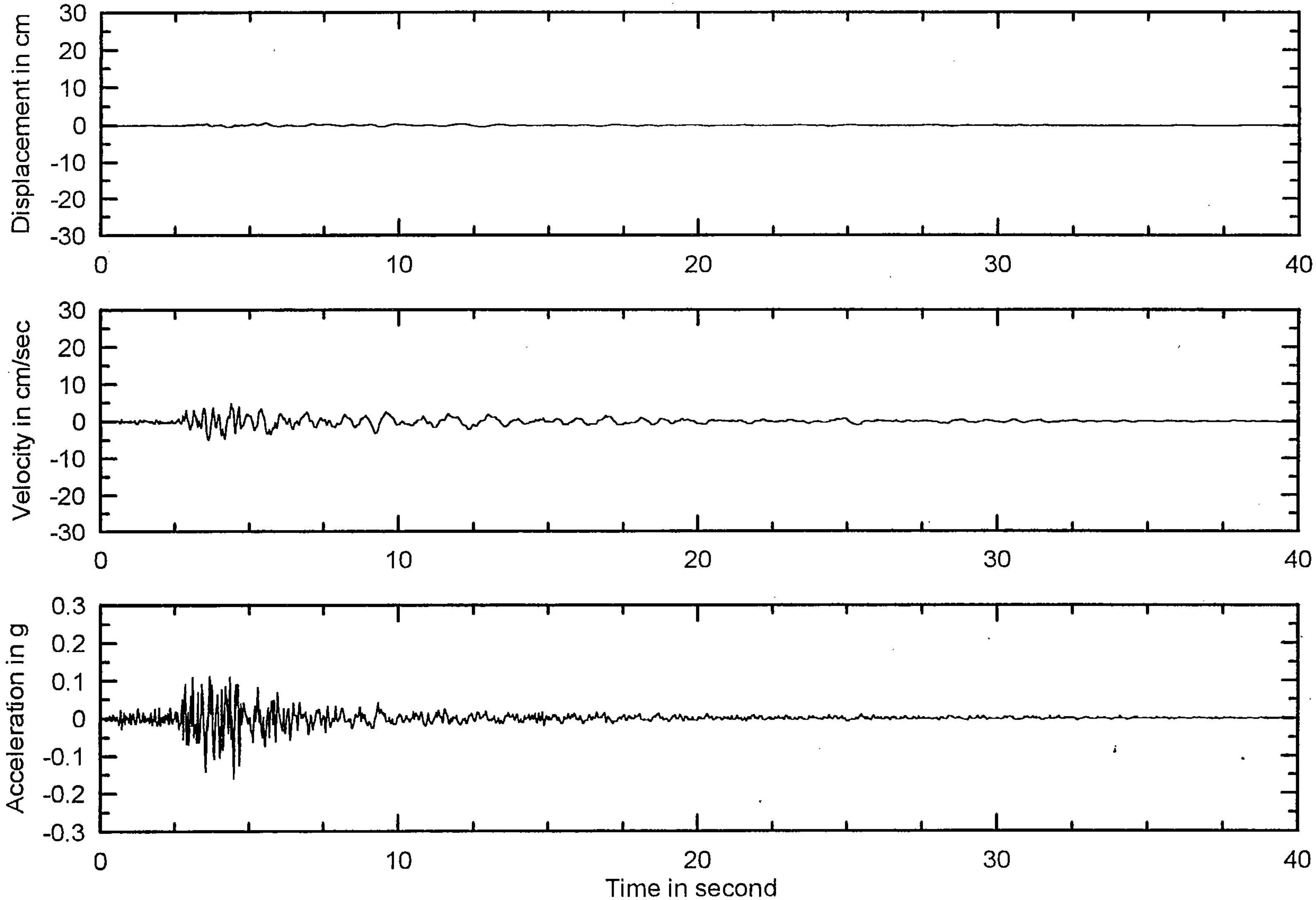
Project No. 410709903000	Delta Wetlands	Design Response Spectrum for Webb Tract and Bacon Island	Figure A.3
URS Greiner Woodward Clyde			

1992 Landers Earthquake at St. 24577 (Fort Irwin), 0 Degree Component
Recorded Ground Motions

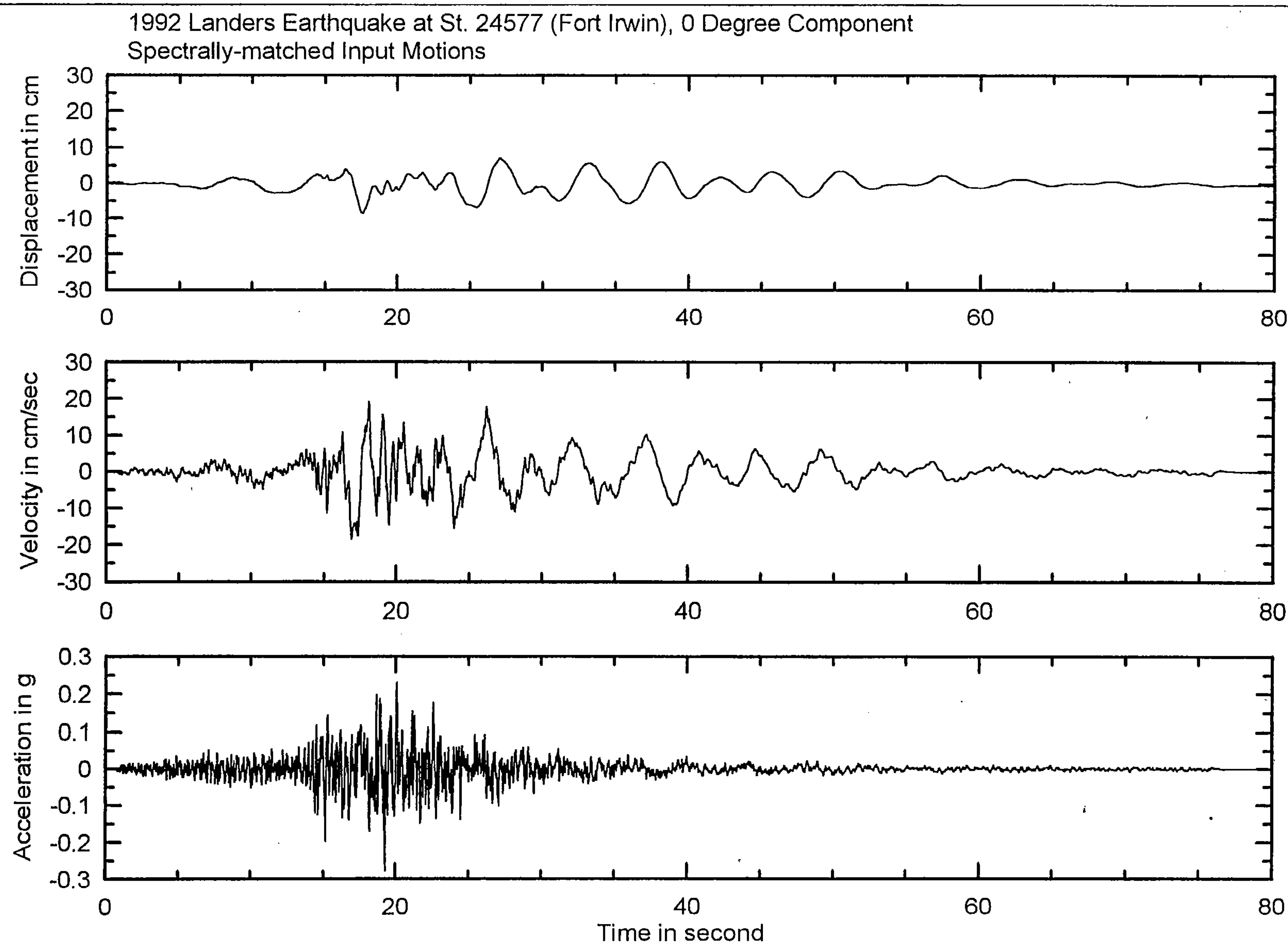


Project No. 410709903000	Delta Wetlands	Recorded Ground Motions for 1992 Landers Earthquake at St. 24577, 0 Degree Component	Figure A.4
URS Greiner Woodward Clyde			

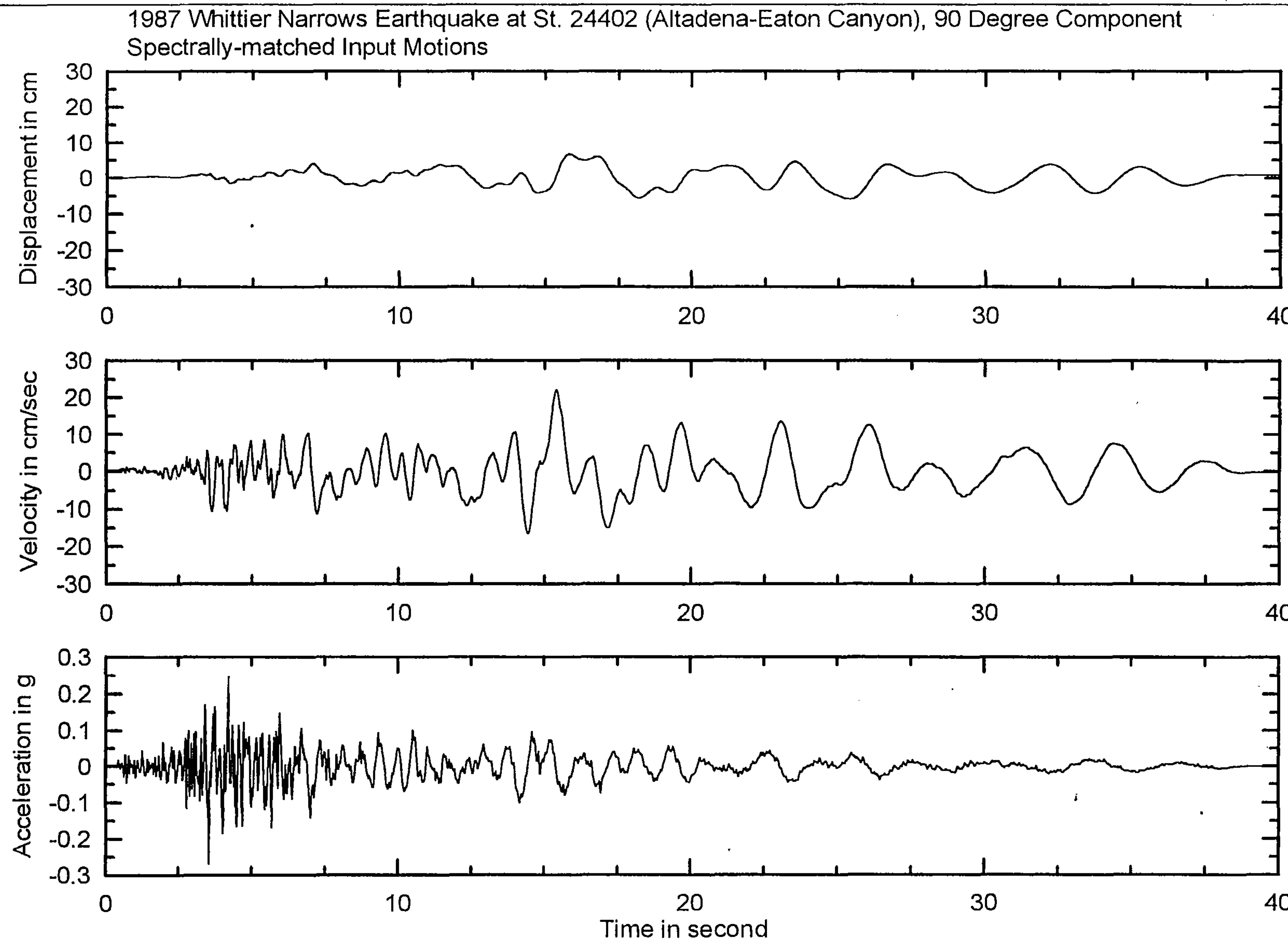
1987 Whittier Narrows Earthquake at St. 24402 (Altadena-Eaton Canyon), 90 Degree Component
Recorded Ground Motions



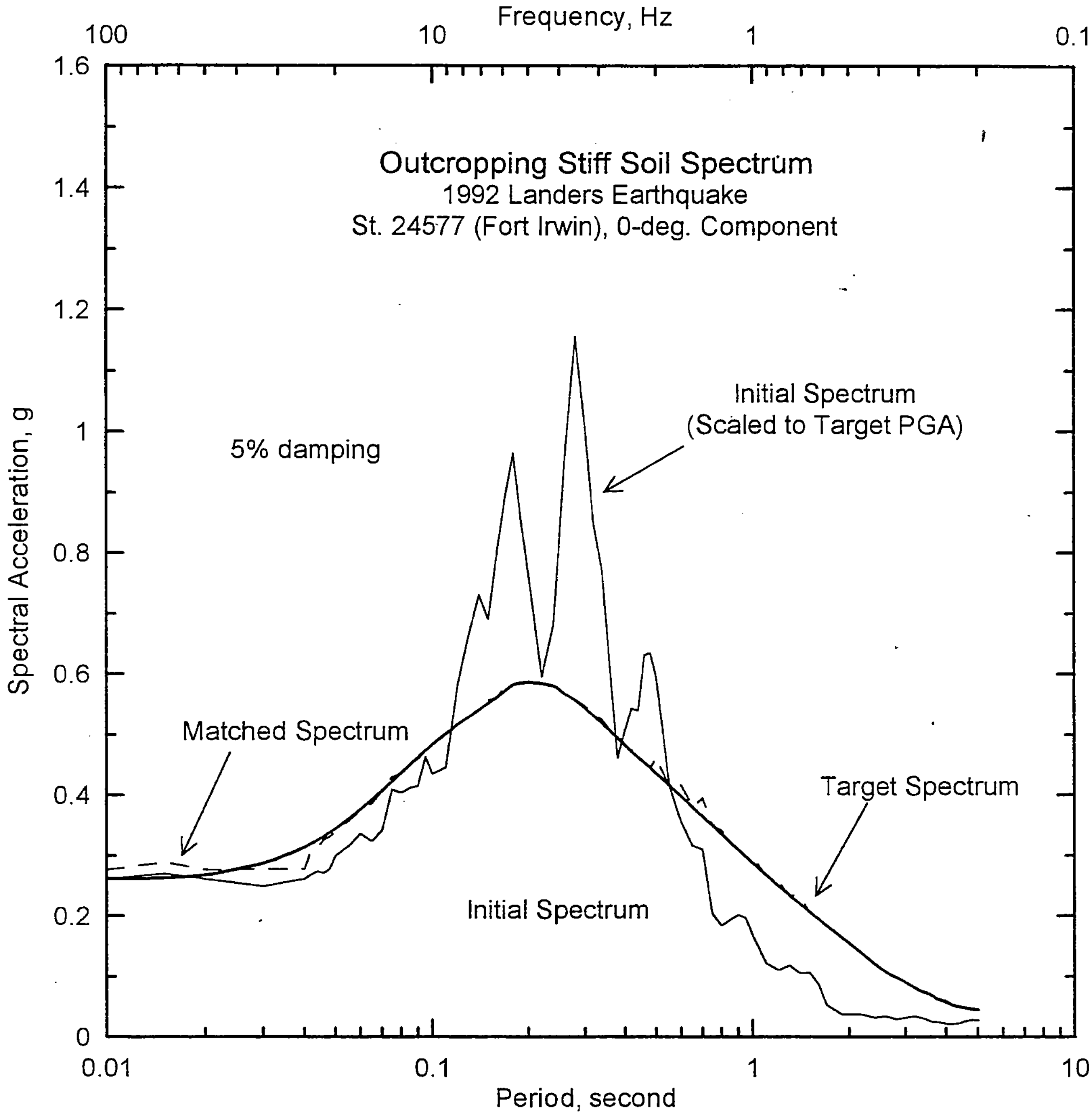
PROJECT NO. 410709903000	Delta Wetlands	Recorded Ground Motions for 1987 Whittier Narrows Earthquake at St. 24402, 90 Degree Component	Figure A.5
URS Greiner Woodward Clyde			



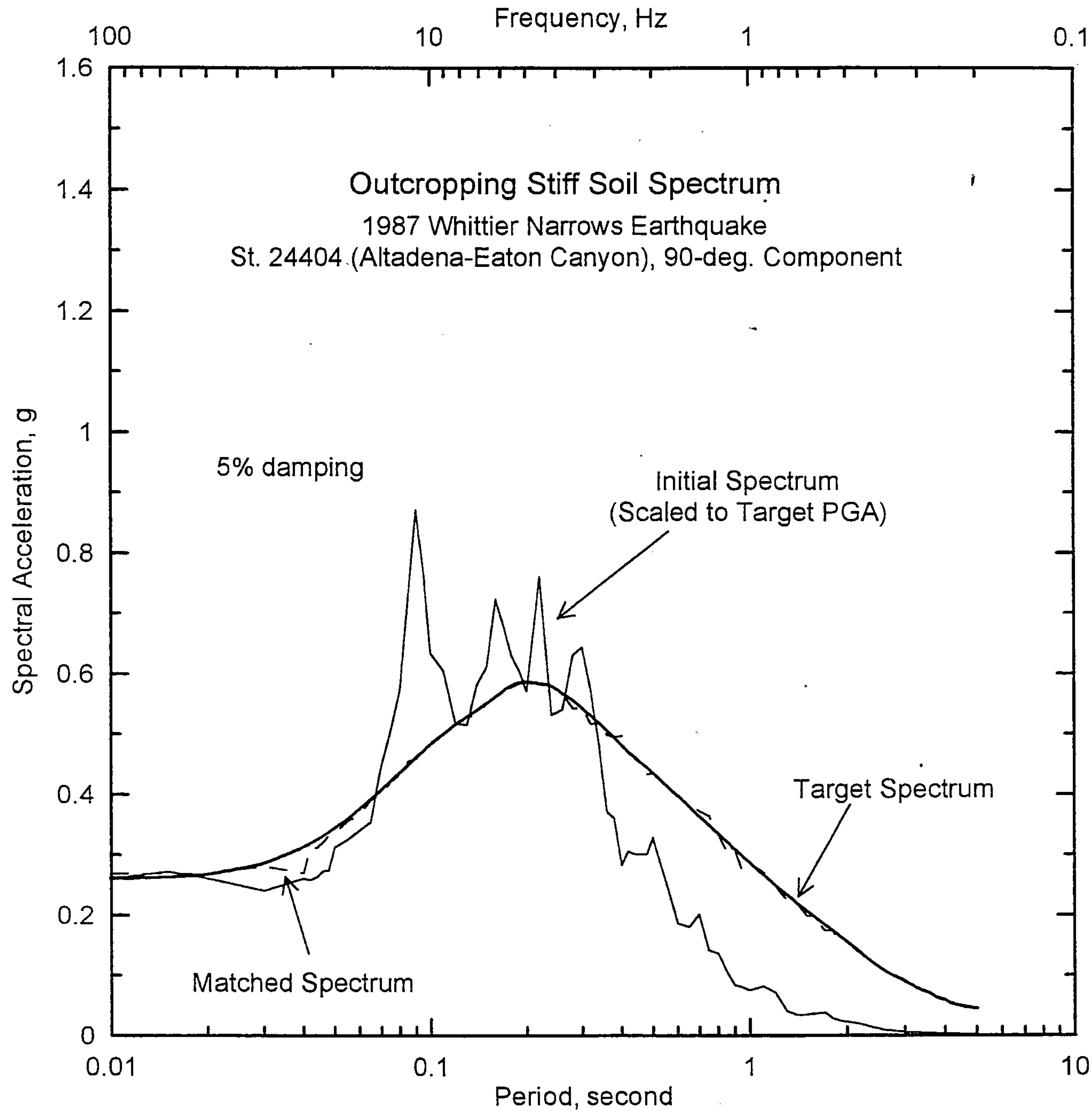
Project No. 410709903000	Delta Wetlands	Spectrally Matched Ground Motions for 1992 Landers Earthquake at St. 24577, 0 Degree Component	Figure A.6
URS Greiner Woodward Clyde			



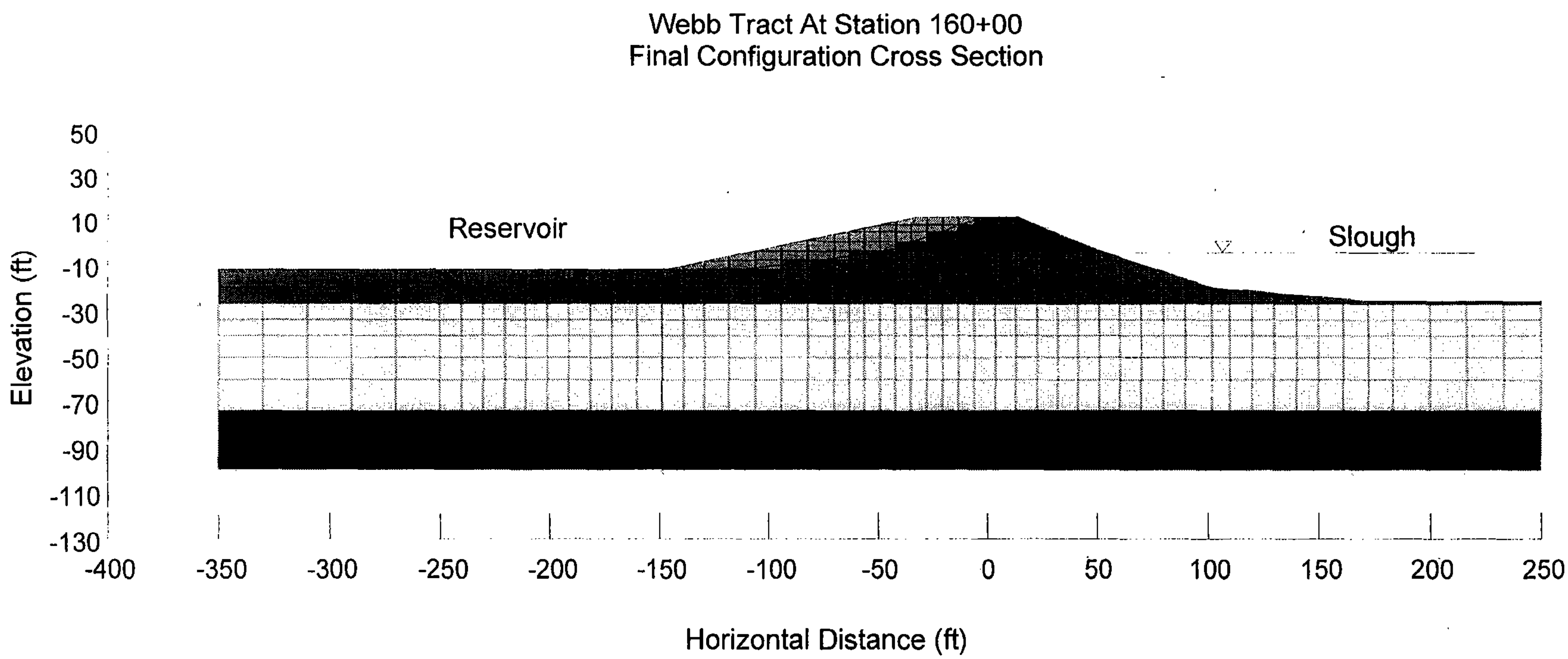
Project No. 410709903000	Delta Wetlands	Spectrally Matched Ground Motions for 1987 Whittier Narrows Earthquake at St. 24402, 90 Degree Component	Figure A.7
URS Greiner Woodward Clyde			



Project No. 410709903000	Delta Wetlands	Design Response Spectrum and Recorded and Modified Spectra for 1992 Landers Earthquake	Figure A.8
URS Greiner Woodward Clyde			



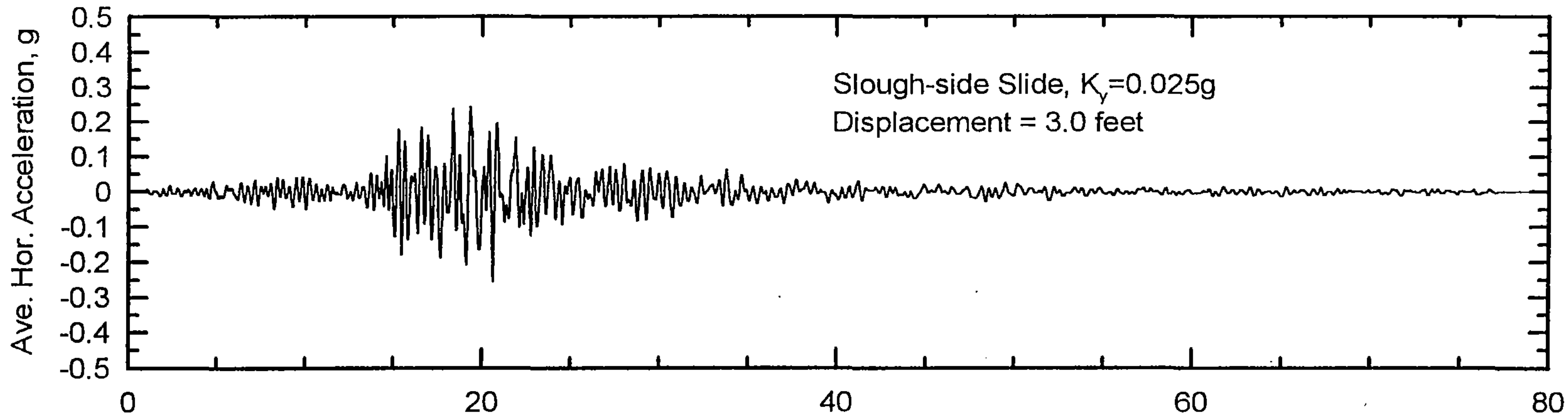
Project No. 410709903000	Delta Wetlands	Design Response Spectrum and Recorded and Modified Spectra for 1987 Whittier Narrows Earthquake	Figure A.9
URS Greiner Woodward Clyde			

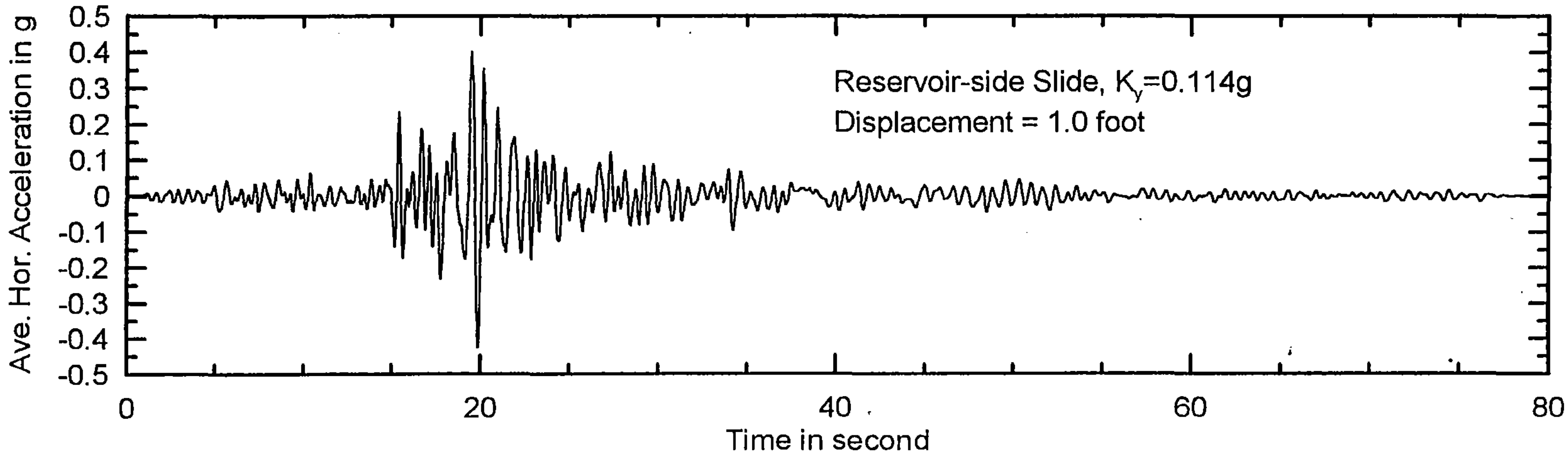


Project No. 410709903000	**Delta Wetlands**	Finite Element Mesh for Webb Tract Levee at Station 160+00	Figure A.10
URS Greiner Woodward Clyde			

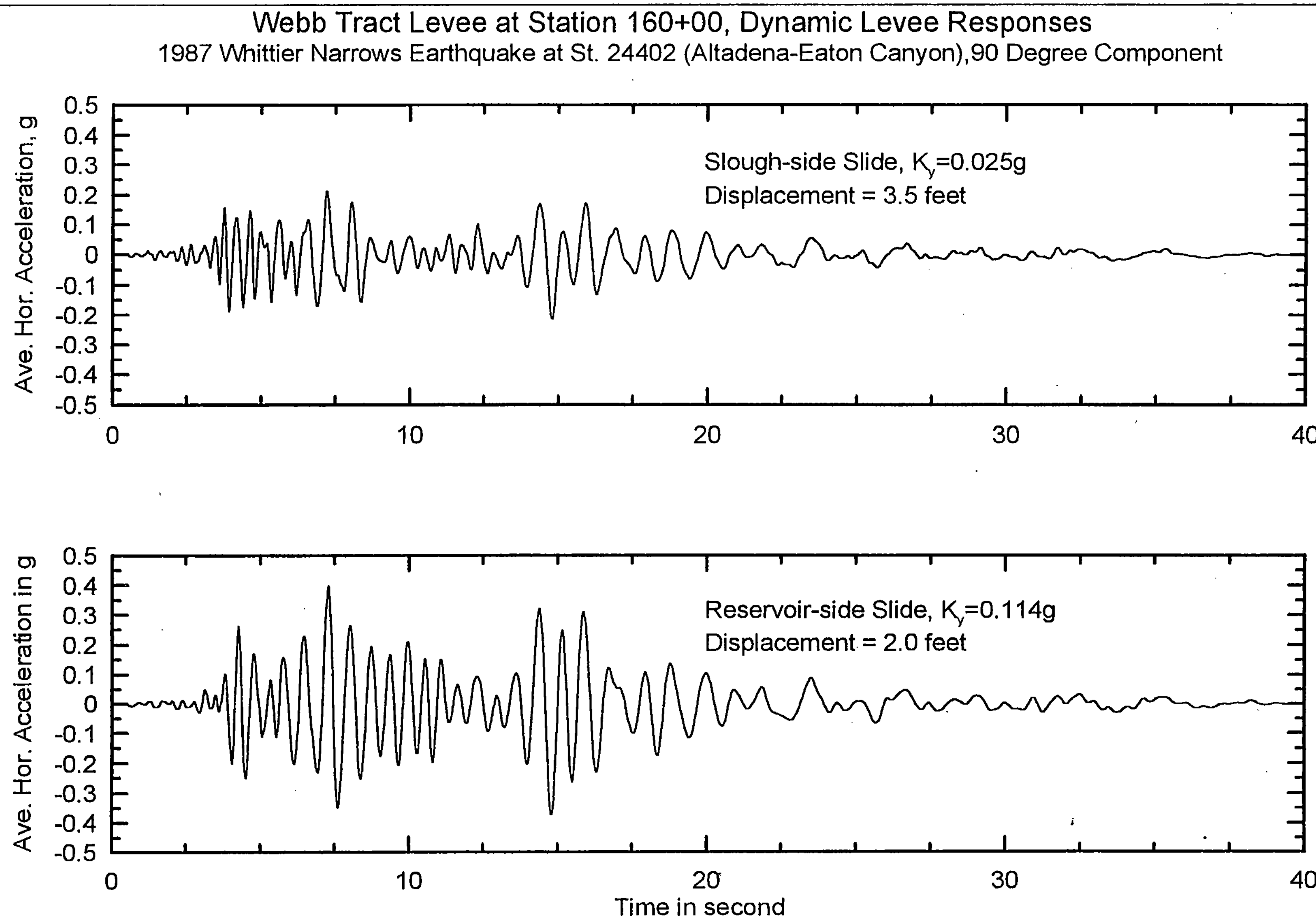
Webb Tract Levee at Station 160+00, Dynamic Levee Responses

1992 Landers Earthquake at St. 24577 (Fort Irwin), 0 Degree Component

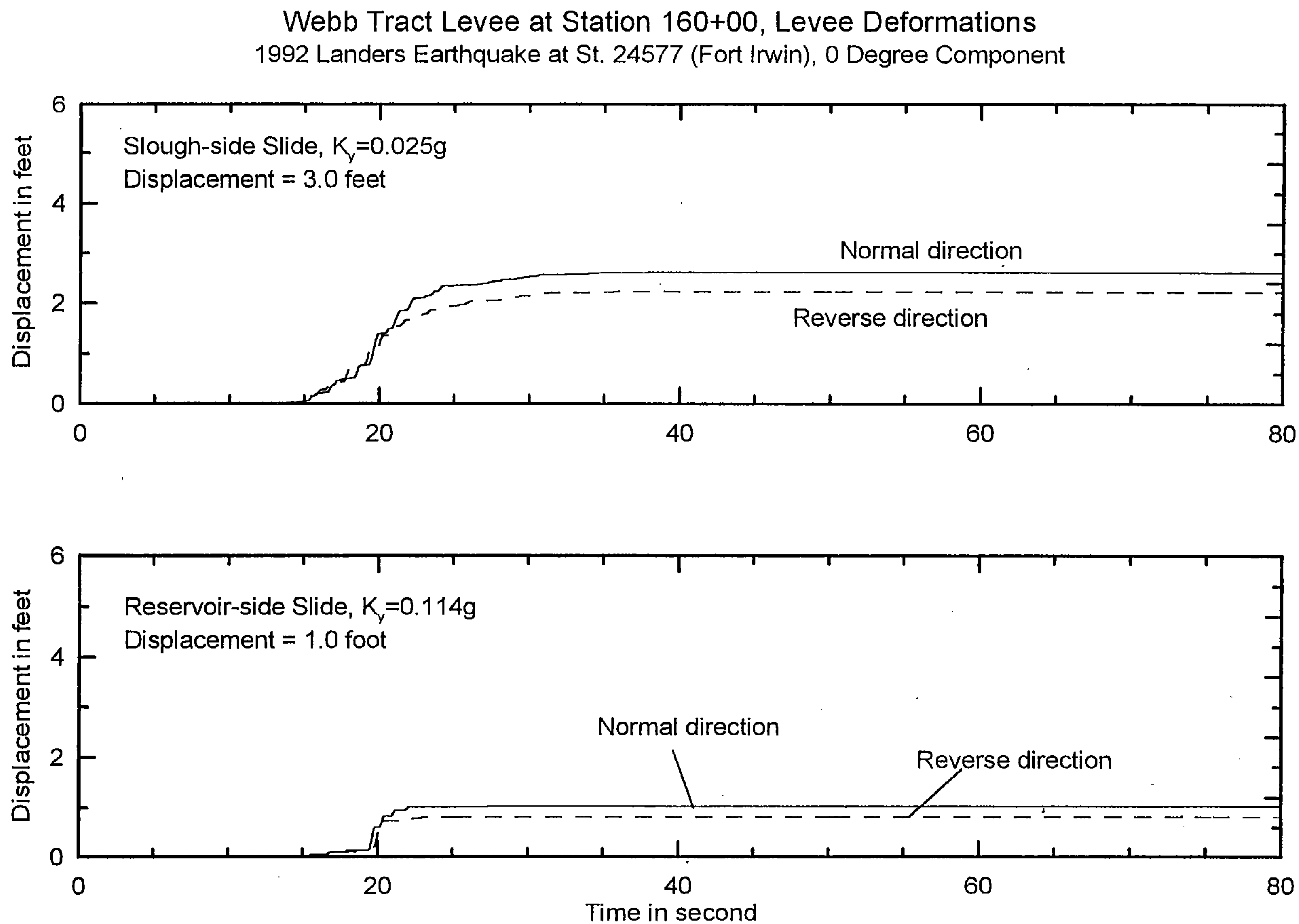




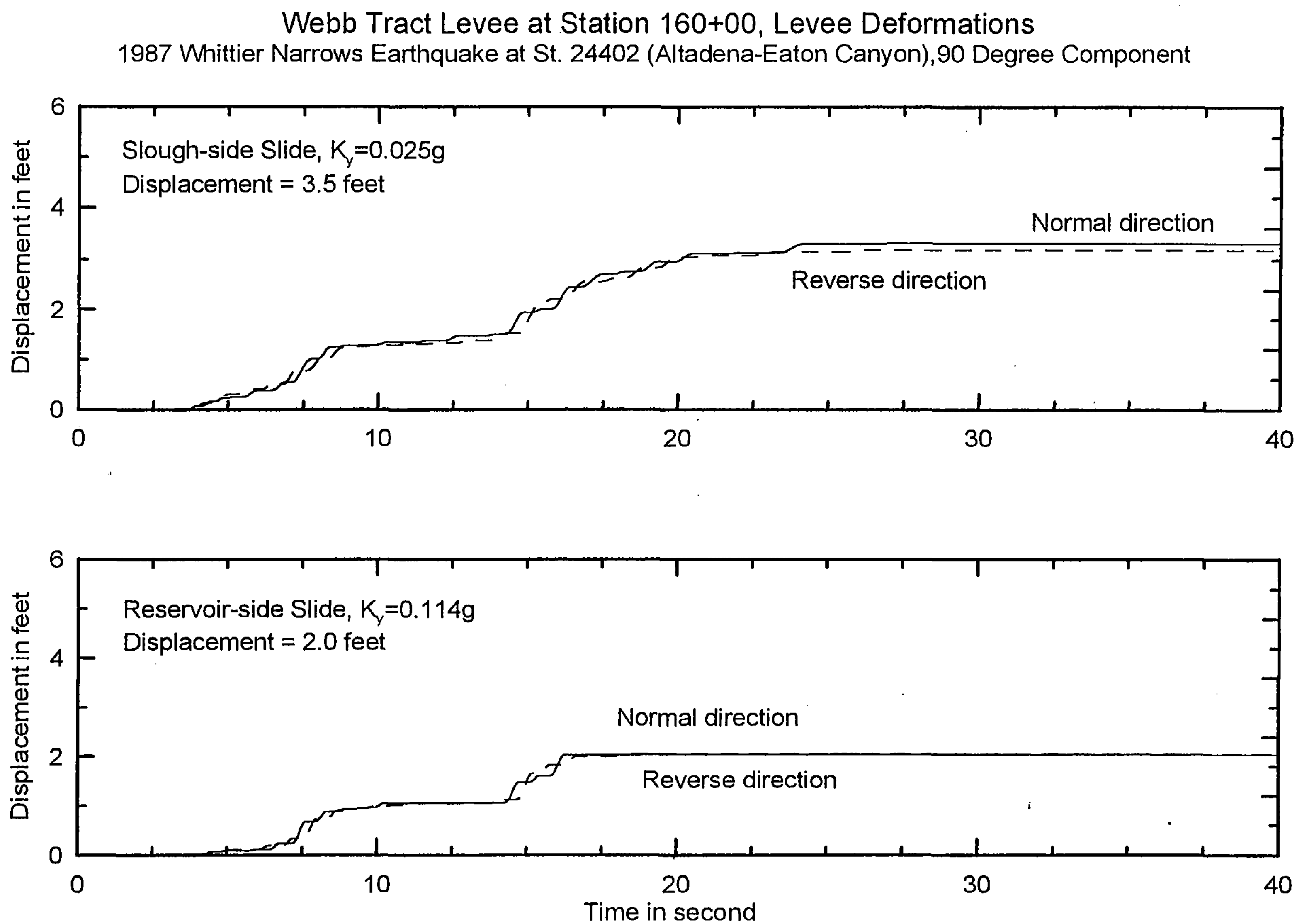
Project No. 410709903000	Delta Wetlands	Average Horizontal Acceleration Time Histories Acting on Critical Slide Masses for 1992 Landers Earthquake - Webb Tract Levee at St. 160+00	Figure A.11
URS Greiner Woodward Clyde			



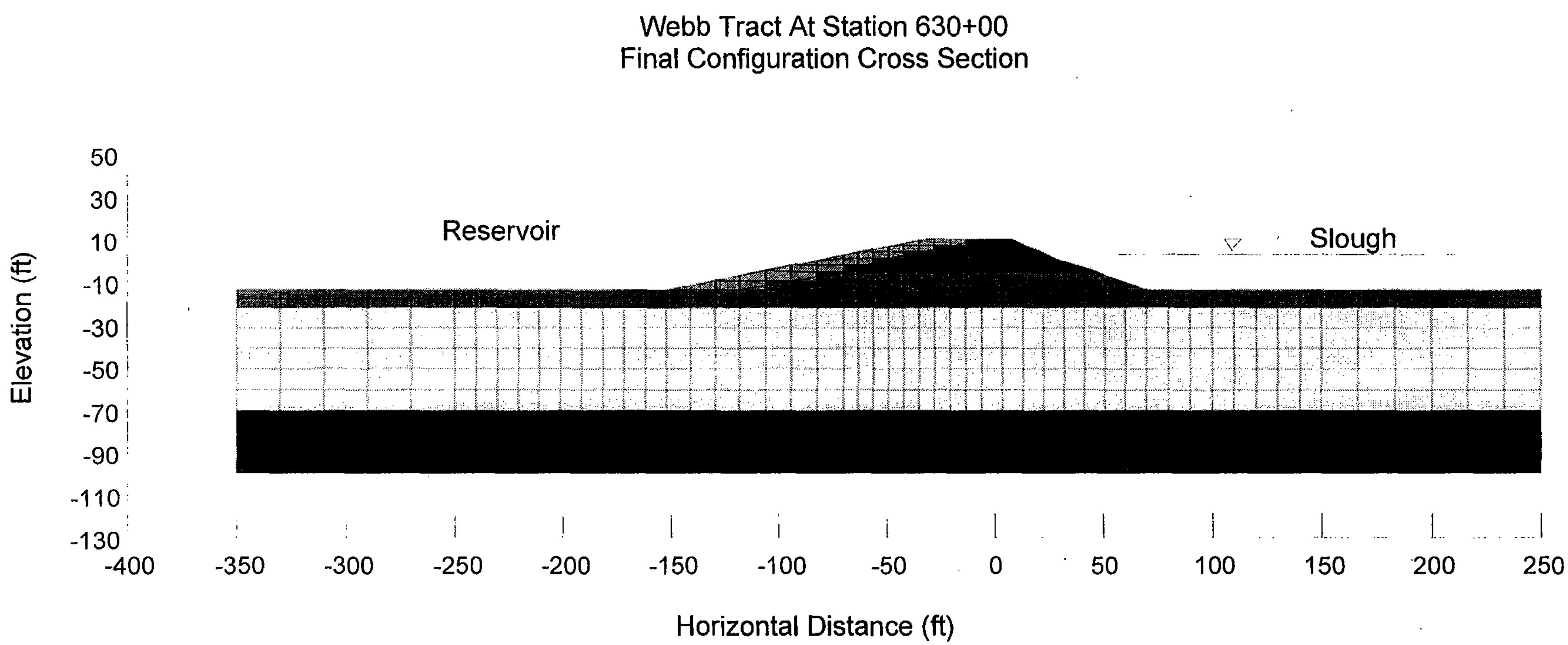
Project No. 410709903000	Delta Wetlands	Average Horizontal Acceleration Time Histories Acting on Critical Slide Masses for 1987 Whittier Narrows Earthquake - Webb Tract Levee at Station 160+00	Figure A.12
URS Greiner Woodward Clyde			



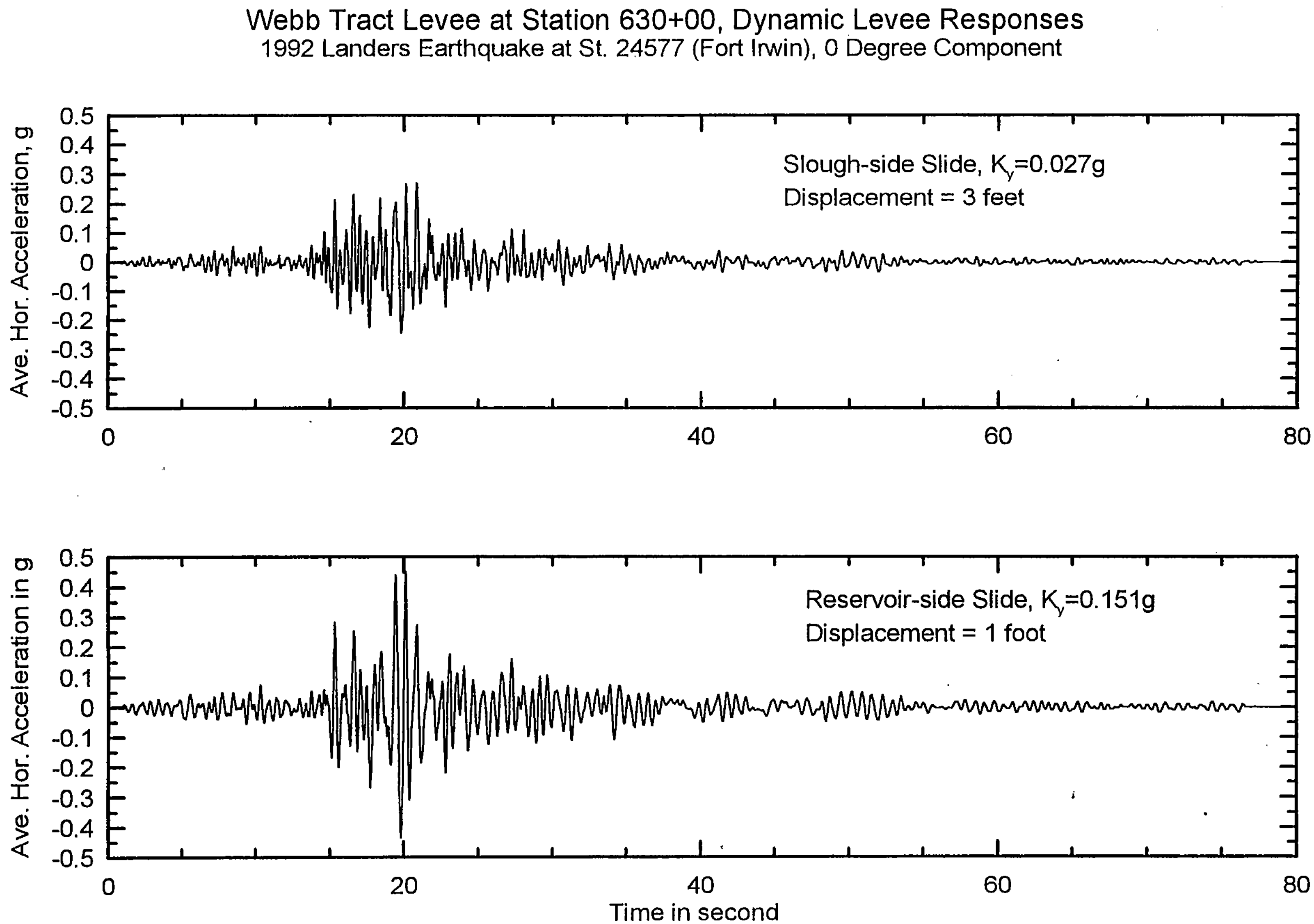
Project No. 410709903000	Delta Wetlands	Permanent Slope Deformation Time Histories of Critical Slide Masses for 1992 Landers Earthquake - Webb Tract Levee at Station 160+00	Figure A.13
URS Greiner Woodward Clyde			



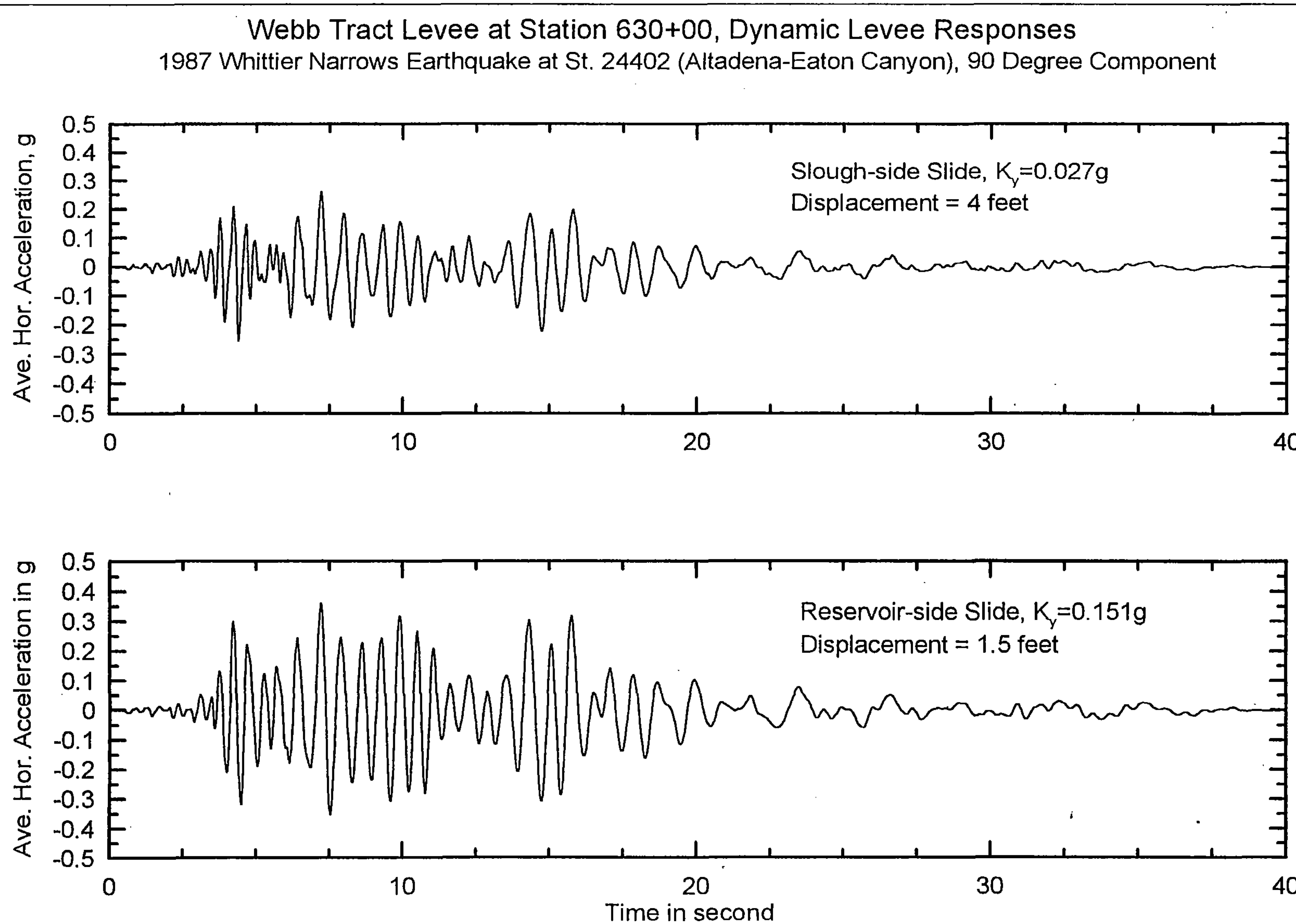
Project No. 410709903000	Delta Wetlands	Permanent Slope Deformation Time Histories of Critical Slide Masses for 1987 Whittier Narrows Earthquake - Webb Tract Levee at Station 160+00	Figure A.14
URS Greiner Woodward Clyde			



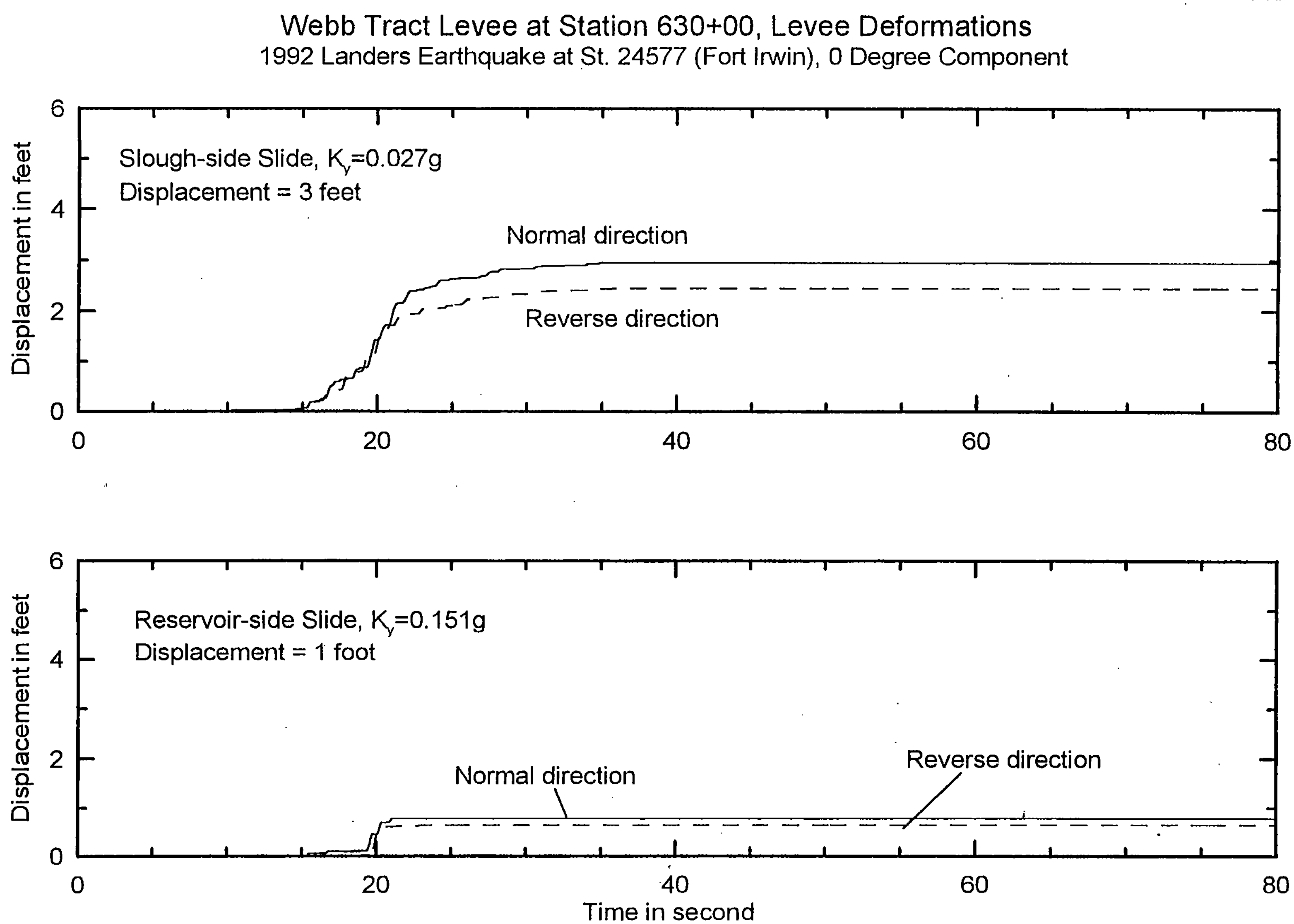
Project No. 410709903000	Delta Wetlands	Finite Element Mesh for Webb Tract Levee at Station 630+00	Figure A.15
URS Greiner Woodward Clyde			



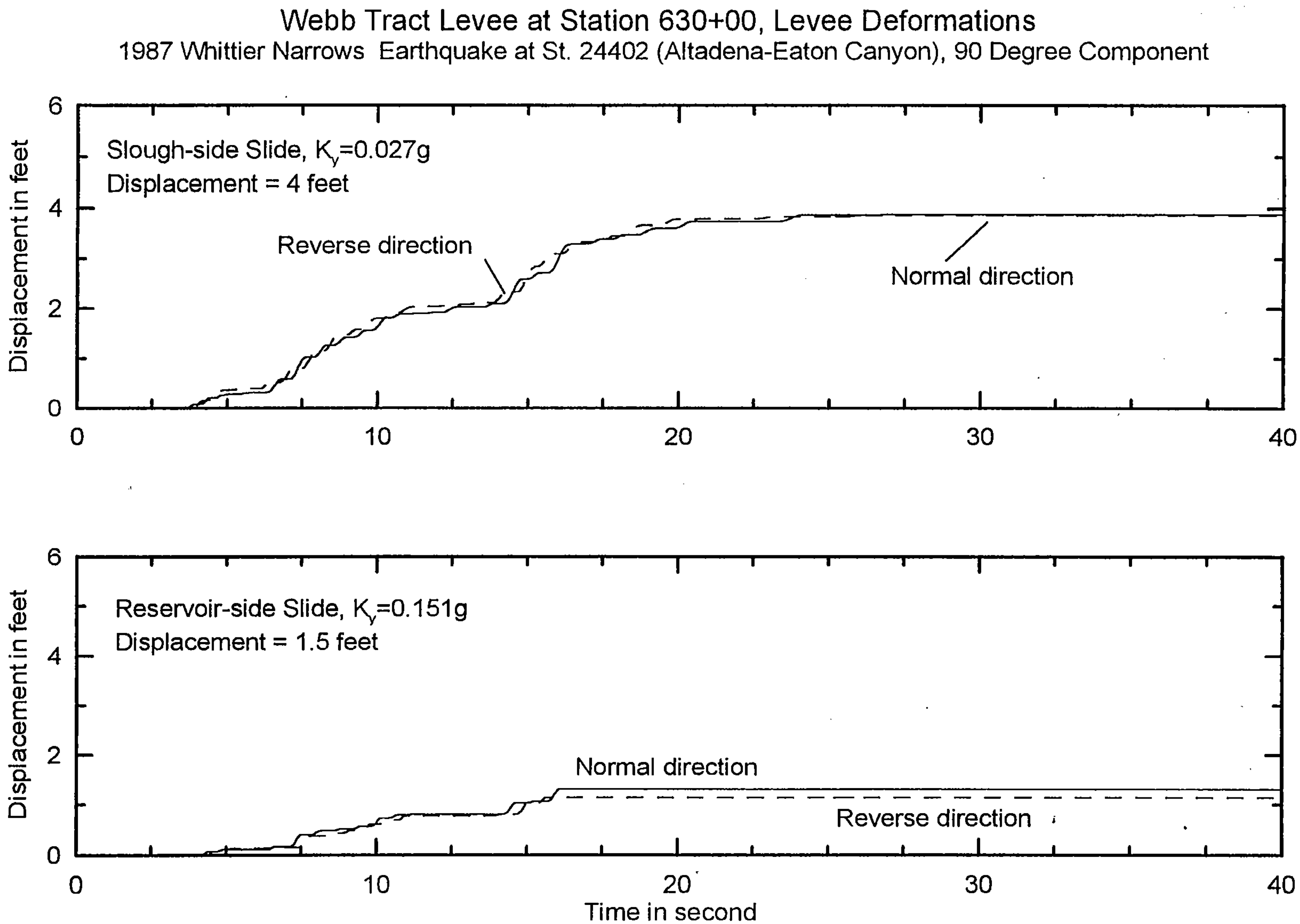
Project No. 410709903000	Delta Wetlands	Average Horizontal Acceleration Time Histories Acting on Critical Slide Masses for 1992 Landers Earthquake - Webb Tract Levee at St. 630+00	Figure A.16
URS Greiner Woodward Clyde			



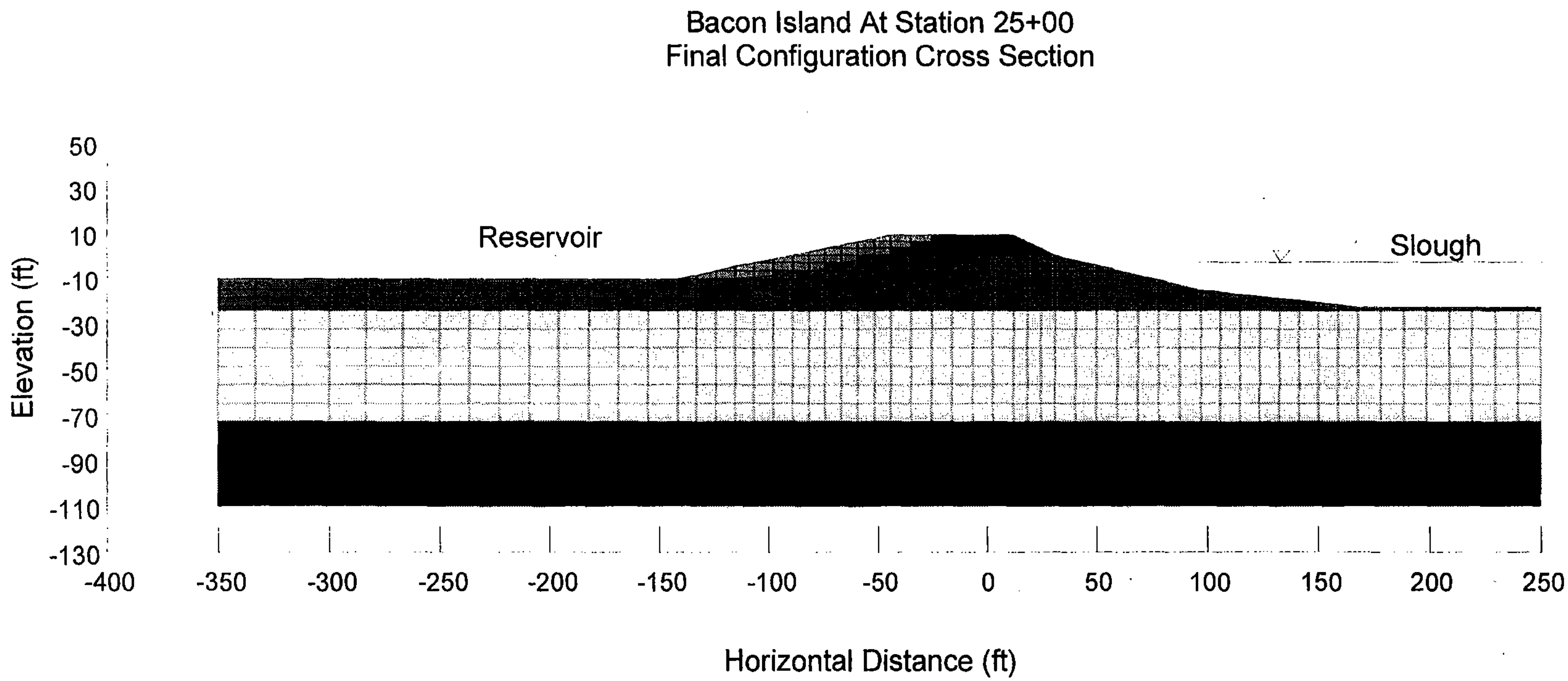
Project No. 410709903000	Delta Wetlands	Average Horizontal Acceleration Time Histories Acting on Critical Slide Masses for 1987 Whittier Narrows Earthquake - Webb Tract Levee at Station 630+00	Figure A.17
URS Greiner Woodward Clyde			



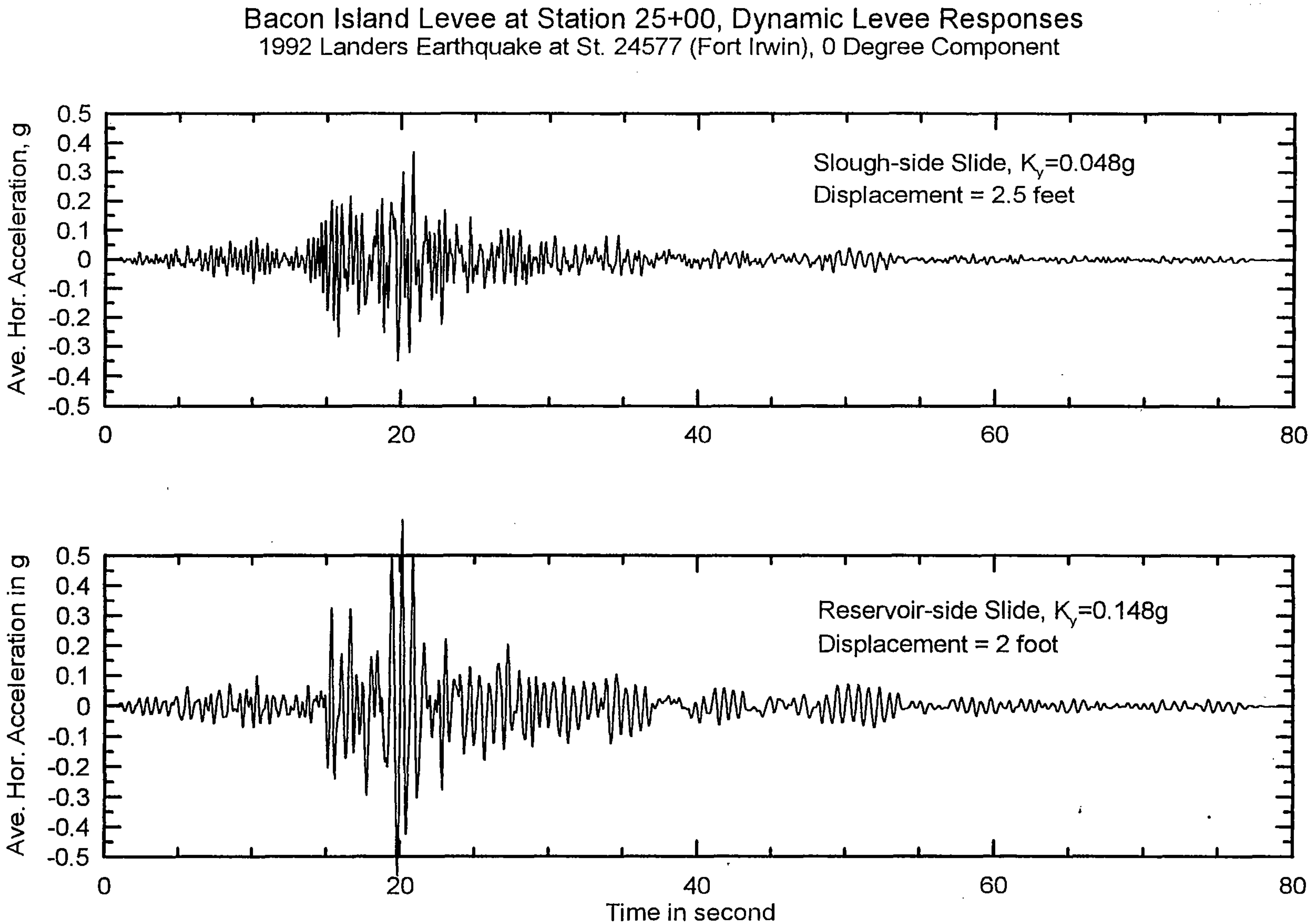
Project No. 410709903000	Delta Wetlands	Permanent Slope Deformation Time Histories of Critical Slide Masses for 1992 Landers Earthquake - Webb Tract Levee at Station 630+00	Figure A.18
	URS Greiner Woodward Clyde		



Project No. 410709903000	Delta Wetlands	Permanent Slope Deformation Time Histories of Critical Slide Masses for 1987 Whittier Narrows Earthquake - Webb Tract Levee at Station 630+00	Figure A.19
URS Greiner Woodward Clyde			



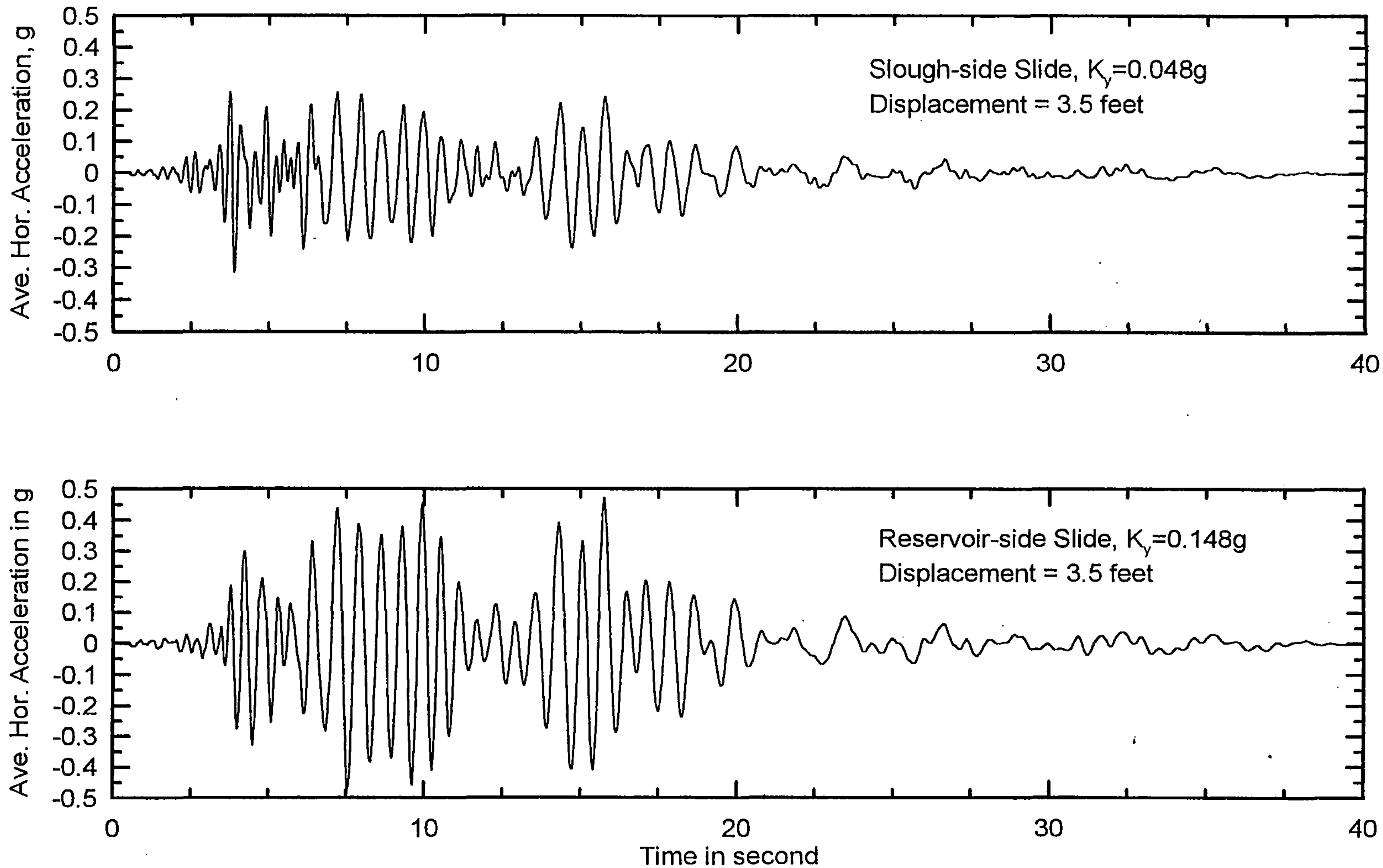
Project No. 410709903000	Delta Wetlands	Finite Element Mesh for Bacon Island Levee at Station 25+00	Figure A.20
	URS Greiner Woodward Clyde		



Project No. 410709903000	Delta Wetlands	Average Horizontal Acceleration Time Histories Acting on Critical Slide Masses for 1992 Landers Earthquake - Bacon Island Levee at St. 25+00	Figure A.21
URS Greiner Woodward Clyde			

Bacon Island Levee at Station 25+00, Dynamic Levee Responses

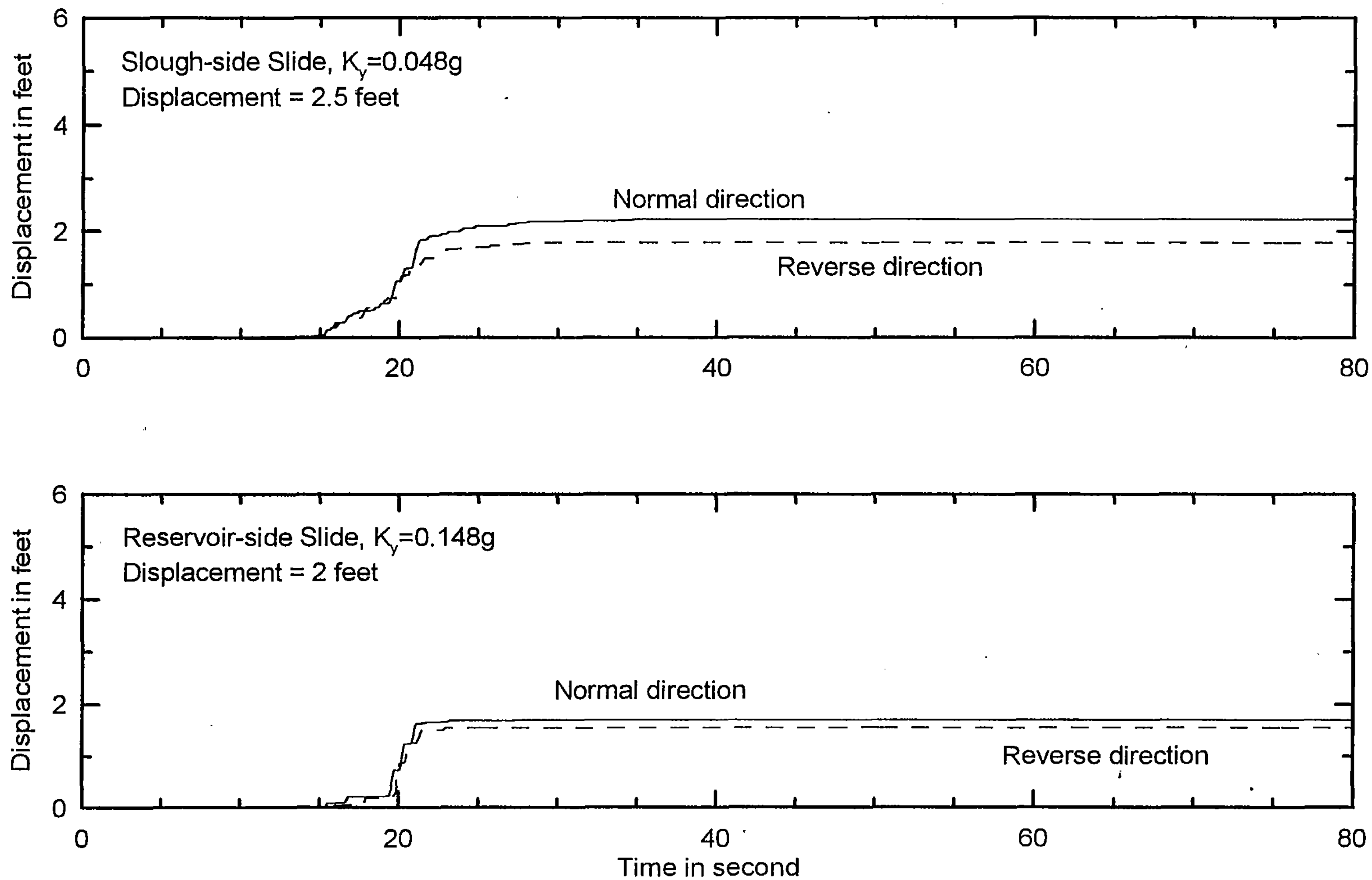
1987 Whittier Narrows Earthquake at St. 24402 (Altadena-Eaton Canyon), 90 Degree Component



Project No. 410709903000	Delta Wetlands	Average Horizontal Acceleration Time Histories Acting on Critical Slide Masses for 1987 Whittier Narrows Earthquake - Bacon Island Levee at Station 25+00	Figure A.22
URS Greiner Woodward Clyde			

Bacon Island Levee at St. 25+00, Levee Deformations

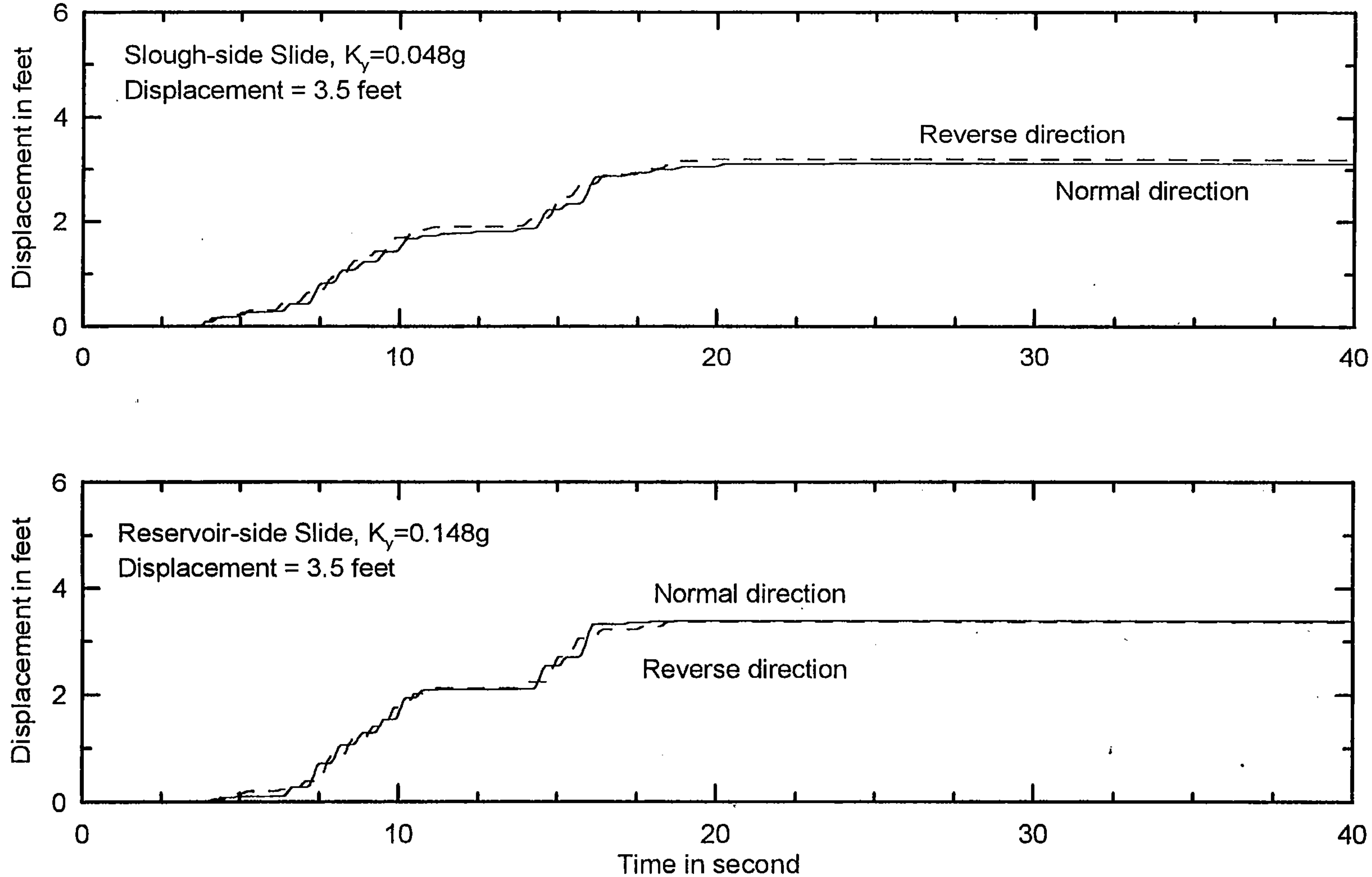
1992 Landers Earthquake at St. 24577 (Fort Irwin), 0 Degree Component



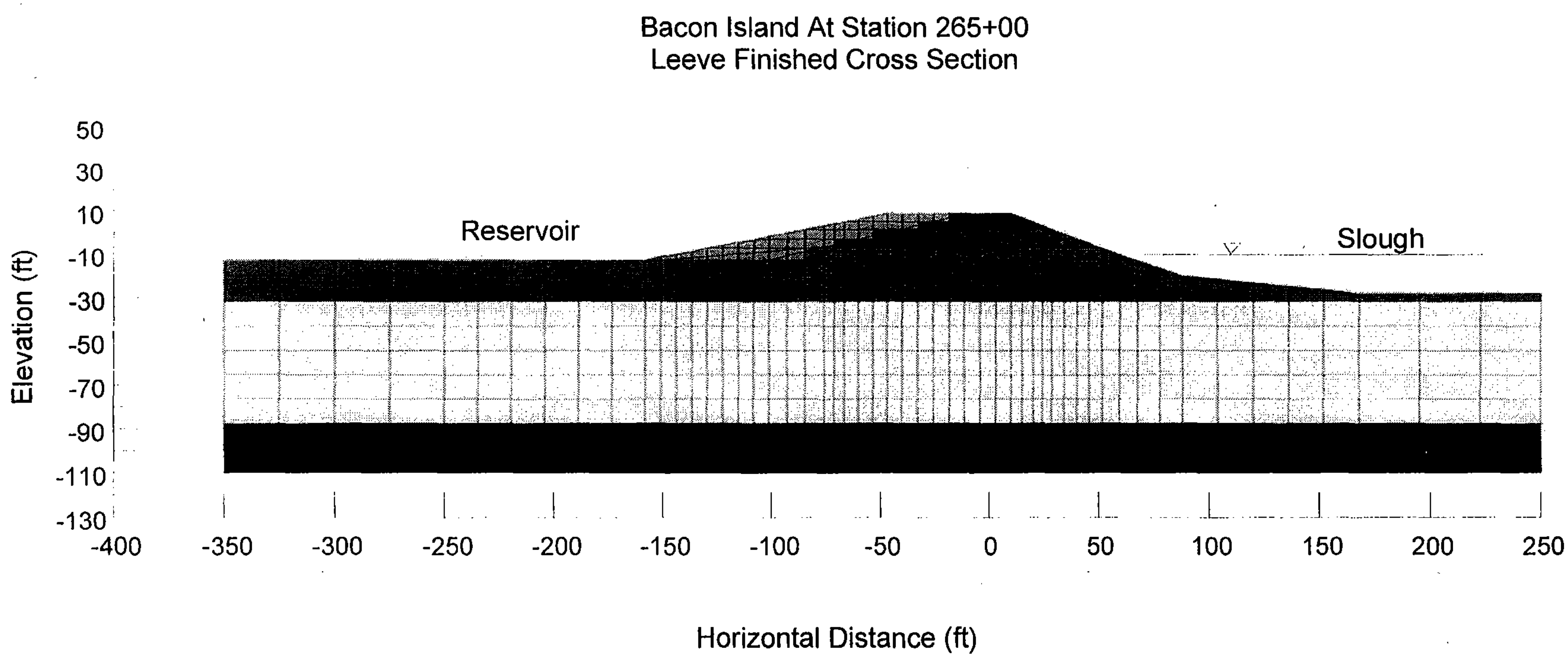
Project No. 410709903000	Delta Wetlands	Permanent Slope Deformation Time Histories of Critical Slide Masses for 1992 Landers Earthquake - Bacon Island Levee at Station 25+00	Figure A.23
URS Greiner Woodward Clyde			

Bacon Island Levee at St. 25+00, Levee Deformations

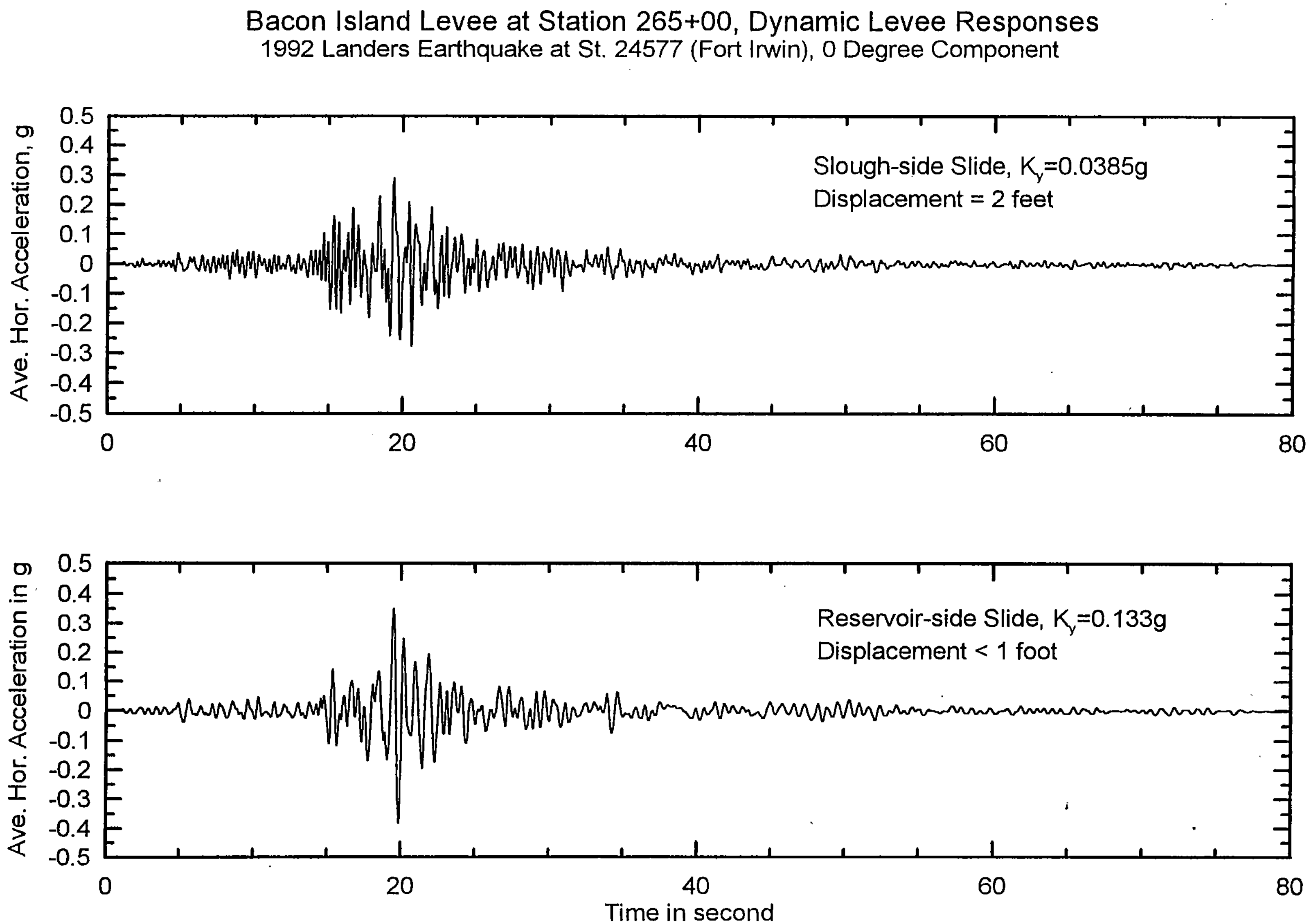
1987 Whittier Narrows Earthquake at St. 24402 (Altadena-Eaton Canyon), 90 Degree Component



Project No. 410709903000	Delta Wetlands	Permanent Slope Deformation Time Histories of Critical Slide Masses for 1987 Whittier Narrows Earthquake - Bacon Island Levee at Station 25+00	Figure A.24
URS Greiner Woodward Clyde			



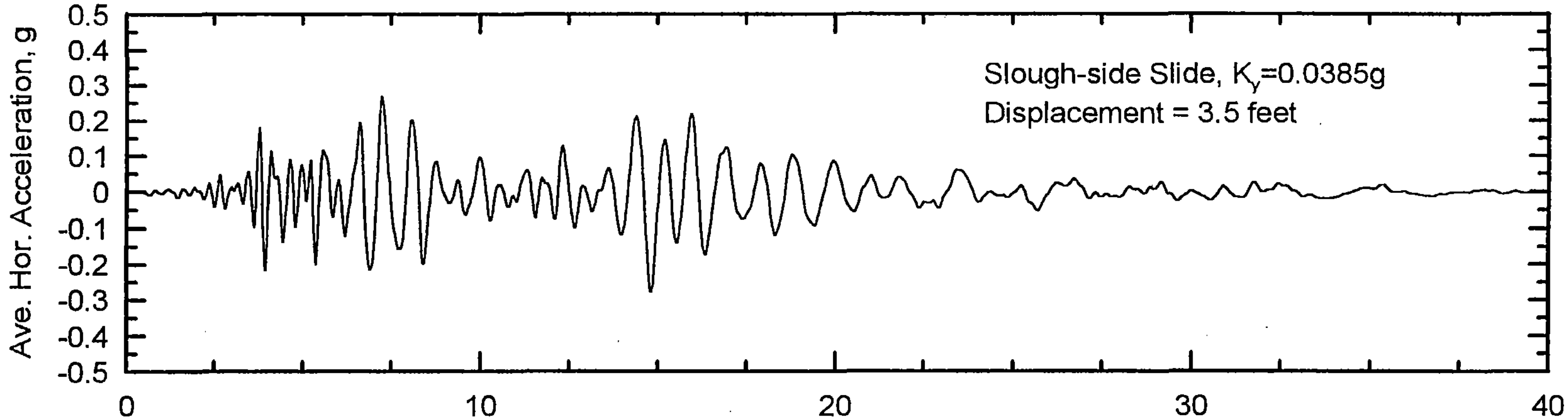
Project No. 410709903000	**Delta Wetlands**	Finite Element Mesh for Bacon Island Levee at Station 265+00	Figure A.25
URS Greiner Woodward Clyde			

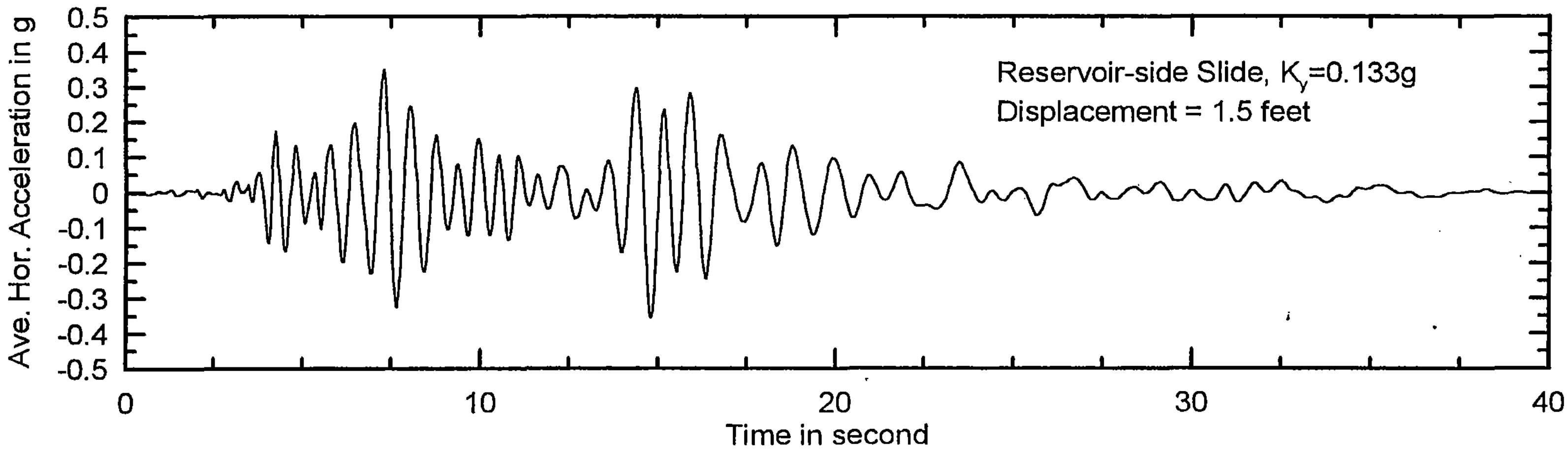


Project No. 410709903000	Delta Wetlands	Average Horizontal Acceleration Time Histories Acting on Critical Slide Masses for 1992 Landers Earthquake - Bacon Island Levee at St. 265+00	Figure A.26
URS Greiner Woodward Clyde			

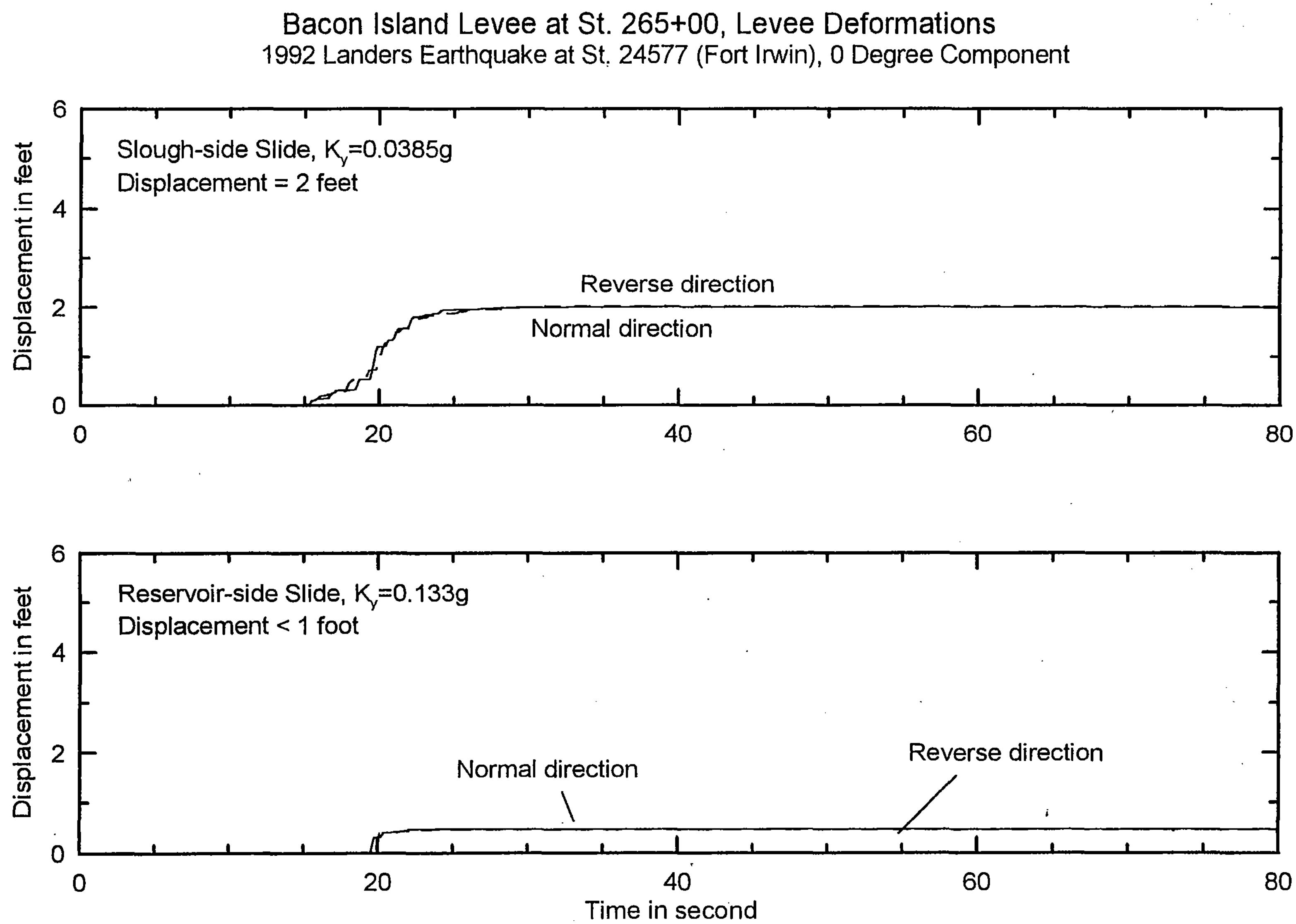
Bacon Island Levee at Station 265+00, Dynamic Levee Responses

1987 Whittier Narrows Earthquake at St. 24402 (Altadena-Eaton Canyon), 90 Degree Component





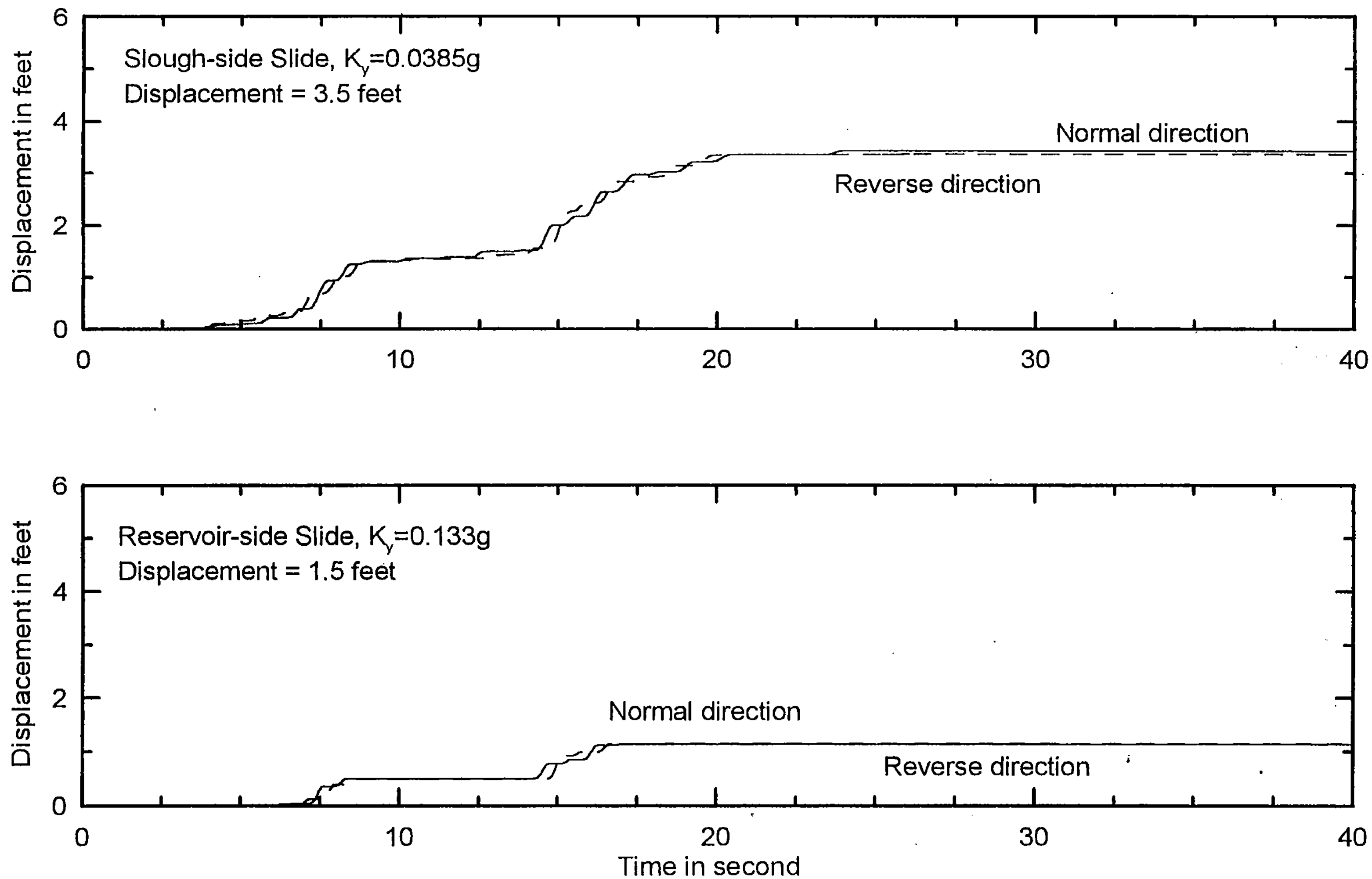
Project No. 410709903000	Delta Wetlands	Average Horizontal Acceleration Time Histories Acting on Critical Slide Masses for 1987 Whittier Narrows Earthquake - Bacon Island Levee at Station 265+00	Figure A.27
URS Greiner Woodward Clyde			



Project No. 410709903000	Delta Wetlands	Permanent Slope Deformation Time Histories of Critical Slide Masses for 1992 Landers Earthquake - Bacon Island Levee at Station 265+00	Figure A.28
URS Greiner Woodward Clyde			

Bacon Island Levee at St. 265+00, Levee Deformations

1987 Whittier Narrows Earthquake at St. 24402 (Altadena-Eaton Canyon), 90 Degree Component



Project No. 410709903000	Delta Wetlands	Permanent Slope Deformation Time Histories of Critical Slide Masses for 1987 Whittier Narrows Earthquake - Bacon Island Levee at Station 265+00	Figure A.29
URS Greiner Woodward Clyde			

Appendix B
Glossary

Anisotropy: The characteristic of having a physical property that varies with direction. For example, it is common for natural river deposits to be anisotropic, as their horizontal hydraulic conductivity can be several to many times higher than their conductivity in the vertical direction.

ASDSO (Slope Stability) Criteria: Set of recommended minimum slope stability Factors of Safety (see definition of Factor of Safety below) recommended for design of embankment dams developed by the ASDSO (Association of State Dam Safety Officials), established in 1983 and based in Lexington, Kentucky.

Cohesionless Soil: Soils like sands and gravel whose grains tend not that remain "stuck" together when free water has been drained. Cohesionless soils tend to let water drain easily. Opposite to this type of soil behavior is that of cohesive soils such as clay and silt. **Cohesive soils** are commonly referred to as fine-grained soils. Although not strictly a cohesive soil, peat is considered in analyses with engineering properties close to those of cohesive soil.

CPT (Cone Penetration Testing): CPT refers to a procedure in which a probe of conical shape is pushed into the soil at a constant rate while the tip and lateral resistances of the probe are measured electronically at regular depth intervals.

Damping Curve: Empirical relationship between damping and shear strain used to model the increase in damping value in cyclic loading.

Deterministic Ground Motions - earthquake ground motions associated with a specific seismic event occurring on a seismic source.

Elastic Half Space Model: A numerical model used to simulate a semi-infinite body of elastic material.

Exit Gradients: The hydraulic gradient that occurs at or just below the ground surface. Excessively high exit gradients can cause a "quick" or "boiling" effect and piping, under which materials can lose strength and be carried away.

Factor of Safety (Slope Stability): The Factor of Safety (FS) is a calculated number representing the degree of safety of a slope against instability. The FS is expressed mathematically as the ratio of stabilizing effects (forces or moments) and destabilizing effects acting on a potentially unstable soil mass in a slope. When the FS is greater than one, the soil mass in the slope is, in theory, stable; when FS is lower than 1, the slope is, in theory, unstable. For a given slope geometry and soil conditions, a calculated FS is associated with a unique slope failure configuration. The most critical failure configuration is associated with the minimum FS calculated in a slope stability analysis. Several agencies (such as ASDSO and USACE) have developed criteria that provide different design FS's stipulated for various slope conditions, e.g. under long-term loading, shortly after construction, etc. These design FS's are typically above one and are minimum values to be achieved for the slope to be considered stable.

Gravity Flow Relief Wells: Wells that provide a means of water release for subsurface sources (typically those under conditions of excess pressure) by providing a free-flowing outlet source. These types of wells do not draw water with pumps, but simply use an outlet source that relies on gravity flow, such as a low-lying outlet or drainage ditch.

Hydraulic Conductivity: A measure of the capacity of a porous medium to transmit water, often expressed in centimeters per second. The hydraulic conductivity is equal to the rate of flow of water through a cross section of one unit area under a unit hydraulic gradient.

Hydraulic Gradient: The rate of change in total hydraulic head per unit of distance of flow in a given direction.

Ky: Pseudo-static horizontal acceleration that will give a calculated factor of safety in slope stability analyses of 1.0; yield acceleration.

Maximum Credible Earthquake (MCE): The maximum earthquake that appears capable of occurring under the presently known tectonic framework. It is a rational and believable event that is in accord with all known geologic and seismologic facts. In determining the maximum credible earthquake, little regard is given to its probability of occurrence, except that its likelihood of occurring is great enough to be of concern. (from CDMG Note Number 43, February 1975). The Uniform Building Code (ICBO, 1991) defines the MCE for seismic-isolated structures as the maximum level of earthquake ground shaking which may ever be expected at the building site within the known geologic framework. For this case, the UBC says that the MCE may be taken as the ground motion that has a 10 percent probability of being exceeded in 250 years.

Most Critical (Water Level) Case: Water level on either side of the levee for the case with stored water and during seismic event. On the channel side, the water level changes daily with the tide and seasonally; on the island side, the (ground) water level also varies. For seismic analyses, these levels are assumed at their expected, mean values. Because it is highly unlikely that the design seismic event that occurs at the same time extreme water levels take place, mean water levels are considered for the seismic case.

Peak Ground Acceleration (PGA): The maximum value of acceleration recorded on a seismograph during an earthquake event.

Permeability: A measure of the capacity of a porous medium to transmit a fluid. See Hydraulic Conductivity.

Piping: The removal of fine soil particles from the soil mass by high hydraulic gradients. For example, excessively high exit hydraulic gradients at the surface may cause upward transport of soil, resulting in sand boils.

Poisson Earthquake Model: A model of earthquake recurrence in which the inter-occurrence time is random and does not depend on the time of the last event.

Pseudo-static Analysis: Seismic slope stability analyses using a static force that is equivalent to the horizontal acceleration experienced during a seismic event.

Pumped Extraction Wells: Wells that draw water from subsurface sources by powered mechanical or hydraulic pumps.

Relief Wells: Wells that passively relieve elevated hydrostatic pressures in an aquifer by allowing flow to the surface.

Representatively Critical (Water Level) Case: Water level on either side of the levee for the existing conditions (case with no stored water). On the channel side, the water level changes daily with the tide and seasonally; on the island side the (ground) water level also varies. For engineering analyses, these levels are assumed at their expected, representative maximum and representative minimum values. Less likely to occur extreme values are not considered in the existing conditions case.

Return Period: The average time between events. Typically, events are defined as the occurrence of an earthquake exceeding a specified magnitude or the occurrence of a ground motion greater than a specified level.

Seepage Flux: The rate of flow of water across a given line or surface, typically expressed in gallons per minute (gpm) or cubic feet per second (cfs). For example, in the finite element model SEEP, the average seepage flux through a levee can be estimated using a cross-sectional model and expressed in gpm per foot of levee length.

Shear Modulus Reduction Curve: Empirical relationship between the ratio of shear modulus and its maximum value and the shear strain used to model the degradation in shear modulus in cyclic loading.

SPT (Soil Penetration Testing): SPT refers to the procedure to determine the soil penetration resistance. In general terms, the penetration resistance is measured by counting the number of blows necessary to drive a soil sampler (steel tube) a specified distance using a hammer of a specified weight into the subsoil at the bottom of the borehole. In the standardized test, commonly referred to as the Standard Penetration Test, the hammer is 140 pounds and is dropped repeatedly 30 inches; the sampler is 1-3/8-inch I.D., 2-inch O.D., and is driven 18 inches into the soil. The penetration resistance is computed by adding the blow counts recorded for last two 6-inch increments of driving length.

Transmissivity: The transmission capability of the entire thickness of an aquifer, often expressed in gallons per day per foot of aquifer thickness. The transmissivity can be determined by multiplying the hydraulic conductivity by the aquifer thickness.

Visco-elastic Material: A material that behaves elastically and absorbs energy (damping).

Appendix C

State Water Resources Control Board Letter Dated November 1998

State Water Resources Control Board

John P. Caffrey, Chairman

.M. Rooney
.retary for Environmental Protection

Executive Office
901 P Street • Sacramento, California 95814 • (916) 657-0941 • FAX (916) 657-0932
Mailing Address: P.O. Box 100 • Sacramento, California 95812-0100
Internet Address: http://www.swrcb.ca.gov

Pete Wilson
Governor

NOV 2 5 1998

Anne Schneider, Esq.
Ellison & Schneider
2015 H Street
Sacramento, CA 95814-3109

Dear Ms. Schneider:

DELTA WETLANDS PROJECT, WATER RIGHT APPLICATIONS 29061, 29062, 29063, 29066, 30267, 30268, 30269, AND 30270: THE NEXT STEPS

As you know, the State Water Resources Control Board (Board) has considered action on the subject applications at two recent executive sessions. The Board has directed me to contact you and seek Delta Wetlands' input before deciding upon a further course of action. That is the purpose of this letter. Among the factors that need to be considered are the following:

- If the project is to be wholly or partially approved the Environmental Impact Report (EIR) will need to be completed. Additional information must be added before the final EIR can be prepared, and this may require recirculation of the document. Because of the additional expense involved, we have not directed Jones & Stokes (JSA) or our staff to proceed with completion as yet. Your response to this inquiry will help determine the course of action.

- You requested inclusion of the new Department of Fish and Game (DFG) Biological Opinion (BO) in the hearing record. Several parties have requested further hearing to allow the cross-examination of DW and DFG witnesses and to submit rebuttal evidence. If the project proceeds, that request will be granted, and the BO will be a subject of hearing.

- On October 21, 1998, you requested certification of the project under section 401 of the federal Clean Water Act (CWA), a necessary prerequisite to issuance of a CWA section 404 permit by the Corps of Engineers. The remaining time within which the Board can act upon that request is very limited, and the Board cannot approve a certification request without a completed California Environmental Quality Act (CEQA) document. As you pointed out, your letter triggered a 60-day time frame for the SWRCB to act on the certification. The

EIR cannot be made final and be certified before the end of the 60-day period triggered by your letter. Therefore, I intend to deny 401 certification, without prejudice, pending completion of an appropriate CEQA document. I will send you a separate letter on that subject.

- Review of the existing hearing record reveals substantial remaining uncertainty regarding several significant issues. A summary of those issues is contained in Attachment A. The Board has made no determination as yet regarding these issues, and any apparent conclusions in Attachment A are preliminary. It is possible that further hearing days will be required in an attempt to better document the potential project effects.

- Review of the existing hearing record reveals no assurance that if the project is constructed and later is abandoned, the cost of mitigation of the project will not be transferred to the public through default. Because of the location of the proposed project and the potential for adverse effects if it is not actively operated, a financial surety may be necessary to ensure that the taxpayers will not bear the burden of mitigation and dismantling costs.

- The Board is aware that the hearing record is well over a year old. Further information developed by others (e.g., Cal-Fed) may be useful in analyzing the issues described above. The applicant, and potentially other entities, may be interested in presenting additional information which bears on project feasibility and methods of dealing with some of the potential adverse impacts.

In view of the foregoing, the Board seeks an expression of preference from the applicant as to alternative courses of action. The alternatives available to the Board are:

1. The Board would issue a decision based upon the existing record.[1]

2. Further hearing would be conducted solely on the new BO. The Board would then issue a decision.

3. Further hearing would be held on the BO and to obtain more evidence on the issues described above and discussed in Attachment A, prior to a Board decision.

[1] A further hearing regarding the new BO appears to be necessary before approving the project.

A decision after a further hearing could entail (1) approval of the project with appropriate conditions, (2) denial and cancellation of the permit applications and change petitions, or (3) denial of the requested applications and petitions without cancelling them and without prejudice to further efforts by the applicant to support the project.

The Board appreciates your efforts and requests your input before deciding on a course of action. Other parties also are welcome to provide input in response to this letter. Please contact me at (916) 657-0941 if you have procedural questions.

Sincerely,

Walt Pettit

Walt Pettit
Executive Director

Attachment

cc: Delta Wetlands Mailing List

bc: SWRCB Members
Walt Pettit, EXEC
Dale Claypoole, EXEC
William Attwater, OCC
Andy Sawyer, OCC
Barbara Leidigh, OCC
Harry Schueller, DWR
Jerry Johns, DWR
Jim Sutton, DWR
Dave Cornelius, DWR
Jim Canaday, DWR

BJLeidigh/mkschmidgall
[11-24-98]
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ATTACHMENT A

I. WATER RIGHT CONSIDERATIONS

DW has stated its intention to withdraw Applications 29061, 29063, 30267, and 30269 to divert water to Bouldin Island and to Holland Tract. DW has designated these two islands as wildlife habitat islands, to offset potential wildlife and wetland impacts of the reservoirs it plans for Webb Tract and Bacon Island. DW claims existing water rights to use water on the habitat islands. Accordingly, the following discussion does not pertain to Applications 29061, 29063, 30267, and 30269.

I. A. No Identified Buyers for the Water

DW[1] presented no evidence that it has any buyers for the project water. The hearing record indicates that DW is not likely to have buyers. DW estimated that the project water would cost buyers in the range of $200 to $300 per acre-foot plus conveyance charges. This estimate may be low. Mitigation and operational limitations in addition to those assumed by DW would be needed before the project could be constructed and operated. In addition, the estimate does not include conveyance charges. At the price DW estimated, agricultural water users are unlikely to buy water from the project. Further, CCWD and CUWA, the representatives of the municipal water purveyors who would be most able to pay the relatively high price that would be asked for the water, provided evidence that the water is likely to substantially increase their water treatment costs. They are looking for ways to get water with less dissolved organic material in it than they currently receive from the Delta. The DW water, and Delta water to which DW water has been added, would generally contain more dissolved organic material than current Delta supplies. Consequently, CCWD and CUWA stated that they will not buy the water and do not want to receive it through DWR or USBR facilities.

With no buyer for the water, there would be no beneficial use of the water. In the absence of a beneficial use of the water, there can be no water right. (Wat. Code § 1240.) Lack of a buyer alone is not a fatal defect, since a permit could be conditioned to require a buyer to be identified before the project is constructed or the reservoirs filled. But DW has failed to establish any likelihood that a buyer will be found.

I. B. Water Availability Considerations

Water likely would be available to the DW Project due to high flows during winter months for limited periods, even in some dry years. DW based its estimate of water availability on a hydrological model referred to as DeltaSOS (DW 63.), which was developed by the EIR/EIS consultant. The model runs take into account the Final

[1] The following abbreviations are used in this Attachment: DW means Delta Wetlands; CCWD means Contra Costa Water District; EBMUD means East Bay Municipal Utility District; DFG means Department of Fish and Game; PG&E means Pacific Gas and Electric Co.; DWR means Department of Water Resources; USBR means United States Bureau of Reclamation; SWRCB means State Water Resources Control Board; CUWA means California Urban Water Agencies; SWP means State Water Project; CVP means Central Valley Project; CALTRANS means California Department of Transportation; and CDWA means Central Delta Water Agency.

Operations Criteria for the biological opinions prepared under the federal Endangered Species Act. The DW analysis suggests that there will be water available for appropriation not only during and after winter storms when high flows are present in the Delta, but also occasionally in the drier months. The analysis shows no water available during April and May because of fish protections, but in all other months the analysis shows that some water will be available in at least some years. The analysis predicts that the largest average amounts of water would be available in October through February, with smaller average amounts available in September and March. (DW 8, table 13.)

The DeltaSOS model runs do not assume that DW would be required to avoid impacts on the diversions of water by CCWD under its senior water rights. DW argued that it did not need to avoid impacts on CCWD's diversions because the relevant constraint on CCWD's diversions is imposed under the Endangered Species Act, not under CCWD's water rights. CCWD's authority to divert water under its own water rights is dependent on the location of the two parts per thousand salinity line (X2) in the Delta.[2] DW argued that this is not a restriction on CCWD's senior water rights, and that DW should not be required to defer to it. CCWD requested that an X2 condition be placed in any permits issued to DW in order to protect CCWD's diversions. (CCWD 3, pp. 12-13.) CCWD's water right permits require CCWD to meet the Endangered Species Act requirements. Although the Endangered Species Act requirements for CCWD could change, CCWD's violation of the requirements that are in effect would simultaneously be a violation of its water right permits. If DW were issued permits, we expect the permits would be conditioned to prevent diversions by DW during periods when CCWD is unable to divert because of the location of X2 in the Delta.

Further, all diversions by the DW Project would be subject to the settlement agreements between DW and the DWR, and between DW and the USBR, to protect the water supplies and senior water rights of the two projects. These agreements effectively preclude diversions to storage by DW when the projects[3] calculate that unappropriated water is not available, as well as preventing discharges by DW when discharges of stored water would require changes in SWP or CVP operations to meet state or federal mandates.

The above factors all affect water availability in some measure. It is uncertain how much water would be available after all of these factors are considered. In particular, CCWD's X2 restriction, plus the restrictions in the biological opinions for the DW Project would especially affect diversions when protected fish are present during the fall and winter and could be harmed by the diversions. The X2 restriction also could restrict diversions during April and May if they were not already restricted for fish protection reasons. Additionally, some of the restrictions in the DW biological opinions would further reduce

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2 See below for a more complete explanation of the X2 restriction.

3 If the DW Project received water right permits, the permits likely would require that in the event of a dispute between DW and one or both of the projects regarding the availability of water for diversion at a given time, DW would bring the dispute to the SWRCB for resolution.

the opportunities of DW to divert water at times when diversions would be injurious to fish. Accordingly, it is uncertain that adequate water is available for the DW Project.

II. WATER QUALITY CONSIDERATIONS

The effect of the DW Project on water quality is a major concern. This issue has two distinct but not entirely separable components: salinity and organic carbon. Salinity affects water quality directly. Salinity also contributes to the formation of precursors of groups of molecules which include trihalomethanes (THM's) and haloacetic acids (HAA's). As discussed below, the evidence shows that during storage there will be an increase in the concentration of both salts and DBP precursors in the water stored in the DW Project reservoirs. Additionally, the DW Project could, under certain circumstances, divert water to storage containing a higher concentration of salts than the concentration of salts in the channels of the Delta during the months when the DW Project would likely release water.

It is the policy of the SWRCB to ensure in any of its water right or water quality actions, that the policy set forth in Resolution 68-16 is followed. Resolution 68-16 provides in pertinent part:

> "1. Whenever the existing quality of water is better than the quality established in policies as of the date on which such policies become effective, such existing high quality will be maintained until it has been demonstrated to the State that any change will be consistent with maximum benefit to the people of the State, will not unreasonably affect present and anticipated beneficial use of such water and will not result in water quality less than that prescribed in the policies."

Applied to the water right applications for the DW Project, Resolution 68-16 means that before the SWRCB will approve the water right applications, the SWRCB must be satisfied that storage of water on DW Project reservoirs and subsequent releases of water into the Delta either will not adversely affect the quality of water in the Delta channels when it is released, or that any reduction in water quality will "be consistent with maximum benefit to the people of the State, [and] will not unreasonably affect present and anticipated beneficial use of such water...."

It does not appear that the SWRCB can make the required finding. During the hearing, the SWRCB received evidence that the release of stored water from the DW islands is not consistent with the interests of purveyors of drinking water who will invariably receive the water if it is released into the channels of the Delta. As discussed herein, such released water would on many occasions contain elevated levels of salts and organic carbons compared with the receiving water, although the exact amount of added salts and organic carbons could vary. A significant increase in these constituents could substantially increase the costs of treating Delta water during the period when DW releases the water. Because any increases in dissolved organics would result in increased treatment cost during the time when DW releases the water, the most likely users of water from the project, urban water suppliers, have stated that they will not buy the water and do not want to receive it as part of the water delivered by DWR or USBR. With no identified beneficial use for this water, its discharge cannot be consistent with the maximum benefit to the people of the state. Moreover, without additional evidence, it cannot be determined that the resulting degradation will not unreasonably affect present and anticipated beneficial uses of the water in the Delta.

II.A. Dissolved Organics

Organic carbon loading is generally expressed in parts per million of either total organic carbon (TOC) or DOC. TOC consists of both DOC and particulate organic carbon (POC), which includes diatoms and other microalgae, dead algae, bacteria, microzooplankton, and decomposing plant material. For purposes of the DW Project, TOC and DOC are nearly interchangeable: DOC represents more than 90 percent of the TOC present in Delta waters (CCWD 4, p. 10; RT pp. 485 – 486, 1067). Except where specified, the term DOC is used in this decision to include all organic carbon.

Storing water on the reservoir islands would increase the DOC content of the water through leaching of peat soils, return flows from interceptor wells, and growth and degradation of plant material. (DEIR/EIS Appendix C-5, Table C5-3; TR 425 – 426; DW 13, Figure V-5; RT pp. 2779 – 2780.) The issue is whether DW operations will have a significant effect on the quality of the receiving waters when stored water is released, and whether the degradation will be offset during the same time period by the cessation of agricultural practices on the project islands. The parties presented conflicting evidence regarding the amount, nature, and effects of DOC loading that would be caused by the DW Project.

(1) Changes in DOC as a Result of the Project

The water will increase in DOC while it is stored, at least during the early years of the project, because of leaching from the peat soils on the floors of the reservoirs. During the release period (primarily July, August and September) in many years, DOC in released water would be higher than in the receiving water (RT pp. 507 – 509, 2545). There would also be some increase in export water DOC levels during the release period in almost every year, regardless of release rate. If project water were released at the rate of 1000 cfs or 10 percent of the total assumed export rate, the average increase in DOC, taking into account reductions in agricultural loading of approximately 2.0 mg/l, would be about 0.2 mg/l.[4] One proposed mitigation measure (CUWA 2, p. 11) would effectively prohibit any release of water for export unless the water was pretreated.

Some evidence suggests that on an <u>average</u> <u>annual</u> basis the quantity of DOC in export water might decrease because agricultural return flows will decrease or cease on the DW islands (DW 13, p. 23). Other evidence rebuts this evidence. (*See*, e.g., CCWD 10.) Compared to the No-Project alternative (intensive agriculture), cessation of agricultural

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[4] This assumes that the loading during storage and evaporation would be equivalent to the estimated present agricultural loading of 2.0 mg/l.

operations on the DW islands could reduce the annual quantity of DOC loading to the Delta (RT pp. 171 – 173).[5] In any event, the timing of the DOC loading would change. DOC loading from agriculture currently occurs primarily in winter. With DW operations, the loading from the reservoir islands would shift to summer. With the higher salinity in the DW reservoir releases (see below), this shift in DOC loading could increase water treatment costs for urban water users.

(2) Loadings of DOC from Initial Fillings

Over the long term, repeated filling and emptying of the DW reservoir islands might leach out most of the soluble organic material. If new plant growth were minimized, annual DOC loading might decline. The first few fillings, however, might have very high levels of DOC, plus residues from pesticides and other island wastes (RT pp. 2549 – 2552). If permits for the DW Project restricted discharges of poor quality water, the opportunities to release these early fillings could be few. One option would be to release water from the islands at a very slow rate,[6] under winter flood conditions, when there is positive (downstream) flow in Old and Middle rivers. (CUWA 2, pp. 11-12.) Under this option, emptying the reservoirs could take several months or even several years. Even with tight restrictions, releases from Bacon Island could still impact the quality of water at the intakes for the SWP and for CCWD in the southern Delta.

Notwithstanding extensive evidence and analysis in the record, including models, hypotheses, and theories about the amount of DOC production when the islands are first filled, none of the predictions regarding DOC loading appears reliable. Depending on the length of time of the initial storage cycles, the reservoir islands could build up substantial loadings of DOC and other constituents that, when discharged, could result in violations of drinking water standards in exported treated water even if the discharge was made under high flow conditions. An experiment on wetland flooding showed a rapid rise to high DOC levels, and while it produced a higher concentration than might be expected in a filled reservoir, it indicates the type of reaction which could occur in the early years of the project (SWRCB 2, Appendix C3, pp. C3-6 to C3-8). Because of the potential for natural disasters involving seismic and storm events in the Delta, it would not be in the public interest to have filled reservoirs in the Delta that would require a slow release; yet a slow release might be needed to avoid impairing beneficial uses of the receiving water for municipal purposes.

(3) Resuspension of Organic Material During Emptying of Reservoir Islands

After the project operated for several years, there might be relatively low concentrations of DOC leached into the stored water from the underlying peat soils, especially when the reservoirs were full. It is reasonable to assume, however, that when the reservoirs are drawn down concentrations of DOC and POC will increase in the remaining water as wind stirs up the bottom. If the water is very shallow, the resuspended material could

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[5] Fertilizer use would also be significantly reduced (RT p. 179).

[6] A discharge rate maximum of 10 percent of Old and Middle rivers flow was suggested during the hearing.

form a slurry of water, peat, silt and other materials (CUWA 10, p. 8). If this water could not be released because of DOC, turbidity, temperature, or other limitations, it could substantially affect project yield. Each foot of water not released from the reservoirs (or not stored), would decrease project yield by approximately 10,000 acre-feet (RT p. 479).

It is likely that there would be at least some resuspension of material, especially in the early years of the project. Even the development of a silt layer in later years would not preclude substantial resuspension in high wind conditions. The evidence shows that some resuspension could occur due to wind fetch on the DW reservoir islands. (RT pp. 2402 - 2404, 952 - 954.) Mitigation could include limits on DOC, turbidity and other relevant water quality parameters in discharged water. Also, installation of barriers, floating curtains, levees or island structures could help reduce fetch size and wave development. Such structures, however, could reduce project storage capacity and yield.

(4) Residence Time

Residence time is an important consideration in estimating loadings of DOC in reservoir water. The water probably would remain on the islands longer than the median length of eight months suggested by DW operational studies, which assumed the highest export frequency, and therefore the shortest residence time. During wet periods, or when export pumping capacity is limited, the water could remain on the islands for several years. Even if the rate of production of DOC decreased over time, evaporation and consequent salinity and DOC increases would continue to occur.

(5) Unwanted Receipt of DW Project Water

Certain municipal water providers would receive, and would have to treat, any incremental increases in DOC that would occur when DW released water, whether they had purchased the water or not. DW discharges could not be isolated from other water diverted at the pumping facilities in the southern Delta. Further, DW discharges could represent a substantial proportion of the total exports from the Delta in late summer. The City of Tracy is the first customer along the Delta–Mendota Canal; the South Bay Aqueduct is the first major distribution branch from the State Water Project's State Aqueduct, and CCWD's Rock Slough intake is located near Bacon Island and "downstream" (under reverse flow conditions) from Webb Tract. CUWA represents numerous urban water agencies that would receive this water if it was discharged into the Delta for export. CUWA's member agencies state that they have no interest in buying this water or in receiving deliveries of water that has been mixed with DW releases.

The only completely effective way to prevent the DW Project from causing increases in pollutants received by the municipal water users would be to require no degradation of receiving water, as proposed by CUWA. If some degradation of receiving water quality were consistent with maximum benefit to the people of the state, as provided in Resolution 68-16, the SWRCB could condition any water right permits on not exceeding an incremental degradation of water quality in the receiving water. In this case, however, there are no willing customers and no overriding public need for the water. On the other side of the balance, there is a potential for harm or substantial expense to municipal water purveyors.

(6) ***Shallow-Water Habitat and DOC Production***

The DW Project includes shallow-water habitat on the reservoir islands when they cannot be filled (RT pp. 259 – 260). The purpose of the habitat would be to provide food and cover for waterfowl for hunting purposes; however, the habitat is not part of the wetlands mitigation requirements.

The evidence regarding the effect on DOC concentrations of creating shallow-water habitat is inconclusive. On the one hand, keeping the soil moist on the reservoir islands, as would occur during storage as well as during the shallow-water flooding proposed during nonstorage periods, would reduce loss of peat soil due to oxidation, and would also reduce release of DOC into the pore water of the peat soil (DW 13, p. 115). On the other hand, the shallow flooding would encourage the growth of shallow water plants (emergent vegetation), which will decompose when the reservoirs are filled.[7] At an average depth of about one foot, considerable aquatic plant growth is likely. Consequently, in the presence of shallow water, the reservoir islands would produce a continuing source of new DOC, at least partially offsetting the benefits of reduced peat oxidation. DOC loading will be less if the DW Project does not grow seasonal wetlands on the reservoir islands. (RT pp. 2568 – 2571; 2812 – 1813.) It might be appropriate to prohibit shallow flooding of the reservoir islands.

(7) ***Wetland and Plant Degradation Experiments***

Much of the information in the draft EIR/EIS on DOC and POC loading that would be caused by the DW Project was based on a series of field and tank experiments. The purpose of these experiments was to estimate DOC release from flooded wetlands, and from degradation of plant material and peat. These experiments were discussed at length in the draft EIR/EIS (SWRCB 2, Appendix C-3). The experiments took place over a short duration (CUWA 5, p. 20), and some experiments were conducted in winter months when the lower temperatures would reduce production of DOC.

The results of the experiments are inconclusive with respect to the proposed project. None of the results are directly related to what would occur on the reservoir islands, especially after multiple years of storage or creation of shallow-water habitat. The DWR is developing new studies on Delta island flooding, but it is not clear that DWR's studies would be helpful in predicting the effects of DW Project operations. (RT pp. 1628 – 1633.) A medium-to-large scale pilot project, or staged development, that addresses these questions would be helpful in evaluating whether DW or a similar project should be allowed to proceed with full-scale development.

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[7] Some evidence suggests that much of the increase in DOC is due to degradation of plant material rather than leaching from peat. Other evidence suggests that more DOC could result from peat than from wetlands. (CUWA 5, p. 19.)

(8) New EPA Requirements

The United States Environmental Protection Agency (USEPA) is currently reviewing the allowable limits on DBP's. The parties presented testimony indicating that USEPA will require implementation of new Safe Drinking Water Act requirements in the next few years. (*See* 42 USCA § 300f through 300j-26.) The new requirements are expected to reduce the allowable amount of DBP's in drinking water in stages. The first stage was projected to take effect in 1998. The hearing evidence indicates that new, more stringent, requirements than existed at the time of the hearing will be in place before the DW Project could begin operations. The restrictions proposed by USEPA would affect both DBP levels and TOC levels in the untreated water. In addition, removal requirements for urban water purveyors receiving the water will vary depending on the level of salinity in the water. The new requirements are expected to increase treatment costs. If these projected changes in regulatory requirements take place, and the DW Project incrementally increases the amount of TOC and salinity in the source water, the operation of the DW Project would add to the increased treatment costs.

II.B. Salinity Impacts

Salinity is usually measured in electrical conductivity (EC), but some of the evidence presented in the hearing was given in terms of total dissolved solids (TDS) or chlorides. The major ions of concern when discussing salinity are chlorides and bromides. Bromide ions are considered to be more reactive in the formation of THM's. The major source of bromides is ocean-derived salinity. Some bromides may also be returned to the system with agricultural return flows (SWRCB 2, pp. 3C-10 & 3C-11).

Salinity increases in the Delta caused by DW Project discharges could have a significant impact before they reach the level of significance defined in the draft EIR/EIS. The draft EIR/EIS assumes that there will be a significant effect if a DW discharge causes a salinity increase equal to 20 percent of the numerical water quality objective, or if the discharge causes the receiving water to exceed 90 percent of the numerical objective (SWRCB 2, pp. 3C-20 to 3C-21). This level was selected because a combination of natural variations in the system, plus inaccuracies in modeling operational effects, might provide sufficient "noise" in the system that water quality changes of less than 20 percent of the standard could not be unequivocally attributed to the effects of DW operations. Under this approach, a change from 50 mg/L chlorides to almost 100 mg/L would not be considered a significant impact on CCWD, since such a change would be less than 20 percent of the current 250 mg/L chlorides objective at Rock Slough (RT pp. 283-290). This level of change in salts in the receiving water, however, would reduce the benefits to CCWD of having Los Vaqueros Reservoir (LVR). The Los Vaqueros intake is on Old River. LVR was built specifically to divert and store fresher water to blend with saltier water diverted at Rock Slough, to improve quality. Permitting release of water that is saltier than the receiving water could reduce the benefits of the LVR project.

It is likely that some degradation of water quality in the receiving water channels of the southern Delta will occur in at least some years when water is discharged from the DW reservoirs. The draft EIR/EIS model results suggested increases of up to 50 mg/L chloride might occur in export water under Alternative 1 (SWRCB 2, Figure 3C-18) during the discharge period.

(1) Salinity Intrusion

DW's high diversion rates during filling could reduce Delta outflow, allowing the head of the saline wedge of ocean water in the estuary to move farther upstream than would otherwise occur. This movement is measured as an increase in X2, an index value defined in the Monismith equation (RT pp. 349 – 356) as the distance in kilometers above the Golden Gate of two parts per thousand (ppt) bottom salinity. A higher value indicates that salinity has penetrated farther up the estuary. Such a movement could impact the water quality of water used by CCWD, the City of Antioch, and several industries (CCWD 4, p. 6), as well as the state and federal pumps in the southern Delta.

CCWD's senior water rights, as expressed in the permit terms and conditions for operation of LVR, include stricter operational restrictions than those set forth in the federal Biological Opinions (BO's) for the DW operations. Under the federal BO's, DW would, under certain circumstances, be able to divert water to storage when CCWD could not divert water (CCWD 3, p. 11.). In addition, the BO's would allow DW to divert when X2 is farther up the estuary than allowable for diversions to LVR. The process of filling the DW reservoirs could hold X2 at a location where CCWD would be unable to divert to LVR, even though it has senior water rights. Such operations could reduce both the quantity and the quality of water taken at CCWD's intakes.

It is possible that such a circumstance would only occur rarely (RT pp. 1411– 1412), and that the incremental change in salinity (and frequency of CCWD diversions) between west of Chipps Island and Collinsville would not be significant.

DW should not be allowed to divert water during periods when senior appropriators cannot divert water under their water rights unless it can be demonstrated that there would be no adverse effect on senior appropriators. These periods include periods when there are restrictions on diversions to protect sensitive fisheries, test periods, and times when CCWD cannot divert to storage in LVR. As discussed above, DW Project diversions could lengthen the period over which these restrictions prevent CCWD from diverting water.

(2) Quality of Diverted Water

The second salinity issue addresses the quality of the water that DW would divert onto the reservoir islands. DW proposes to fill the islands with surplus flows primarily in the late fall and winter months when storms provide surplus flows (CCWD 4, Figure 9). This water would be released into the Delta for export primarily in July, August and September (CCWD 4, Figure 10). Surplus flows from late fall and early winter storms could include substantial amounts of salts from agricultural runoff, especially from San Joaquin River tributaries (CCWD 4, p. 11), and from salty flushing flows from Delta agricultural fields (CCWD 4, p. 20). Even if there was no subsequent evaporation on the reservoir islands, this water could have higher TDS levels than the receiving water in southern Delta channels, which in late summer is often provided water of relatively good quality released from Sacramento River reservoirs.

In the absence of restrictions on diversions, DW would fill its reservoirs as early in the autumn as allowed, to ensure that the reservoirs are more likely to be filled should the winter turn drier. Terms of the BO's prohibit DW from diverting for some days after the onset of the first winter storm (elevated outflow) to avoid harming outmigrating fish. In addition, the BO's require DW to reduce diversion rates. The early storms carry salts and other chemicals from agricultural lands, which often elevates the salinity of the early flows. Later in the winter, many of the agricultural Delta islands release salty water from soil leaching. These restrictions could delay the onset of filling by DW until water quality improves after a succession of winter storms. A delay should both move X2 farther west (reducing salinity intrusion) and transport salts from agricultural return flows out of the Delta. Depending on the circumstances of a particular year, the requirements in the BO's could result in severe restrictions in DW's operations, or even prevent DW from diverting water.

(3) Evaporation

Water stored on the reservoir islands for later release would increase in salinity through evaporation, especially during the spring and summer. About 35,000 acre-feet of evaporation would occur on the reservoir islands each year (RT p. 278). This would concentrate salts in the reservoir water, and it is unlikely that they could be diluted over the summer months while the water was in the reservoir. DW's final operations criteria prepared for its endangered species consultations contains a topping off provision for June through October that could allow diversion of high quality water onto the islands to dilute the accumulated salts, if water is available during those months. In those months in most years there is no water available for appropriation to storage under the water right priority of DW's applications, however. (RT pp. 277 – 278.)

Stored water might be held on the islands for extended periods. DW assumed that the water usually would be sold and discharged in the late summer after it had been stored the previous winter. The draft EIR/EIS identifies this type of operation as the "worst-case" for determination of environmental impacts. During a succession of wet years, however, or when customers or pumping capacity are unavailable, DW might store the water for several years before being able to sell it. Due to evaporation, the salt load of the stored water would increase over time. Winter topping off could dilute the salinity of the stored water somewhat.

Additionally, DW's plan to operate the reservoir islands as shallow-water habitat during periods when there are not sufficient surplus flows to fill the reservoir islands (RT pp. 259 – 260; RT pp. 2647 – 2650) could add to the salt load discharged to the Delta channels. Shallow-water habitat operations might continue for several years during a drought. For example, model runs show the islands essentially empty throughout the period 1987 – 1991 (CCWD 3, p. 26).

(4)   Salinity Effects on Water Users

If the DW Project caused only a small increase in salinity in the Delta channels, it might be possible to dilute the releases enough to make the effects on the end user insignificant. At an expected DW release rate averaging about 4,000 cfs for a month, however, and assuming the total exports in late summer will be 8,000 cfs to 12,000 cfs, water released from the DW reservoirs could amount to 33 percent to 50 percent or more of the total amount of water exported from the Delta. While some water released from Webb Tract might be tidally mixed and not transported to the export pumps, virtually all water released from Bacon Island would be exported, because the export pumps cause the flows to reverse in Old and Middle rivers when there is low Delta inflow. Most of the water released from the DW reservoirs would flow into Clifton Court Forebay. Some could reach the USBR Tracy pumps. The municipalities in the Santa Clara County area, served by the South Bay Aqueduct, would receive the DW water diluted only by the water in the Delta channels.[8] CCWD also would receive this water directly, because its intakes at Rock Slough and Old River are near the DW discharge points. This effect would continue during the time needed to empty the reservoirs, approximately one to two months if there are no restrictions on the discharge rate to control increases in salinity or DOC in the Delta channels.

(5)   Potential Net Reductions in Salinity Due to Foregone Agricultural Activities

DW argued that the DW Project would cause a net improvement in salinity in the Delta on an average annual basis because of the cessation of agricultural activities on, as well as return flows from, the project islands.[9] In most years, however, this reduction would be counterbalanced by an increase of salinity in the receiving waters (Delta channels) when water is released from the reservoir islands.

Foregoing irrigation on the project islands would not usually cause an increase in Delta outflow that would improve water quality, as suggested by DW. (RT pp. 306 - 311.) When the Delta is in "balanced conditions", the DWR and USBR release only enough water from upstream reservoirs to maintain the water quality standards. (CCWD 4, pp. 18-20, exhibit 8.) Any saving in Delta consumptive use would either be exported or saved in upstream reservoirs for later use.

III. POTENTIAL PHYSICAL IMPACTS OF THE PROJECT

CDWA, PG&E, and CALTRANS raised concerns regarding levee stability, potential damage to and interference with PG&E's gas lines, seepage impacts, and impacts to State

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8 If the municipalities have regulating reservoirs in their systems, they could further dilute the salts before treatment.

9 In a comparison of the model estimates of the salinity of agricultural return flows from Bacon Island with actual measured salinity (CUWA 7a; CCWD 8, figures 2-6), the measured values were significantly lower than the modeled values. Therefore, the degree of water quality improvement to be expected as a result of foregone agriculture apparently would be less than DW predicts.

Highway 12. DW argued that the protests of CDWA, PG&E, and CALTRANS[10] were matters raising disputes over real property rights and were outside the authority of the SWRCB to resolve. The evidence indicates that the DW Project could cause property damage to them or to their constituents. While DW might be liable to them if such damage occurs, the bases for the protests by these parties are that by harming these parties DW would be acting contrary to the public interest. Other parties, including EBMUD, also raised some of the following issues concerning the public interest. The following paragraphs address the harm that could be caused to the public interest by the DW Project.

The CDWA suggested that the SWRCB require DW to provide funding and financial security to ensure that neighbors of the project who are affected by it can financially deal with problems caused by the project and can ensure that the project is operated to avoid damage on neighboring islands. While DW has indicated it is willing to put money into a trust fund each year to ensure that operating costs of project mitigation devices are met, such as operating the interceptor wells or emptying the reservoirs in an emergency, DW has refused to offer any kind of surety bonds or other security to pay for property damages on neighboring islands. Damages could occur to PG&E's gas pipeline, EBMUD's water pipelines, railroads, levees, farmland, and other uses of Delta islands. DW should provide information on the surety bonds or other assurances it would be willing to provide to pay for any damage caused by the DW Project.

No statute specifically states that the SWRCB has authority to require financial assurances in cases where protestants may suffer property damage as a result of the SWRCB's action.[11] (D-1587; D-1011.) Nevertheless, the SWRCB has broad public interest authority, and if the SWRCB finds that it is not in the public interest to allow a particular activity unless potential impacts are mitigated, then the SWRCB can condition any permits it issues upon the permittees providing adequate mitigation. (Wat. Code § 1253.) In this case, reasonable mitigation could include a term or condition requiring that the permittee obtain and maintain insurance or other financial assurances adequate to pay for damages caused to neighboring property by the appropriation of water. On the current hearing record, however, there is inadequate evidence to determine the amount of insurance or other financing that would be needed. Additionally, if the SWRCB were to

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[10] The CALTRANS request is to exclude a 100-foot strip of land from conversion to wetlands on the south side of the highway as it crosses Bouldin Island, which is a proposed habitat island. CALTRANS was seeking to avoid having to mitigate for impacts to a new wetland if and when it widens Highway 12. The modification requested by CALTRANS would reduce the amount of land included within the habitat management plan as mitigation for the effects of reservoir storage on wildlife. It does not appear to be in the public interest to reduce the amount of mitigation for the DW Project in this situation. Accordingly, the the restrictions requested by CALTRANS are not recommended for the DW Project.

[11] CDWA cited a statute that provides for financial assurances to guarantee that mitigation measures will be carried out, but it deals with real property development, not water rights. (*See* Gov. Code § 66499 et seq.) Also, the law cited by CDWA assures the county that mitigation will be done. It does not provide assurances to neighboring property owners whose property might be damaged.

issue permits, it would be helpful to receive additional evidence and recommendations regarding mechanisms for administering financial assurances.

III.A. Seepage

The hearing record shows that in the absence of active measures, seepage will occur between the channels of the Delta, the DW reservoirs, and neighboring islands. (SWRCB 2, pp. 3D-8 through 3D-15.) Agricultural uses on neighboring islands could be impaired by seepage-induced flooding or moisture damage from DW reservoirs. (CDWA 14.) Seepage onto Delta islands is a common occurrence in the Delta. (SWRCB 2, p. 3D-4.) Two kinds of seepage occur: "high" seepage passing through or immediately beneath a levee and "deep" seepage passing through permeable materials beneath the peat and silt that underlies most Delta levees. (SWRCB 2, p. 3D-3.) High seepage accounts for wet places near levees, and comes from the adjacent Delta channel. Deep seepage causes wet areas on the interior of an island. The typical practice in the Delta is to capture seepage in interceptor trenches or relief wells on the islands near the levees and pump the seepage back into the adjacent channel. (DW 17, pp. 7-8.)

The draft EIR/EIS describes the dynamics of deep seepage as follows:

> "The amount of seepage that occurs is controlled by the permeability of soils, length of the seepage path, and height of the hydraulic head (i.e., the pressure created by water within a given volume). The problem is worsened in the Delta by the decline in the level of peat soils, which increases the hydraulic head between channel water surfaces and the islands, and by the presence of permeable subsurface sand layers. Seepage has been reported to increase after flooding of an adjacent island and to cease after the flooded island has been drained." (Citations omitted.) (SWRCB 2, p. 3D-3.)

Two kinds of adverse effects could result from seepage associated with the DW Project. First, there could be impacts to agriculture on neighboring islands due to seepage from the DW reservoirs while they are storing water. This seepage could cause property and crop damage. (CDWA 13 & 14.) Second, there could be seepage from the channels of the Delta onto the DW islands when the water elevation in the reservoirs is less than the water elevation in the surrounding channels. This seepage could result in DW collecting water to storage either outside DW's authorized diversion season or during periods when there is no water available for appropriation under DW's water right priority. If the water came from the channels in the Delta, DW could deplete water for which a senior water right holder has a claim. In this circumstance, DW could be illegally diverting water.

The DW Project reservoir islands and most of the islands in the central part of the Delta are underlaid by a single sand aquifer. (RT p. 130.) The aquifer ranges from 20 to 50 feet thick. Water will move through the sand aquifer in response to hydrostatic pressure on the aquifer.[12] When an island reservoir is filled with water, there will be hydrostatic pressure on the bottom of the island. Because the bottom of the island is permeable, the pressure will also be applied to the aquifer. Water in the aquifer will flow at a rate proportional to the hydraulic head. (SWRCB 2, pp. 3D-2 through 3D -3.)

DW proposes to control seepage and maintain "no net seepage impact" by installing up to 900 interceptor wells drilled through the reservoir island levees, on about 20 miles of the 26.6 miles of perimeter levees encircling the two reservoir islands. (DW 17, p. 9; DW 62, p. 7.) A 1991 estimate by DW assumed that the interceptor wells would be spaced 160 feet apart, be 50 feet deep, and discharge 70 gallons per minute. There is evidence in the record that a much closer spacing would be needed. The purpose of the interceptor well system would be to maintain the water table under the islands at or near the water table elevation in the absence of a filled reservoir. The theory is that the wells would eliminate hydraulic forces that would cause seepage on adjacent islands. DW would put monitoring wells on neighboring islands to assess the effect of the reservoirs on the neighboring islands. DW proposes to return the intercepted seepage water to the reservoirs. (SWRCB 2, pp. 3D-8 and 3D-9.)

To test the concept of using interceptor wells, DW's consultant conducted a demonstration project on McDonald Island, which is receiving seepage from Mildred Island (flooded since 1983). The wells lowered the underground water level during the test, making it possible to run a light tractor on the fields, but the test was conducted over a relatively short period. Even during the short testing period, some test wells experienced difficulties. (CDWA 13 & 14; see also SWRCB 2, p. 3D-10.) CDWA's witness, whose land on McDonald Island was used for the test, testified that while the seepage was reduced within a few feet of the wells, and a light tractor could be driven over his land, his land remained unfarmable because the farming equipment that would be pulled by a tractor would become stuck. (CDWA 13 and RT pp. 796 - 809.) The test differed somewhat from DW's current proposal, since the wells were drilled on the adjacent island, not through the levees on the flooded island. (CDWA 13.) As discussed below, it is uncertain whether the Division of Safety of Dams would authorize DW to perforate its reservoir levees with up to 900 interceptor wells, as this might weaken the levees.

DW proposed monitoring, along with a significance standard for determining whether seepage onto neighboring islands merited action by DW, in addition to proposing seepage control measures. CDWA presented testimony to show that the significance standard and the proposed seepage control system are not adequate to protect CDWA's members. (CDWA 13, pp. 3-4.) Evidence regarding routine seepage problems in the Delta and the effects of the test calls into question the effectiveness of DW's plans for monitoring and seepage control measures. (DWR 24, CDWA 8.) The effectiveness of this type of

[12] This is an expression of Darcy's Law: The amount of seepage that occurs is controlled by the permeability of the soils, length of seepage path, and height of the hydraulic head (i.e., pressure created by water within a given volume.) (See also, SWRCB 2, p. 3D-3.)

system on a large scale has not been demonstrated and does not address the varied soil conditions that exist in the Delta. (CDWA 13, p. 3.) Other potential methods of seepage control are mentioned in the draft EIR, but some would require easements on neighboring islands. The record contains no indication that DW has, or could obtain, easements on neighboring islands except for the limited access DW obtained during the McDonald Island demonstration project.

Seepage from the reservoir islands could be exacerbated if DW carried out its proposal to obtain construction material from the reservoir islands to raise and widen the levees. DW proposed to obtain sand from borrow pits on the reservoir islands to use as construction material.[13] Taking material from borrow pits would involve removing a blanket of silt and peat about 10-15 feet deep from the floor of the islands at each borrow site, to reach the sand. The peat and silt layer impedes percolation of water, and with it removed, exposed areas in the borrow pits could be subjected to as much as 24 feet of hydraulic pressure. (SWRCB 2, p. 3D-13.) This could increase the seepage rate to adjacent islands. Conversely, when the reservoir islands are empty, water could enter the islands under pressure by way of the borrow pits.

The draft EIR (SWRCB 2 at 3D-11) suggests that where seepage restrictions are needed, a 2000 foot setback from the final toe of an improved levee is the closest excavation that should be allowed for purposes of obtaining levee materials. The 2000 foot setback would apparently be required for all borrow sites, since seepage sites cannot be adequately identified prior to filling the reservoirs. (CDWA 13.) Because of concerns about the feasibility of DW's interceptor well system proposal, financial assurances also would need to be required to pay for any damage to farming on adjacent islands as a result of seepage from the DW reservoirs. DW objected to providing financial assurances.

The interceptor well system would have to operate whenever water was in storage, even during power failures. With the potential for seepage, it also would have to operate even if DW abandoned the project with water remaining in the reservoirs. Maintenance and operation of the seepage control system by others if the project were abandoned could unfairly burden other parties. Accordingly, a way to assure payment of these costs is essential to the project.

Additionally, since DW intends that the proposed interceptor wells would return any water they pumped to the island, the interceptor wells could divert water from the sand underneath the Delta channels and levees outside DW's diversion season as well as catching seepage. Such diversions could affect the flow of water in the channels of the Delta. In the summer, the water diverted likely would be water from CVP and SWP storage upstream of the Delta. To avoid an illegal diversion, it would be necessary to require the DW Project to avoid any increases in storage outside its diversion season. In

[13] It is not clear whether DW plans to use earth moving equipment or hydraulic dredging to move the material. If hydraulic fill is used, it may not be stable.

most years, this would mean that DW could not divert water during the summer to compensate for evaporation and would have to discharge water to the Delta channels from the interceptor wells.

The SWRCB has previously held that it can deny or restrict a project if the hearing record contains substantial evidence showing that property damage is likely and that it would be contrary to the public interest to authorize the project in light of the damage. (SWRCB Decisions 1523; 1280.) Additional support for this position is provided in the Water Code and in case law. (Wat. Code §§ 1253, 1255, 1256; *Johnson Rancho County Water District* v. *State Water Rights Board* (1965) 235 Cal.App.2d 863 [45 Cal.Rptr. 589].) Accordingly, the SWRCB may, in the public interest, prevent potential damages to neighboring landowners by denying the applications, requiring financial assurances, or requiring additional measures to ensure the stability of the facilities.

III.B. Levee Stability

Levees in the Delta are used to prevent inundation of the islands and serve to define the channels in the Delta. Many levees are fragile. The draft EIR/EIS includes the following statements about the Delta levees:

> "The Delta levee system initially served to control island flooding. Today the levees are necessary to prevent inundation of island interiors during normal runoff and tidal cycles because island interiors have been lowered by extensive soil subsidence. [...] Delta lands have historically subsided at rates that are among the highest in the world." (SWRCB 2, p. 3D-2.)
>
> "Levee failures occur as a consequence of overtopping or levee instability." (*Id.*)
>
> "Factors contributing to levee instability include seepage, settlement, erosion, subsidence, and seismicity." (SWRCB 2, p. 3D-3.)

Delta levees are highly important, both for flood control and to safeguard the export water supply of the SWP and the CVP. In the Delta Flood Protection Act, enacted in 1988, DWR was allocated $12 million per year until January 1, 1999, to develop two programs: the Delta Levee Maintenance Subventions Program and the Special Flood Control Program. (DWR 25, p. 40.) In particular, the Special Flood Control Program requires protection of the towns of Walnut Grove and Thornton and the following islands: Bethel, Bradford, Holland, Hotchkiss, Jersey, Sherman, Twitchell, and Webb. The eight islands are considered critical to the protection of water quality in the Delta, and breaching the levees on any of the eight islands would allow salinity intrusion. (DWR 25, pp. 40-41.) Some of the measures DWR is considering for the islands include rehabilitating levees using imported material and upgrading the levees to the standards contained in DWR Bulletin 192-82, *Delta Levees Investigation* (1982). (DW 24; DW 25, p. 41.)

DW had not prepared a complete engineered design for the DW reservoir levees before the water right hearing. Without a detailed design to focus on, parties in the hearing raised numerous concerns as to the stability of the project levees and the potential for the DW reservoir perimeter and interior levees to fail or be overtopped. (CDWA 13.) Evidence addressed expected weather and seismic conditions, the potential effects of the proposed interceptor well system on levee structural integrity, and the methods to be used for levee construction and maintenance. (SWRCB 2, pp. 3D-3 through 3D-4.) Based on the evidence, an inadequately constructed, maintained, or protected reservoir levee could suddenly crack or gradually erode, causing damage to property on neighboring islands.

Because other agencies have authority to approve dams and levees for large projects, the SWRCB is not obliged to conduct a detailed examination of the engineering aspects of the DW reservoirs. The SWRCB's regulations do not require the applicant to provide an engineered design in connection with an application to appropriate water. Nevertheless, the SWRCB can order a permittee to obtain approvals of the levees from the agencies that regulate dams and levees.

The structural safety of the perimeter and interior levees would be regulated by the Division of Safety of Dams (DSOD) of the Department of Water Resources if the reservoirs could be filled to 4 feet above mean sea level or higher. (Water Code § 6004(c).) DW proposes to fill the reservoirs to 6 feet above mean sea level. Additionally, the perimeter and interior levees are subject to permitting by the USACE and possibly other agencies. Although the SWRCB would not itself need to address the engineering aspects of the levees if it were to permit the DW applications, the SWRCB would require DW to obtain all required permits and approvals from other agencies and would consider requiring DW to obtain, at DW's expense, an evaluation of all of its levees from the DSOD regardless of whether the DSOD's approval is statutorily required.

III.C. PG&E Lines

DW has not made arrangements with PG&E to ensure that PG&E's natural gas pipeline, which crosses Bacon Island, will be protected and will remain accessible to PG&E at times when Bacon Island reservoir is storing water. As discussed above in connection with the seepage issues, the SWRCB has authority to decide whether or not it is in the public interest to allow DW to appropriate water to storage on Bacon Island. If the SWRCB finds, based on the evidence, that the appropriation will present a substantial threat to PG&E's ability to serve natural gas users, the SWRCB can condition a permit or deny an application.

Two primary concerns were raised regarding the gas pipeline. First, is it in the public interest to allow the gas pipeline to be flooded, and if so, under what circumstances? The SWRCB is required to take into consideration the public interest when deciding whether to approve water right applications, and shall reject an application when in its judgment the appropriation would not best conserve water in the public interest. (Wat. Code §§ 1253, 1255.) The gas pipeline involved is one of PG&E's main lines for connecting underground gas storage to users in northern California. This pipeline can transport approximately one-third of PG&E's total system capacity of gas when gas is withdrawn from storage at the maximum rated. (PG&E 2, p. 2; SWRCB 8, pp. 64-65.) It is not in the public interest to allow DW to make the gas line inaccessible to emergency maintenance; nor should it be flooded without protective measures to ensure the integrity of the gas pipe.

Additionally, the SWRCB notes that there is a real property access issue between DW and PG&E because of easements held by PG&E to run its gas pipeline across Bacon Island. The SWRCB is not the proper forum to decide whether or not the applicant or the protestant has the right to occupy or use land or other property necessary to the proposed appropriation. (SWRCB Decision 1516.) This limitation is explicitly set forth at California Code of Regulations, title 23, section 777. Accordingly, while the SWRCB has jurisdiction to authorize the diversion of water to storage on Bacon Island, such authorization could not be adequate by itself to authorize DW to flood the parts of Bacon Island where PG&E's gas pipelines are buried. This is a property ownership issue between DW and PG&E that should be resolved between the parties in court if they are not able to resolve it through negotiation. Any permits the SWRCB issued to store water on Bacon Island would be conditioned to avoid authorizing flooding that would illegally impact PG&E's property rights. Additionally, the SWRCB could defer any actions until the property rights are judicially determined.

IV. PROJECT FEASIBILITY

The SWRCB is required to condition any permit it issues to best develop, conserve, and utilize in the public interest the water to be appropriated. (Wat. Code § 1253.) If the SWRCB finds that a proposed appropriation will not best conserve the public interest, it is required to reject the application. (Wat. Code § 1255.) Numerous factors are relevant to a determination of public interest. In the hearing on the DW Project, the relevant factors raised by the parties included water quality impacts on domestic water supplies, lack of a market for the water, financial feasibility of the project, feasibility of constructing levees and seepage control facilities to contain the water, potential damage to neighboring property, and impacts on fish and wildlife. The SWRCB has broad discretion to decide whether a proposed project would best conserve the public interest. (*Bank of America N.T. & S.A.* v. *SWRCB* (1974) 42 Cal.App.3d 198 [116 Cal.Rptr. 770]; *Johnson Rancho County Water District* v. *State Water Rights Board* (1965) 235 Cal.App.2d 863 [45 Cal.Rptr. 589].)

DW presented testimony to the effect that it could break even on the project if it could yield an average of 160,000 acre-feet of water per year. As discussed below, it is unlikely, with the additional terms and conditions that would be needed to protect other legal users of water, provide seepage control, and minimize impacts from dissolved organics, that the DW Project could yield this quantity. Further, there is not always capacity at the pumps in the southern Delta to move the water DW would develop. Finally, it is unlikely that DW would be able to sell water during wet years because there is less demand in wet years, and any needed supplemental water supplies could be bought at lower prices.

To approve the DW Project, the SWRCB must be satisfied that the project is adequately designed, mitigated, and assured of having a profitable market for its water supply so that it will continue to operate for the expected life of the project. It would not be in the public interest for the DW Project to be abandoned after construction. If the DW Project failed and was abandoned, some of the adverse impacts that would be avoided or mitigated by an operating project could occur. If the reservoir islands were not operating, but nevertheless filled with water from subsurface seepage or from levee breaks, they could cause seepage onto neighboring islands and could present a danger of impacting neighboring islands as a result of levee breakage. They also could contribute DOC to Delta waters.

Without a source of income from selling water, DW might not be able to maintain expensive mitigation measures such as the proposed active seepage control measures and levee maintenance. Further, the benefits upon which any finding of overriding consideration under CEQA might be based would not be realized, making the approval action vulnerable under CEQA.

Approving the DW Project would make the water unavailable to subsequent water right applicants until the permits were revoked. If the permits were held unused for a period of years, they could discourage other applications from being filed.

IV.A. Availability of Conveyance Capacity for Export of Water

To be financially feasible, the DW Project needs to convey water to a place or places of use south or west of the Delta, using the export pumping and conveyance facilities of the CVP or the SWP. If there is no conveyance capacity or inadequate conveyance capacity available to DW, or if DW is unable to make arrangements to exchange water with the CVP or SWP at the times when DW has a customer, DW will not be able to sell its water for export. If it cannot sell its water and export it, the project is not feasible.

DW based its assumptions regarding conveyance capacity on the historic availability of conveyance capacity at the CVP and SWP export facilities. Currently, it is assumed that from July 1 through October there is some capacity available at the SWP facilities to wheel water. DW assumes for the purpose of estimating feasibility, that it will be able to sell and deliver water for up to 50 years. The existing capacity, however, has constraints, and less capacity could be available in the future as the demands of the SWP water users increase.

The chiefs of operations for both the USBR and the DWR testified that conveyance capacity may not be available in the future, and that neither project has previously entered into the type of long-term wheeling agreement that would be needed to assure that DW's water could reliably be wheeled. (RT pp. 1524; 1587.) Both projects already have set priorities for allocating wheeling capacity, and DW's wheeling priority would come after the existing priorities. The USBR chief of operations stated the USBR has virtually no available capacity at any time. DW's expert agreed with this assessment. (RT p. 1525.) DWR presented testimony that (1) there is limited surplus capacity available in the state facilities, (2) there were no negotiations underway for DW to secure wheeling capacity, and (3) DWR was not in a position to guarantee DW it would have wheeling capacity. (RT pp. 1587 - 1588.) As the demands of the SWP contractors increase, DWR will deliver more water to its contractors from its existing unused water rights, further reducing the capacity for other wheeling. (RT p. 1653.) Additionally, DWR will deliver purchased water for its contractors in preference to other water. The DW Project should make a better showing that the water developed by the project can be wheeled reliably. Such a showing could take the form of a contract with the DWR or the USBR, plus an estimate of the frequency and amount of water that would be wheeled.

IV.B. Project Yield With Mitigation

DW's witness stated during the hearing that the lender for the project would not agree to a yield reduction that would drop the project yield below approximately 160,000 afa. (RT p. 2333.) The current estimate is 154,000 afa, which DW considers to be essentially the same as 160,000 afa for purposes of financial feasibility.

Originally, the DW Project yield was estimated at 235,000 afa. The current estimate of 154,000 afa (RT pp. 2334 - 2335) is based on an assumption that any approval of the project issued either by the SWRCB or the Corps will impose no additional terms and conditions that affect yield over and above the impacts of the mitigation measures in the draft EIR and the impacts of the federal biological opinions. The SWRCB commonly imposes conditions on a project in addition to the mitigation measures that may be recommended in an EIR, to address matters that involve other water rights and the public interest. In this case, the SWRCB would likely add a number of terms and conditions that could have a substantial, undetermined impact on project yield. The issues that could result in such terms are discussed in greater detail in other parts of this decision, and they include (1) protection of CCWD's senior water rights by ensuring that operation of the DW Project does not cause the location of the X2 salinity line to move upstream to a point where CCWD cannot divert water under its own rights during its diversion season; (2) constraints to protect water quality in the receiving water; (3) control of seepage between islands; (4) avoidance of inadvertent diversions to storage outside the diversion season by pumping from interceptor wells; (5) levee design and construction and the likelihood of storing water at plus 6 feet above mean sea level;[14] (6) the feasibility of the project after a complete analysis of yield that would take into account the likely level of demand for the water and the probable conveyance capacity in addition to modeling the presence of water in the Delta; and (7) measures to protect the PG&E gas pipeline. The DW yield estimate does not take into account any additional terms and conditions that would be imposed to address these issues. A further analysis would be needed if these items are addressed in the future, to determine whether the project is feasible.

[14] A lowering of the maximum water storage elevation to plus 4 feet above mean sea level would reduce the project yield by approximately 20,000 afa (RT p. 2579.)

Appendix D

Revised Scope of Work and Response to DW Comments by URS Greiner Woodward Clyde

URS Greiner Woodward Clyde
A Division of URS Corporation

500 12th Street, Suite 200
Oakland, CA 94607-4014
Tel: 510.893.3600
Fax: 510.874.3268
Offices Worldwide

July 6, 1999

Ms. Aimee Dour-Smith
Jones & Stokes Associates, Inc.
2699 V Street, Sacramento, CA 95818-1914
Ph. (916) 737-3000
Fx (916) 737-3030

Subject: Geotechnical Scope of Services in Support of the Supplemental EIR/EIS, Delta Wetlands Project, California

Dear Ms. Dour-Smith:

In accordance with our meeting on April 29, 1999 and the review of the State Water Resources Control Board's (SWRCB) letter dated November 25, 1998 on the subject project, we have prepared a technical scope of work addressing the geotechnical issues requiring responses and/or further development. The scope of work prepared below was also based on our understanding the geotechnical issues from our review of the work preformed by Harding Lawson Associates (reports prepared from 1988 to 1992), the project EIR/EIS main volume and appendices, and review or other pertinent literature to the Bay Delta area from DWR, USACE, and published technical papers.

The outline of the proposed scope of work was developed along the content of Attachment A of the SWRCB's letter, specifically related to Item "III.A Seepage" and Item "III.B Levee Stability".

Further, in response to comments at the June 14, 1999 Scoping Meeting, the proposed work has been divided into two phases. Phase 1 includes Task 1, the review of existing data, which initially included a review of the existing data only. Task 1 is now expanded to include a review of the solutions prepared as part of the EIR/EIS and assess their adequacy in relation to the Board's comments. Depending on the adequacy of the solutions in the geotechnical reference documents to the EIR/EIS, revisions (if deemed appropriate) will be made to the scope of Phase 2 as presently proposed. Phase 2 includes all other tasks, but their scope is now considered preliminary and subject to revision following Phase 1.

1. REVIEW EXISTING DATA AND SOLUTIONS, AND REVISE SCOPE OF LATER TASKS AS NEEDED

Background Information:

Harding and Lawson Associates (HLA) had conducted extensive subsurface soil investigation and groundwater monitoring on the Delta Wetlands project site from 1989 to 1992. We have performed a cursory review of these documents for the preparation of this scope of work and will review them in more detail in Task 1. We will also include in our review the on-going work by the California Department of Water Resources (DWR) on the Delta levees investigation and evaluation, the USACE's levee investigations, surveys, and flood damage repairs reports, and CALFED's levee integrity subcommittee released reports. Other relevant published papers (i.e. UC Davis, UC Berkeley) will also be reviewed and used to supplement data needed for the proposed analyses discussed below.

As previously noted, we have developed the proposed scope of our work in seepage and slope stability primarily on the basis of the SWRCB comments on the EIR/EIS of November 25, 1999. It has been pointed out by the applicants that they believe that some of the issues questioned in that letter had actually been adequately addressed in the EIR/EIS. Therefore as a part of the review of background documentation, we will contact Mr. Ed Hultgren and have him point out issues questioned by the SWRCB that to his understanding are addressed adequately in the existing documentation. Based on these discussions, we will specifically review those parts of the documentation, and relate them to the SWRCB's comments. Based on this review, we will adjust the scope of the recommended Phase II supplemental studies if deemed necessary.

Scope of Work:

As discussed, we will review the existing project documentation, primarily in view of establishing data bases for the following work, judging the adequacy and completeness of the past work, and adjusting the scope of the Phase II proposed studies. As a part of this review, we will meet with Mr. Ed Hultgren to obtain his input. The review of the background documentation will be used to:

- Evaluate subsurface soil and groundwater data collected for the project and other relevant documents,
- Review and evaluate the geologic profiles and cross sections proposed for the various analyses,
- Collect and assign material parameters and properties to support the seepage analyses and the levee stability analyses for both static and seismic conditions,
- Review and, if necessary, revise the scope of the following Phase 2 studies,

We will attend three meetings in Sacramento, (1) one meeting with Mr. Ed Hultgren and the project team members to receive and discuss the proposed geotechnical studies relevant to the Board's comments, (2) one meeting to report back to the project team on our findings and evaluation of its adequacy, and (3) one meeting to present the revised scope of Phase 2.

Based on our cursory review of the available data, we do not anticipate to perform additional field exploration and laboratory tests. As discussed, the remainder of the scope of Phase 2 is preliminary and subject to change based on the results of Phase 1.

2. PERFORM SEEPAGE ANALYSES

2.1 Interceptor Wells

Background Information:

Active interceptor or relief wells are proposed for mitigating potential seepage impact on the neighboring islands as a resulting of filling the reservoir islands (Webb Track and Bacon Island). Field groundwater drawdown programs were conducted by HLA on the McDonald Island in 1989-1990 (Phase I) and 1990 (Phase II). The McDonald Island is located adjacent to the Mildred Island that was flooded at the time of demonstration. The field test was conducted to evaluate the feasibility and effectiveness of the interceptor (relief) wells in lowering the hydraulic head in the sand aquifer. HLA (1991) also performed groundwater numerical modeling to simulate various systems of interceptor wells and the required rate of discharge (groundwater withdrawal) that would maintain the existing groundwater conditions at the neighboring islands.

An independent evaluation of the effectiveness and the active interceptor wells will be conducted to provide response to the SWRCB concerns about their adequacy. The activities proposed under this task will include:

Scope of Work:

- Review the test data and conclusions made for the field drawdown program for use as a calibration to the numerical seepage model,
- Develop a baseline condition for the groundwater at the project site (part of Task 1 scope of work). This baseline condition represents the existing groundwater and seepage condition before the installation of interceptor wells and will be used to measure the effectiveness of any proposed well system,
- Develop numerical models and analytical procedures for the groundwater withdrawal simulation,
- Reconcile soil and groundwater parameters used in analyses with the field data (calibration),

- Perform sensitivity analyses,
- Evaluate the interceptor well system (diameter, spacing, depth, screened length) proposed by DW to maintain the existing groundwater condition at the affected islands during high storage in the reservoir islands, and develop recommendations for an optimal system,
- Address the variation in subsurface soil conditions at the project site and its effects on the interceptor well system.

We will utilize computer program SEEP/W (Geo-Slope, 1998) for these analyses. SEEP/W is a two-dimensional finite element computer program used to model the groundwater flow through the porous media. The program is capable of running both steady state and transient time-dependent analyses.

2.2 Effectiveness of Monitoring System and Procedures

Background Information:

HLA developed a monitoring system for groundwater seepage. The monitoring system provides a standard of performance against which project related seepage can be determined.

Scope of Work:

We propose the following subtasks:

- Review the proposed standard monitoring procedures developed for the Delta Wetlands project,
- Assess the adequacy and effectiveness of the proposed procedures to monitor the project related seepage to the neighboring islands,
- Determine volume and time-dependent variation of seepage under various groundwater and subsurface soil conditions (sensitivity analyses),
- Evaluate the monitoring procedure proposed by DW using results of the sensitivity analyses. The existing monitoring procedures may be used and expanded to incorporate analysis findings,
- Evaluate the criteria (termed "significance standard") developed by DW to determine whether seepage onto neighboring islands merited action by DW. Develop alternate criteria as needed, including easily usable tools such as plots and/or tables of correlation among various groundwater parameters, and set thresholds for different levels of response, including reporting to various agencies and the needs for emergency response.

2.3 Routine Maintenance of Interceptor Wells

Background Information:

The SWQCB has expressed concern about the long-term reliability of the proposed extensive groundwater pumping, especially in view of some difficulties reportedly encountered during DW's demonstration project.

Scope of Work:

We propose the following subtasks:

- Evaluate the long-term reliability of the selected well system including its power supply.
- Estimate, using the models developed in Task 2.1, the effects of various plausible pumping outages
- Develop routine monitoring procedures to identify and respond to outages or lack of performance of individual wells, well groups or the entire system.
- Develop routine maintenance procedures/guidelines for the selected system..

2.4 'Unauthorized' Water Diversion into the Storage Islands through Seepage

Background Information:

The SWRCB is concerned that during certain water level conditions in the storage islands and the adjacent channels the pumping from the interceptor wells or direct seepage may constitute "unauthorized" water diversion into the storage islands. A methodology is needed to prevent or account for such unauthorized diversions. We propose to conduct the following analyses to assess this potential impact.

Scope of Work:

- Perform analyses to simulate the potential of inverse flow of the channel water into the proposed storage islands using the groundwater numerical models developed in Task 2.1
- Utilize the hydrograph of the channel water to quantify the seepage into the storage islands at various times during the year and under various groundwater conditions,
- Estimate seepage flow into the storage islands during and outside the DW diversion seasons,
- Use the rate of pond water evaporation consistent with the hydrologic model and incorporate the results into the analyses.

2.5 Effects of Borrow Pits on Seepage

Background Information:

The project proposes to utilize borrow material from the storage islands to strengthen the island's levees. The SWRCB has expressed concern that the limitations on locations of borrow pits proposed by DW may not be adequate to prevent excessive seepage increases in the underlying sand aquifer due to the borrow pits. We propose to perform the following seepage analyses to assess this condition.

Scope of Work:

- Assess the feasibility and effects of borrow pits on the seepage conditions using seepage numerical models developed in Task 2.1,
- Evaluate the proposed size, depth, and setback locations of borrow pits, and make recommendations on an optimal system.

2.6 Settlement Caused by Filling and Pumping of Water

Background Information:

Rapid filling of the storage islands with water causes additional stresses on underlying soil layers. Groundwater pumping from under the levees also causes additional soil stresses. Both of these factors may cause additional settlements of levees and interiors of both storage islands and adjacent islands. This issue appears not to have been addressed in detail. For levee design as well as overall impacts on the project, such settlements should be addressed.

Scope of Work:

- Estimate changes in stress conditions at locations of concern, both periodically changing and permanent. Locations of concern are expected to be the levees, and the interiors of both storage and adjacent islands.
- Estimate the associated settlements and their time histories.

3. LEVEE STABILITY

3.1 Levee Strengthening

Background Information:

HLA (1989, 1992) performed geotechnical investigation and engineering analyses for the Delta Wetlands levees. The study included field investigation, soil laboratory testing, analyses of embankment stability, construction sequence, settlement and seepage through the dam. Design criteria for the levees were also prepared for the California Department of Water Resources, Division of Safety of Dams (DSOD) permit approval.

As part of this study, HLA also developed site-specific static and dynamic soil properties by conducting geophysical surveys and laboratory testing. In addition, HLA developed seismic design load criteria and performed one-dimensional site response analyses. Liquefaction potential evaluation and seismic-induced deformation analyses were also performed.

More recently (1998), probabilistic seismic hazard analysis and levee failure probabilistic evaluation were conducted for the Sacramento/San Joaquin Delta levees by the Seismic Vulnerability Sub-Team of CALFED's Levees and Channels Technical Team. In this study, the delta region was divided into four groups based on their expected seismic ground motions and the levee fragility to failure. Estimates for levee failure due to scenario earthquake events from nearby dominant seismic sources were also developed.

The SWRCB identified various issues associated with the stability of the Delta Levees which included subsidence, static and seismic stability and deformation, settlement, erosion, and overtopping. Although additional work addressing these issues was not requested in the November 25, 1998 letter, during subsequent meetings between the lead agencies and the engineers it was decided that additional engineering analysis of these items was required. Accordingly, we propose to perform the following activities to verify compliance with the state regulatory agencies on reservoir stability issues.

Scope of Work:

- Evaluate the proposed strengthening design for the delta levees,
- Evaluate analysis results from previous studies on the levee stability, including soil engineering parameters used,
- Assess various assumptions on the subsurface soil and groundwater conditions,
- Update dynamic soil parameters based on recent findings,
- Review the various ground motion studies conducted for the Delta Wetlands project

- Develop site-specific seismic load for the project that include peak ground acceleration, design response spectra, shaking duration and acceleration time histories.
- Evaluate the analyses done by DW of the safety of the strengthened levees against static and earthquake induced loads. Implement additional analyses as deemed needed. Failure mechanism should include slope failure, inadequate bearing capacity, excessive slope deformations and settlement, critical seepage conditions and others,
- Evaluate the during-construction, long-term and rapid drawdown static stability of the levee systems, and compare the stability parameters to existing conditions,
- Evaluate the maximum pond water elevation proposed by DW for a safe operation of the reservoir, and recommend a different elevation if needed,
- Evaluate geologic hazards associated with earthquake event, such as liquefaction, loss of bearing capacity and dynamic soil compaction,
- Address the potential for levee overtopping during a seismic induced seiche,
- Address erosion by wind fetch and wave runup,
- Address the constructibility of the selected levee system. We will evaluate the volume and gradation of the materials used to strengthen the levees (see Task II.5 for borrow pits).

For the static stability analyses of the levee systems, we will use limit equilibrium computer programs such as UTEXAS-3. For the seismic evaluation of the levee systems, simplified procedures such as the Newmark sliding block and Makdisi & Seed procedure will used to estimate the expected earthquake induced deformation. We will also run one cross-section using a non-linear 2-D finite element model to validate the calculated deformations from the simplified procedures.

Dynamic soil properties and characteristics (i.e., shear wave velocity and the degradation and damping curves) will be developed using the results of the available studies on similar soils. These studies include: HLA (1992), Stokoe et al. (1994), Kramer (1996) and Boulanger et al. (1998). The selected design seismic loads will be used as the inputs to these analyses.

The stability analysis procedures and criteria proposed in this task will be discussed with DSOD for review and approval. We anticipate a one meeting with DSOD to discuss this matter.

For purposes of the cost proposal, this task has been divided into static aspects and dynamic aspects of the review of stability.

3.2 Assess Effects of Interceptor Wells on Levee Stability.

Background Information:

As several interceptor wells will be installed in the levees, the impact of the construction of the wells on the levee structural integrity will be evaluated. Input from DSOD will also be sought as well as guidelines for installing dewatering wells along levees.

Scope of Work:

We propose the following subtasks:

- Review the practice of construction and operation of water on levee systems as a precedent. We will also performed simplified stability analyses to evaluate the impact of the wells on the structural integrity of the levees.

4. REPORT

We will document the completed work and its results and conclusions in a technical report. As an alternative, we can report separately on seepage and stability aspects. The report(s) will first be submitted in draft form and will subsequently be revised in response to comments by you and the agencies.

OPTIONAL TASKS

Optional Task 1 - Assess Potential Damage to Neighboring Island in Event of DW Levee Breach or Project Abandonment

Background Information:

The SWQCB has expressed concern about potential damages to adjacent islands in the event of a levee failure of a storage island and in the event of project abandonment by the owner. Some effort to address these concerns, using various plausible scenarios, appears justified.

Scope of Work:

We propose the following scope for these contingency events:

- Formulate scenarios of levee failure of storage islands that might damage adjacent islands; one example is levee failure with full storage island (elevation +6 feet) and extremely low water in the channels.

- Estimate potential effect of these event on levee across a narrow channel, and judge the likelihood of any catastrophic damages (some erosion damage could easily be repaired after the event)
- Formulate scenarios of levee abandonment at critical times in the storage islands' annual use cycle, or after a damaging event such as an earthquake (but that does not cause a levee failure)
- Estimate storage islands' behavior for these scenarios, and seepage conditions that could negatively impact adjacent islands; estimate the potential for significant short- and long-range damages to adjacent islands.
- Work with Jones and Stokes' hydraulic modelers to estimate the probability that these conditions could happen.

Optional Task 2 - Attendance at Project Meetings

As a second optional task, attendance by three URSGWC personnel at two project meetings is included in the scope.

Optional Task 3 - Participation at two Agency Hearings

As a third optional task, two senior URSGWC personnel will participate in two agency hearings. Some preparation for these hearings is also included.

SCHEDULE

As discussed with you, we anticipate that this work, through submission of a draft report, will be completed in 3 to 4 months. Modifying the report in response to comments is expected to require 1 to 3 weeks, depending on the number and extent of comments.

CLOSING

We will be happy to discuss this proposed scope of work with you at your convenience. Thank you for including us in your team for this interesting project.

Sincerely,

URS Greiner Woodward Clyde

Said Salah-Mars, Ph.D., P.E.
Senior Project Manager

Michael P. Stuhr, P.E. for
Project Manager

URS Greiner Woodward Clyde
A Division of URS Corporation

500 12th Street, Suite 200
Oakland, CA 94607-4014
Tel: 510.893.3600
Fax: 510.874.3268
Offices Worldwide

September 13, 1999

Ms. Aimee Dour-Smith
Jones and Stokes Associates, Inc.
2699 V Street
Sacramento, CA 95818-1914

Subject: Report on Task 1 - Review Existing Data and Solutions, and Revise Scope of Later Tasks as Needed. Geotechnical Services in Support of Supplemental EIR/EIS, Delta Wetlands Project, California

Dear Ms. Dour-Smith:

This letter report presents the results of our Task 1 of the subject geotechnical services. It contains the results of our review, responses to comments prepared by Hultgren-Tillis Engineers (HTE) on our proposed scope of work in the later tasks, and our recommendations for changes in some of the later tasks based on the review and comments.

1.0 INTRODUCTION

The following text is organized according to the sections in our Scope of Services dated July 6, 1999. Typically the text first provides our "Background" of a scope item from the July letter, then the specific task description from the July letter, followed by HTE' comments, and finally by our response to the comments and conclusions on changes in the scope of work where deemed warranted. In two scope sections (2.1 and 3.0), HTE also provided comments on our background statements, and these comments are also responded to.

We would like to note that the "tasks" numbered by HTE were actually bulleted scope items in our Scope of Services, and in this sense represented work items within a task rather than stand-alone tasks. Because HTE discussed them as tasks, we have adopted this format for this review.

We also note that on many tasks (as defined above), HTE provided no comments, rather only gave citations. We have reviewed all citations and noted where they will be of assistance.

2.0 PERFORM SEEPAGE ANALYSES

2.1 INTERCEPTOR WELLS

Background Information:

Active interceptor or relief wells are proposed for mitigating potential seepage impact on the neighboring islands as a result of filling the reservoir islands (Webb Tract and Bacon Island). Field groundwater drawdown programs were conducted by HLA on McDonald Island in 1989-1990 (Phase I) and 1990 (Phase II). McDonald Island is located adjacent to Mildred Island that was flooded at the time of the demonstration. The field test was conducted to evaluate the feasibility and effectiveness of the interceptor (relief) wells in lowering the hydraulic head in the sand aquifer. HLA (1991) also performed groundwater numerical modeling to simulate various systems of interceptor wells and the required rate of discharge (groundwater withdrawal) that would maintain the existing groundwater conditions at the neighboring islands.

An independent evaluation of the effectiveness and the active interceptor wells will be conducted to provide response to the SWRCB concerns about their adequacy. The activities proposed under this task will include:

HTE Comment: Our assessment of the November 25, 1998 letter form the State Board is that hearing participants were not convinced that a pumped well system could reliably control any groundwater seepage. We are confident that as a groundwater flow control mechanism, wells can control seepage. We believe URSGWC should review the concerns presented in the testimony to check that the concerns have been fully addressed.

URSGWC Response: Based on our review of the reference documents and the testimony cited above, we believe that the concerns raised by SWRCB are not fully addressed and supplemental analyses addressing specifically these concerns are needed. The justification is further developed in our responses to the comments in the following paragraphs.

2.1.1 Review the test data and conclusions made for the field drawdown program for use as a calibration to the numerical seepage model,

HTE Comment: The McDonald Island demonstration was not intended to be a basis of calibration. The nature of the recharge is not precisely known. McDonald Island landowners reported increased seepage impacts following the inundation of Mildred Island. However, some of the reported effects may be related to local deep dredging for levee construction materials that may have occurred in Latham Slough immediately adjacent to the levee.

For the Demonstration Test pumping, the fifteen wells were interconnected with a sealed header connected to a single pump. As a result, the individual drawdown and flow rate of each well is not known for the pumped test. The drawdown and flow rates were recorded for the gravity flow test. The key output from the McDonald Island drawdown tests are the changes that occurred in the hydraulic grade lines as measured by the piezometers.

URSGWC Response: The purpose of this task is to run a 2-D computer model with the same geometry and input conditions as those during the drawdown test to check what material permeability best fits the groundwater table measured in McDonald Island during the test. Gradation curves can than be compared to other island aquifers to make necessary adjustments to the permeability values. We consequently, recommend pursuing this analysis because it will help provide a higher comfort level in the material permeabilities.

2.1.2 Develop a baseline condition for the groundwater at the project site (part of Task 1 scope of work). This baseline condition represents the existing groundwater and seepage condition before the installation of interceptor wells and will be used to measure the effectiveness of any proposed well system.

HTE Comment: The three "groundwater" baseline data points that are available include (a) the mean tidal level in the slough or river; (b) the groundwater level measured by monitoring wells in the aquifer immediately below the levee; and (c) the groundwater level beneath interior portions of the island. This last point is not supported by existing monitoring wells and must be estimated. The groundwater levels in the aquifer below the perimeter levees are presented in the groundwater monitoring reports. What we found was that the groundwater level beneath perimeter levees was typically within 5 feet (above or below) the ground surface elevation at the levee toe (HTA 1992c, p. 3).

URSGWC Response: Mr. Hultgren provided insightful information on the baseline condition of the groundwater. Particularly the reference on groundwater monitoring program dated 1995c is very useful. The data from that report will be used in our subsequent analyses. A reduced effort is anticipated for this task.

2.1.3 Develop numerical models and analytical procedures for the groundwater withdrawal simulation.

HTE Comment: None.

URSGWC Response: The task on the numerical modeling of the groundwater withdrawal simulation will be conducted because it will allow the assessment of the potential impact on the neighboring islands' background groundwater (to assess the no-net change condition). The review of the references cited in HTE's comments indicates a very simplified model (1-D) was used which does not fully characterize the seepage through the silt and peat layer into the aquifer in the reservoir island, and out of the top layer in the neighboring islands.

2.1.4 Reconcile soil and groundwater parameters used in analyses with the field data (calibration)

HTE Comment: (Also see 2.1.1 and 2.1.2) The range of permeabilities in the sand can be estimated from grain size analyses. These are available in the preliminary geotechnical investigation and groundwater monitoring reports. Permeability of peat was measured for the Wilkerson Dam investigation. Infiltration from adjacent waterways is affected by past dredging; subsequent sedimentation; the nature of the original material beneath the slough, river or man-made cut; evapo-transpiration extraction; and irrigation practices.

URSGWC Response: This task will be rolled into task 2.1.3. If the channel stages are known along with the piezometers data in project and neighboring islands, some level of model validation should be tested before the production runs are launched (reduced scope).

2.1.5 Perform sensitivity analyses.

HTE Comment: None.

URSGWC Response: This task will consider applying a reasonable range of variation to the aquifer transmissibility (thickness and permeability) as reported in the various boring and wells logs. This task will be rolled into or combined with task 2.1.7 to minimize effort in analysis.

2.1.6 Evaluate the interceptor well system (diameter, spacing, depth, screened length) proposed by DW to maintain the existing groundwater condition at the affected islands during high storage in the reservoir islands, and develop recommendations for an optimal system,

HTE Comment: DW has not selected final diameter or spacing of interceptor wells. In making preliminary evaluations for cost estimates, we assumed typical spacings of 150 to 160 feet. We assumed 12-inch diameter wells with 6-inch diameter screened casings. We further assumed that the aquifer will be fully screened.

URSGWC Response: Because some concerns were raised regarding the adequacy of the pumping wells, this task will be an evaluation of DW's proposed well configuration and will determine the sensitivity of the pumping wells system to well spacing, diameter, and pumping rate. Based on the findings from the analyses, mitigation measures will be recommended as appropriate. We will assume that the wells are screened within the aquifer.

2.1.7 Address the variation in subsurface soil conditions at the project site and its effects on the interceptor well system.

HTE Comment: See comments in 2.1.4.

URSGWC Response: Task merged into 2.1.5.

2.2 EFFECTIVENESS OF MONITORING SYSTEM AND PROCEDURES

Background Information:

HLA developed a monitoring system for groundwater seepage. The monitoring system provides a standard of performance against which project related seepage can be determined.

2.2.1 and 2.2.2 Review the proposed standard monitoring procedures developed for the Delta Wetlands project, and assess the adequacy and effectiveness of the proposed procedures to monitor the project related seepage to the neighboring islands.

HTE Comment: None.

URSGWC Response: In this task we propose to assess the adequacy of the effectiveness of the monitoring program and provide recommendations if deemed necessary. Some of these recommendations may be derived from the model analyses proposed in tasks 2.1. In evaluating this task, we have reviewed the list of references provided by Mr. Hultgren and noted where the existing information will be of assistance in our analysis.

2.2.3 Determine volume and time-dependent variation of seepage under various groundwater and subsurface soil conditions (sensitivity analyses).

HTE Comment: (A) in our assessment, neighbors are impacted by changes in the elevation of the groundwater, regardless of flow quantity. (B) We do not understand the significance of doing time-dependent evaluations.

URSGWC Response: This task is mainly related to the issue of whether a time-delay exists between the stage filling of the reservoir and the increased piezometric head in the neighboring islands and the capacity of the pumping wells to relieve the excess head in the aquifer in due time. The outcome of this task may impact the rate of filling of the reservoir and also impact the interpretation of the monitoring program.

2.2.4 Evaluate the monitoring procedure proposed by DW using results of the sensitivity analyses. The existing monitoring procedures may be used and expanded to incorporate analysis findings

HTE Comment: None.

URSGWC Response: This task will be rolled into Task 2.2.2. We will evaluate changes to the proposed monitoring procedures as deemed needed.

2.2.5 Evaluate the criteria (termed "significance standard") developed by DW to determine whether seepage onto neighboring islands merited action by DW. Develop alternate criteria as needed, including easily usable tools such as plots and/or tables of correlation among various groundwater parameters, and set thresholds for different levels of response, including reporting to various agencies and the needs for emergency response.

HTE Comment: The significance standard was developed with the Seepage Committee who agreed to the final criteria.

URSGWC Response: This task will focus on evaluating how the proposed significance criteria translates into changes in groundwater conditions from the no-project conditions.

2.3 ROUTINE MAINTENANCE OF INTERCEPTOR WELLS

Background Information:

The SWQCB has expressed concern about the long-term reliability of the proposed extensive groundwater pumping, especially in view of some difficulties reportedly encountered during DW's demonstration project.

2.3.1 Evaluate the long-term reliability of the selected well system including its power supply.

HTE Comment: The McDonald Island demonstration project provided very useful and reliable information, however, when assessing the long term reliability of wells, limited weight should be put on the McDonald Island demonstration project. These wells were put in with the single purpose of conducting a short term test. We did not focus on filter pack gradation or well development. The permanent wells will be designed, installed and developed with the goal to be efficient and for long-term reliability. They also will be regularly maintained.

URSGWC Response: We agree with HTE's comments on the purpose and objective of the McDonald Island Test. Our input on this task will consist of evaluating the feasibility and long term viability of the proposed well system and, as needed, providing recommendations and general guide specifications to mitigate for inadequacies in the proposed installation and operation of permanent dewatering wells.

2.3.2 and 2.3.3 Estimate, using the models developed in Task 2.1, the effects of various plausible pumping outages, and develop routine monitoring procedures to identify and respond to outages or lack of performance of individual wells, well groups or the entire system.

HTE Comment: The obvious place to monitor "reportable" data is at the receptor (neighboring island). We believe no reportable monitoring beyond what we have already recommended is needed. DW will have additional monitoring and maintenance systems to keep their interceptor wells working effectively.

URSGWC Response: This task responds to the concern about potential outage of some or all pumping wells. This evaluation will identify the potential impact on the groundwater in neighboring islands from wells outage, and, as needed, recommend changes to the proposed monitoring program to respond to outages.

2.3.4 Develop routine maintenance procedures/guidelines for the selected system.

HTE Comment: Developing routine maintenance procedures will be part of final design.

URSGWC Response: Task deleted.

2.4 'UNAUTHORIZED' WATER DIVERSION INTO THE STORAGE ISLANDS THROUGH SEEPAGE

Background Information:

The SWRCB is concerned that during certain water level conditions in the storage islands and the adjacent channels the pumping from the interceptor wells or direct seepage may constitute "unauthorized" water diversion into the storage islands. A methodology is needed to prevent or account for such unauthorized diversions. We propose to conduct the following analyses to assess this potential impact.

HTE Comment: None

URSGWC Response: None. Scope is not changed.

2.5 EFFECTS OF BORROW PITS ON SEEPAGE

Background Information:

The project proposes to utilize borrow material from the storage islands to strengthen the island's levees. The SWRCB has expressed concern that the limitations on locations of borrow pits proposed by DW may not be adequate to prevent excessive seepage increases in the underlying sand aquifer due to the borrow pits. We propose to perform the following seepage analyses to assess this condition.

2.5.1 Assess the feasibility and effects of borrow pits on the seepage conditions using seepage numerical models developed in Task 2.1.

HTE Comment: At the time of our 1991 interceptor well study (HLA 1991B), the project envisioned long and wide borrow pits to develop the large quantity of fill material for the spending beaches. The current project envisions using fill quantities associated with recognized levee upgrading practices such as Bulletin 192-82. The fact that borrow pit proximity to perimeter levees impacts well spacing and pumping rates is already established. Borrow pit placement will be selected during final design, considering depth of overburden, haul road locations, and proximity to perimeter levees.

URSGWC Response: The scope of Section 2.5 will be condensed into one task. The two cases analyzed one-dimensionally by HTE will be used; however, further variations of width, excavation geometry and optimum location with respect to the reservoir levee will be identified and analyzed.

2.5.2 Evaluate the proposed size, depth, and setback locations of borrow pits, and make recommendations on an optimal system.

HTE Comment: None

URSGWC Response: May be optional depending on the results of the analyses of Task 2.5.1.

2.6 SETTLEMENT CAUSED BY FILLING AND PUMPING OF WATER

Background Information:

Rapid changes in the reservoir water level cause additional stresses on underlying soil layers. Groundwater pumping from under the levees also causes additional soil stresses. Both of these factors may cause additional settlements of levees and interiors of both storage islands and adjacent islands. This issue appears not to have been addressed in detail. For levee design as well as overall impacts on the project, such settlements should be addressed.

HTE Comment: None

URSGWC Response: None. Scope is not changed.

3.0 LEVEE STABILITY

Background Information

HLA (1989, 1992) performed geotechnical investigations and engineering analyses for the Delta Wetland levees. The study included field investigation, soil laboratory testing, analyses of levee stability, settlement and seepage through and under the levees.

As part of this study, HLA also developed site-specific static and dynamic soil properties by conducting geophysical surveys and laboratory testing. In addition, HLA developed seismic design load criteria and performed one-dimensional site response analyses. Liquefaction potential evaluation and seismic-induced deformation analyses were also performed.

More recently (1998), probabilistic seismic hazard analysis and levee failure probabilistic evaluation were conducted for the Sacramento/San Joaquin Delta levees by the Seismic Vulnerability Sub-Team of CALFED's Levees and Channels Technical Team. In this study, the delta region was divided into four groups based on their expected seismic ground motions and the levee fragility to failure. Estimates for levee failure due to scenario earthquake events from nearby dominant seismic sources were also developed.

The SWRCB identified various issues associated with the stability of the Delta Levees which included subsidence, static and seismic stability and deformation, settlement, erosion, and overtopping. Although additional work addressing these issues was not requested in the November 25, 1998 letter, during subsequent meetings between the lead agencies and the engineers it was decided that additional engineering analysis of these items was required. Accordingly, we propose to perform the following activities to verify compliance with the state regulatory agencies on reservoir stability issues.

HTE Comments:

Levee Stability Review Criteria - The approach taken by URSGWC applies to dams; that is, water retention structures under the jurisdiction of DSOD. In their opening paragraph, the reviewer states that "design criteria for levees were also prepared for DSOD permit approval." This is not correct. Nothing we did for "levees" was ever intended to be under the jurisdiction of DSOD. The reviewer may be confusing the Wilkerson Dam work with what we did for levees.

We conducted our analysis of the reservoir project at the maximum pool elevation of +6 feet to evaluate the worst case conditions. It is possible that once the project is permitted and enters the *final design stage that other requirements may dictate a reduced pool elevation. One of the technical factors that may limit pool elevation is wave runup during high wind events.*

Before URSGWC begins Phase 2 tasks, DW will review the Phase I work taking into consideration the costs and feasibility of storage at a +6 elevation. DW has always expected to make a decision at the time of final design as to whether to build the reservoirs to +6, but as a result of the REIRIS and the levee concerns raised by the SWRCB November 25th letter it appears it may be necessary to make that decision at the time of approval of the Phase 2 tasks.

<u>CEQA Evaluation:</u> In their November 25, 1998 letter, the SWRCB makes the point that "an inadequately constructed, maintained, or protected reservoir levee could suddenly crack or gradually erode, causing damage to property and neighboring islands." Perhaps a helpful restatement might be that existing levees in their current state of construction, maintenance or protections are at a higher risk of suddenly cracking or gradually eroding and causing damage to property and neighboring islands under current practices than will be for a methodically designed and carefully constructed reservoir island levee.

All of the investigative and preliminary design work described herein and in other documents which are a part of the SWRCB hearing record constitute what we consider preliminary investigation and design work. The level of rigor was directed to satisfy CEQA requirements and additionally provide the project proponent with enough design information that a reasonable economic analysis could be developed.

For the CEQA and preliminary design stages, our studies were made with the concept of comparing proposed levees with conditions that currently exist and will exist without the project. HE 1995a describes the overall benefits of the project compared to current alternatives. The project intends to substantially improve the existing levees by widening crests, flattening slopes and improving erosion protection. The preliminary analysis for the levees indicates that the reservoir levees should be more reliable when compared to existing levees. Further, the reservoir levees should be better able to withstand flooding should a section of levee fall. With its interior erosion protection, groundwater control system and export pumping system in place, the consequences of a breach occurring at a reservoir island are much less than for a farmed island without these facilities.

In the cumulative impact analysis of the no-project condition, conditions will exist many years from now if farming practice continues on the islands that need to be considered. The islands currently subside at 2 to 3 inches per year from farming practices. This means that 30 years from now the total effective height of the levees will be 5 to 7.5 feet greater than current conditions. Levee stability and reliability on farmed islands underlain with peat soil will tend to decrease with time and seepage will increase with time as the islands subside. Switching the land use to a water storage project will greatly decrease subsidence. The project has performed the level of analysis deemed appropriate to evaluate CEQA level impacts on perimeter levees.

Seismic issues: *We believe the recently completed CALFED Seismic Vulnerability of the Sacramento-San Joaquin Delta Levees (December 1998) will provide sufficient input for CEQA evaluations.*

URSGWC Response

Levee Stability Review Criteria - If the storage volume exceeds 50 acre-feet and the retention structure is higher than 6 feet, the reservoir falls under DSOD jurisdiction as we understand the criteria. Moreover, the SWRCB has indicated that they would consider requiring Delta Wetlands to obtain DSOD evaluation regardless of statutory requirements. Considering these facts, it is our judgment that the feasibility evaluation of Delta Wetland's levee designs requires at least a preliminary evaluation according to DSOD criteria.

CEQA Evaluations - We recognize that, in the most limited interpretation, CEQA requires a comparison between the present condition and the future with-project condition. In the context of the project proposed by DW, more specific information is needed on future impacts, both to better define the proposed project, its specific impacts and costs, and thereby to judge the broader impacts and implications, including feasibility of the project. Specific issues that we consider as needing additional evaluation at this time, without waiting for final design, include, based on our review of the project documentation:

- more information on planned construction sequence and time history
- more specific documentation of stability analyses, including soil strength parameters, critical failure surfaces, factors of safety
- absolute stability factors of safety, not just relative numbers
- more information on time effects, including estimated time history of construction, time history of dissipation of excess pore pressures and settlement, and time history of factors of safety
- more specifics on development of required quantity of borrow material

Seismic Issues - We do not agree that earthquake stability is adequately addressed by the general comparisons to earthquake reliability presented in the draft EIR/EIS and the reference to CALFED's probabilistic study of seismic vulnerability of the Delta levees of December 1998. A project of this significance commonly requires at least preliminary site-specific considerations, analyses and conclusions on seismic stability and seismic impacts already in the EIR/EIS stage.

Summary of 3.0 Levee Stability

We conclude that the uncertainties and gaps in the existing DW documentation on slope stability are such that the additional studies recommended in the Scope of Work are still needed, and recommend that they be implemented.

Additional responses only on those specific items where HTE had comments follow. Those scope items in the URSGWC SOW not commented on by HTE require no response or changes to the proposed scope.

3.1 LEVEE STRENGTHENING

3.1.2 Evaluate analysis results from previous studies on levee stability, including soil engineering parameters used.

HTE Comment: Undrained strength parameters for peat and soft clay were measured for Wilkerson Dam study on Bouldin Island.

URSGWC Response: The results of these studies on Bouldin Island are valuable, yet must be extrapolated to other islands judiciously.

3.1.4 Update dynamic soil parameters based on recent findings.

HTE Comment: Site specific studies are not needed. The EIR/EIS preparer should rely on the CALFED Seismic Vulnerability of the Sacramento-San Joaquin Delta Levees (December 1998) as the final source document for seismic reliability.

URSGWC Response: As noted under Section 3.0, we disagree with the concept that a Delta-wide, programmatic study would be an adequate basis for the EIR/EIS-level assessment of seismic risk.

3.1.7 Evaluate analyses done by DW of the safety of the strengthened levees against static and earthquake-induced loads. Implement additional analyses as deemed needed. Failure mechanisms should include slope failures, inadequate bearing capacity, excessive slope deformation and settlement, critical seepage conditions, piping and internal erosion around well screens, and others.

HTE Comment: Need to compare against existing conditions per CEQA.

URSGWC Response: See Section 3.0 URSGWC discussion regarding details of analysis required.

3.1.8 Evaluate the during-construction, long-term and rapid drawdown static stability of the levee systems, and compare the stability parameters to existing conditions.

<u>HTE Comment:</u> *Analyses previously performed by HLA. In considering a rapid drawdown condition, URSGWC should be aware that the reservoirs would be drawn down at a rate of up to 12 inches per day.*

<u>URSGWC Response:</u> Working with Jones & Stokes Associates we will make determinations on the maximum daily rate. Whether 12 or 18 inches, these rates are high enough that a rapid drawdown condition should be considered.

3.1.12 Address erosion by wind fetch and wave runup.

<u>HTE Comment:</u> *DW has an initial internal study for soil cement and riprap on various slopes. Documents can be made available.*

<u>URSGWC Response:</u> We will certainly review DW's additional documentation as a part of our study.

3.1.13 Address constructability of selected levee system. We will evaluate the gradation of the materials used to strengthen the levees (see Task II.5 for borrow pits).

<u>HTE Comment:</u> *Final system not selected. Likely to be similar to Bulletin 192-82 but with a wider crest.*

<u>URSGWC Response:</u> Issue addressed here is constructability, not selected levee system. The need to address constructability (i.e., staging of construction, lag time to allow consolidation between stages, and total construction duration) is discussed in our discussion in Section 3.0.

3.1.14 Review with DSOD

<u>HTE Comment:</u> *See Comment 3.0*

<u>URSGWC Response:</u> See Section 3.0, URSGWC Response.

Summary of 3.1 Levee Strengthening

HTE's comments explain DW's approach and position, but result in no significant change, in our opinion, on the scope of work proposed under task 3.0. Accordingly, we recommend that the scope of this task remain as proposed; we will consider HTE's comments and references when conducting the analysis.

3.2 ASSESS EFFECTS OF INTERCEPTOR WELLS ON LEVEE STABILITY

There were no HTE comments on this section and no change in the proposed scope is considered. However, the lead agency has requested that, in addition to the previous variables to be addressed regarding levee stability, the effect of potential internal erosion and piping around well screens be evaluated and, as needed, mitigation or monitoring measures be recommended.

4.1 OPTIONAL TASK 1 - ASSESS POTENTIAL DAMAGE TO NEIGHBORING ISLANDS IN EVENT OF LEVEE BREACH OR PROJECT ABANDONMENT

Background Information:

The SWQCB has expressed concern about potential damages to adjacent islands in the event of a levee failure of a storage island and in the event of project abandonment by the owner. Some effort to address these concerns, using various plausible scenarios, appears justified.

4.1.1 Formulate scenarios of levee failure of storage islands that might damage adjacent islands; one example is levee failure with full storage island (elevation +6 feet) and extremely low water in the channels.

HTE Comment: Other examples should be no-project alternate during both Delta flood and Delta drought conditions.

URSGWC Response: The no-project alternative can be considered. While this alternative is valid in a relative sense (comparing with-project to without-project), it does not address the absolute potential effects of the project, which we believe is needed, as indicated in Section 3.0.

4.1.2 Estimate potential effects of these events on levee across a narrow channel, and judge the likelihood of any catastrophic damages (some erosion damage could easily be repaired after the event).

HTE Comment: Should also consider no-project alternate.

URSGWC Response: Same as response to 4.1.1.

4.1.3 Formulate scenarios of levee abandonment at critical times in the storage islands' annual use cycle, or after a damaging event such as an earthquake (but that does not cause a levee failure).

HTE Comment: Scenarios should also consider abandonment when farming became uneconomical (no-project alternate).

URSGWC Response: Essentially same as response to 4.1.1.

4.1.4 Estimate storage islands' behavior for these scenarios, and seepage conditions that could negatively impact adjacent islands; estimate the potential for significant short- and long-range damages to adjacent islands.

HTE Comment: Reviewer should also address beneficial impacts of an abandoned storage island.

URSGWC Response: Essentially same as response to 4.1.1

4.1.5 Work with Jones and Stokes' hydraulic modelers to estimate the probability that these conditions could happen.

HTE Comment: Abandonment will be an economic event. It will also be a function of ownership.

URSGWC Response: Clearly the nature and stability of the ownership affect the probability of abandonment, and will be considered.

Summary of Optional Task 4.1

HTE's comments, if implemented, would broaden the scope of the review slightly, but do not eliminate any of the proposed scope of work. Accordingly, we recommend that the proposed scope of Option 1 be implemented essentially as proposed, considering HTE's comments as appropriate.

Please call with any comments.

Sincerely,

URS GREINER WOODWARD CLYDE

Said Salah-Mars, Ph.D., P.E.
Senior Project Manager

Michael Stuhr, P.E.
Program Manager

Appendix I. Distribution List for the Revised Draft EIR/EIS

Mr. Alex Hildebrand
23442 South Hays Road
Manteca, CA 95336

Al Warren Hoslett, Esq.
504 Bank of Stockton Building
311 E. Main Street
Stockton, CA 95202

Mr. Donald Paff
P.O. Box 1445
Mesquite, NV 89024

Mr. Bob Murphy
P.O. Box 97
Brooks, CA 95606

Michael Jackson, Esq.
P.O. Box 207
Quincy, CA 95971-0207

Mr. William J. Miller, Consulting Engineer
P.O. Box 5995
Berkeley, CA 94705

Mr. Wendell Miller
10853 Mooney Flat Road
Smartville, CA 94977

Kyser Shimasaki
4412 Mallard Creek Circle
Stockton, CA 95207

Peter M. Margiotta
122 Castle Creek Road
Alamo, CA 94595

Mr. Kenneth Henneman
3142 Montpelier Court
Pleasanton, CA 94588

Mr. Jerome B. Gilbert
324 Tappan Terrace
Orinda, CA 94563

Advisory Council on Historic Preservation
Director, Western Office of Review
12136 West Bayland Ave., Ste. 330
Lakewood, CO 80228

Antioch Public Library
501 West 18th Street
Antioch, CA 94509

Assembly Water, Parks & Wildlife Committee
Ms. Linda Adams, Chief Consultant
State Capitol, Room 5136
Sacramento, CA 95814

Association of California Water Agencies
910 K Street, Suite 100
Sacramento, CA 95814

Bartkiewicz, Kronick & Shanahan, P.C.
Alan B. Lilly, Esq.
1011 22nd Street, Suite 100
Sacramento, CA 95816-4907

Bold, Polisner, Maddow, Nelson & Judson
Robert B. Maddow, Esq.
500 Ygnacio Valley Road, Suite 325
Walnut Creek, CA 94596-3840

Bradford Reclamation District No. 2059
504 Bank of Stockton Building
311 East Main Street
Stockton, CA 95202

Brent L. and E. E. Gilbert
c/o Richard Rockwell, Attorney
1610 A Street
Antioch, CA 94509

Brentwood Library
Ms. Jane Coker
751 Third Street
Brentwood, CA 94513

Burns Engineering
Ms. Barbara Burns
P.O. Box 761
Bethel Island, CA 94511

CALFED
David Fullerton
1416 Ninth Street, Room 1155
Sacramento, CA 95814

CALFED
Mr. Dick Daniel, Ecosystem Planning Branch
1416 Ninth Street, Room 1155
Sacramento, CA 95814

CALFED
Steve Ritchie, Executive Director
1416 Ninth Street, Room 1155
Sacramento, CA 95814

CALFED Water Management Branch
Mark Cowin, Assistant Director
1416 Ninth Street, Room 1155
Sacramento, CA 95814

California Central Valley Flood Control Association
Robert Clark, Manager
703 Elks Building
921 11th Street
Sacramento, CA 95813

California Department of Boating and Waterways
Mr. Bill Curry
2000 Evergreen Street, Suite 100
Sacramento, CA 95815

California Department of Fish and Game
Director
1416 Ninth Street
Sacramento, CA 95814

California Department of Fish and Game
Waterfowl, Wildlife Management Div.
Mr. Dan Connely
1416 Ninth Street, 12th Floor
Sacramento, CA 95814

California Department of Fish and Game
Bay-Delta Division
Frank Wernette
4001 North Wilson Way
Stockton, CA 95205

California Department of Fish and Game Region 3
Brian Hunter
P.O. Box 47
Yountville, CA 94599

California Department of Food and Agriculture
Tad Bell
1220 N Street, Room 409
Sacramento, CA 95814

California Department of Health Services
Toxic Substances Control Program
601 North 7th Street
Sacramento, CA 95814

California Department of Parks & Recreation
State Office of Historic Preservation
1416 Ninth Street, Room 1442-7
Sacramento, CA 95814

California Department of Parks & Recreation
Resource Management Division
Richard G. Rayburn, Chief
1416 Ninth Street
Sacramento, CA 95814

California Department of Transportation District 10
Transportation Planning Division
Mr. Dana Cowell, Chief
1976 East Charter Way
Stockton, CA 95205

California Department of Water Resources
Office of the Chief Counsel, Room1118
Ms. Cathy Crothers
1416 Ninth Street
Sacramento, CA 95814

California Department of Water Resources
Office of State Water Project Planning, Room 204
Mr. John Pacheco
1416 9th Street
Sacramento, CA 95814

California Department of Water Resources
Environmental Services Office
Mr. Dale Hoffman-Floerke
3251 S Street
Sacramento, CA 95816

California Department of Water Resources
Division of Planning and Local Assistance
William J. Bennett
1020 9th Street, Third Floor
Sacramento, CA 95814-3515

California Department of Water Resources
Gary Hester
1416 Ninth Street
Sacramento, CA 95814

California Department of Water Resources
Kathy Kelley
1416 Ninth Street
Sacramento, CA 95814

California Department of Water Resources
Larry Gage, Chief of Operations
1416 Ninth Street
Sacramento, CA 95814

California Department of Water Resources
Nasir Bateni
1416 Ninth Street
Sacramento, CA 95814

California Department of Fish and Game
Legal Affairs Division
Steve Adams, Esq.
1416 Ninth Street, 12th Floor
Sacramento, CA 95814-5511

California Environmental Protection Agency
Winston H. Hickox
555 Capitol Mall, Suite 235
Sacramento, CA 95814

California Farm Bureau Federation
Mary Ann Warmerdam, Natural Resources Consultant
1127 11th Street, Suite 626
Sacramento, CA 95814

California Regional Water Quality Control Board
Central Valley Region
Gary M. Carlton, Executive Officer
3443 Routier Road, Suite A
Sacramento, CA 95827-3003

California Regional Water Quality Control Board
Los Angeles Region
Dennis Dickerson, Executive Officer
320 W. 4th Street, Suite 200
Los Angeles, CA 90013

California Regional Water Quality Control Board
San Francisco Bay Region
Loretta K. Barsamian
1515 Clay Street, Suite 1400
Oakland, CA 94612

California Research Bureau, California State Library
LEC II
900 N Street
Sacramento, CA 95814

California Resources Agency
Mary D. Nichols, Secretary
1416 Ninth Street, Suite 1311
Sacramento, CA 95814

California Sportfishing Protection Alliance
Robert J. Baiocchi, Consultant
P.O. Box 357
Quincy, CA 95971

California State Lands Commission
Division of Environmental Planning
Dwight E. Sanders, Chief
100 Howe Avenue, Suite 100 South
Sacramento, CA 95825-8202

California State Library (2)
Government Publications
4201 Sierra Point Drive, Suite 112
Sacramento, CA 95834

California State University, Sacramento
Government Documents Library
Ben Amata
2000 Jed Smith Drive
Sacramento, CA 95819-6039

California Trout
Mr. Jim Edmondson, President
9770 Sombra Terrace
Shadow Hills, CA 91040

California Urban Water Agencies (2)
Byron M. Buck, Exec. Director
455 Capitol Mall, #705
Sacramento, CA 95814

California Waterfowl Association
Dr. Robert McLandress
4630 Northgate Boulevard, Suite 150
Sacramento, CA 95834

Capitol Press
Craig Anderson
5059 N. Alfalfa Street
Linden, CA 95236

Central Basin Municipal Water District
Mr. Richard W. Atwater
17140 South Avalon Boulevard, Suite 210
Carson, CA 90746-1218

Central California Information Center
Coordinator
801 West Monte Vista Avenue
Turlock, CA 95382

Central Valley Project Water Association
Mr. Jason Peltier
1521 I Street
Sacramento, CA 95814

Cesar Chavez Central Library
605 North El Dorado
Stockton, CA 95202

Concord Public Library
2900 Salvio Street
Concord, CA 94519

Congressman Bob Filner
50th Congressional District
333 F Street, Suite A
Chula Vista, CA 91910

Congressman Gary Condit
Dorene D' Adamo, Legal Counsel
920 16th Street, Suite C
Modesto, CA 95354

Congressman Richard Pombo
Mr. Mike Wackman, Field Representative
2495 W. March Lane, Suite 104
Stockton, CA 95207

Consolidated Farm Service Agency
Attn: State Director
1303 J Street
Sacramento, CA 95814

Contra Costa County
Board of Supervisors
651 Pine Street, Room 107
Martinez, CA 94553

Contra Costa County Community Development Department
Assistant Director, Comprehensive Planning
651 Pine Street, Fourth Floor North Wing
Martinez, CA 94553-0095

Contra Costa County FC & WCD
255 Glacier Drive
Martinez, CA 94553

Contra Costa County Library Documents Unit
1750 Oak Park Boulevard
Pleasant Hill, CA 94523-4497

Contra Costa County Planning Department
651 Pine Street, North Wing, 4th Floor
Martinez, CA 94553

Contra Costa Water District
Richard Denton, Water Quality Manager
P.O. Box H2O
Concord, CA 94524-2099

County of Sacramento Water Resources Division
Steven M. Pedretti, Senior Civil Engineer
827 Seventh Street, Room 301
Sacramento, CA 95814

D & L Farms
Leisha Robertson
P.O. Box 620
Linden, CA 95236

Delta Protection Commission
Margit Aramburu, Executive Director
P.O. Box 530, 14125 River Road
Walnut Grove, CA 95690

Delta Wetlands
Dave Forkel
2295 Gateway Oaks Drive, Suite 140
Sacramento, CA 95833

Delta Wetlands
Jim Easton
2295 Gateway Oaks Drive, Suite 140
Sacramento, CA 95833

Delta Wetlands
John Winther
3697 Mt. Diablo Blvd., Suite 100
Lafayette, CA 94549

Department of Health and Human
Services Special Programs Group (F29)
Kenneth M. Holt, M.S.E.H.
National Centers for Disease Control
Atlanta, GA 30341-3724

Department of Housing & Urban Development
Regional Office
925 L Street
Sacramento, CA 95814

Deputy Secretary of Interior
Mr. David Hayes
1849 C St. NW, #5100
Washington, DC 20240

Diablo Water District
c/o Frederick Bold Jr., Esq.
1201 California Street
San Francisco, CA 94109

Downey Brand Seymour & Rohwer
Kevin O'Brien
555 Capitol Mall, 10th Floor
Sacramento, CA 95814

Ducks Unlimited
Mr. Jack Payne
9823 Old Winery Place, Suite 16
Sacramento, CA 95827

East Bay Municipal Util. Dist.- MS904
Fred S. Etheridge
P.O. Box 24055
Oakland, CA 94623

East Bay Regional Park District
Mr. Tom Lindenmeyer, Environmental Coordinator
P.O. Box 5381
Oakland, CA 94605-0381

Ellison & Schneider (4)
Barbara Brenner, Esq.
2015 H Street
Sacramento, CA 95814

Environmental Defense Fund
Mr. Tom Graff
5655 College Avenue, Suite 304
Oakland, CA 94618

Federal Emergency Management Agency
500 C Street SW, Room 714
Washington, DC 20472

Federal Highway Administration
Federal Building California Division
Regional Administrator
980 9th Street
Sacramento, CA 95818

Friant Water Users Authority
Dick Moss, General Manager
854 North Harvard Avenue
Lindsay, CA 93247-1715

Friends of the River
128 J Street, 2nd Floor
Sacramento, CA 95814

University of Southern California
VonKleinSmid Library, Government Documents
3518 Trousdale Park
Los Angeles, CA 90089-0182

Hastings College of Law The Hastings Law Library
200 McAllister Street
San Francisco, CA 94102

Hultgren-Tillis Engineers
Mr. Edwin M. Hultgren
2520 Stanwell Drive, Suite 240
Concord, CA 94520

J. P. Dunlap and Bruce Belton
Bella Vista Water District
11368 E. Stillwater Way
Redding, CA 96003

John F. Kennedy Library
505 Santa Clara Street
Vallejo, CA 94590

Kern County Water Agency
Gary Bucher, Water Resources Manager
P.O. Box 58
Bakersfield, CA 93302

Kjeldsen, Sinnock & Neudeck, Inc.
Mr. Chris Neudeck
711 North Pershing Avenue
Stockton, CA 95203

Lodi Library
201 West Locust Street
Lodi, CA 95240

Madera Irrigation District
Steve Ottermoeller, General Manager
12152 Road 28 1/4
Madera, CA 93637-9199

Malcolm Pirnie, Inc.
Dr. Mike Kavanaugh
180 Grand Avenue, Suite 725
Oakland, CA 94512

Marin Audubon Society
Mr. Peter Margiotta
122 Castle Crest Road
Walnut Creek, CA 94595

Martinez Public Library
740 Court Street
Martinez, CA 94553

Meriam Library
Ms. Alice Brannen
California State University, Chico
Chico, CA 95929-0295

Metropolitan Water District of Southern California
Mr. Ed Winkler
1121 L Street, Suite 900
Sacramento, CA 95814

Metropolitan Water District of Southern California
Mr. Stuart Krasner
P.O. Box 54153
Los Angeles, CA 90054-0153

National Audubon Society
Mr. Glen Olson
555 Audubon Place
Sacramento, CA 95825

National Marine Fisheries Service
Mike Aceituno
650 Capitol Mall, Ste. 6070
Sacramento, CA 95814

Native American Heritage Commission
Mr. Larry Myers, Executive Secretary
915 Capitol Mall, Room 364
Sacramento, CA 95814

Natural Heritage Institute
David Fullerton, Staff Scientist
2140 Shattuck Avenue, 5th Floor
Berkelely, CA 94704

Natural Resources Conservation Service
Mr. Ron Schultze
430 G Street, #4164
Davis, CA 95616-4164

Natural Resources Defense Council
Mr. Hamilton Candee, Staff Attorney
71 Stevenson Street, #1825
San Francisco, CA 94105

Nomellini, Grilli & McDaniel
Dante John Nomellini, Esq.
P.O. Box 1461
Stockton, CA 95201-1461

North Delta Water Agency
Mr. Dennis Leary
901 K Street
Sacramento, CA 95814

Northern California Water Association
David Guy, Executive Director
455 Capitol Mall, Suite 335
Sacramento, CA 95814-4496

Oakland Public Library
1330 Broadway, Suite 555
Oakland, CA 94612

Pacific Coast Federation of Fishermen's Associations
Mr. Zeke Grader
P.O. Box 29730
San Francisco, CA 94129

Patrick Johnston
California State Senate
State Capitol, Room 5066
Sacramento, CA 95814

Perkins Coie
Mr. Guy Martin
607 14th St. NW
Washington, DC 20005-2011

PG&E - Gas System Maintenance
Mr. Doug Davies, Manager
375 North Wiget Lane
Walnut Creek, CA 94598

PG&E - Law
Mr. Richard H. Moss, Esq.
P.O. Box 7442
San Francisco, CA 94120

Planning and Conservation League
Gerald H. Meral, Executive Director
926 J Street, Room 612
Sacramento, CA 95814

Reclamation District #2038
Mr. Tom Rosten
227 Alvarado Way
Tracy, CA 95376

Reclamation District No. 830
David N. Bauer
P.O. Box 1105
Oakley, CA 94561-1105

Reclamation Districts 563, 556, 554, and 2111
Mr. George C. Wilson
P.O. Box 238
Walnut Grove, CA 95690

Rio Vista Library
44 South Second Street
Rio Vista, CA 94571

Riverside Elevators, RD 2111, Kay Dix
Daniel M. Wilson
P.O. Box 248
Walnut Grove, CA 95690

Sacramento Public Library
828 "I" Street
Sacramento, CA 95814

Salmon & Steelhead Advisory Committee
Mr. Bill Kier
120 Schoonmaker Point
Sausalito, CA 94965

San Francisco Estuary Project
Ms. Jean Auer
2101 Webster Street, Suite 50
Oakland, CA 94612

San Francisco Public Utility Commission
Michael Carlin, Water Resources and Planning Manager
1155 Market Street, 4th Floor
San Francisco, CA 94103

San Joaquin County Board of Supervisors
County Court House
222 East Weber Avenue
Stockton, CA 95202

San Joaquin County Community Development Department
Peggy Keranen, Deputy Director
1810 East Hazelton Avenue
Stockton, CA 95205-6232

San Joaquin County Council of Governments
Andrew T. Chesley, Deputy Executive Director
6 South El Dorado Street
Stockton, CA 95202-2804

San Joaquin County Department of Planning
Director
1810 East Hazelton Avenue
Stockton, CA 95205

San Joaquin County Department of Public Works
A. J. Tschirky, Real Property Agent
1810 East Hazelton Avenue
Stockton, CA 95201

San Joaquin County FC&WCD
c/o William N. Sousa
1810 East Hazelton Avenue
Stockton, CA 95205

San Joaquin County Planning & Building Insp.
Mr. Chet Davisson
1810 East Hazelton Avenue
Stockton, CA 95205

San Joaquin River Group
Allen Short, Coordinator
P.O. Box 4060
Modesto, CA 95352

San Joaquin Tributaries Association
P.O. Box 4060
Modesto, CA 95352

San Jose City College Library
2100 Moorpark Avenue
San Jose, CA 95128-2799

San Luis and Delta Mendota Water Authority
Francis Mizuno, Operations and Maintenance
P.O Box 2157
Los Banos, CA 93635

Santa Clara Valley Water District
Ms. Amy Fowler
5750 Almaden Expressway
San Jose, CA 95118-3686

Save San Francisco Bay Association
Mr. Barry Nelson
1600 Broadway, Suite 300
Oakland, CA 94612

Senator Boxer's Office
Mr. Thomas J. Bohigian, Field Representative
2300 Tulare Street, Suite 120
Fresno, CA 93721

Senator Feinstein's Office
Mr. Ken Price
1130 O Street, Suite 2446
Fresno, CA 93721

Shasta County Board of Supervisors
Molly Wilson, District 4
1815 Yuba Street, Suite 1
Redding, CA 96001

Shasta Lake Business Owners' Assocation
Robert Lefebvre
P.O. Box 709
Lakehead, CA 96051

Sherwin, Zuckerman & Sargent
Mr. Thomas Zuckerman
Sperry Building
146-148 West Weber Avenue
Stockton, CA 95202

Sierra Club
85 Second Street, Fourth Floor
San Francisco, CA 94105

Solano County
Ms. Cynthia Copeland
601 Texas Street
Fairfield, CA 94533

Solano County Library
1150 Kentucky Street
Fairfield, CA 94533

Southern Nevada Water Authority
Ms. Patricia Mulroy, General Manager
1001 South Valley View Blvd.
Las Vegas, NV 89153

Stanford University Libraries
State and Local Documents
Ms. Anna Latta, Bibliographer
Green Library, Bing Wing, First Floor
Stanford, CA 94305-6004

State Clearinghouse (15)
1400 Tenth Street, Room 222
Sacramento, CA 95814

State Water Contractors
Director
555 Capitol Mall, Suite 725
Sacramento, CA 95814

The Bay Institute of San Francisco
Gary Bobker, Policy Analyst
55 Shaver Street, Suite 330
San Rafael, CA 94901

University of California at Riverside Library
Government Publications
P.O. Box 5900
Riverside, CA 92517-5900

The Nature Conservancy
Mr. Chris Unkel
1330 21st Street, Suite 103
Sacramento, CA 95814

Tracy Public Library
20 East Eaton Avenue
Tracy, CA 95376

U.S. Bureau of Reclamation
Susan Hoffman, Planning Division Chief
2800 Cottage Way
Sacramento, CA 95825

U.S. Bureau of Reclamation
Lowell Ploss, Operations Manager
2800 Cottage Way
Sacramento, CA 95825

U.S. Bureau of Reclamation
Susan Ramos, CALFED Program Manager
2800 Cottage Way
Sacramento, CA 95825

U.S. Department of the Interior
Mr. Ralph Mihan, Solicitor General
600 Harrison Street
San Francisco, CA 94107

U.S. Army Corps of Engineers, Headquarters
Attn: CECW-OR
Casimir Pulaski Building
20 Massachusetts Avenue, NW
Washington, DC 20314-1000

U.S. Army Engineer Division, South Pacific
Attn: CESPD-CO-R
630 Sansome Street, Room 1216
San Francisco, CA 94111-2206

U.S. Bureau of Land Management Division of Resources
State Director
2800 Cottage Way, W-1834
Sacramento, CA 95825-1886

U.S. Bureau of Reclamation
Richard Whitson
2800 Cottage Way, MP-700
Sacramento, CA 95825

U.S. Coast Guard Commander, 11th Coast Guard District
Coast Guard Island
Building 10, Room 51-1
Alameda, CA 94501-5100

U.S. Department of Commerce
Office for Oceans and Atmosphere
Director for the Under Secretary
Ecology and Conservation Office
Washington, DC 20230

U.S. Department of the Interior
Office of Environmental Policy and Compliance
Patricia Sanderson Port, Regional Environmental Officer
600 Harrison Street, Suite 515
San Francisco, CA 94107-1376

U.S. Department of the Interior
Office of Environmental Project Review (18)
Interior Building
18th & C Streets NW
Washington, DC 20240

U.S. Department of the Interior
James E. Turner, Esq., Assistant Regional Solicitor
2800 Cottage Way, Room E-1712
Sacramento, CA 95825-1898

U.S. Environmental Protection Agency
Michael Boots/Karen Schwinn
975 Hawthorne Street
San Francsico, CA 94105

U.S. Environmental Protection Agency (5)
Director, Office of Federal Activities
1200 Pennsylvania Avenue, NW
Washington, DC 20460

U.S. Environmental Protection Agency Region IX
Wetlands & Water Division
Director
75 Hawthorne Street
San Francisco, CA 94105

U.S. Fish & Wildlife Service Division of Ecological Services
Wayne White/Ken Sanch
2800 Cottage Way, Room W-2605
Sacramento, CA 95825

U.S. Fish and Wildlife Service
David Cottingham
1849 C Street, N.W.
Washington, DC 20240

U.S. Geological Survey
Mr. Roger Fujii
Placer Hall, 6000 J Street
Sacramento, CA 95819-6129

United Anglers of California
Mr. John Beuttler
5200 Huntington Avenue #300
Richmond, CA 94804

University of California, Davis
Shields Library, Government Information and Maps
100 N.W. Quad
Davis, CA 95616

University of California, Santa Barbara
Davidson Library
Government Information Center
Santa Barbara, CA 93106

University Research Library
Public Affairs
University of California, Los Angeles
Los Angeles, CA 90024-1575

USAED, San Francisco Planning Division
Mr. Craig Vassel
211 Main Street, Room 918
San Francisco, CA 94105

Water Education Foundation
Ms. Rita Schmidt-Sudman
717 K Street, Suite 317
Sacramento, CA 95814

Water Resources Center Archives
University of California
410 O'Brien Hall
Berkeley, CA 94720-1718

Westlands Water District
Dave Orth, General Manager
P.O. Box 6056
Fresno, CA 93703-6056

Wildlife Conservation Board
Ms. Marilyn Cundiff-Gee
801 K Street, Suite 806
Sacramento, CA 95814